

**STUDIES ON PERFORMANCE OF STEM CUTTING
UNDER DIFFERENT GROWING CONDITIONS AS
AFFECTED BY ZINC APPLICATION ON GUAVA
PLANTS**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Horticulture (Fruit Science)

By

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**LOVELY PROFESSIONAL UNIVERSITY, PUNJAB
2025**

DECLARATION

I, hereby declared that the presented work in the thesis entitled “**Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants**” in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr. Gurpreet Singh**, working as Professor, in the **Department of Horticulture**, School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled **Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants**” submitted in fulfilment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the **Department of Horticulture, School of Agriculture**, is a research work carried out by **Vishal Vijayvargiya,12020536** is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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CERTIFICATE-II

This is to certify that the work reported in the Ph. D, thesis entitled " **“Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants”**" submitted by Vishal Vijayvargiya (Registration No. 1220536) to Lovely Professional University, Phagwara in the partial fulfilment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of **Horticulture (Fruit Science)** has been approved by Advisory Committee after oral examination of the student in collaboration with an external examiner.

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ABSTRACT

Background

Propagation of guava through stem cuttings is effective but influenced by nutrient availability and rooting hormones. Zinc, a crucial micronutrient, impacts plant growth, enzyme activation, and cell division. Stem cuttings often need rooting hormones like IBA and IAA for successful rooting, which can be challenging to apply and potentially toxic if misused. This study investigates the impact of different zinc application methods and concentrations on guava stem cuttings, focusing on rooting efficiency.

Methods

A split-plot design was used with main plots for zinc application methods (foliar vs. basal) and concentrations, and sub-factors for application timing (30 vs. 60 after dormant stage). Treatments included foliar zinc (0.25%, 0.50%, 0.75%), basal zinc (50g/tree, 75g/tree, 100g/tree), IBA (5000 ppm, 10000 ppm), and a control. Rooting parameters was assessed 90 days after planting.

Results

After 60 days of the dormant stage, applying zinc at a basal dose of 75 g per tree resulted in a rooting efficiency of 52.13% under shade net conditions, compared to 26.28% in open field conditions. The control group, without any zinc treatment, showed a lower rooting efficiency of 31.11%. These results indicate that this optimal zinc dose, particularly when combined with shade net conditions, is most effective for improving guava propagation.

Keywords

Basal Application, Foliar Application, IBA, Micronutrients, Open Field Conditions, Rooting Efficiency, Rooting Hormones, Shade Net.

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Place: Lovely Professional University, Phagwara

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LIST OF ABBREVIATIONS

CD	- Critical Difference
CV	- Coefficient of Variation
FYM	- Farm Yard Manure
IBA	- Indole-3-butyric Acid
mg/g	- Milligram per gram
NAA	- Naphthaleneacetic Acid
PGR	- Plant Growth Regulator
ppm	- Parts per million
SE	- Standard Error
SPD	- Split Plot Design
Zn	- Zinc
ZnSO ₄	- Zinc Sulphate

INTRODUCTION

Guava (*Psidium guajava* Linn.) originated in tropical America and spread to India in the early 17th century. Today, it covers about 60,000 acres in India (Sathe, 2015).

P. guajava is the most widely spread and well-known species in the *Psidium* genus, which has over 150 species of perennial leafy shrubs. Propagation of seeds is employed in breeding operations to enhance rootstock development and increase population sizes for early screening. An approach to vegetative propagation is employed to perpetuate the traits of each cultivar by cloning specific genotypes from these initiatives and commercial orchards (Pereira *et al.*, 2016).

Guava is currently planted in every corner of India. Guava is known by several names, such as Amrud, Seed Pandu, Peru, Piyara, Koyya, and Jamakaya. Guava is one of India's most successful commercial fruit crops. The fruit is called "the fruit of the poor guy" or "Tropical apple." It is a typical tropical and subtropical fruit tree. Regarding sustainability, hardness, adaptability, and vitamin C content, most other fruit crops excel for those who enjoy tropical or subtropical fruits. Other fruit crops do better regarding sustainability, hardness, adaptability, and vitamin C content. To fruit enthusiasts who have become acquainted with its deep aroma. Guava is among the most pleasant and intriguing fruits (Adhau *et al.*, 2014).

The scientific community has recently become interested in guava because of its high phenolic content and other bioactive ingredients like lycopene; in fact, some authors have dubbed it a "superfruit" (Corrêa *et al.*, 2014; Flores, Wu, Negrin, and Kennelly, 2015; Oliveira *et al.*, 2020).

It has been discovered that *Psidium guajava* has a wide range of chemically varied biologically active chemicals with enormous therapeutic potential. Crude extracts from many parts of *P. Guajava* have therapeutic uses, but the production of contemporary pharmaceuticals requires extensive study into the components' bioactivity, mechanism of action, pharmacotherapeutics, toxicity, and appropriate standardization. Extracts of roots, bark, and leaves are used in folk medicine to treat

wounds, gastroenteritis, vomiting, diarrhea, toothaches, coughs, sore throats, and swollen gums (Barad *et al.*, 2013).

Popular guava varieties include yellow-fruited cherry, apple, strawberry, and red apple guava. This herb has numerous health benefits, including antibacterial, anti-diarrheal, anti-hypertensive, anti-inflammatory, anticancer, antifungal, antipyretic, and high nutritional value. This plant's whole fruit is edible. The fruit can be eaten raw or fried. Fruits are sliced and added to salads and desserts. Drinks are frequently prepared from fruit pulp. The fruit is used to make a variety of delights, including jam, guava paste, and guava cheese. The leaves include both nutritional and therapeutic benefits. Uzzaman *et al.* (2018) recommend increasing the production of essential fruits to meet nutritional needs at a lower cost.

Guava is referred to as Paravata or Peruka in Sanskrit. In Ayurveda, it is called tridosha nashaka and is recommended in Ayagni. Its fruits, bark, leaves, and roots treat various illnesses, including fever, constipation, diarrheal cough, gum disease, and foul breath. It is hepatotoxic and beneficial to the heart, intestines, liver, and digestive system. Guava is also a food that diabetics and people with renal and liver problems can eat. Dietary fiber, protein, phosphorus, calcium, iron, vitamin B1, vitamin A, ascorbic acid, riboflavin, niacin, potassium, copper, and folic acid are all present in guavas. Rich in antioxidants, it guards against cellular deterioration. With this prosperity, guava is a beneficial medication and a nutritious replacement. Guava is currently profitable and a success. Commercialized fruit is frequently utilized in the food business. These days, guava is widely used in fruit salads, ice cream, soft drinks, jams, jellies, and flavored tea. (Kumari *et al.*, 2013).

The Guajava (*Psidium L.*) grows successfully at 2740 meters above sea level. It needs at least some partial sunlight, but it likes full sun. The plant develops best at summer temperatures over 150C on average but cannot endure very high temperatures. It is only resistant to moderate frost. It grows more berries in places with different winter seasons. Although it can withstand drought, 1000 and 20,000 mm of precipitation is required annually. Tolerates a variety of soil types. However, it favors slightly acidic

soils with good drainage. It prefers a variety of soil pH but may survive 4.5–9.4 (Singh *et al.*, 2017).

The guava has various guava fruit varieties, such as Lucknow 49 (roundish Ovate), Allahabad Safeda (roundish), and seedless fruits. In contrast, Banarsi (round), Chitridar (sub-globose), Apple colour (spherical), Behat coconut (round), Hafshi (spherical), Safed jam (roundish), etc., are considered to be excellent. The red variant, which is oblong, is regarded as a low-quality fruit (Sahu *et al.*, 2016). The main types planted in India are Allahabad Surkha CISHG -1, CISHG}2, CISHG-3., Bangalore, Dharwar, Akra Mridula, Arka Amulya, Harijha, Lucknow-49, Chittidar, Nagpur Seedless, etc. (Chavan *et al.*, 2015). Guavas come in a variety of kinds. The most common variety is the apple guava (*Psidium guajava*), which contains the most significant fruits of all the guavas and is usually seen in supermarkets. The well-liked, pink-fleshed cultivar "Homestead" comes from That delicious Florida. The red-flesh variant "Ruby" is prized for its superb flavor and exotic scent. Because of their firm structure, apple guavas are a great fruit to slice and add to fruit platters. *Psidium cattleianum*, or strawberry guavas, has smaller leaves and fruits resembling shrubs. The most well-liked type of lemon guava, distinguished by its delicious flavor and yellow skin, and pineapple guavas (*Feijoa sellowiana*) withstand temperatures as low as 15 degrees. They are more brutal and colder than the other varieties. As their name implies, they have a distinct flavor and are a common landscape plant in California (Vora *et al.*, 2018).

The guava tree is a perennial that is said to have originated in southern Mexico and Central America. Because of its wider adaptability, it is produced commercially in Pakistan, Bangladesh, India, Thailand, Mexico, Brazil, and many other tropical and subtropical nations worldwide. It is crucial to determine the promising variants by incorporating suitable cultivars through hybridization or selection among the well-established ones with the better genotype. The current study determined that the Sweta, Lucknow-49, and Philippines varieties are superior (Sarkar *et al.*, 2016).

India, Sudan, Egypt, Pakistan, Brazil, Mexico, Indonesia, and Bangladesh are leading guava producers. The total area under guava cultivation was 276 thousand ha, and the production was 4253 thousand MT in 2018, which increased to a total production of

4359 thousand MT, which covered 290 thousand ha area in 2020 (NHB, 2020). The technology utilized for nursery tree production, orchards, and post-harvest management varies by country (Pereira *et al.*, 2016).

The top guava-producing states in India are Uttar Pradesh, Madhya Pradesh, Bihar, Punjab, Haryana, West Bengal, and Gujarat. Uttar Pradesh leads the country with an annual production of 983.59 thousand tonnes, followed by Bihar with 776.75 thousand tonnes and Madhya Pradesh producing 434.41 thousand tonnes (NHB, 2023).

In Punjab, guava ranks as the second most cultivated fruit after citrus, covering an area of 8.2 thousand hectares with an annual yield of 183.4 thousand tonnes (NHB, 2023). The primary districts involved in guava farming in Punjab include Patiala, Ludhiana, Jalandhar, Muktsar Sahib, Sangrur, and Bathinda.

It originated in tropical America, from Mexico to Peru, and has become a commercial crop in Brazil, Mexico, China, Malaysia, Hawaii, Cuba, and India. The crop has acquired popularity due to its excellent nutritional content, lovely aroma, delicious taste, and affordable price—substantial importance in our country, particularly Karnataka (Singh *et al.*, 2017).

Guava, a nutritional powerhouse, offers an impressive array of essential nutrients per 100 grams, as outlined by Kumari *et al.* in their 2013 study. It contains approximately 14-17 grams of carbohydrates, including 8-11 grams of sugar and 5-7 grams of dietary fiber, beneficial for digestive health. Guava's fat content falls between 0.95 and 1.2 grams, while it offers 2.5-3.0 grams of protein, aiding in muscle repair and growth. Additionally, guava is a rich source of vital minerals, including 0.26 milligrams of iron, 18 milligrams of calcium, 22 milligrams of magnesium, 40 milligrams of phosphorus, and a notable potassium content of 417 milligrams, with minimal sodium at 2 milligrams. Furthermore, guava is packed with various vitamins, such as Vitamin A equivalent (31µg), Vitamin B6 (0.11mg), beta-carotene (374µg), folate (Vitamin B9) (49µg), thiamine (Vitamin B1) (0.067mg), choline (7.6mg), riboflavin (Vitamin B2) (0.04mg), Vitamin C (228.3mg), niacin (Vitamin B3) (1.084mg), Vitamin K (2.2µg), and pantothenic acid (Vitamin B5) (0.45mg). Notably, it contains a

significant amount of lycopene, providing 5204 micrograms per 100 grams, contributing to its antioxidant properties. These nutritional attributes highlight the potential health benefits associated with incorporating guava into one's diet. Guava, a nutritional powerhouse, offers an impressive array of essential nutrients per 100 grams, as outlined by Kumari et al. in their 2013 study. It contains approximately 14-17 grams of carbohydrates, including 8-11 grams of sugar and 5-7 grams of dietary fiber, beneficial for digestive health. Guava's fat content falls between 0.95 and 1.2 grams, while it offers 2.5-3.0 grams of protein, aiding in muscle repair and growth. Additionally, guava is a rich source of vital minerals, including 0.26 milligrams of iron, 18 milligrams of calcium, 22 milligrams of magnesium, 40 milligrams of phosphorus, and a notable potassium content of 417 milligrams, with minimal sodium at 2 milligrams. Furthermore, guava is packed with various vitamins, such as Vitamin A equivalent (31µg), Vitamin B6 (0.11mg), beta-carotene (374µg), folate (Vitamin B9) (49µg), thiamine (Vitamin B1) (0.067mg), choline (7.6mg), riboflavin (Vitamin B2) (0.04mg), Vitamin C (228.3mg), niacin (Vitamin B3) (1.084mg), Vitamin K (2.2µg), and pantothenic acid (Vitamin B5) (0.45mg). Notably, it contains a significant amount of lycopene, providing 5204 micrograms per 100 grams, contributing to its antioxidant properties. These nutritional attributes highlight the potential health benefits associated with incorporating guava into one's diet.

Guava is commercially propagated using vegetative and direct seeding methods with commercial-grade fruits. Plants can only reproduce by vegetative progeny. Guava can be propagated vegetatively through budding, air layering, stooling, and inarching (Nagata & Yukita, 2023, Singh *et al.*, 2019) Direct seedling produces non-uniform progeny because of character segregation and recombination. Plants produced by seeds mature later than those propagated through cuttings. (Maan *et al.*, 2023) suggest that clonal propagation of guava can ensure uniformity and high-quality fruit production. Guava orchards require true-to-type planting material to produce high-quality and abundant fruits.

Propagation by cuttings offers advantages such as ease of operation, minimal production costs, and easy reestablishment. Thus, this mode of propagation is convenient. And economically important. (Joshi,2024) . Exogenous auxin

administration improves stem-cutting rooting efficiency and quality. IBA, NAA, and NAd are often used as rooting ingredients.

Indole-3-butyric acid (IBA) is a synthetic auxin used in horticulture to promote root development in cuttings, including guava. IBA plays a crucial role in stimulating the formation of adventitious roots, particularly in semi-hardwood or hardwood cuttings where natural rooting hormones may be insufficient. When applied to the base of a cutting, IBA acts as a signaling molecule, triggering the initiation of root primordia and promoting cell division and elongation at the cutting's base. This hormone also helps to overcome the inhibitory effects of apical dominance, allowing for the development of a robust root system. Additionally, IBA enhances the production of root hairs, increasing the surface area for water and nutrient absorption, thereby improving the cutting's ability to establish itself in the soil. However, it is essential to apply IBA judiciously, as excessive concentrations can lead to adverse effects such as root deformation or inhibition of shoot growth. Proper dosage and application methods are critical to maximizing the rooting response while minimizing potential negative impacts. The strategic use of IBA can significantly enhance rooting success rates in guava cuttings, contributing to efficient propagation and the establishment of healthy guava plants.

Media types have a significant impact on cuttings' roots and vegetative growth. Growing media should be evaluated. The type of media employed affects rooting competence, making it an essential aspect of the propagation system. According to Farooq (2018), the rooting media directly impacts the quality and proportion of roots. A potting medium's biological and physicochemical properties impact plant and root growth (Abebe, 2017). Good growth media serves as a reservoir for plant nutrients, water retention, gas exchange, and plant anchoring (Galavi *et al.*, 2013).

The use of cocopeat, sphagnum moss, and vermicompost can have a significant impact on the rooting of guava cuttings. These organic amendments are vital in providing a favorable substrate environment for root development. Cocopeat, derived from coconut husks, offers excellent water retention capacity while promoting

aeration within the rooting medium. Its fibrous structure aids in moisture management, preventing waterlogging and ensuring adequate oxygen supply to developing roots. Sphagnum moss, known for its high water retention capacity and acidic pH, helps maintain optimal moisture levels around the cuttings, promoting root hydration and growth. Additionally, sphagnum moss contains natural antifungal properties, reducing the risk of root rot and other diseases during the rooting process. Vermicompost, a nutrient-rich organic fertilizer produced from earthworms, provides essential nutrients and beneficial microorganisms to the rooting medium. Its balanced nutrient composition stimulates root growth and vigor, while its microbial activity enhances nutrient availability and uptake by the developing roots. Furthermore, vermicompost contributes to the overall health of the rooting environment, fostering beneficial soil microbial communities that support root development. By incorporating cocopeat, sphagnum moss, and vermicompost into the rooting substrate, growers can create an ideal environment conducive to successful root initiation and establishment in guava cuttings. Further research into optimal substrate compositions and management practices can refine rooting protocols and improve propagation success rates in guava cultivation.

Zinc, an essential micronutrient, plays a crucial role in the rooting process of plants, including guava. Studies have indicated that zinc influences various physiological and biochemical processes associated with root development, impacting rooting efficiency. Zinc facilitates the synthesis of auxins, which are plant hormones crucial for root initiation and elongation. Additionally, zinc regulates enzyme activities in cell division and differentiation, vital processes during root formation. Furthermore, zinc plays a role in maintaining cell membrane integrity and function, ensuring optimal nutrient uptake and transport, essential for root growth. Adequate zinc levels correlate with improved root vigor and development in various plant species. However, excessive zinc concentrations can harm rooting, leading to toxicity symptoms such as stunted root growth and reduced rooting capacity. Therefore, maintaining an optimal zinc balance is essential for promoting healthy root development and enhancing rooting efficiency in guava and other plants. Further research into how zinc influences

rooting processes can provide valuable insights for optimizing rooting protocols and improving guava propagation practices.

The optimal timing for taking cuttings after applying zinc (Zn) to the mother plant depends on the chosen application method and desired outcomes. For basal application, 60 days is generally recommended to allow the plant to fully absorb and utilize the zinc, resulting in healthier and potentially faster-rooting cuttings. This period ensures sufficient time for zinc to move through the soil, be taken up by the roots, and be transported throughout the plant. Conversely, for foliar application, the timing is less clear-cut and can range from 30 to 60 days, depending on the severity of zinc deficiency and the plant's response. Taking cuttings after 30 days might capture peak zinc concentration in the leaves, mainly if deficiency signs were evident. However, waiting 60 days allows optimal zinc uptake from the soil, although the zinc benefit from foliar application might diminish by this time. Overall, prioritizing a basal application 60 days before taking cuttings is recommended for the best results, ensuring healthy cuttings with a higher potential for successful rooting. Additional considerations include plant species' sensitivity to zinc deficiency and the severity of the deficiency observed in the mother plant.

The condition of shed netting can significantly impact the rooting process of guava cuttings. Shed net structures are commonly used in horticultural settings to modify environmental conditions and protect plants. The shed net material's choice, density, and placement all play critical roles in influencing rooting outcomes. Properly designed shed netting can help regulate environmental factors such as light intensity, temperature, and humidity, creating an optimal microclimate for root development. By providing partial shade, shed netting can mitigate excessive sunlight exposure, which can stress cuttings and inhibit root formation. Additionally, shed netting can help maintain stable temperatures and humidity levels conducive to root initiation and elongation. However, inadequate shed netting, such as damaged or improperly installed structures, can compromise rooting success. Poorly maintained netting may fail to provide adequate shade or protection from harsh environmental conditions, leading to suboptimal rooting outcomes. Therefore, careful attention to the condition and maintenance of shed netting is essential to ensure favorable rooting conditions.

and promote the successful propagation of guava cuttings. Further research into the optimal design and management of shed net structures can enhance rooting efficiency and contribute to the development of sustainable guava propagation practices.

Studies on Performance of stem cutting under Different Growing Conditions as affected By Zinc Application on Guava Plants

- ☐ To compare the method of zinc application through foliar and basal application on root induction ability of the stem cutting.
- ☐ To find out the appropriate time of zinc application for rooting ability of the stem.
- ☐ To standardize suitable dose of zinc application for rooting ability of the stem.
- ☐ To compare the rooting ability of zinc applied stem cuttings with IBA treated stem cuttings.

REVIEW OF LITERATURE

The present investigation entitled **“Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants”** was carried out at the School of Agriculture Farm and Department of Horticulture, Lovely Professional University,

2.1 Effect of zinc on rooting of guava cutting.

Adequate zinc levels are essential for optimal root architecture. Zinc deficiency has been linked to reduced root length and biomass, negatively affecting the plant's ability to absorb water and nutrients (Cakmak, 2000).

Yamashita *et al.* (2006) found shorter, non-lignified cuttings yielded better rooting outcomes for Taiwan native strain mangoes. Zinc combined with auxin enhanced rooting, with 87.5% success using NAA and $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$. Higher concentrations led to decreased success.

Zinc is indispensable for several plant processes, including enzyme activation, protein synthesis, and growth hormone production. It is a structural component of various proteins and enzymes and is involved in the synthesis of chlorophyll and certain carbohydrates (Alloway, 2008).

Rahdari *et al.* (2010) investigated the impact of various concentrations of Zinc Sulphate, Indole butyric acid (IBA), Naphthaleneacetic acid (NAA), and their combinations on the rooting of semi-hardwood cuttings of *Aralia elegantissima*. They found that the highest rooting percentage occurred with 3000 ppm of ZnSO_4 , while the best root length was observed in cuttings treated with 2000 ppm of IBA. Additionally, the cuttings treated with 3000 ppm of ZnSO_4 exhibited the highest number of roots and dry weight of roots. Furthermore, the highest fresh weight was obtained with 3000 ppm of ZnSO_4 and with a combination of 1000 ppm of NAA and 1000 ppm of IBA.

Studies on citrus plants have demonstrated that Zn application enhances root and shoot growth, increases leaf chlorophyll content, and improves overall plant health. Zinc treatment in lemon seedlings resulted in better growth performance and higher nutrient uptake efficiency (Tandon & Tiwari, 2010)

Zinc is a crucial component of enzymes like carbonic anhydrase and superoxide dismutase. These enzymes help maintain cellular functions and protect against oxidative damage, which can otherwise impair root growth (Broadley *et al.*, 2012).

Zinc influences the biosynthesis of growth hormones such as auxins. Auxins are essential for cell elongation and division, especially in roots. Zinc deficiency can disrupt auxin production, leading to stunted root development (Marschner, 2012).

Soil microorganisms can influence zinc availability. Certain microbes can solubilize zinc, making it more accessible to plant roots. Research into the use of zinc-solubilizing bacteria offers promising avenues for improving zinc uptake in plants (Prasad *et al.*, 2012).

Somkuwar *et al.* (2013) investigated the impact of zinc application on the rooting success and establishment of Dogridge rootstock mother vines under nursery conditions. They found that zinc application improved rooting success and facilitated early bud sprouting, resulting in enhanced plant growth and increased leaf area.

Ahmed *et al.* (2014) demonstrated that zinc supplementation in guava cuttings increased root length and dry weight. This suggests that zinc plays a vital role in rooting through hormonal regulation and enzyme activity.

2.2 Effect of IBA on rooting of cuttings

Pandey and Upadhyay (1981) studied the effect of IBA at concentrations of 2000-2500 ppm with a bottom heat of 21°C. They reported 100% rooting in peach cuttings treated with IBA at both 2000 and 2500 ppm, with final survival rates of 80% and 68.7% respectively for each concentration.

Rathore (1984) observed the highest rooting rate of 70.90% in softwood cuttings of Chinese gooseberry treated with 5000 ppm IBA, compared to only 40% rooting in the untreated control.

Purohit and Shekharappa (1985) presented the findings of their experiment on pomegranate cutting rooting. They observed the highest rooting and survival percentage, along with an increase in the number and length of roots and shoots, when the cuttings were treated with 5000 ppm IBA using the quick dip method, surpassing treatments with 2500 ppm, 7500 ppm, and 10,000 ppm IBA.

Sulladamath (1985) discovered that basal and medium cuttings of pomegranate achieved 75% rooting when the base was soaked in 50 ppm IBA for 18 hours and 66% rooting with a quick dip in 500 ppm IBA for 20 seconds. Additionally, basal cuttings treated with 5000 ppm IBA induced a large number of primary roots and had the highest number of leaves per cutting.

Singh and Pande (1986) documented the highest survival percentage (77.5%) in hardwood cuttings of sweet lime treated with 1500 ppm IBA, followed by 1500 ppm NAA. They observed that IBA treatments were more effective compared to NAA. However, they noted that the establishment of cuttings was reduced beyond the concentration of 1500 ppm for both auxins.

Reddy and Singh (1987) reported the highest rooting percentage in hardwood cuttings of mango treated with 5000 ppm IBA, while wounding alone did not produce any response.

Sharma and Sharma (1987) conducted a study where hardwood and semi-hardwood cuttings of pomegranate were treated with IBA at a concentration of 4000 ppm, which showed enhancing effects on all root and shoot characteristics in both types of cuttings. Hardwood and semi-hardwood cuttings exhibited 69.52% rooting, respectively. Overall, the beneficial effects of IBA application remained significant, particularly in semi-hardwood cuttings, affecting parameters such as the length of main roots, shoot growth and survival percentage of rooted cuttings. However, in hardwood cuttings, improvements were observed in rooting percentage, survival, and root number, while root length, root diameter, and shoot growth decreased, possibly due to environmental conditions.

Ghosh *et al.* (1988) observed that treating pomegranate cuttings with 5000 ppm IBA resulted in maximum rooting success, with an 83.33% rooting rate.

Ozean, *et al.* (1990) examined the impact of plant growth regulators on cuttings of sour orange, trifoliate orange, and rough lemon cultivars. They noted the most favorable outcomes with 4000 ppm IBA resulting in 57.77% rooting for sour orange, 2000 ppm IBA resulting in 100% rooting for flying Dragon trifoliate orange, and 4000 ppm NAA for common trifoliate orange.

Reddy and Reddy (1990) conducted an experiment where hardwood cuttings of pomegranate cv. Bassian seedless were treated with IBA and NAA, each at 2500 ppm, either alone or in combination, applied in talc or in solution to basally wounded or intact cuttings. These treated cuttings were then planted in pots, which were either covered with polythene film or left open and placed in the shade. They found that treatment with IBA + NAA in talc resulted in the highest percentage of rooting in covered cuttings (55.40%). The highest number of roots per cutting (8.08) was obtained with IBA + NAA in solution on covered cuttings, while the highest mean root length (6.32 cm) was obtained with IBA solution on covered cuttings.

Sharma, *et al.* (1990) achieved optimal rooting and high survival rates (72%) in the litchi cultivars Shahi and China, with the highest survival rate reaching 74% when shoots received treatment with IBA at 2500 ppm, administered two weeks after ringing.

Sabbah, *et al.* (1991) discovered significant variations in root production among different clones of citrus stem cuttings in response to treatments with NAA and IBA. The lowest concentration of NAA (1000 ppm) and the highest concentration of IBA (3000 ppm) resulted in the highest rooting percentage (75%) across all selections.

Dhillon and Sharma (1992) observed that pomegranate cuttings treated with a low concentration of IBA at 100 ppm and soaked for 24 hours exhibited the highest root length.

Abd-El-Hamed *et al.* (1993) reported that cuttings of the plum cultivar 'Clymax' treated with IBA (500-2500 ppm), either alone or in combination with other chemicals, showed no rooting in the absence of IBA.

Kaundal, *et al.* (1993) conducted a study on hardwood cuttings of peach cultivars, including Flordasun, Shan-i-Punjab, Flordared, Sharbati, and Nemaguard, treated with various concentrations of IBA and Seradix B3. The rooting response varied from 25.4% to 38.6% in Flordasun, 15.4% to 43.2% in Shan-i-Punjab, 20.6% to 51.8% in Flordared, and 21.6% to 45.9% in Sharbati. Nemaguard did not respond to any tested concentrations of growth regulators. Among the treatments, IBA at 500 ppm showed the best rooting response for Flordasun, Shan-i-Punjab, and Flordared, while for Sharbati, IBA at 1500 ppm was optimal. Additionally, IBA at 1500 ppm resulted in the best plant height across all cultivars of peach, except for Flordasun, where 500 ppm IBA demonstrated the maximum effect on plant growth.

Ceonal *et al.* (1994) studied the effect of growth regulators on litchi cuttings. They observed that the survival rate of cuttings varied from 32% to 37% with IBA. Cuttings treated with 0.5% IBA and 0.5% NAA exhibited similar rooting percentages of 4.16% and 1.72%, respectively.

Hore and Sen (1994) investigated the interaction of a non-auxin compound with NAA in root regeneration in stem cuttings of water apple (*Syzygium javanica*). They discovered that when cuttings were taken in May and July, the best rooting occurred with PHB + 2500 ppm NAA, resulting in 96% and 98% rooting, respectively, compared to 40% and 46% for the control. They also noted that in July, Ferulic acid + 5000 ppm NAA yielded 98% rooting, which was similar to the result obtained with PHB + NAA.

Kumar *et al.* (1995) investigated the impact of IBA and PHB on lemon cutting propagation. Cuttings were treated with IBA at concentrations of 1500 ppm and 2000 ppm, combined with PHB at concentrations of 1000 ppm or 2000 ppm before planting in nursery beds. They observed that the combination of IBA at 2000 ppm with PHB at 2000 ppm resulted in the highest rooting percentage (55.55%). Additionally, 6000 ppm NAA was found to yield a rooting percentage of 44.44% for Rudidoux trifoliate orange.

Gautam and Negi (1997) observed that treating cherry cuttings with 2500 ppm IBA resulted in 68.9% rooting. This treatment also enhanced root growth, root diameter, and plant height.

Mukhtar *et al.* (1998) reported that the highest rooting percentage (93%) was achieved with the application of 4000 ppm IBA in softwood cuttings of guava.

Saroj and Pathak (1998) observed that among various species of Psidium, the longest roots were documented at lower concentrations (5000 ppm) of either IBA alone or in conjunction with NAA. However, a further increase in concentration (10,000 ppm) had a detrimental impact on rooting potential and subsequent establishment of rooted shoots under field conditions.

Mohammad, *et al.* (1999) found significant results in various parameters for hardwood cuttings of apples treated with 3000 ppm IBA. The treatment yielded the highest number of leaves per cutting, the shortest time to bud sprouting (15.00 days), the maximum number of shoots (3.00), the longest shoot length (8.00 cm), the longest root length (11.25 cm), and the best plant survival rate (78.67%).

Nath (2000) observed that apical shoots of lemon (*Citrus limon*) cv. Assam treated with IBA (1000, 2000, 3000, and 4000 ppm) and planted in two rooting media (sand and soil) showed significant results. Rooting and root characteristics were recorded 70 days after planting, and survivability of rooted cuttings was studied one month after replanting in a nursery bed. The highest percentage of rooting (98.5%) and survival (100%) were recorded for cuttings treated with 3000 ppm IBA in a sand medium, while untreated cuttings showed the lowest rooting and survival rates. Cuttings grown in sand with 3000 ppm IBA were significantly superior in the number of primary roots, root length, dry weight of roots, number of leaves, and shoot length per cutting. Higher concentrations of IBA (above 3000 ppm) showed an inhibitory effect on rooting and root characteristics.

Kishore, *et al.* (2001), found that in hardwood cuttings of kiwifruit, the application of IBA at 3000 ppm led to the highest development of fibrous roots (19.75) and secondary roots (18.48), along with new shoot growth measuring 12.47 cm.

Ercisli, *et al.* (2002) reported that the stem cuttings of Sour cherry cv. Kuthaya exhibited the highest rooting percentage (70%) when treated with 2000 ppm of IBA

Navjot and Kanlon (2002) observed that cuttings of pomegranate cv. Khandhari treated with 100 ppm IBA recorded the highest values for root number (32.72), root length (34.00 cm), plant height (49.79 cm), number of shoots (4.76), and shoot length (13.75 cm).

Attri and Singh (2003) observed that the highest survival rate (90%), along with a greater number of leaves (25.0), primary branches (6.60), and secondary branches (6.60), was documented in cherry cuttings treated with 1500 ppm IBA.

Muhammed *et al.* (2003) found that 2500 ppm was the optimal concentration of IBA for propagating GF-655 rootstock through cuttings in peaches.

According to Pandey *et al.* (2003), the plant growth regulator IBA at a concentration of 2000 ppm exhibited superiority in terms of cutting success percentage (84.00%), root growth, and survival percentage (96.66%) in citrus.

Prasad and Singh (2003) experimented to assess the impact of various concentrations of IBA on the rooting of semi-hardwood cuttings of pomegranate cv. "Jalore seedless". They found that the application of 200 ppm IBA significantly improved several growth parameters, including the percentage of rooted cuttings, plant height, dry weight of roots and shoots, as well as the number and length of roots. Specifically, treatment with 200 ppm IBA resulted in the highest values for plant height, number of branches, dry weight of roots, weight of top, number of roots, length of roots, and the percentage of rooted cuttings (78.8%).

Nag and Shukla (2005) found that hardwood cuttings of pomegranate cv. Ganesh, when treated with 2000 ppm IBA, demonstrated optimal rooting, shooting, and root growth, along with a high final survival percentage.

Ram *et al.* (2005) experimented to assess the effects of IBA (2500 and 5000 ppm) and p-hydroxybenzoic acid (PHB, 1500 ppm), applied alone or in combination, on the regeneration of stem cuttings of pomegranate cultivars Ganesh and Khandhari in a field setting. The highest numbers of sprouts and leaves were observed with the

combined application of 2500 ppm IBA and 1500 ppm PHB. Additionally, the number of days to flowering was minimized, while values for the diameter of the thickest shoot, the length of the longest shoot, the number of roots per cutting, and rooting and survival percentages were maximized with the combination of 5000 ppm IBA and 1500 ppm PHB.

Ullah *et al.* (2005) conducted a study on different types of guava cuttings and found that softwood cuttings treated with 1000 ppm IBA produced the highest number of roots (59.66) and the longest shoots (8.24 cm). Additionally, the application of 1000 ppm NAA to softwood and semi-hardwood cuttings resulted in the largest root size and the shortest time to sprouting (17.68 days), respectively.

Singh, *et al.* (2006) noted significant alterations in all root characteristics of fig (*Ficus carica*) with the application of IBA at 1500 ppm under a mist chamber, including the day of first sprouting (4.75 days), number of leaves per cutting (3.83), and number of roots per cutting (19.20).

Upadhyay and Badyal (2007) conducted trials on hardwood cuttings of pomegranate, which were subjected to quick dip treatments in IBA (1000, 2000, 3000, and 4000 ppm), NAA (100, 200, 300, and 400 ppm), and various combinations thereof (NAA 100 ppm + IBA 1000 ppm, NAA 100 ppm + IBA 2000 ppm, NAA 200 ppm + IBA 1000 ppm, NAA 200 ppm + IBA 2000 ppm). The findings indicated that cuttings treated with IBA at 2000 ppm exhibited the highest percentage survival rate at 81.33%, followed by 76.85% in those treated with NAA at 100 ppm + IBA at 2000 ppm. Moreover, IBA at 2000 ppm also yielded the best results in terms of root number, root length, and plant height.

Antumes, *et al.* (2008) observed that the highest success rate in rooting fig cuttings was achieved with the application of 100 ppm IBA.

Kumar, *et al.* (2008) documented that the highest rooting percentage, root length, fresh weight, and dry weight of roots were observed in cuttings treated with IBA at 1000 mg/l using the quick dip method in passion fruit cv. Kaveri.

Melgarejio, *et al.* (2008) discovered that hardwood cuttings of pomegranate exhibited the highest rooting percentage when treated with 1200 ppm IBA for 5 seconds before planting.

Reddy, *et al.* (2008) discovered that the highest survival percentage of rooted fig cuttings was achieved with the application of IBA at 2500 ppm in combination with PHB at 2000 ppm. Additionally, they noted that the use of 2500 ppm IBA significantly enhanced the rooting percentage.

Deb, *et al.* (2009), in their quest for rapid and accurate multiplication of lemon, employed semi-hardwood cuttings treated with various concentrations of NAA (1000, 1250, and 1500 ppm) and IBA (2000, 2500, and 3000 ppm) for 30 minutes using a chalk powder slurry. These treated cuttings were then transplanted into raised nursery beds containing sandy loam soil. After 75 days, different observations were made. The highest survival rate (89.83%), number of branches (5.08), leaves (34.30), and roots (35.66) were observed in the cuttings treated with IBA at 2500 ppm. Additionally, the highest leaf chlorophyll content (45.41 mg/100 g), stem diameter (10.64 mm), and root diameter (2.68 mm) were observed under the same treatment. Moreover, the greatest average root length (15.83 cm), maximum root dry weight (1.48 mg), and shoot dry weight (22.73 mg) were also recorded in the same treatment. Conversely, higher doses of IBA exhibited inhibitory effects on most of the observed characteristics. Higher values for most of the parameters were noted under NAA at 1250 ppm treatment.

Polat and Caliskan's 2009 study on pomegranate cuttings using 1,000 ppm Indole3-butyric acid (IBA) as a rooting hormone found that the highest rooting percentage was observed in 31-N-01, while the lowest in 31-N-05. The 1,000 ppm IBA treatment slightly increased the rooting percentage and root number, but not to a satisfactory level. The 31-N-01 type showed more favorable results in terms of root length. The study suggests that increasing the IBA dose could be beneficial.

Sharma, *et al.* (2009) noted that the highest rooting number and root length were achieved in hardwood cuttings of pomegranate treated with a combination of IBA at 500 ppm and Borax at 1%

Sharma *et al.* (2009) conducted experiments on the vegetative propagation of pomegranate (*Punica granatum* L.) through cuttings, a method known for its convenience and affordability in obtaining true-to-type, fully developed plants in a relatively short time frame. To enhance rooting and reduce mortality rates, the use of growth regulators and optimal cutting times have been standardized. It was observed that maximum rooting, root number, and root length were achieved with IBA at 500 ppm + Borax at 1%, for both semi-hard and hardwood cuttings. Additionally, the field survival of cuttings treated with IBA at 500 ppm + Borax at 1%, IBA at 300 ppm + Borax at 2%, and IBA at 5000 ppm remained at the highest levels. Notably, hardwood cuttings displayed a more favorable response to hormonal treatment compared to semi-hardwood cuttings.

Bhatt and Tomar (2010) experimented with Garhwal University Srinagar, India, to examine the effect of rooting hormones and modified growing conditions on the rooting characteristics of *Citrus aurantifolia* Swingle cuttings under valley conditions of Garhwal Himalaya. They found that cuttings treated with IBA 500 ppm performed best in all aspects, with open area growing conditions increasing cutting success rates.

Owais (2010) conducted a study on pomegranate to assess the rooting response of five pomegranate varieties to different concentrations of Indole Butyric Acid (IBA) and cutting age. The research revealed that the highest percentage of rooted cuttings was observed in Hmadee, Hmaree (70%), Zeklovee (69%), and Malesse (73%). In comparison, the lowest rooting percentage was recorded in Kndaree Hello (58%) and Kdree, Sfaree (49%) varieties. Zeklavee and Hmedee, Hmardee varieties exhibited more favorable results compared to other varieties when treated with IBA concentrations ranging from 6000 to 9000 ppm. This treatment led to higher percentages of rooted cuttings, increased number of roots per cutting, and enhanced root weight per cutting, regardless of whether semi-hardwood or hardwood cuttings were used.

Shukla *et al.* (2010) examined the effects of IBA, PHB, and boron on the rooting and shoot growth of hardwood stem cuttings of peach cv. Saharanpur Prabhat. The experiment included three levels of IBA (1000, 2000, 3000 ppm), one level of PHB (1000 ppm), boron (50 ppm), combinations of all IBA concentrations with PHB +

1000 ppm, all IBA concentrations with PHB 1000 ppm with 50 ppm of boron, and a control, replicated thrice in a completely randomized design. The results indicated that cuttings treated with 2000 ppm IBA + 1000 ppm PHB + 50 ppm B exhibited early sprouting (29.54 and 29.20 days), higher sprouting percentage (78.33 and 78.80%), increased number of shoots (4.43 and 4.77), larger sprout diameter (2.58 and 2.66 mm), increased number of leaves (28.35 and 29.64), longer (5.69 and 6.10 cm) and wider (1.95 and 2.01 cm) leaves, higher number of roots (9.96 and 10.25) with longest (9.80 and 9.96 cm) and thickest size (1.52 and 1.64 mm), more root formation zone (4.87 and 4.94 cm), better rooting (66.63 and 67.35%), and higher survival percentage (68.33 and 77.45%) during both years.

Dvin, *et al.* (2011) observed the highest rooting percentage when employing a concentration of 2500 mg/L of IBA in hardwood cuttings of Azayesh apple rootstock

Karimi (2011) discovered that the highest sprouting percentage was achieved with a concentration of 500 mg/L of IBA in hardwood cuttings of pomegranate.

Pires, *et al.* (2011) observed that the highest rooting percentage, fresh weight of roots, dry weight of roots, as well as fresh and dry weight of the tops, along with the number of shoots and leaves in cuttings of sour passion fruit and the Australian purple passion fruit were achieved when the cuttings were soaked for 2 minutes in a solution containing 500 ppm of IBA.

Pratima and Rana (2011) noted that the application of IBA at 5000 ppm significantly improved several roots and shoot attributes of kiwi fruit, including fresh weight and dry weight of roots, shoot length, and diameter, as well as fresh and dry weight of shoots.

Singh *et al.* (2011) investigated the impact of planting time and varying concentrations of IBA (Indole-3-Butyric Acid) on the rooting and vegetative growth of 'Ganesh' pomegranate cuttings during 2007-2008. Cuttings were treated with different IBA concentrations (0, 50, 100, and 200 ppm for a slow dip; 1000, 1500, and 2000 ppm for a quick dip) and planted at different times to assess their effects on sprouting rooting behavior, and overall plant growth. The treated cuttings exhibited synchronized root formation and enhanced shoot growth potential. Notably, IBA

concentrations of 100 and 2000 ppm proved to be the most effective in promoting rooting and stimulating shoot growth. Cuttings treated with 100 ppm IBA (slow dip) and 2000 ppm IBA (quick dip) and planted in January showed positive effects on sprouting percentage, rooting percentage, number of roots per cutting, length of longest root, root weight, plant height, and shoot girth. Additionally, cuttings planted in December also exhibited satisfactory sprouting results.

The study by Bemkaireima *et al.* (2012) examined the impact of different sizes and growth regulators on passion fruit cuttings under semi-controlled greenhouse conditions. Four levels of IBA (250, 500, 750, and 1000 ppm) were used, with three node cuttings performing better in various parameters. Four node cuttings showed better survival percentage, number of leaves, longest root, root diameter, and leaf area. 750 ppm was found to be the best concentration in many parameters.

Dvin *et al.* (2012) found that the highest rooting percentage (37.03%) and the greatest number of roots (11.33) were achieved with an IBA concentration of 2500 mg/L. However, the maximum root length (9.83 cm) was observed with an IBA concentration of 1500 mg/L in hardwood cuttings of the apple clonal rootstock cv. MM-111.

Damar *et al.* (2014) discovered that the combination treatment of PSB and 2000 ppm IBA resulted in significantly superior success rates in terms of cutting percentage, number of shoots per cutting, number of leaves per shoot, total number of leaves per cutting, root diameter, dry matter percentage of roots, number of roots per cutting, root length, and fresh weight of roots in pomegranate hardwood cuttings.

Sarrou *et al.* (2014) investigated the impact of cutting wounding and different concentrations of Indole-3-butyric acid (IBA) and Gibberellic acid (GA) on shoot-cutting rooting under mist conditions in *Punica granatum* L. cv. Wonderful. Their findings revealed that IBA had a beneficial effect on rooting percentages in both wounded and non-wounded cuttings. Optimal rooting occurred with very thin cuttings (3-4 mm in diameter). The rooting percentage (100%) and the number of roots per plant (15.2 ± 2.4) were positively influenced when the cutting was severed at an

internode. However, the combination of GA3 at 5000 mg with 1000 mg-1 of IBA concentration decreased root length.

Sivajit *et al.* (2014) conducted a study to identify the most suitable cuttings and IBA concentrations for fig propagation under open conditions. They found that basal cuttings showed the best results for rooting and survival percentage, as well as root and shoot parameters such as root and shoot length, number of roots and shoots, number of leaves, and fresh and dry weights of roots and shoots. Among the various IBA concentrations tested, 3000 ppm yielded the highest values for these parameters. Specifically, basal cuttings treated with 3000 ppm IBA exhibited superior performance across all metrics, including field survival percentage of rooted cuttings. Conversely, the shortest time to first sprouting was observed in apical cuttings treated with 3000 ppm IBA. The least favorable results for rooting, shooting, and field establishment were recorded in apical cuttings treated with 1000 ppm IBA. Therefore, for optimal fig propagation in open conditions, basal cuttings treated with 3000 ppm IBA are recommended.

Singh (2014) observed that treating hardwood cuttings of pomegranate (*Punica granatum* L.) cv. Ganesh with 5000 ppm IBA resulted in the maximum number of sprouts per cutting (7.33), average sprout length (20.53 cm), average number of leaves (25.33), percentage of rooted cuttings (73.33%), number of primary roots (29.26), and average root length (24.88 cm).

Kumar *et al.* (2015) observed that treating guava cuttings with IBA at 3000 ppm significantly increased rooting percentage compared to untreated controls.

Kaur (2015) observed that treating hardwood cuttings of peach cv. Shan-i-Punjab with 3000 ppm of IBA for 1-2 minutes significantly reduced the number of days to sprouting. This treatment also resulted in the highest sprouting percentage, survival percentage, average number of roots, length of the main root, root girth, root weight, plant height, plant girth, number of branches, number of leaves, and leaf area.

Raut *et al.* (2015) studied the effects of two types of cuttings (semi-hardwood and hardwood) and various IBA concentrations (50, 100, 200, 2500, 5000 ppm, and control) on pomegranate propagation. The results from three years of pooled data

revealed that hardwood cuttings exhibited the highest sprouting percentage (72.62%) and success rate (52.42%). Additionally, hardwood cuttings showed the greatest shoot length (21.50 cm), root length (20.30 cm), number of shoots (20.87), number of leaves (66.45), and number of roots per cutting (26.34). Among the different IBA levels, IBA at 5000 ppm resulted in the highest success percentage (74.24%), number of leaves per cutting (80.72), and root length (22.80 cm). However, IBA at 2500 ppm recorded the highest sprouting percentage (75.25%), shoot length (25.55 cm), number of shoots per cutting (28.33), and number of roots per cutting (31.59) in pomegranate.

Seran and Thiresh (2015) conducted a study to determine the optimal concentration of IBA for establishing dragon fruit stem cuttings. Stem cuttings were dipped in various concentrations and planted in polythene bags. The results indicated that cuttings treated with 8000 ppm IBA exhibited the most robust root growth, while those dipped in a concentration of 6000 ppm showed higher shoot length, fresh weight, and dry weights. Consequently, the study concluded that 6000 ppm IBA is more effective for the establishment of dragon fruit cuttings.

Singh and Bahadur (2015) highlighted that vegetative propagation of phalsa (*Grewia subinaequalis* L.) through cuttings is a convenient and cost-effective method to obtain fully developed plants in a shorter time frame. To enhance rooting and reduce mortality, the use of growth regulators and optimal establishment times for cuttings have been standardized. It was observed that hardwood cuttings treated with a solution of IBA at 400 ppm and NAA at 200 ppm, through a 24-hour dipping process, exhibited maximum rooting, root number, and root length. Moreover, the field survival rate of plants propagated from hard wood cuttings treated with IBA at 400 ppm and NAA at 200 ppm, as well as IBA at 100 ppm and IBA at 400 ppm, was found to be the highest.

Kaur and Kaur (2016) revealed in their pomegranate trial that the combination of 1000 ppm IBA and 750 ppm PHB produced the best results. This treatment achieved the highest percentage of sprouted cuttings (86.40%), the highest survival percentage (86.73%), and the greatest number of shoots (7.71) with an average shoot diameter of 1.29 mm. Additionally, it resulted in the highest number of leaves (126.00), total leaf

area (259.48 cm²), the most roots (24.65), the longest root length (15.40 cm), and the greatest root weight (2.4 g).

Kaur *et al.* (2016) investigated the rooting ability of pomegranate cuttings in response to treatments with IBA, PHB, and their combinations. The study was conducted in both August and January using uniform-sized cuttings of pencil thickness, 20 cm long, taken from healthy pomegranate plants. The growth regulators (IBA and PHB) were applied using a quick dip method for one minute. The results showed that the treatment with 1000 ppm IBA and 750 ppm PHB yielded the highest percentage of sprouted cuttings (85.45%), survival percentage (85.88%), number of roots (18.58), root length (11.13 cm), and root weight (1.80 g).

Kareem *et al.* (2016) effectively rooted softwood cuttings of the Gola variety of guava using a quick dip method in a solution containing indole-3-butyric acid (IBA). Their findings revealed a notable positive influence of various IBA concentrations on the establishment of guava plants. Notably, the concentration of IBA at 4000 ppm demonstrated superior outcomes across multiple parameters, including days to sprout, sprouted cuttings, sprouting percentage, average number of roots per cutting, average root length, and survival percentage. This method holds promise for commercial propagators seeking to enhance the development of robust root systems in guava cuttings.

Khan *et al.* (2016) observed that treating guava cuttings with 4000 ppm IBA resulted in the earliest sprouting (22.0 days) and the highest sprouting percentage (68.22%). The treatment also produced the longest average root length (31.65 cm), the highest number of sprouted cuttings (40.11), the greatest survival percentage (57.82%), and the highest average number of roots per cutting (31.65).

Mewar *et al.* (2016) conducted a study to explore the propagation potential of wild fig (*Ficus palamata Farsk*), a widely distributed edible wild fruit plant in Uttarakhand, using stem cuttings. Propagating wild fig through stem cuttings is a simple technique but requires specific treatments, such as the application of auxins, and suitable planting seasons. The study aimed to identify the ideal concentration of Indole Butyric Acid (IBA) and the best planting time. A randomized block design with three

replications was employed, testing various concentrations of IBA (3000, 6000, 9000 ppm, and a control) and two planting times (February and July). Parameters assessed included the number of sprouted cuttings, sprouts per cutting, percentage of rooted cuttings, root count per cutting, length of the longest root, and survival rate of cuttings. The findings revealed that cuttings treated with 6000 ppm IBA planted in July performed the best, achieving the highest values across all parameters, including the maximum survival rate of cuttings.

Panda and Bhushon (2016) investigated the effects of different rooting hormones on hardwood cuttings of pomegranate cv. Dholka, sourced from ten-year-old mother plants. The treatments included various concentrations of IBA (200, 300, 400, and 500 ppm), NAA (200, 300, 400, and 500 ppm), combinations of IBA and NAA (200 ppm each, 300 ppm each, and 500 ppm each), and a control treated with distilled water. The cuttings were planted in August. The results showed that the treatment with 200 ppm IBA combined with 200 ppm NAA resulted in the highest rooting percentage, the greatest number of roots per cutting, the longest roots, and the shortest time to root initiation compared to the untreated control. This treatment also produced the best shoot characteristics, including the highest sprouting percentage and the longest individual sprouts, followed by treatments with 200 ppm IBA alone and 200 ppm NAA alone. The combination of 300 ppm IBA and 300 ppm NAA led to faster root initiation and higher rooting percentages. Overall, these treatments significantly enhanced the survival and growth of pomegranate cv. Phule Arakta cuttings.

Rajkumar *et al.* (2016) studied the effect of growth regulators IBA concentration and medium efficiency on root and shoot development in pomegranate cv. Phule Arakta stem cuttings. They found that IBA at 2500 ppm and vermiculite substrate was the most effective treatment for enhancing the establishment, survival, and growth of the cutting, with maximum rooting and survival percentages.

Seiar (2016) examined the impact of different concentrations of Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) on the rooting and growth performance of semi-hardwood pomegranate cuttings. The cuttings, measuring 20 to 30 cm in length, with 4 to 5 nodes and a thickness ranging from 0.75 to 1.0 cm, were obtained from healthy twigs and treated for 8 hours with varying combinations of IBA (500, 1000,

and 1500 ppm) and NAA (500, 1000, and 1500 ppm). The findings revealed that the combination of 1500 ppm IBA + 1500 ppm NAA resulted in the highest sprouting percentage (68.00%), rooting percentage (60.40%), number of sprouts (2.09), sprout diameter (0.59 mm), root length (18.9 cm), and root diameter (1.62 mm). Furthermore, cuttings treated with 1500 ppm IBA + 1000 ppm NAA showed the longest sprouts (34.50 cm), the highest count of primary roots (10.30) and secondary roots (62.70), as well as the greatest fresh weight of sprouts (9.03 g), dry weight of shoots (4.66 g), fresh root weight (2.70 g), and dry root weight (1.63 g) per cutting.

Soni *et al.* (2016) studied the effects of different rooting media on hardwood and semi-hardwood guava cuttings in a net house environment. They found that treating the cuttings with 3000 ppm IBA resulted in high survival rates, with 33.09% for hardwood cuttings and 36.63% for semi-hardwood cuttings. The same IBA treatment also produced the longest shoots, measuring 7.76 cm in softwood cuttings and 10.91 cm in semi-hardwood cuttings. The study concluded that this technique produces true-to-type plants suitable for high-density planting.

Chater *et al.* (2017) evaluated rooting percentage and vegetative growth attributes of twelve pomegranate cultivars using basal in a dip in a gel formulation of 3 g/l-1 Indole-3-butyric acid (IBA). The study found that the concentration of IBA affected rooting percentage and growth attributes. Ambrosia rooted best with 3 g/l-1 IBA, while Green Globe rooting was similar. The plant of wonderful had significantly more green leaf area. Stem diameter did not affect rooting.

Ghosh *et al.* (2017) conducted a study to assess the effects of different concentrations of IBA and NAA on the rooting and shooting of hardwood cuttings of Phalsa. The experiment, carried out under the AICRP on tropical fruit crops, followed a Completely Randomized Design (CRD) with three replications. The findings revealed that hardwood cuttings treated with 200 ppm IBA, by immersing them in the solution for 24 hours, achieved the highest rooting percentage (70.55%), root number (40.85), and root length (27.47 cm). Moreover, plants derived from hardwood cuttings treated with 200 ppm IBA exhibited the best field survival rate (37.82%), followed by those treated with 200 ppm NAA (30.47%).

Kabir *et al.* (2017) conducted a trial on the vegetative propagation of *Punica granatum* using stem cuttings in a non-mist propagation setup in Bangladesh. The results demonstrated that the highest rooting percentage (70%), longest root length (11.75 cm), greatest root number (32), maximum root diameter, and highest survival percentage (73.5%) were achieved with the application of 0.4% IBA. This low-cost, non-mist propagation method proved that 0.4% IBA treatment is highly effective for the mass production of planting stocks.

Kamboj *et al.* (2017) conducted a trial to study the effect of Indole butyric acid (IBA) on the rooting and vegetative parameters of pomegranate (*Punica granatum* L.) at D.A.V. College, Jodhpur, India. The results indicated that cuttings treated with 1000 ppm IBA showed the highest average diameter, leaf number, root number per plant, root length, and root weight.

Kumari *et al.* (2017) investigated the effects of different concentrations of IBA (500 ppm, 1000 ppm, 1500 ppm, and control) on the stem cuttings of *Punica granatum* L. cv. Ganesh used the quick dip method. The results showed that the 500 ppm IBA treatment produced the highest percentage of sprouted cuttings (71.0%), the lowest percentage of unsprouted cuttings (15.5%), and the lowest percentage of dead cuttings (13.3%). Additionally, this treatment resulted in the highest number of sprouts per cutting (9.10), an average sprout length of (19.22 cm), an average sprout diameter of (0.36 mm), and the highest number of leaves and roots per cutting (66.81). The percentage of rooted cuttings was 69.14%, with the number of primary roots per cutting at (40.03), the length of the longest root per cutting at (27.88 cm), and the diameter of the thickest root per cutting at (0.22 mm). The fresh weight of roots per cutting was (1.77 g), and the dry weight of roots per cutting was (1.02 mg).

Dahale *et al.* (2018) experimented to assess the effects of plant growth regulators on the rooting and survival of hardwood cuttings in Fig. The findings revealed that the combined treatment of 1000 ppm IBA + 1000 ppm NAA resulted in the highest shoot growth, root growth, rooting percentage, and survival percentage. Specifically, this treatment achieved 58.66% rooting and 82.50% survival of rooted cuttings, compared to 32.80% rooting and 64.26% survival in the control group.

Hakim *et al.* (2018) studied the effects of bio-fertilizers and auxins on the growth and rooting of pomegranate (*Punica granatum* L.) cuttings, specifically the Bhagwa and Ruby cultivars. The results showed that early sprouting (8.60 and 7.80 days), number of sprouted cuttings (18.33 and 17.67), longest root length (39.73 and 41.53 cm), number of leaves (41.67 and 44.60), fresh weight of shoots (10.80 and 12.60 g), dry weight of shoots (5.80 and 6.60 g), number of primary roots (11.67 and 10.73), number of secondary roots (58.60 and 54.67), root length (27.56 and 25.80 cm), fresh weight of roots (2.56 and 2.75 g), and dry weight of roots (1.62 and 1.85 g) were significantly highest in both cultivars Bhagwa and Ruby with the application of 1500 ppm IBA + 1500 ppm NAA. Additionally, the number of sprouts (3.07) and sprout diameter (3.16 mm) were highest in cv. Bhagwa with the treatment of 1500 ppm IBA + 1500 ppm NAA + PSB + PGPR. Conversely, all the mentioned parameters were significantly lower in the control group.

Kumari *et al.* (2018) studied the effects of various plant growth regulators on the rooting of hardwood grape cuttings, using IAA at concentrations of 100, 300, and 500 ppm, IBA at 1000, 2000, and 3000 ppm, GA3 at 50, 100, and 150 ppm, and a control. The results showed a significant influence of these treatments on most shoot and root characteristics of the cuttings. After 90 days, the treatment with 2000 ppm IBA yielded the highest values for several parameters, including the number of leaves (21.6), the average number of buds per cutting (9.93), the average number of roots per cutting (30.54), the average root formation zone (29.74 cm), the length of the longest root (28.24 cm), and the thickness of the thickest root (1.78 mm). These results were closely followed by the treatment with 3000 ppm IBA. The control treatment produced the least favorable results. Therefore, the application of 2000 ppm IBA was found to be the most effective for maximizing rooting, growth, and success of grape cuttings, with 3000 ppm IBA being the next best treatment.

Mehta *et al.* (2018) investigated the impact of different concentrations of IBA (500 ppm, 1000 ppm, and a control) on rooting in pomegranate (*Punica granatum* L.). Their findings revealed that IBA at 1000 ppm resulted in the highest values for the number of sprouted cuttings (7.11), sprouts per cutting (4.00), leaves on new shoots (10.89), and the rooting percentage (71.11%). Similarly, the application of IBA at 500

ppm recorded the highest values for the number of sprouted cuttings (7.33), sprouts per cutting (4.66), the length of the longest sprout (7.28 cm), leaves on new shoots (10.66), and the rooting percentage (73.33%).

Narula and Kaur (2018) conducted an experiment involving ten treatments of IBA and PHB, including a control, replicated three times in a randomized block design. Uniform-sized cuttings (40 per replication) were treated with various concentrations of growth regulators using either a slow dip method (24 hours) or a quick dip method (2 minutes), and then planted on beds measuring 1m×1m with 20 cuttings per bed. The results indicated that IBA at 2000 ppm with a quick dip significantly enhanced shoot and root characteristics in cuttings, yielding a maximum shoot length of 16.87 cm, average shoot girth of 0.46 cm, shoot number of 4.22, fresh shoot weight of 6.82 g, dry shoot weight of 1.43 mg, leaf number of 154.28, average leaf area of 305.79 cm², root number of 44.90, average root length of 10.88 cm, longest root length of 13.5 cm, fresh root weight of 1.52 g, and dry root weight of 1.09 g. Meanwhile, cuttings treated with a slow dip of IBA at 150 ppm showed the highest survival percentage (77.00%), percentage of rooted cuttings (74.33%), and sprouting percentage (75.17%). Treatment T3 was comparable to treatment T6 (IBA 2000 ppm), achieving a survival percentage of 70.67%, 64.17% of rooted cuttings, and a sprouting percentage of 70.67%.

Poudel, *et al.* (2018) investigated the impact of Indole-3-Butyric Acid (IBA) on pomegranate propagation through stem cuttings in a poly-house environment at the horticulture farm of Agricultural Research Station, Pakhribas. The experiment involved five different concentrations of IBA (3000, 6000, 9000, 12000 ppm) applied to hardwood stem cuttings of pomegranate. Throughout the study, data were collected on the success rate of the cuttings, the number, and length of roots, as well as the fresh and dry weights of the roots. The varying concentrations of IBA influenced the rooting success of the hardwood cuttings. The treatment with 9000 ppm concentration of IBA exhibited the highest number of sprouts per cutting (4.1), number of roots per cutting (14.92), fresh weight of roots (1.04g), and dry weight of roots per cutting (0.68 g), while the longest root (10.65 cm) was observed in the treatment with 12000

ppm concentration of IBA. Notably, the experiment demonstrated that the 9000 ppm concentration of IBA resulted in the highest success rate of 67.5%.

Prakash *et al.* (2018) examined the effects of different plant growth regulators on the rooting and sprouting of guava stem cuttings under mist chamber conditions. They applied Indole-3-Butyric Acid (IBA), Indole-3-Acetic Acid (IAA), and Naphthalene Acetic Acid (NAA) to softwood, semi-hardwood, and hardwood cuttings. The findings revealed that softwood cuttings treated with 4000 ppm IBA achieved the highest sprouting percentage (76.66%) and the greatest number of leaves (25.80) at 90 days after planting. Softwood cuttings were identified as the most effective explants for rapid multiplication.

Rani *et al.* (2018) investigated the impact of IBA (Indole-3-butyric acid) on terminal cuttings of Guava cv. Taiwan Pink. Their findings indicated that a concentration of 3000 ppm IBA yielded the most favorable results, including the highest rooting percentage, shoot dry weight, number of leaves, leaf area, chlorophyll content, and survival rate of the cuttings.

Yasir Ali (2018) experimented on guava cuttings using various concentrations of IBA to evaluate their effects. The study found that a concentration of 2000 ppm IBA resulted in the highest survival rate of the cuttings, while a concentration of 4000 ppm IBA led to the highest rooting percentage in guava stem cuttings.

Dhand et al. (2019) conducted an experiment to evaluate the effects of IBA and sucrose on the performance of pear cuttings (cv. Patharnakh). The study involved applying different concentrations of IBA (1000, 1500, 2000, 2500, and 3000 ppm) and sucrose (1000, 1500, 2000, 2500, and 3000 ppm) using the quick dip method, along with a control group. The results indicated that the application of 2500 ppm IBA produced the most favorable results, including the shortest time to first sprouting (23.15 days), highest sprouting percentage (69.72%), and survival percentage (47.29%). Furthermore, cuttings treated with 2500 ppm sucrose recorded the highest number of roots per cutting (5.00) and the longest root length (11.50 cm). The maximum number of shoots per cutting (4.66) and the thickest average shoot diameter (2.11 mm) were also observed in cuttings treated with sucrose at 2500 ppm.

Mahmood and Altememy (2019) studied the influence of IBA on rooting percentages in four pomegranate varieties—Salimi, Hlo, Khadrawi, and Wonderful—and its effectiveness in enhancing shoot and root development while shortening the nursery period. The experiment included three IBA concentrations (0, 2000, and 4000 mg.L⁻¹) and was arranged in a randomized complete block design (RCBD) with three replications, each consisting of five cuttings. The results demonstrated that cuttings treated with 4000 mg.L⁻¹ of IBA showed significant improvements in rooting percentage, root number and length, root dry weight, shoot length, leaf number, and the dry weight of vegetative parts compared to the other treatments. Among the varieties, the Salimi cultivar outperformed the others in terms of both vegetative growth and root development. The responsiveness to IBA varied across the varieties, with the Salimi variety treated with 4000 mg.L⁻¹ achieving the highest performance, followed by the Hlo variety.

Malakar *et al.* (2019) developed a method to enhance the quality of planting material in acid lime cuttings. Their study revealed that treating hardwood cuttings of Cv. Kagzi lime with 500 ppm IBA resulted in significant improvements in rooting characteristics. Specifically, they observed the highest number of primary roots (11.10), lengthy roots (15.47 cm), and a rooting percentage of 44.44%.

Mejury *et al.* (2019) conducted a study to explore the influence of indole-3-butyric acid (IBA) hormone concentration and media on the rooting of *Duranta erecta* from tip cuttings in greenhouse conditions. The results indicated that there was no interaction between IBA concentration and media for all measured parameters. The optimal concentration was determined to be 5000 ppm, while pine bark demonstrated the highest levels of survival and shoot number. However, media type did not affect root number, root length, or shoot number.

Al-Jabbari *et al.* (2020) evaluated the rooting performance of two pomegranate varieties: Salakhani, a local variety from Iraq, and Zivzik (*Punica granatum* L.), a local variety from Siirt. The study investigated the influence of different concentrations of Indole Butyric Acid (IBA) (0, 1000, 2000, 4000, and 6000 mg/L) on rooting. The findings showed that IBA at 4000 ppm yielded the best results in terms of shoot number, leaf number, and root length. Additionally, a concentration of 6000

ppm was found to be the most effective for improving survival and rooting rates. For root number alone, 1000 ppm emerged as the optimal hormone dose among the treatments tested.

Kiruthika et al. (2020) studied the impact of rooting hormones and auxin concentrations on the rooting and growth characteristics of the mulberry (*Morus indica* L.) variety 'V1' using Mini-clonal technology. The experiment involved the application of two hormones, Indole-3-Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA), at varying concentrations (1000, 2000, 3000, 4000, and 5000 ppm), alongside a control, with four replications. Apical shoot cuttings were treated with these hormone concentrations and grown in a suitable rooting medium under greenhouse conditions. Key parameters, including rooting percentage, the number of roots per plant, root length (cm), and the number of leaves per plant, were assessed on the 90th day. The results indicated that IBA at 3000 ppm was the most effective in enhancing rooting and growth traits in mini cuttings of mulberry.

Kumar and Singh (2020) investigated the propagation of Kagzi lime through hardwood cuttings, focusing on the influence of IBA and PHB on the regeneration of cuttings. Their findings indicated that treatment with 2500 ppm IBA and 1000 ppm PHB resulted in the most favorable outcomes, including the shortest time to sprouting (20.64 days), the highest number of sprouts per cutting (5.88), the highest sprouting percentage (17.68%), the longest sprout length (14.88 cm), the largest sprout diameter (3.28 cm), the greatest number of roots per cutting (42.02), the longest root length (2.24 cm), the thickest root diameter (6.24 mm), the highest percentage of rooted cuttings (70.12%), and the highest survival percentage (82.66%). Conversely, treatment with 2000 ppm IBA and 1000 ppm PHB resulted in the maximum number of leaves (21.02) and the longest leaf length (6.38 cm). The control treatment exhibited the least favorable results, with the longest time to sprouting (32.00 days), the fewest sprouts per cutting (3.64), the lowest sprouting percentage (11.28%), the shortest sprout length (7.85 cm), the smallest sprout diameter (1.98 cm), the fewest leaves per cutting (14.40), the shortest leaf length (4.10 cm), the narrowest leaf width (3.20 cm), the fewest roots per cutting (29.80), the shortest root length (1.10 cm), the

smallest root diameter (2.57 mm), the lowest percentage of rooted cuttings (48.02%), and the lowest survival percentage (48.26%).

Kumar *et al.* (2020) conducted an experiment using a factorial randomized block design (RBD) to evaluate the effects of different IBA treatments on pomegranate stem cuttings. The treatments included a control, IBA at 1000 ppm, IBA at 2000 ppm, IBA at 1000 ppm with 1% Boric Acid, and IBA at 2000 ppm with 1% Boric Acid. The results showed that stem cuttings treated with IBA at 2000 ppm combined with 1% Boric Acid exhibited significantly superior shoot and root growth. Conversely, the treatments with only IBA or Boric Acid resulted in comparatively poorer shoot and root development.

Sujin *et al.* (2020) observed that the treatment of IBA at 3000 ppm resulted in significantly higher rooting percentage (89.62%), number of roots per cutting (12.52), root length (13.51 cm), fresh weight of roots (1.96 g), and dry weight of roots (73.88 mg). Conversely, the control exhibited the lowest root parameters. Furthermore, various shoot parameters including days required for bud sprouting (14.08), number of sprouts per cutting (3.22), fresh weight of shoot (4.17 g), dry weight of shoot (1.52 mg), survival percentage of rooted cuttings (90.49%), and length of shoot (11.15 cm) were observed to be maximum in the hardwood cuttings treated with IBA at 3000 ppm compared to the control. Therefore, it can be concluded that the growth regulator IBA at 3000 ppm yielded the best performance based on both root and shoot parameters when compared to other treatments.

Sujin *et al.* (2020) conducted a study to assess the impact of the growth regulator IBA at a concentration of 3000 ppm on the rooting parameters of hardwood cuttings. The research found significant enhancements in rooting percentage, number of roots per cutting, root length, fresh weight, and dry weight of roots when compared to the control group. Moreover, the highest shoot parameters were observed in the hardwood cuttings treated with IBA. These findings suggest that IBA at 3000 ppm exhibited superior performance in terms of both root and shoot parameters.

Rajamanickam *et al.* (2021) investigated the impact of various IBA concentrations on rooting in guava softwood cuttings. Nine different IBA concentrations were tested,

and the results indicated that cuttings treated with a 3000 ppm IBA solution exhibited the highest values across all measured traits. This finding suggests that an IBA concentration of 3000 ppm is a promising method for guava seedling propagation.

Reo *et al.* (2021) conducted a trial to assess the effect of plant growth hormones on the rooting ability of pomegranate cuttings. This study was carried out in the Division of Fruit Science block at Sher-e-Kashmir University of Agriculture Science and Technology of Kashmir. The experiment consisted of five concentrations of IBA (0, 2000, 3000, 4000, and 5000 ppm) and ten pomegranate varieties (Chawla, Nabha, Khandhari, Kabuli, Ichakdana, Bhagwa, Arakta, Muskat, Mridula, P-23, and Jodhpur Red) arranged in a randomized complete block design with five replications. The results revealed significant effects of different concentrations of IBA and varieties on rooting and other root growth parameters. The highest percentage of rooting was observed when cuttings were treated with 5000 ppm IBA across all varieties, with Chawla recording the highest rooting percentage (62.24%) compared to other varieties. Regarding varietal performance, Chawla, Nabha, and Khandhari Kabuli demonstrated significant results concerning all root parameters. The study concluded that cuttings treated with 5000 ppm IBA exhibited superior results compared to other treatments.

Singh *et al.* (2021) conducted an experiment to evaluate the influence of IBA concentrations and hardwood cutting lengths on the rooting performance of pomegranate. The study revealed that the application of 3000 ppm IBA combined with a cutting length of 25 cm resulted in the highest values for the number of roots per cutting (25.57), root fresh weight (1.24 g), root dry weight (0.79 g), and rooting percentage (79.15%). In contrast, the maximum root length (24.53 cm) was observed when 3000 ppm IBA was applied to cuttings with a length of 50 cm.

Singh *et al.* (2021) conducted an experiment to evaluate the effects of IBA concentration and hardwood cutting length on the rooting performance of pomegranate. Their results indicated that treating 25 cm cuttings with 3000 ppm IBA yielded the best outcomes in terms of the number of roots per rooted cutting (25.57), root fresh weight (1.24 g), root dry weight (0.79 g), and rooting percentage (79.15%).

However, the greatest root length (24.53 cm) was observed in 50 cm cuttings treated with 3000 ppm IBA.

Anamika *et al.* (2022) evaluated the impact of plant growth regulators and cutting maturity on guava cuttings. The results demonstrated that semi-hardwood cuttings treated with 4000 ppm IBA exhibited superior bud emergence, sprouting, leaf emergence, number of leaves and branches, rooting percentage, root length, and overall survival percentage.

Raut *et al.* (2022) conducted a field experiment to assess the impact of various IBA levels on the nursery performance of dragon fruit cuttings. The study, conducted in Akola, employed a Completely Randomized Design (CRD) with six treatments. The findings revealed that dragon fruit stem cuttings treated with IBA, particularly at 2000 ppm, exhibited enhanced rooting, shooting, and survivability (95.87%). This indicates the commercial viability of using IBA for propagating dragon fruit under Akola conditions.

Reddy *et al.* (2022) explored the impact of varying IBA concentrations on the rooting of Guava softwood cuttings. Softwood cuttings were treated with different concentrations of IBA, and subsequent observations revealed notable improvements compared to untreated cuttings. Specifically, those treated with IBA exhibited reduced sprouting time, increased sprouting percentage, and enhanced survival rates. Remarkably, the optimal results across all parameters were observed in cuttings treated with IBA at a concentration of 3000 ppm. This suggests that IBA treatment at 3000 ppm offers a promising alternative for the multiplication of Guava seedlings.

Sarkar *et al.* (2023) demonstrated that *Psidium guajava* L. can be successfully propagated using stem cuttings from three-year-old plants. The cuttings, treated with different concentrations of auxins and rooted in black polybags, showed significant differences in rooting and growth based on IBA treatment. The highest root development was observed in cuttings treated with a 0.6% IBA solution, closely followed by those treated with a 0.8% IBA solution. Additionally, the maximum survival percentage was recorded in the cuttings treated with the 0.6% IBA solution.

MATERIALS AND METHODS

The present study entitled “**Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants**” was conducted in the experimental field of the Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara during the cropping season of 2021-2022 and the field research trial was again conducted in the next year of 2022-2023. A brief description of climate and edaphic conditions prevailing during the experiment period, fruit crop and material used whose experimental procedure followed, and technique in field and laboratory has been given in this chapter under the following heads:

3.1 Experimental site

Lovely Professional University, Phagwara, Punjab is situated at a latitude of 31.22°N and a longitude of 75.7°E, with an elevation of 234 meters above sea level.

3.2 Layout

The experiment was laid out in a Split plot design. There were 9 treatments with zinc sulfate. A total of 30 stem cuttings were taken in each treatment and replicated thrice. The details of the treatment are depicted below.

3.3 Experiment details

The experiment was laid out as per the split-plot design and the treatments were categorized as main and sub-treatment. The details of these treatments are given below:

3.3.1 Main treatments

The experiment was designed with pre-cutting and post-cutting treatments. Zinc Sulphate was applied as a pre-cutting treatment, while Indole butyric acid (IBA) was applied as a post-cutting treatment.

Pre-cutting treatment details: Zinc Sulphate was applied as pre-cutting treatment during the second week of May coinciding with a relatively dormant phase (pre-pruning stage) from a growth point of view. Zinc sulfate was provided to plants by foliar and basal application. The foliar spray of zinc sulfate was done with three different concentrations (0.25%, 0.50%, and 0.755) while the basal application was done in three different doses (50g/plant, 75g/plant, and 100g/plant).

Zinc Calculation in Zinc Sulfate Treatments: The zinc content in the zinc sulfate doses for treatments, with zinc constituting 33% of zinc sulfate, was sourced from the LPU store. For foliar application, the required amounts of zinc sulfate per tree were calculated as follows: 113.64 g for 0.25%, 227.27 g for 0.50%, and 340.91 g for 0.75%. For basal application, the zinc sulfate quantities per tree were determined as 151.50 g to supply 50 g of zinc, 227.27 g to supply 75 g of zinc, and 303.03 g to supply 100 g of zinc. These measurements ensured accurate zinc supplementation for the experimental treatments.

Post-cutting treatment details: Indole-3-butyric acid (IBA) was applied at concentrations of 5000 ppm and 10000 ppm along with the control group (untreated).

3.3.2 Sub-treatments

The sub-treatment includes the stage of taking cuttings viz., at 30 days and 60 days after the dormant stage for which the pre-cutting application date was taken as reference.

3.3.3 Details Experiment Conditions

The study was carried out under open field and shade net conditions. The treatments were systematically applied to evaluate their effects on rooting, and growth.

The experimental details can be summarised as below:

1.	Crop	:	Guava (<i>Psidium guajava</i> L.)
2.	Variety	:	Allahabad Safeda
3.	Design	:	Split Plot Design

4. Number of replications : 3
5. Main plot treatments
 - A) Method of application : 3
 - A₁: Pre-cutting foliar application of Zn
 - A₂: Pre-cutting basal application of Zn
 - A₃: Post-cutting Dipping of IBA
 - B) Concentration : 3 (Foliar - 0.25%, 0.50%, and 0.75%; Basal - 50g, 75g and 100g/tree; IBA - 5000 ppm, 10000 ppm, and No treatment)
6. Sub-plot treatments : 2
 - (C₁: 30 days after the dormant stage, and C₂: 60 days after the dormant stage)
7. Number of treatments : 18 (3×3×2)
8. Total cuttings : 1300
9. Plot size : 9.6 m X 1.6 m
10. Growing condition : Open field condition
Shed net condition
11. Fertilizer :
12. Irrigation :

Rationale of using Zn and IBA in the experiment

The concentrations of zinc and Indole-3-butyric acid (IBA) used in this study were selected based on a combination of previous research findings, crop-specific recommendations, and preliminary trials. Zinc was applied at 0.75% (foliar) and 75 g per plant (basal), concentrations that have been found effective in enhancing root development and overall plant vigor in guava and similar fruit crops (Sourati et al., 2022; Somkuwar *et al.*, 2013). These levels are within the optimal range reported in the literature, ensuring efficacy without risking phytotoxicity.

Similarly, the IBA concentration selected (5000/10,000 ppm) is widely recognized in propagation research for promoting rooting in semi-hardwood cuttings. It was chosen based on prior successful applications in guava and related species, where it consistently improved rooting percentage, root length, and survival rate IBA was used to compare the performance of guava cuttings treated with zinc application and those treated with IBA. Our objective was to develop alternative methods of guava propagation through stem cuttings without the use of IBA, as outlined in the problem statement.

These concentrations were finalized to achieve a balance between physiological effectiveness and practical applicability for field conditions, ensuring that the findings can be replicated and scaled by farmers and horticulturists.

3.3.4. Treatment combinations

Application methods	Concentration	30 days after dormant stage (C ₁)	60 days after dormant stage (C ₂)
Pre-cutting foliar application (A₁)	B ₁ (0.25%)	A ₁ B ₁ C ₁	A ₁ B ₁ C ₂
	B ₂ (0.50%,)	A ₁ B ₂ C ₁	A ₁ B ₂ C ₂
	B ₃ (0.75%)	A ₁ B ₃ C ₁	A ₁ B ₂ C ₂
Pre-cutting basal application (A₂)	B ₁ (50g/tree)	A ₂ B ₁ C ₁	A ₂ B ₁ C ₂
	B ₂ (75g/tree)	A ₂ B ₂ C ₁	A ₂ B ₂ C ₂
	B ₃ (100g/tree)	A ₂ B ₃ C ₁	A ₂ B ₃ C ₂
Post-cutting treatments by dipping (A₃)	B ₁ (5000 ppm)	A ₃ B ₁ C ₁	A ₃ B ₁ C ₂
	B ₂ (10000 ppm)	A ₃ B ₂ C ₁	A ₃ B ₂ C ₂
	B ₃ Control (Untreated)	A ₃ B ₃ C ₁	A ₃ B ₃ C ₂

Treatment Symbol	Treatment details
T₁	Zinc (0.25%) + 30 days after the dormant stage + field condition
T₂	Zinc (0.25%) + 60 days after the dormant stage + field condition
T₃	Zinc (0.50%) + 30 days after the dormant stage + field condition
T₄	Zinc (0.50%) + 60 days after the dormant stage + field condition
T₅	Zinc (0.75%) + 30 days after the dormant stage + field condition
T₆	Zinc (0.75%) + 60 days after the dormant stage + field condition
T₇	Zinc (50g/tree) + 30 days after the dormant stage + field condition
T₈	Zinc (50g/tree) + 60 days after the dormant stage + field condition
T₉	Zinc (75g/tree) + 30 days after the dormant stage + field condition
T₁₀	Zinc (75g/tree) + 60 days after the dormant stage + field condition
T₁₁	Zinc(100g/tree) + 30 days after the dormant stage + field condition
T₁₂	Zinc(100g/tree) + 60 days after the dormant stage + field condition
T₁₃	IBA 5000 ppm + 30 days after the dormant stage + field condition
T₁₄	IBA 5000 ppm + 60 days after the dormant stage + field condition
T₁₅	IBA10000 ppm + 30 days after the dormant stage + field condition
T₁₆	IBA 10000 ppm + 60 days after the dormant stage+ field condition
T₁₇	Control (Untreated)+30 days after the dormant stage +field condition
T₁₈	Control (Untreated) +60 days after the dormant stage +field condition

3.4 Preparing of rooting media and cuttings

Polybags were filled with a well-mixed growing medium consisting of garden soil, cocopeat, sphagnum moss, and vermicompost in equal proportions (1:1:1:1, v/v), supplemented with farmyard manure (FYM). Stem cuttings, ranging from 20 to 25 cm in length and each containing 3-4 viable buds, were harvested using secateurs from guava plants previously treated with varying levels of zinc sulphate solution. This treatment was applied approximately one month before the cuttings were taken. Each cutting received a clean, slanting cut at the base to optimize the root development surface area without causing damage to the bark.

3.5 Preparation of Zinc solution

zinc sulphate was dissolved in distilled water to prepare the zinc solution at the required concentration. The solution was carefully mixed until all the zinc sulphate dissolved completely. pH adjustments were made as needed. The prepared solution was stored in labelled containers and used according to experimental protocols, following safety precautions.

3.6 Preparation of IBA Solution

The IBA solution for different concentrations of 5000 ppm and 10000 ppm was reared by dissolving 5g and 10 g of IBA in a small quantity of 0.2 N NaOH solution and the volume in each concentration was made up to 1000 ml by adding distilled water.

3.7 Planting of cuttings

Cuttings were planted at various intervals following zinc application to evaluate their growth under different conditions. Initially, cuttings were taken 30 days after zinc was applied to either foliar or basal. These cuttings were then planted in poly bags filled with a well-mixed growing medium consisting of garden soil, cocopeat, sphagnum moss, and vermicompost in equal parts. A second set of cuttings was collected 60 days after zinc application and planted under the same conditions. To assess the effects of different growing environments, some cuttings were placed under a shade net with 75% light transmission, while others were grown in open field conditions. This

method allowed for a comprehensive analysis of how zinc application timing and growing conditions impact the performance and rooting success of guava stem cuttings.

3.8 Observation to be recorded.

3.8.1 Initial Stage (Before Rooting)

3.8.1.1 Callus formation.

Callus formation was assessed visually on stem cuttings after the experimental period. Each cutting's basal end was examined and scored on a scale from 0% to 100% based on the extent of callus formation.

3.8.2 Rooting Stage

3.8.2.1 Days to root initiation

The days taken to first root initiation were analyzed and recorded based on visual observation from one day after planting of cuttings

3.8.2.2 Rooting %

Rooting percentage data were collected by comparing the count of cuttings with developed roots to those without. The rooting percentage was determined by dividing the number of rooted cuttings by the total number of cuttings planted.

3.8.2.3 Number of primary roots

To record the primary number of roots, the planted cuttings were gently removed from the polybags and washed off with clean water to remove the adhered soil. Their applications were considered for each treatment. The number of primary roots per cutting was calculated manually, and the subsequent data was recorded.

3.8.2.4 Number of secondary roots

To record the number of primary roots, the planted cuttings were gently removed from the polybags and washed off with clean water to remove the adhered soil. Three replications were considered for each treatment. The number of secondary roots per cutting was calculated manually, and the subsequent data was recorded.

3.8.2.5 Length of primary roots (cm)

To measure the length of the primary root, each plant or cutting in the treatment groups had its primary root carefully selected. Using a ruler or calipers, the length of each primary root was measured from its tip to its base at the plant's stem, ensuring accurate placement and recording.

3.8.2.6. Length of secondary roots (cm)

To measure the length of the secondary root, each plant or cutting in the treatment groups had its primary root carefully selected. Using a ruler or calipers, the length of each primary root was measured from its tip to its base at the plant's stem, ensuring accurate placement and recording.

3.8.2.7 Diameter of primary roots (mm)

The diameter of the primary root from each cutting in each treatment was measured using vernier callipers, and the average diameter was calculated in millimetres.

3.8.2.8 Diameter of secondary roots (mm)

The diameter of the secondary root from each cutting in each treatment was measured using vernier callipers, and the average diameter was calculated in millimetres.

3.8.2.9 Fresh weight of primary roots (g)

The painted cutting was pulled out after 90 days of planting and washed off to remove the adhered soil. Then, the cuttings were immediately weighted on a weighing scale to record the fresh weight of the rooted cuttings.

3.8.2.10 Fresh weight of secondary roots (g)

The painted cutting was pulled out after 90 days of planting and washed off to remove the adhered soil. Then, the cuttings were immediately weighted on a weighing scale to record the fresh weight of the rooted cuttings.

3.8.2.11 Dry weight of primary roots (g)

The same samples of fresh roots from five cuttings per replication were also dried to a constant weight in an oven set to $58 \pm 2^{\circ}\text{C}$ to determine the dry weight (g).

3.8.2.12 Dry weight of secondary roots (g)

The same samples of fresh roots from five cuttings per replication were also dried to a constant weight in an oven set to $58 \pm 2^{\circ}\text{C}$ to determine the dry weight (g).

3.8.3 Shoot Development Stage

3.8.3.1 Days to sprout.

The days taken to first sprouting were analyzed and recorded based on visual observation from one day after planting the cuttings.

3.8.3.2 Sprouting %

The percentage sprouting was counted 90 days after planting by taking the ratio of the number of cuttings sprouted to the number of cuttings planted and multiplied by 100. The same was calculated by the formula and expressed in percentage (%).

3.8.3.3 Number of sprouts

The number of sprouts that emerged from the planted cuttings was counted every 30 days, starting from 30 days after planting and continuing for 90 days. As a result, information about the subsequent sprouting of fresh sprouts was noted.

3.8.3.4 Fresh weight of shoot (g)

The shoots were detached from the sample cuttings, and their fresh weight was measured using an electronic balance. The mean weight was calculated and expressed in grams (g).

3.8.3.5 Dry weight of shoot (g)

After recording the fresh weight, the same shoots were dried in a hot air oven at 65°C until a constant weight was achieved. The mean dry weight was expressed in grams (g).

3.8.3.6 Number of leaves

The planted cuttings were monitored for the emergence of new leaves from 30 days after planting up to 90 days, at 30-day intervals. The corresponding data on leaf emergence were recorded accordingly.

3.8.3.7 Leaf area (Cm²)

To record observations regarding leaf area, representative leaves from each plant or cutting in the treatment groups were selected. The leaf area was measured using a leaf area meter, by tracing the leaf outline on graph paper, or through image analysis software. The measurements were recorded in a data sheet, including details such as plant or cutting ID, treatment group, and date of measurement.

3.8.3.8 Chlorophyll

To calculate the chlorophyll content in leaves, readings were taken from SPAD. Leaves with varying levels of greenness were used to determine the chlorophyll content using the SPAD meter.

3.8.3.9 Fresh weight of leaves(g)

The planted cuttings were gently removed from polybags and washed off with clean water to remove any adhered soil. The leaves were gently plucked out manually and weighed immediately on a weighing scale to record the fresh weight of the leaves.

3.8.3.10 Dry weight of leaves (g)

To determine the dry weight of leaves, collected leaves were dried in a hot air oven at 65°C until a constant weight was achieved. The dried leaves were then weighed using an electronic balance, and the mean dry weight was calculated and recorded in grams (g).

3.8.4 Overall Plant Health

3.8.4.1 Root-to-shoot ratio

The root-to-shoot ratio was calculated by the dry weight of the root to the dry weight of the shoot

3.8.4.2 Root index

The rooting index was calculated by the following formula.

Root index = (root number) x (root length)

3.8.4.3 Survival %

The survival rate of the cuttings in each treatment was recorded after three months at the end of the experiment. The percentage survival of the cuttings was calculated using the following formula:

Percentage of survival of cuttings = $\frac{\text{Number of cuttings survived}}{\text{Total number of cutting}} \times 100$

3.8.4.4 Mortality %

The mortality percentage was calculated by dividing the number of dead cuttings (that failed to survive) by the total number of cuttings planted.

3.9 Statistical Analysis

The data collected during the investigations were analyzed statistically using a split-plot design, as outlined by Snedecor and Cochran (1968). The analysis was carried out using OPSTAT statistical software (CCS HAU, Hisar, India). Valid conclusions were drawn after determining the significance of differences between treatments at the 5% and 1% probability levels. To compare the treatment means, the critical difference was calculated. The experimental results are presented using tables, diagrams, and photographs .



A



B



C

Figure 3.1 a) Basal dose of zinc, b) Cuttings taken after zinc application, c) Sprout initials

RESULT AND DISCUSSION

The present study entitled “**Studies on performance of stem cutting under different growing conditions as affected by Zinc application on Guava Plants**” was conducted in the experimental field of the Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara. The field research trial was carried out during the cropping season of **May to September 2022** and was subsequently repeated in the next year, **May to September 2023**. The experimental findings of different experiments are being discussed below to provide a relevant explanation of the experimental outcomes considering the available kinds of literature:

4.1 Experiment 1 Studies on performance of stem cutting under open field conditions as affected by Zinc application on Guava Plants.

4.1.1 Callus formation (mm)

Callus formation was significantly influenced by zinc foliar application in 2022. At 30 days after pre-cutting treatment, the maximum callus formation was recorded in treatment A₁B₃ (0.75%), with a value of (3.86 mm), while the minimum was observed in treatment A₁B₁ (0.25%) with the value of (2.71 mm), showing a significant difference among the various levels of zinc foliar application (Table 4.1, Figure 4.1). Among the zinc as pre-cutting basal treatments, the maximum callus formation was observed in treatment A₂B₂ (75g/tree) (4.82 mm), while the minimum was in A₂B₁ (50g/tree) (4.13 mm). For post-cutting treatments, IBA at 5000 ppm concentration resulted in the highest callus formation at 8.71 mm, with the control group showing the least at 1.05 mm.

At 60 days after pre-cutting treatment, similar trends were observed. The maximum callus formation was recorded in treatment A₁B₃ (0.75%) (3.95 mm), while the minimum was in treatment A₁B₁(0.25%) (2.96 mm). Among zinc basal treatments, A₂B₂ (75 g/tree) showed the highest callus formation (4.99 mm), and A₂B₁ (50g/tree) the lowest (4.42 mm). For post-cutting treatments, IBA at 5000 ppm showed the

maximum callus formation at 8.91mm, while the control group showed the least at 1.48 mm

In 2023, zinc foliar application continued to significantly influence callus formation. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) showed the highest callus formation (3.95mm), while A₁B₁(0.25%) had the lowest (2.71mm) (Table 4.1, Figure 4.1). Among zinc basal treatments, A₂B₂ (75 g/tree) (4.99mm), while the minimum was in treatment A₂B₁(50g/tree) had the minimum (4.35mm). For post-cutting treatments, IBA at 5000 ppm concentration again resulted in the highest callus formation at 8.91mm, with the control group showed the least at 1.05mm.

At 60 days after pre-cutting treatment in 2023, the maximum callus formation was recorded in treatment A₁B₃ (0.75%) (3.95mm), while the minimum was in A₁B₁(0.25%) (2.96mm). Among zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) produced the highest callus formation (4.99mm), A₂B₁ (50 g/tree) the lowest (4.85mm). For post-cutting treatment with IBA at 5000 ppm concentration resulted in the highest callus formation at 8.91mm, with the control group had the least 1.48 mm.

When analysing the pooled data for both years, at 30 days after pre-cutting treatment, the maximum callus formation was observed in treatment A₁B₃ (0.75%) (4.32mm), while the minimum was recoded in A₁B₁ (0.25%) (3.37mm) (Table 4.1, Figure 4.1). Among zinc basal treatments, the highest polled callus formation was observed in A₂B₂ (75 g/tree) (5.43mm), while A₂B₁ (50 g/tree) recoded the least (4.64mm). Similarly, for post-cutting treatments, IBA at 5000 ppm concentration consistently yielded the maximum callus formation 9.47mm while, the control group showed the least (1.46mm) (Table 4.1, Figure 4.1).

Table 4.1 Effect of zinc (Zn) and IBA treatments on callus formation (mm) in guava cuttings taken on different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	2.71	2.96	2.84	3.62	3.80	3.72	3.17	3.37	3.27
A₁B₂	3.39	3.81	3.61	4.52	4.73	4.63	3.96	4.27	4.12
A₁B₃	3.86	3.95	3.91	4.77	4.96	4.87	4.32	4.46	4.39
A₂B₁	4.13	4.42	4.28	5.15	5.74	5.45	4.64	5.08	4.86
A₂B₂	4.82	4.99	4.91	6.04	5.61	5.83	5.43	5.31	5.37
A₂B₃	4.35	4.86	4.61	5.27	5.87	5.57	4.81	5.36	5.09
A₃B₁	8.71	8.91	8.81	9.61	10.03	9.82	9.16	9.47	9.32
A₃B₂	8.07	8.31	8.19	8.89	9.63	9.26	8.48	8.97	8.73
A₃B₃	1.05	1.48	1.27	1.86	2.42	2.14	1.46	1.95	1.71
Mean	4.57	4.85		5.53	5.86		5.05	5.36	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.008	0.003	0.008	0.003	0.006	0.002
Factor B	0.008	0.003	0.008	0.003	0.006	0.002
Factor C	0.006	0.002	0.006	0.002	0.003	0.001
Interaction A X B	0.014	0.005	0.014	0.005	0.010	0.003
Interaction A X C	0.011	0.004	0.010	0.003	0.006	0.002
Interaction B X C	0.011	0.004	0.010	0.003	0.006	0.002
Interaction A X B X C	0.018	0.006	0.017	0.006	0.010	0.003

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

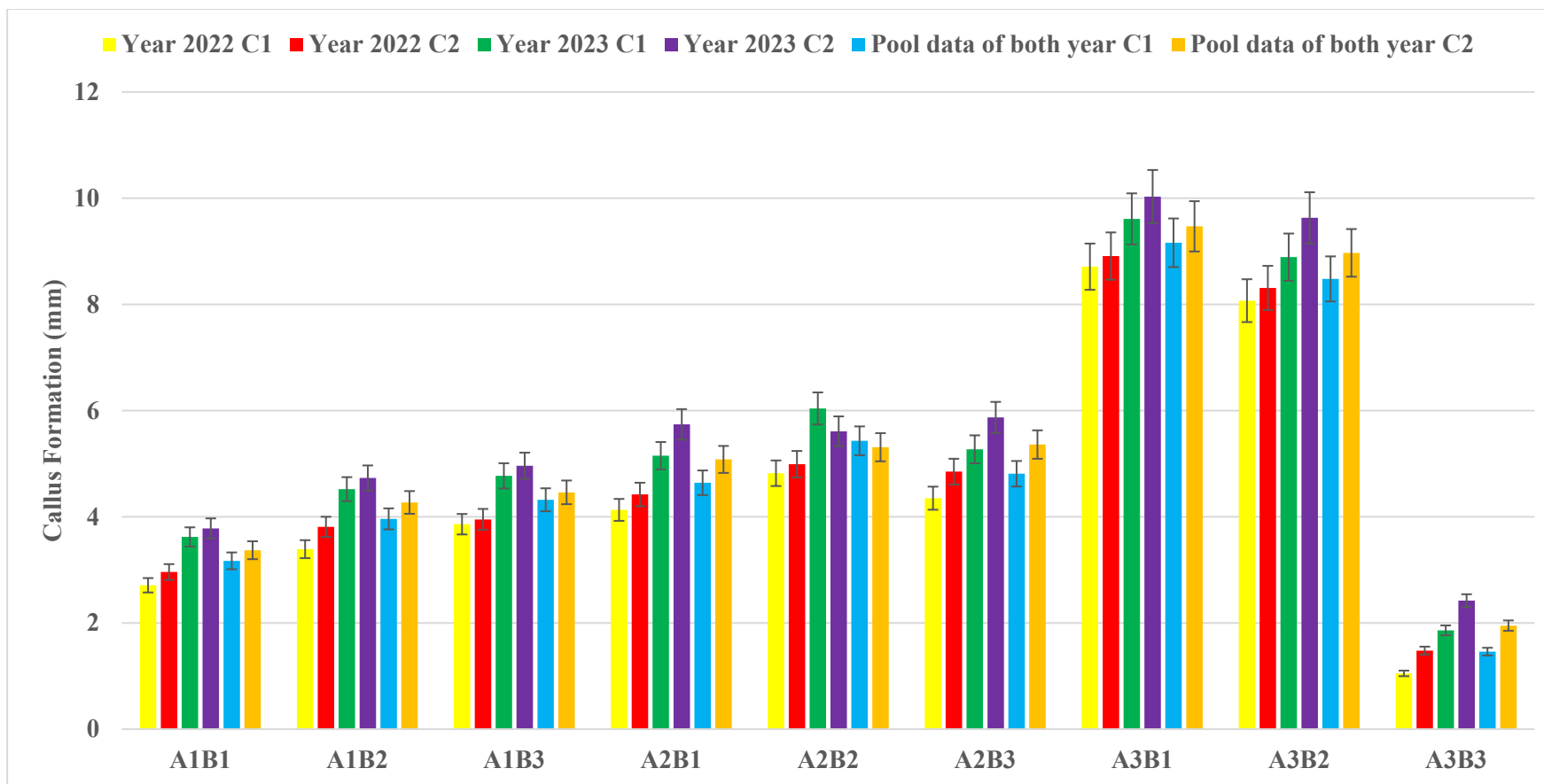


Figure 4.1 Graphical representation of the effect of zinc (Zn) and IBA treatments on callus formation (mm) in guava cuttings at different days.

At 60 days after pre-cutting treatment, the pooled data showed that treatment A₁B₃ (0.75%) (4.46mm) resulted in the highest callus formation, while A₁B₁ (0.25%) recorded the lowest (3.37mm). Among zinc basal treatments, A₂B₂ (75 g/tree) remained the best performer with the highest callus formation (5.31mm), and A₂B₁ (50 g/tree) recorded the least (4.13 mm). For post-cutting treatments with IBA at 5000 ppm resulted in the maximum pooled callus formation (8.71 mm), and the control group consistently showed the least (1.05mm).

The effect of the number of days after pre-cutting treatment with zinc on dormant-stage guava was also significant in influencing callus formation in cuttings. The cuttings taken after 60 days exhibited maximum callus formation (5.36mm) compared with cuttings taken after 30 days (5.05mm). The effect of the application method and all interactions (AxB, BxC, AxC, and AxBxC) was also significant for the number of days taken for callus formation, and the maximum callus formation was observed in A₃B₁C₂ (9.47mm) cuttings taken after 60 days of the dormant stage and dipped in 5000 ppm IBA.

Zinc (Zn) plays a pivotal role in the physiological and biochemical processes essential for plant growth and development, including callus formation. The impact of Zn on callus formation in guava stem cuttings was evident in this study, where varying concentrations and methods of zinc application significantly influenced the extent of callus formation.

Zinc is a crucial component of many enzymes and proteins that regulate various cellular processes. It acts as a catalytic or structural cofactor in over 300 enzymes, including those involved in DNA synthesis and repair, protein synthesis, and hormonal regulation (Cakmak, 2000). These functions are particularly relevant during the early stages of callus formation, where rapid cell division and differentiation occur. Zn's role in stabilizing the structures of proteins and membranes is critical in maintaining cellular integrity under stress conditions, thereby enhancing callus formation (Broadley *et al.*, 2007).

The study demonstrated that basal application of zinc at 75 g/tree (A₂B₂) significantly enhanced callus formation compared to foliar applications and the control group. This

can be attributed to the direct availability of zinc to the root zone, ensuring a steady supply for uptake and utilization in cellular processes critical for callus initiation and development. Previous research has shown that zinc deficiency can lead to poor callus formation and compromised root growth, highlighting the importance of adequate zinc supply (Alloway, 2008). Present findings are fully supported by the results of Alizadeh and Dumanoglu (2022) in olive and Yamashita *et al.* (2006) in mango.

4.1.2 Days to Root Initiation

At 30 days after pre-cutting treatment in 2022, zinc foliar application significantly influenced the days to root initiation. The minimum days were recorded in treatment A₁B₃ (0.75%) at 38.59 days, while the maximum days were observed in treatment A₁B₁ (0.25%) at 39.22 days, indicating a significant difference among the various levels of zinc foliar application (Table 4.2, Figure 4.2). Among the various levels of zinc as pre-cutting basal treatments, the minimum days to root initiation were observed in treatment A₂B₂ (75 g/tree) at 36.46 days, while the maximum was in treatment A₂B₁ (50 g/tree). For post-cutting treatments, IBA at 10,000 ppm concentration resulted in the minimum days to root initiation at 27.01 days, with the control group showing the maximum at 43.37 days.

At 60 days after pre-cutting treatment, the minimum days to root initiation were recorded in treatment A₁B₃ (0.75%) at 5 days, while the maximum was in treatment A₁B₁ (0.25%) at 38.86 days. Among the various levels of zinc as pre-cutting basal treatments, the minimum was observed in treatment A₂B₂ (75 g/tree) at 35.88 days, while the maximum was in treatment A₂B₁ (50 g/tree) at 36.31 days. For post-cutting treatments, IBA at 5000 ppm concentration showed the minimum days to root initiation at 27.35 days, with the control group showing the maximum at 42.61 days.

In 2023, zinc foliar application continued to significantly influence days to root initiation. At 30 days after pre-cutting after treatment, the minimum days were recorded in treatment ZF₃ (0.75%) at 36.25 days, while the maximum was in treatment ZF₁ (0.25%) at 36.81 days. Among the various levels of zinc as pre-cutting basal treatments, the minimum days to root initiation were observed in treatment A₂B₂ (75 g/tree) at 34.68 days, while the maximum was in treatment A₂B₁ (50 g/tree) at

35.91 days. For post-cutting treatments, IBA at 5000 ppm concentration resulted in the minimum days to root initiation at 25.11 days, with the control group showing the maximum at 41 days.

At 60 days after pre-cutting treatment, the minimum days to root initiation were recorded in treatment A₁B₃ (0.75%) at 35.02 days, while the maximum was in treatment A₁B₁ (0.25%) at 36.68 days. Among the various levels of zinc as pre-cutting basal treatments, the minimum was observed in treatment A₂B₂ (75 g/tree) at 32.89 days, while the maximum was in treatment ZB₁ (50 g/tree). For post-cutting treatments, IBA at 5000 ppm concentration showed the minimum days to root initiation at 25 days, with the control group showing the maximum at 40.80 days.

When analyzing the pooled data for both years, the minimum days to root initiation at 30 days after pre-cutting treatment was recorded in treatment A₁B₃ (0.75%) at 37.42 days, while the maximum was in treatment A₂B₁ (0.25%) at 38.02 days, demonstrating consistent results across both years (Table 2). Among the various levels of zinc a pre-cutting basal treatment, the minimum days to root initiation was observed in treatment A₂B₂ (75 g/tree) at 35.57 days, while the maximum was in treatment A₂B₁ (50 g/tree) at 36.84 days. Similarly, for post-cutting treatments, IBA at 5000 ppm concentrations consistently showed the minimum days to root initiation with a mean value of 26.26 days, and the control group had the maximum at 42.19 days.

At 60 days after pre-cutting treatment, the pooled data indicated that treatment A₁B₃ (0.75%) resulted in the minimum days to root initiation at 36.29 days, while A₁B₁ (0.25%) had the maximum at 37.77 days. For zinc basal treatments, A₂B₂ (75 g/tree) was consistently the best performer at 34.39 days, while A₂B₁ (50 g/tree) had the maximum days to root initiation at 35.43 days. For post-cutting treatments, IBA at 5000 ppm concentration maintained its lead in promoting minimum days to root initiation with a pooled mean value of 26.18 days, and the control group had the maximum at 41.71 days (Table 4.2, Figure 4.2).

The effect of the number of days after pre-cutting treatment with zinc or dormant-stage guava was also significant in regulating the root initiation in cuttings. The

cuttings taken after 60 days showed early root initiation (34.53 days) compared with the cuttings taken after 30 days (35.23 days). The effect of the application method and all interactions (AxB, BxC, AxC, and AxBxC) was also significant for the number of days taken for root initiation, and the earliest initiation was noticed in A₃B₁C₂ (26.18 days), i.e. cuttings were taken after 60 days of the dormant stage and dipping of cuttings in 5000 ppm IBA.

4.1.3 Rooting Percentage

The influence of zinc foliar application on rooting percentage was notable in both 2022 and 2023. In 2022, 30 days after pre-cutting treatment with the foliar application of zinc, the highest rooting percentage (23.99%) was achieved with the A₁B₃ treatment (0.75%), whereas the lowest (22.17%) was observed in the A₁B₁ treatment (0.25%), demonstrating a significant variation between different zinc foliar application levels (Table 4.3, Figure 4.3). Zinc as pre-cutting basal treatments showed the highest rooting percentage (25.81%) in A₂B₂ (75 g/tree), while A₂B₁ (50 g/tree) recorded the lowest (24.32%). For post-cutting treatment of IBA, 5000-ppm concentration yielded the highest rooting percentage (44.40%), contrasting sharply with the control group's minimal rooting percentage (15.26%). At 60 days after pre-cutting treatment, the pattern remained consistent with A₁B₃ (0.75%) leading in rooting percentage (24.28%) and A₁B₁ (0.25%) trailing (22.22%). Among the various levels of zinc as pre-cutting basal treatments again saw A₂B₂ (75 g/tree) achieving the highest rooting percentage (26.02%) and A₂B₁ (50 g/tree) the lowest (24.67%). Post-cutting treatment of IBA 5000 ppm continued to show superior results with a rooting percentage of 44.91%, while the control group remained the lowest at 15.31%.

The trend persisted in 2023, where at 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the highest rooting percentage (25.14%), and A₁B₁ (0.25%) the lowest (24.61%) among zinc foliar applications (Table 4.3, Figure 4.3). For various levels of zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) at the forefront with a rooting percentage of 26.25%, while A₂B₁ (50 g/tree) had the lowest (25.59%). The post-cutting treatment of IBA 5000 ppm again led with the highest rooting percentage (46.12%), in stark contrast to the control group (17.15%).

Table 4.2 Effect of zinc (Zn) and IBA treatments on days to root Initiation in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	39.22	38.86	39.04	36.81	36.68	36.75	38.04	37.78	37.91
A ₁ B ₂	38.85	38.2	38.53	36.49	36.41	36.45	37.68	37.34	0.25%
A ₁ B ₃	38.59	37.91	38.07	36.25	35.02	35.63	37.42	36.29	36.86
A ₂ B ₁	37.77	36.31	37.04	35.91	35.55	35.73	36.84	35.43	36.14
A ₂ B ₂	36.46	35.88	36.17	34.68	32.89	33.79	35.57	34.39	34.98
A ₂ B ₃	37.15	36.02	36.58	35.61	34.31	34.96	36.38	35.17	35.78
A ₃ B ₁	27.42	27.35	27.39	25.11	25.02	25.06	26.26	26.18	26.22
A ₃ B ₂	27.01	27.82	27.42	26.45	25.23	25.84	26.73	26.53	26.63
A ₃ B ₃	43.37	42.61	42.99	41.02	40.81	40.91	42.19	41.71	41.95
Mean	36.21	35.62		34.26	33.54		35.23	34.53	
			Year 2022		Year 2023		Pool data		
Factors			CD	SE(m)	CD	SE(m)	CD	SE(m)	
Factor A			0.098	0.033	0.286	0.095	0.025	0.008	
Factor B			0.098	0.033	0.286	0.095	0.025	0.008	
Factor C			0.077	0.026	0.231	0.077	0.006	0.002	
Interaction A X B			0.169	0.056	0.496	0.165	0.043	0.014	
Interaction A X C			0.133	0.048	0.398	0.134	0.011	0.004	
Interaction B X C			0.133	0.048	0.398	0.134	0.011	0.004	
Interaction A X B X C			0.231	0.078	0.689	0.232	0.019	0.007	

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

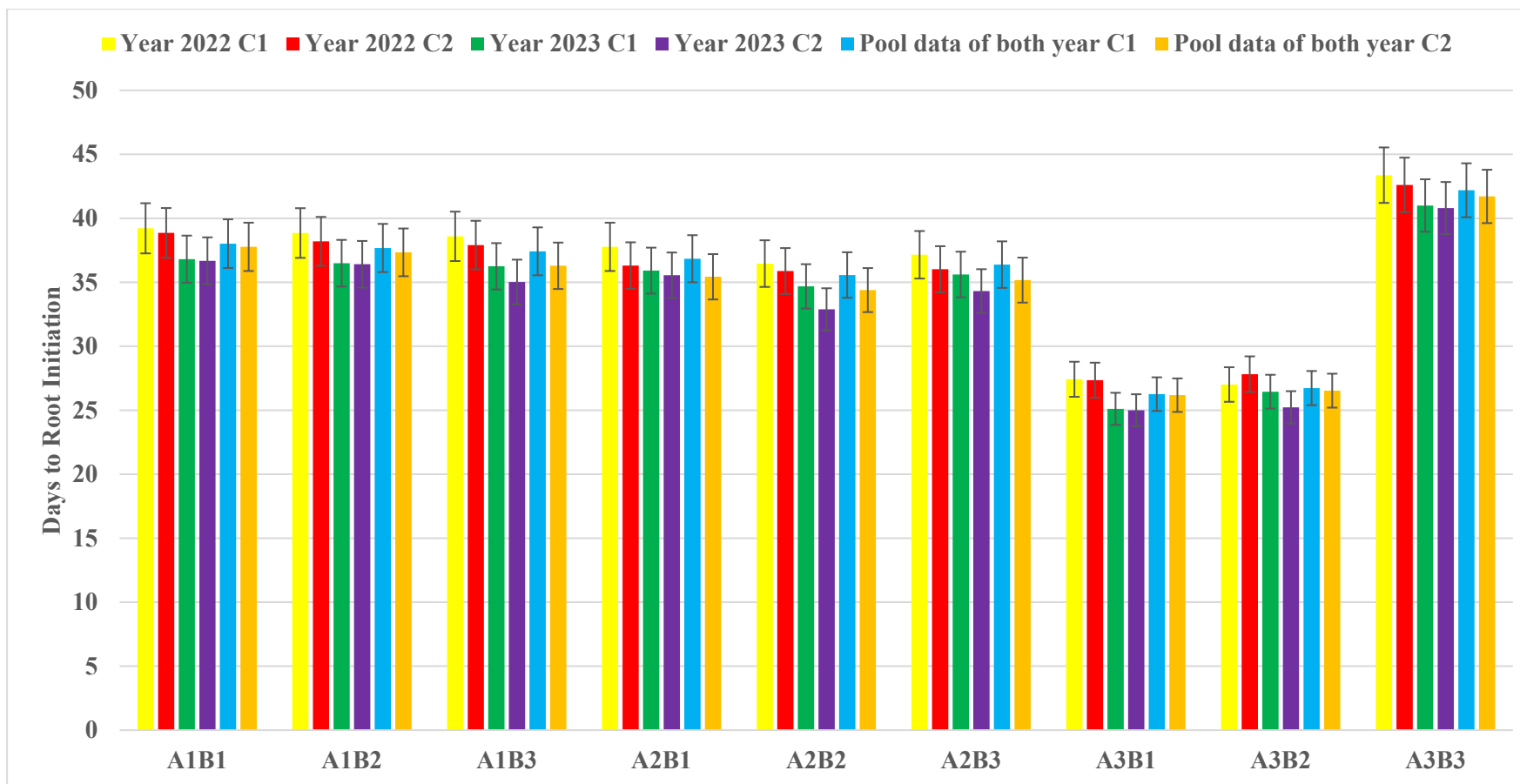


Figure 4.2 Graphical representation of the effect of zinc (Zn) and IBA treatments on days to root initiation in guava cuttings at different days.

At 60 days of pre-cutting treatment in 2023, A₁B₃ (0.75%) had the highest rooting percentage (25.16%), and A₁B₁ (0.25%) was the lowest (24.70%). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest rooting percentage (26.53%), whereas A₂B₁ (50 g/tree) recorded the lowest (25.86%). The post-cutting treatment IBA 5000 ppm sustained its performance with a maximum rooting percentage (46.23%), and the control group remained the lowest at 17.10%.

When pooling data from both years, the results consistently showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest average rooting percentage (24.57%), while A₁B₁ (0.25%) had the lowest (23.46%) (Table 4.3, Figure 4.3). among various levels of zinc as pre-cutting basal treatments reflected similar trends, with A₂B₂ (75 g/tree) having the highest average rooting percentage (26.03%) and A₂B₃ (100 g/tree) the lowest (25.11%). The post-cutting treatment of IBA 5000 ppm consistently exhibited the highest average rooting percentage (45.26%), while the control group remained the lowest at 16.21%.

At 60 days after pre-cutting treatment, the pooled data indicated that A₁B₃ (0.75%) had the highest average rooting percentage (24.72%), with A₁B₁ (0.25%) having the lowest (23.45%). Among various levels of zinc as pre-cutting basal treatments continued to show A₂B₂ (75 g/tree) with the highest average rooting percentage (26.28%) and A₂B₃ (50 g/tree) with the lowest (25.39%). The post-cutting treatment of IBA 5000 ppm maintained the highest average rooting percentage (45.57%), and the control group had the lowest at 16.21%.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the rooting percentage in cuttings. Cuttings collected after 60 days exhibited a higher rooting percentage (28.45%) than those collected after 30 days (28.27%). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) had a significant effect on the rooting percentage. The highest rooting percentage (45.57%) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Table 4.3 Effect of zinc (Zn) and IBA treatments on rooting percentage in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	22.17	22.32	22.25	24.72	24.72	24.71	23.46	23.45	23.46
A₁B₂	23.47	23.82	23.65	24.61	24.73	24.67	24.04	24.28	24.16
A₁B₃	23.99	24.28	24.14	25.14	25.16	25.15	24.57	24.72	24.65
A₂B₁	24.32	24.72	24.52	25.89	25.95	25.92	25.11	25.39	25.25
A₂B₂	25.81	26.02	25.92	26.25	26.53	26.39	26.03	26.28	26.16
A₂B₃	25.56	25.66	25.61	25.59	25.86	25.73	25.58	25.76	25.67
A₃B₁	44.45	44.91	44.68	46.12	46.23	46.18	45.26	45.57	45.42
A₃B₂	43.92	44.05	43.99	44.45	44.69	44.57	44.18	44.35	44.27
A₃B₃	15.26	15.31	15.29	17.15	17.11	17.13	16.21	16.21	16.21
Mean	27.66	27.88		28.88	28.99		28.27	28.45	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.023	0.008	0.023	0.008
Factor B	0.007	0.002	0.023	0.008	0.023	0.008
Factor C	0.008	0.003	0.007	0.002	0.025	0.008
Interaction A X B	0.013	0.004	0.039	0.013	0.041	0.013
Interaction A X C	0.013	0.004	0.012	0.004	0.043	0.015
Interaction B X C	0.013	0.004	0.012	0.004	0.043	0.015
Interaction A X B X C	0.023	0.008	0.021	0.007	0.075	0.025

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

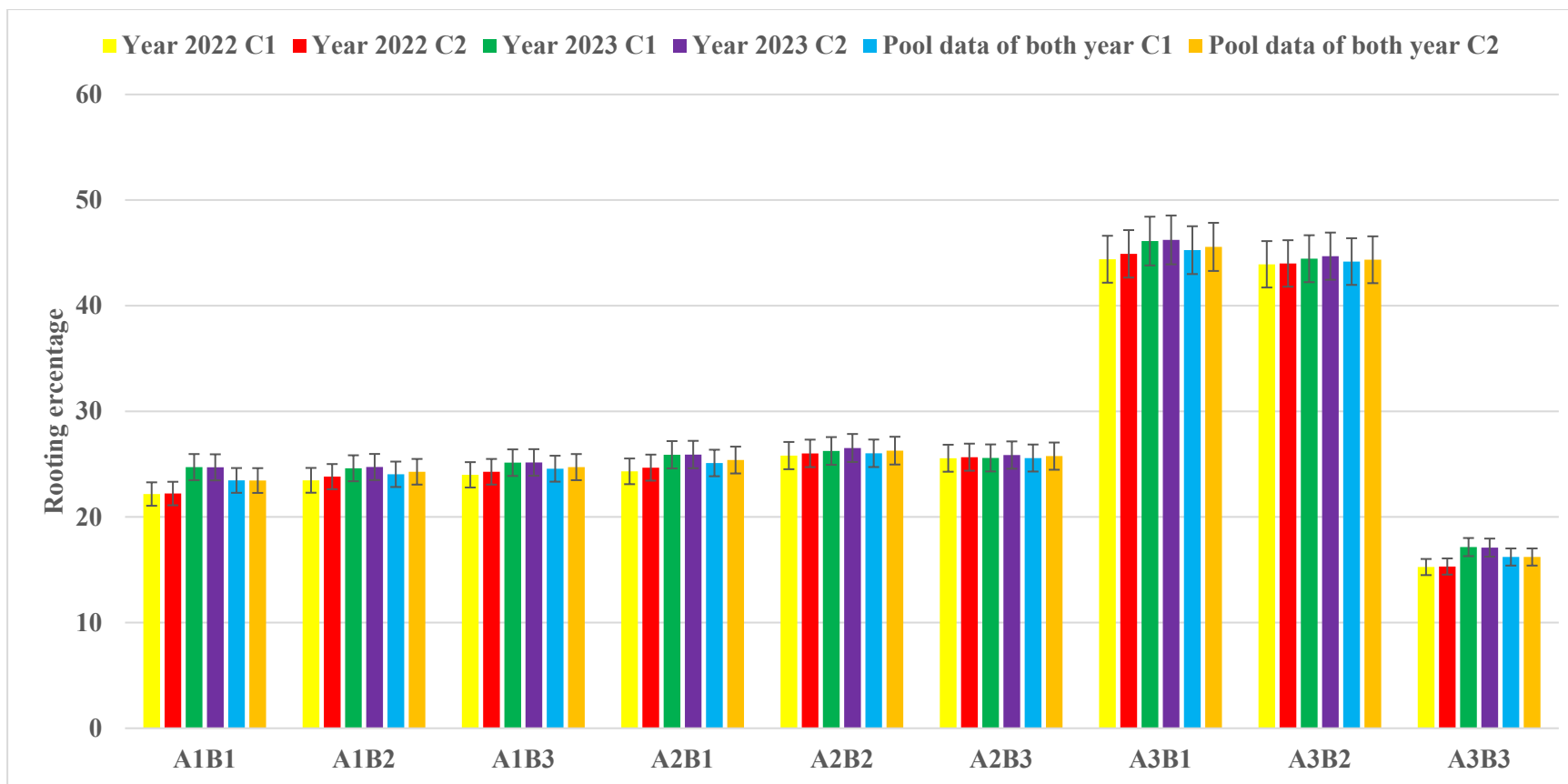


Figure 4.3 Graphical representation of the effect of zinc (Zn) and IBA treatment on rooting percentage in guava cuttings at different days.



Figure 4.3 a After 30 days after dormant stage a) Zinc foliar 0.75% per tree, b) IBA 5000 ppm, c) Zinc basal 75 g per tree, d) Zinc foliar 75 g per tree



Figure 4.3 b-After 60 days after dormant stage a) Zinc basal 75 g per tree, b) Untreated, c) IBA 5000 ppm, d) Zinc foliar 0.75% per tree, e) Zinc basal 75 g per tree

Table 4.4 Effect of zinc (Zn) and IBA treatments on primary root number in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	2.32	2.49	2.41	3.28	3.46	3.37	2.80	2.97	2.89
A ₁ B ₂	2.57	2.84	2.71	3.82	4.03	3.93	3.18	3.45	3.31
A ₁ B ₃	3.03	3.32	3.18	4.01	4.14	4.08	3.52	3.73	3.63
A ₂ B ₁	4.28	4.54	4.41	5.39	5.58	5.49	4.84	5.06	4.95
A ₂ B ₂	5.88	6.17	6.03	6.97	7.86	7.42	6.43	7.02	6.73
A ₂ B ₃	4.64	4.91	4.78	5.82	6.53	6.18	5.23	5.72	5.48
A ₃ B ₁	10.25	10.51	10.38	11.23	11.48	11.36	10.74	11.01	10.87
A ₃ B ₂	9.79	10.07	9.93	10.89	11.22	11.06	10.34	10.62	10.48
A ₃ B ₃	1.56	1.85	1.71	2.55	2.69	2.62	2.04	2.27	2.16
Mean	4.92	5.18		5.99	6.33		5.46	5.76	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.007	0.002	0.009	0.003	0.007	0.002
Factor B	0.007	0.002	0.009	0.003	0.007	0.002
Factor C	0.007	0.002	0.009	0.003	0.005	0.002
Interaction A X B	0.012	0.004	0.016	0.005	0.012	0.004
Interaction A X C	0.012	0.004	0.015	0.005	0.009	0.003
Interaction B X C	0.012	0.004	0.015	0.005	0.009	0.003
Interaction A X B X C	0.021	0.007	0.026	0.009	0.016	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

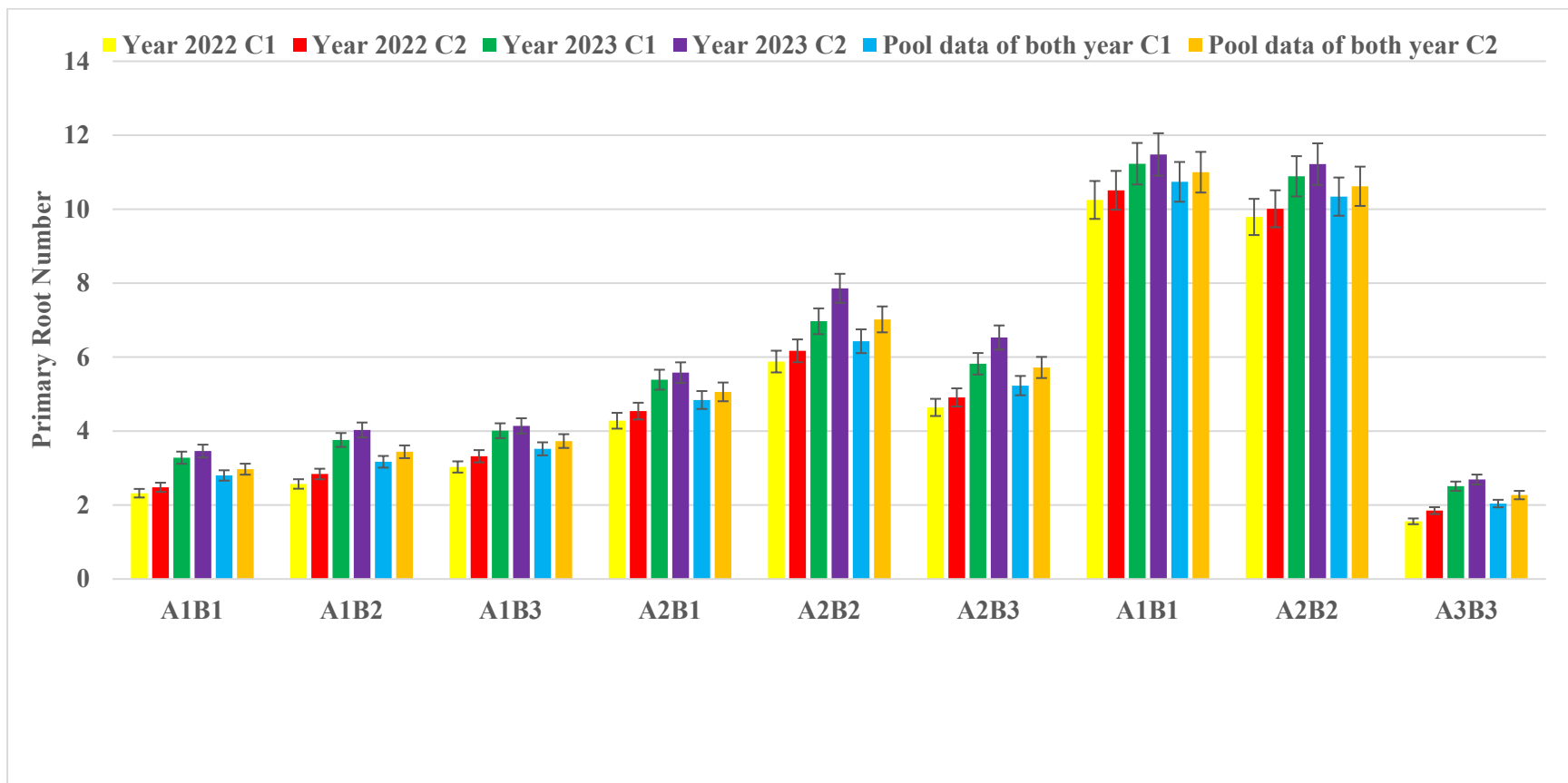


Figure 4.4 Graphical representation of the effect of zinc (Zn) and IBA treatments on the primary root number in guava cuttings at different days.

In this study, we investigated the role of zinc in root initiation and auxin metabolism. Zinc is a key cofactor for enzymes involved in DNA synthesis and auxin metabolism, both critical for root initiation. Auxins, plant hormones that promote root initiation and elongation, are significantly influenced by zinc's role in their metabolism. Adequate zinc levels enhance auxin production and activity, thereby stimulating root initiation. Our results showed that basal zinc application at 75 g/tree (A₂B₂) had the highest rooting percentage, significantly increasing compared to foliar applications and the control group. These findings are consistent with Broadley *et al.* (2007), who reported that zinc deficiency can lead to poor root initiation and reduced rooting percentages. Present findings are fully supported by the results of Sourati *et al.* (2022) in Mulberry and Somkuwar *et al.* (2013) in dog ridge rootstock.

4.1.4 Primary Root Number

Zinc foliar application significantly influenced primary root numbers in both 2022 and 2023. In 2022, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) showed the highest primary root numbers (3.03), while A₁B₁ (0.25%) had the lowest (2.32), highlighting significant variations among zinc foliar application levels (Table 4.4). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) produced the highest primary root numbers (5.88), with A₂B₁ (50 g/tree) recording the lowest (4.28). For post-cutting treatments, IBA at 5000 ppm resulted in the highest primary root numbers (10.25), while the control group had the lowest (1.56).

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) again exhibited the highest primary root numbers (3.32), while A₁B₁ (0.25%) showed the lowest (2.48), indicating significant differences among zinc basal application levels. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the highest primary root numbers (6.17), whereas A₂B₂ (100g/tree) recorded the lowest (4.54). For post-cutting treatments, IBA at 5000 ppm concentration showed the highest primary root numbers (10.51), with the control group at its lowest (1.85).

In 2023, zinc foliar application continued to significantly affect primary root numbers. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest primary root numbers (4.01), while A₁B₁ (0.25%) had the lowest (3.28). Among the various

zinc basal treatments, A₂B₂ (75 g/tree) yielded the highest primary root numbers (6.97), and A₂B₁ (100g/tree) had the lowest (5.39). For post-cutting treatments, IBA at 5000 ppm concentration resulted in the highest primary root numbers (11.23), with the control group at its lowest (2.51).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the highest primary root numbers (4.14), while A₁B₁ (0.25%) exhibited the lowest (3.46), demonstrating significant differences among zinc basal application levels. A₂B₂ (75 g/tree) continued to yield the highest primary root numbers (7.86), with A₂B₁ (75 g/tree) showing the lowest (5.58). For post-cutting treatments, IBA at 5000 ppm concentration maintained its lead with the highest primary root numbers (11.48), while the control group recorded the lowest (2.69).

Pooling data from both years consistently showed treatment A₁B₃ (0.75%) with the highest primary root numbers at 30 days after pre-cutting treatment (3.52), while A₁B₁ (0.25%) had the lowest (2.80). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently performed best (6.43), with A₂B₁ (50 g/tree) showing the minimum (4.84). For post-cutting treatments IBA at 5000 ppm concentration consistently promoted the highest primary root numbers, averaging (10.74), whereas the control group consistently showed the lowest (2.04). At 60 days after treatment, A₁B₃ (0.75%) remained the top performer (3.73), with A₁B₁ (0.25%) exhibiting the least effectiveness (2.97). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) continued to excel (7.02), while A₂B₁ (50 g/tree) had the lowest primary root numbers (5.06). For post-cutting treatments of IBA 5000 ppm concentration maintained its lead with a pooled mean of (11), whereas the control group recorded the lowest (2.27) (Table 4.4, Figure 4.4).

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced primary root numbers in cuttings. Cuttings collected 60 days after treatment produced a higher number of primary roots (5.76) compared to those collected after 30 days (5.46). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The highest primary root number (11.01) was recorded in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

Table 4.5 Effect of zinc (Zn) and IBA treatments on secondary root number in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	4.36	4.51	4.44	4.85	4.97	4.91	4.61	4.74	4.68
A ₁ B ₂	4.66	5.01	4.83	5.3	5.24	5.27	4.98	5.12	5.05
A ₁ B ₃	5.05	5.35	5.2	5.78	5.81	5.8	5.42	5.58	5.51
A ₂ B ₁	5.91	6.04	5.98	7.15	7.22	7.18	6.53	6.62	6.58
A ₂ B ₂	7.02	7.11	7.06	8.42	8.57	8.5	7.71	7.84	7.78
A ₂ B ₃	6.62	6.81	6.71	7.34	7.37	7.36	6.98	7.09	7.04
A ₃ B ₁	12.47	12.62	12.55	14.79	15.2	15.11	13.63	13.91	13.77
A ₃ B ₂	11.94	12.18	12.06	14	14.25	14.12	12.97	13.22	13.11
A ₃ B ₃	1.51	1.65	1.58	2.04	2.07	2.06	1.78	1.86	1.82
Mean	6.61	6.81		7.74	7.85		7.18	7.33	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.003	0.013	0.004	0.007	0.002
Factor B	0.011	0.003	0.013	0.004	0.007	0.002
Factor C	0.008	0.003	0.011	0.004	0.008	0.003
Interaction A X B	0.017	0.006	0.023	0.008	0.012	0.004
Interaction A X C	0.013	0.004	0.018	0.006	0.015	0.005
Interaction B X C	0.013	0.004	0.018	0.006	0.015	0.005
Interaction A X B X C	0.023	0.008	0.032	0.011	0.025	0.008

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

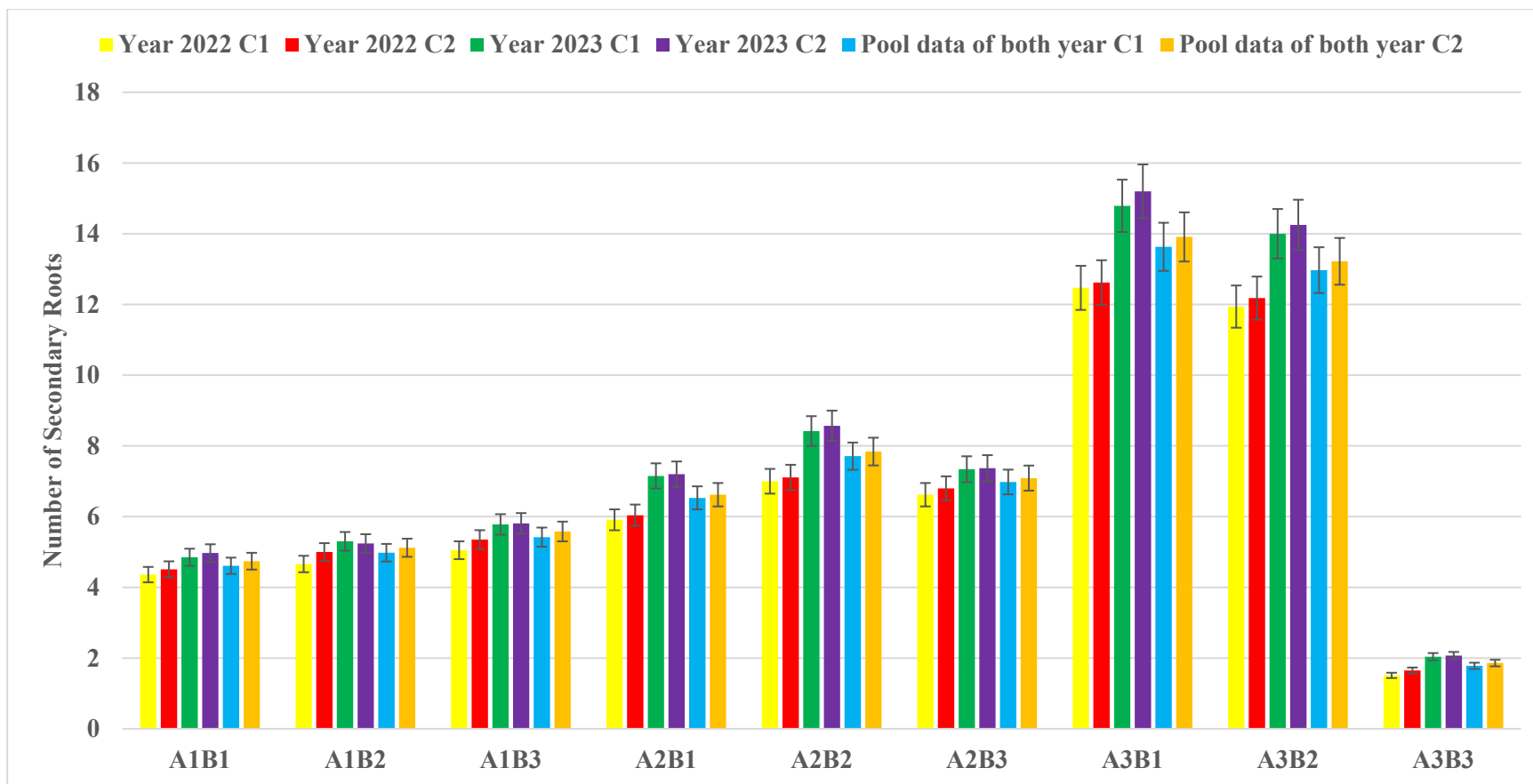


Figure 4.5 Graphical representation of the effect of zinc (zn) and IBA on the secondary root number in guava cuttings at different days.

4.1.5 Number of Secondary Roots

In the year 2022, the number of secondary roots was notably influenced by zinc foliar application. At 30 days after pre-cutting treatment, the highest number of secondary roots (5.05) was recorded in the A₁B₃ treatment (0.75%), while the lowest (4.36) was observed in the A₁B₁ treatment (0.25%), indicating a significant variation across different levels of zinc foliar application (Table 4.5). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) produced the highest number of secondary roots (7.00), whereas A₂B₁ (50 g/tree) had the lowest (5.91). For post-cutting treatments of IBA 5000 ppm concentration resulted in the highest number of secondary roots (12.47), contrasting sharply with the control group, which had the fewest secondary roots (1.51).

By 60 days after pre-cutting treatment, the pattern remained similar, with A₁B₃ (0.75%) maintaining the highest number of secondary roots (5.35) and A₁B₁ (0.25%) the lowest (4.51). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) again led with 7.11 secondary roots, while A₂B₁ (50 g/tree) had the fewest (6.04). Post-cutting treatments of IBA 5000 ppm concentration showed a continued high performance with 12.62 secondary roots, whereas the control group had the least (1.65).

In 2023, the trend persisted. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest number of secondary roots (5.78), while A₁B₁ (0.25%) had the lowest (4.85), again indicating significant differences among zinc foliar applications (Table 4.5, Figure 4.5). Among the various levels of zinc as pre-cutting basal treatments, revealed A₂B₂ (75 g/tree) with the highest number (8.42), and A₂B₁ (50 g/tree) with the lowest (7.15). For post-cutting treatments of IBA 5000 ppm concentration reached the peak number of secondary roots (14.79), while the control group had the fewest (2.04). At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) achieved the highest number of secondary roots (5.81), and A₁B₁ (0.25%) the lowest (4.97). Among various levels of zinc as pre-cutting basal treatments continued to show A₂B₂ (75 g/tree) with the highest number (8.57), and A₂B₁ (50 g/tree) with the lowest (7.20). For post cutting

Table 4.6 Effect of zinc (Zn) and IBA treatments on length of primary root (cm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	1.37	1.44	1.42	1.67	1.68	1.68	1.52	1.55	1.54
A ₁ B ₂	1.47	1.53	1.51	1.75	1.79	1.77	1.61	1.66	1.64
A ₁ B ₃	1.69	1.74	1.72	1.96	2.01	1.99	1.83	1.87	1.85
A ₂ B ₁	2.02	2.05	2.03	2.25	2.31	2.28	2.13	2.18	2.16
A ₂ B ₂	2.42	2.56	2.49	2.84	2.89	2.87	2.63	2.73	2.68
A ₂ B ₃	2.19	2.25	2.22	2.51	2.51	2.51	2.35	2.38	2.37
A ₃ B ₁	4.22	4.22	4.22	5.01	5.01	5.01	4.61	4.65	4.63
A ₃ B ₂	3.91	4.02	3.97	4.62	4.67	4.65	4.27	4.34	4.31
A ₃ B ₃	1.01	1.02	1.01	1.06	1.06	1.06	1.03	1.04	1.04
Mean	2.25	2.31		2.63	2.66		2.44	2.48	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.011	0.003	0.011	0.004	0.011	0.003
Factor B	0.011	0.003	0.011	0.004	0.011	0.003
Factor C	0.004	0.001	0.006	0.002	0.006	0.002
Interaction A X B	0.017	0.006	0.019	0.006	0.017	0.006
Interaction A X C	0.007	0.002	0.011	0.003	0.011	0.003
Interaction B X C	0.007	0.002	0.011	0.003	0.011	0.003
Interaction A X B X C	0.012	0.004	0.018	0.006	0.018	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

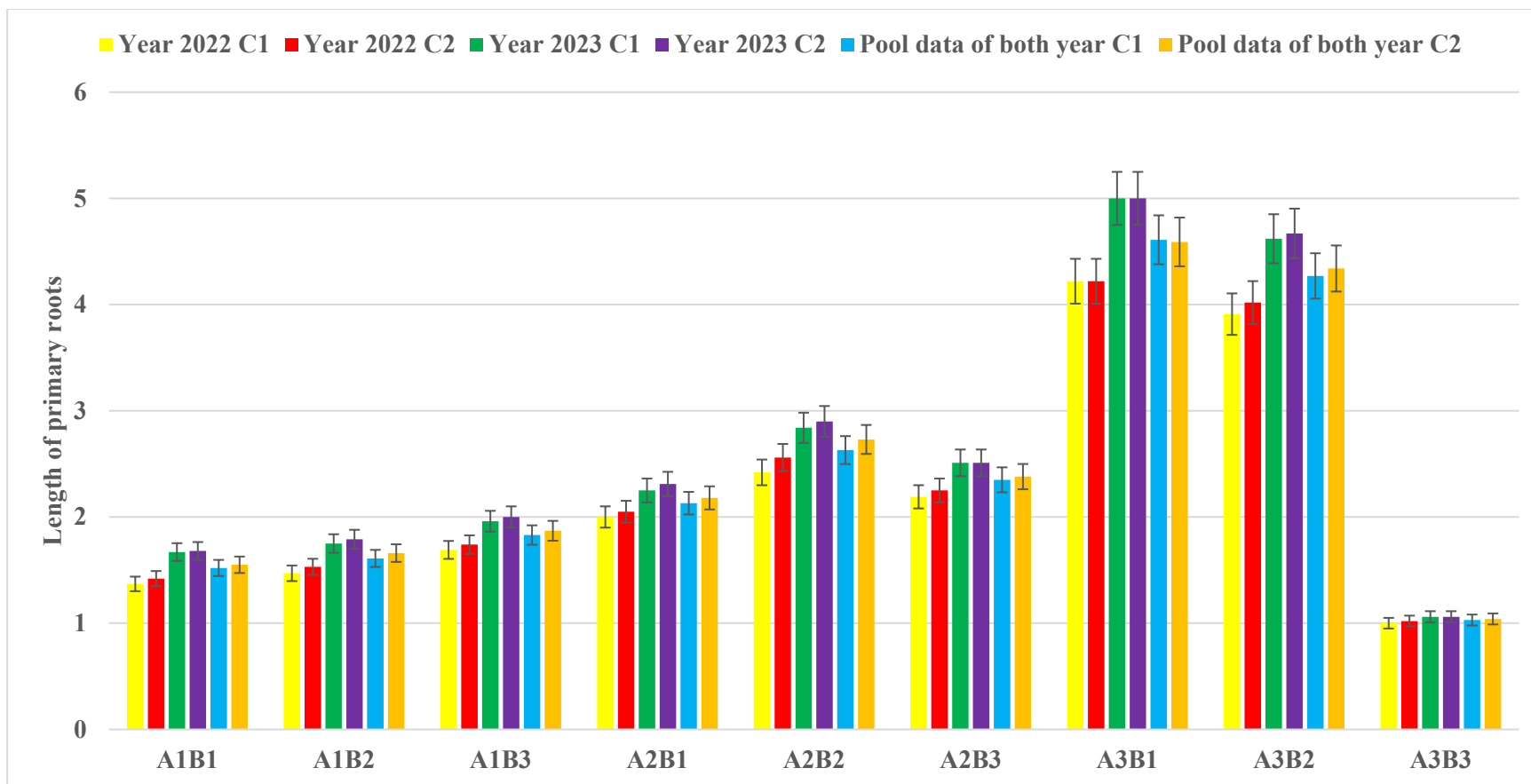


Figure 4.6 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the length of primary roots (cm) in guava cuttings at different days.

treatment of IBA 5000 ppm concentration maintained the highest number of secondary roots (15.20), with the control group having the fewest (2.07).

When pooling data for both years, the results consistently showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest average number of secondary roots (5.42), while A₁B₁ (0.25%) had the lowest (4.61) (Table 5). Among various levels of zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest average (7.71) and A₂B₁ (50 g/tree) with the lowest (6.53). For post-cutting treatment of IBA 5000 ppm concentration consistently had the highest average number of secondary roots (13.63), while the control group had the lowest (1.78).

At 60 days after pre-cutting treatment, the pooled data indicated that A₁B₃ (0.75%) resulted in the highest average number of secondary roots (5.58), while A₁B₁ (0.25%) had the lowest (4.72). Among various levels of zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) as the best performer with 7.84 secondary roots, while A₂B₁ (50 g/tree) had the lowest (6.62). For post-cutting treatment of IBA, 5000 ppm concentration maintained its lead with an average of 13.91 secondary roots, and the control group remained the lowest at 1.86 (Table 4.5, Figure 4.5).

Secondary root numbers in cuttings were significantly influenced by the timing of pre-cutting zinc treatments or the dormant stage of guava. Cuttings collected after 60 days produced more secondary roots (7.33) compared to those collected after 30 days (7.18). Additionally, the method of application and interactions (AxB, BxC, AxC, AxBxC) significantly affected the number of secondary roots. The highest secondary root number (13.91) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

The development of primary and secondary roots is critical for the overall root architecture and health of the plant. In this study, zinc application significantly influenced both primary and secondary root development. The basal application of zinc at 75 g/tree (A₂B₂) led to a substantial increase in the number of primary and secondary roots. Additionally, the primary root length and diameter were notably enhanced, providing a strong foundation for further root growth. Similarly, the secondary roots exhibited increased length and diameter, contributing to a more

extensive and robust root system. These improvements in primary and secondary root development underscore the importance of zinc in maintaining optimal root architecture, consistent with findings by Alloway (2008). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Yamashita *et al.* (2006) in mango.

4.1.6 Length of primary roots (cm)

In 2022, the primary root length was significantly influenced by zinc foliar application. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest primary root length (1.69 cm), while A₁B₃ (0.25%) had the lowest (1.37 cm), indicating significant differences among zinc foliar application levels (Table 4.6). For pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) produced the longest primary root length (2.42 cm), with A₂B₁ (50 g/tree) recorded the shortest (2cm). Regarding post-cutting treatment, 5000-ppm IBA resulted in the longest primary root length (4.22 cm), whereas the control group exhibited the shortest (1 cm). At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) again showed the longest primary root length (1.74 cm), while A₁B₁ (0.25%) had the shortest (1.42 cm). Among pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) recorded the longest primary root length (2.56 cm), while A₂B₁ (50 g/tree) had the shortest (2.05 cm). Post-cutting treatment with 5000-ppm IBA resulted in the longest primary root length (4.22 cm), while the control group recorded the shortest (1.02 cm).

In 2023, zinc foliar application continued to significantly influence primary root length. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the longest primary root length (1.96 cm), while A₁B₁ (0.25%) had the shortest (1.67 cm). For pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) produced the longest primary root length (2.84 cm), while A₂B₁ (50 g/tree) recorded the shortest (2.25 cm). In post-cutting treatment, 5000-ppm IBA resulted in the longest primary root length (5 cm), with the control group showing the shortest (1.06 cm). At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the longest primary root length (2 cm), while A₁B₁ (0.25%) had the shortest (1.68 cm). For pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) recorded the longest primary root length (2.90 cm), while A₂B₁ (50 g/tree) showed the shortest (2.31 cm). Post-cutting treatment

Table 4.7 Effect of zinc (Zn) and IBA treatments on length of secondary root(cm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.82	0.82	0.82	0.86	0.86	0.86	0.84	0.84	0.84
A₁B₂	0.91	0.91	0.91	0.95	0.98	0.97	0.93	0.95	0.94
A₁B₃	1.01	1.02	1.02	1.06	1.08	1.07	1.04	1.05	1.05
A₂B₁	1.07	1.09	1.08	1.14	1.16	1.15	1.11	1.13	1.12
A₂B₂	1.25	1.27	1.26	1.29	1.32	1.31	1.27	1.31	1.29
A₂B₃	1.16	1.18	1.17	1.21	1.23	1.22	1.19	1.23	1.21
A₃B₁	2.63	2.81	2.72	2.76	2.82	2.79	2.7	2.82	2.76
A₃B₂	2.29	2.32	2.31	2.48	2.57	2.53	2.39	2.45	2.42
A₃B₃	0.26	0.27	0.27	0.28	0.29	0.29	0.27	0.28	0.28
Mean	1.27	1.30		1.34	1.37		1.31	1.34	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.006	0.002	0.011	0.004	0.006	0.002
Factor B	0.006	0.002	0.011	0.004	0.006	0.002
Factor C	0.006	0.002	0.008	0.003	0.004	0.001
Interaction A X B	0.011	0.003	0.018	0.006	0.011	0.003
Interaction A X C	0.011	0.003	0.013	0.004	0.007	0.002
Interaction B X C	0.011	0.003	0.013	0.004	0.007	0.002
Interaction A X B X C	0.018	0.006	0.023	0.008	0.013	0.004

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

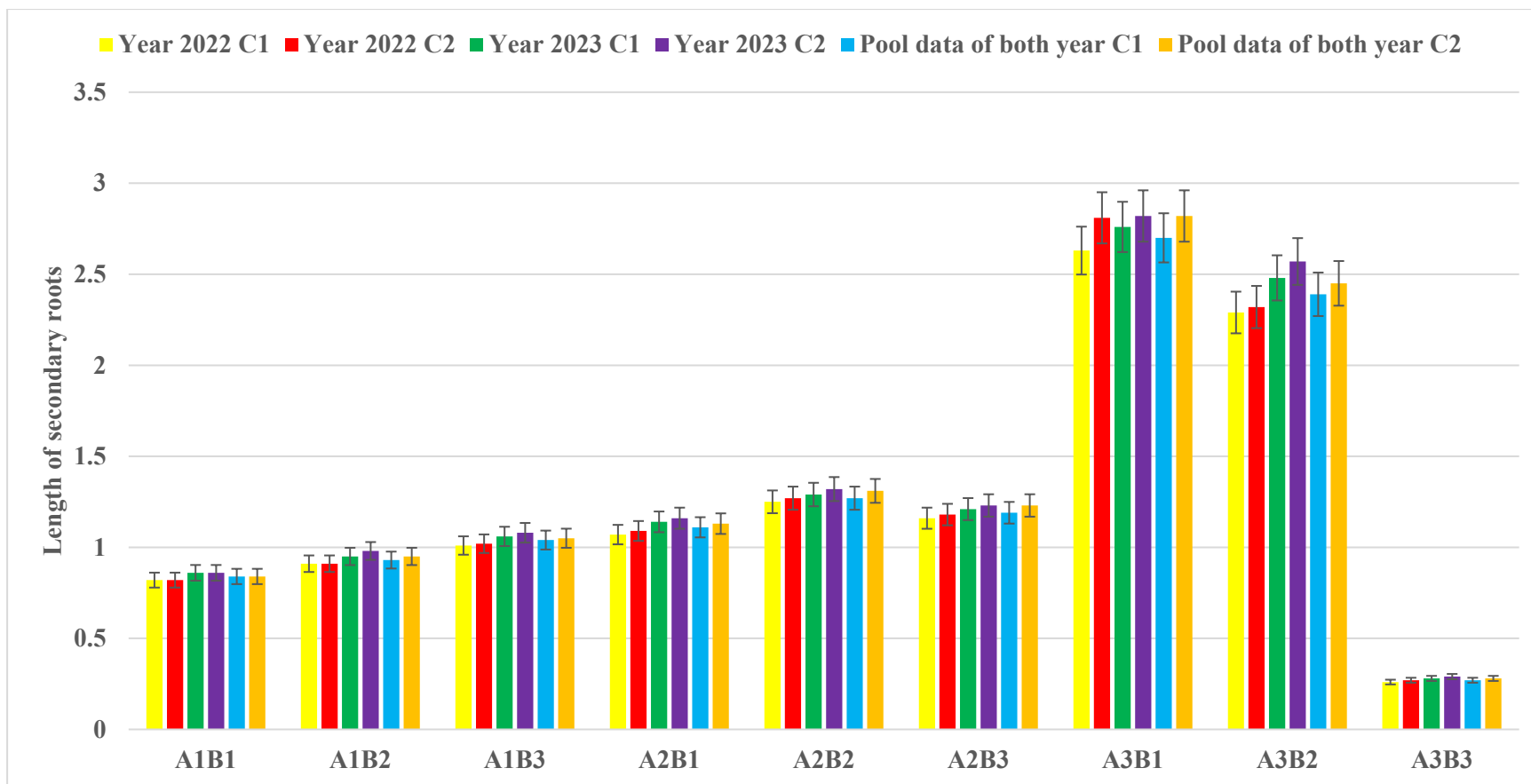


Figure 4.7 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the length of secondary roots (cm) in guava cuttings at different days.

with 5000-ppm IBA consistently produced the longest primary root length (5 cm), and the control group had the shortest (1.06 cm).

Pooling data from both years, A₁B₃ (0.75%) consistently resulted in the longest primary root length at 30 days after post-cutting treatment (1.83 cm), while A₁B₁ (0.25%) had the shortest (1.52 cm). Among pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) showed the longest primary root length (2.63 cm), while A₂B₁ (50 g/tree) recorded the shortest (2.13 cm). Post-cutting treatment with 5000-ppm IBA consistently produced the longest root length (4.61 cm), while the control group had the shortest (1.03 cm).

At 60 days, pooled data indicated that A₁B₃ (0.75%) produced the longest primary root length (1.87 cm), while A₁B₁ (0.25%) had the shortest (1.55 cm). For pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) consistently showed the longest primary root length (2.73 cm), with A₂B₁ (50 g/tree) recording the shortest (2.18 cm). Post-cutting treatment with 5000-ppm IBA resulted in the longest primary root length (4.59 cm), while the control group had the shortest (1.04 cm).

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced primary root length in cuttings. Cuttings collected after 60 days exhibited longer primary roots (2.48 cm) than those collected after 30 days (2.44 cm). The method of application and interactions (AxB, BxC, AxC, AxBxC) also had a significant impact. The greatest primary root length (4.45 cm) was observed in the A₃B₁C₂ treatment, where cuttings were taken after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.7 Length of secondary roots (cm)

In 2022, zinc foliar application significantly impacted secondary root length. At 30 days after post-cutting treatment, the longest secondary roots were observed in treatment A₁B₃ (0.75%) at 1.01 cm, while the shortest were in treatment A₁B₁ (0.25%) at 0.82 cm, indicating a significant difference among the various levels of zinc foliar application (Table 4.7, Figure 4.7). For pre-cutting basal zinc treatments, A₂B₂ (75 g/tree) resulted in the longest secondary roots at 1.25 cm, with A₂B₁ (50 g/tree) recorded the shortest at 1.07 cm. In post-cutting treatment, the application of 5000-

ppm IBA produced the longest secondary roots at 2.63 cm, whereas the control group had the shortest at 0.26 cm.

At 60 days after pre-cutting treatment in 2022, the longest secondary roots were recorded in treatment A₁B₃ (0.75%) at 1.02 cm, while A₁B₁ (0.25%) at 0.82 cm, Among the pre-cutting basal zinc treatments. A₂B₂ (75 g/tree) again produced the longest roots at 1.27 cm, and A₂B₁ (50 g/tree) had the shortest at 1.09 cm. For post-cutting treatment 5000-ppm IBA resulted in the longest secondary roots at 2.81 cm, while the control group recorded the shortest at 0.27 cm (Table 4.7, Figure 4.7).

In 2023, zinc foliar application continued to influence secondary root length significantly. At 30 days after pre-cutting treatment, treatment ZF₃ (0.75% /tree) recorded the longest secondary roots at 1.06 cm, while ZF₁ (0.25%/tree) had the shortest at 0.86 cm. For pre-cutting basal zinc treatments, ZB₂ (75 g/tree) produced the longest roots at 1.29 cm, whereas ZB₁ (50 g/tree) recorded the shortest at 1.14 cm. Post-cutting treatment with 5000-ppm IBA resulted in the longest secondary roots at 2.76 cm, while the control group had the shortest at 2.48 cm (Table 4.7, Figure 4.7).

At 60 days after treatment in 2023, ZF₃ (0.75%) had the longest secondary root at 1.08 cm, while ZF₁ (0.25%) had the shortest at 0.86 cm. Among pre-cutting basal zinc treatments, ZB₂ (75 g/tree) recorded the longest roots at 1.32 cm, and ZB₁ (50 g/tree) had the shortest at 1.16 cm. For post-cutting treatment, 5000 ppm led to the longest secondary roots at 2.82 cm, while the control group recorded the shortest at 0.29 cm (Table 4.7, Figure 4.7).

When analysing pooled data for both years, at 30 days after pre-cutting treatment the longest secondary roots were recorded in treatment A₁B₃ (0.75% /tree) at 1.04 cm, while the shortest were in A₁B₁ (0.25%/tree) at 0.84 cm. Among pre-cutting basal treatments, A₂B₂ resulted in the roots at 1.27 cm, while A₂B₁ had the shortest at 1.11 cm. post-cutting treatment with 5000-ppm IBA consistently produced the longest secondary roots with a mean value of 2.70 cm, and the control group had the shortest at 2.39 cm.

Table 4.8 Effect of zinc (Zn) and IBA treatments on diameter of primary root (mm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.27	0.29	0.28	0.28	0.32	0.31	0.28	0.31	0.29
A ₁ B ₂	0.46	0.46	0.46	0.49	0.51	0.5	0.48	0.49	0.48
A ₁ B ₃	0.65	0.66	0.66	0.65	0.68	0.67	0.65	0.67	0.66
A ₂ B ₁	0.81	0.81	0.81	0.84	0.85	0.85	0.83	0.83	0.83
A ₂ B ₂	1.13	1.12	1.12	1.11	1.16	1.14	1.12	1.14	1.13
A ₂ B ₃	0.97	0.99	0.98	0.98	0.99	0.99	0.98	0.99	0.98
A ₃ B ₁	1.48	1.61	1.55	1.52	1.64	1.58	1.50	1.63	1.56
A ₃ B ₂	1.32	1.34	1.33	1.36	1.42	1.39	1.34	1.38	1.36
A ₃ B ₃	0.12	0.13	0.13	0.15	0.16	0.16	0.14	0.15	0.14
Mean	0.80	0.83		0.82	0.86		0.81	0.85	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.007	0.002	0.011	0.003	0.008	0.003
Factor B	0.007	0.002	0.011	0.003	0.008	0.003
Factor C	0.008	0.003	0.006	0.002	0.007	0.002
Interaction A X B	0.012	0.004	0.017	0.006	0.014	0.005
Interaction A X C	0.014	0.005	0.011	0.003	0.013	0.004
Interaction B X C	0.014	0.005	0.011	0.003	0.013	0.004
Interaction A X B X C	0.023	0.008	0.018	0.006	0.022	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

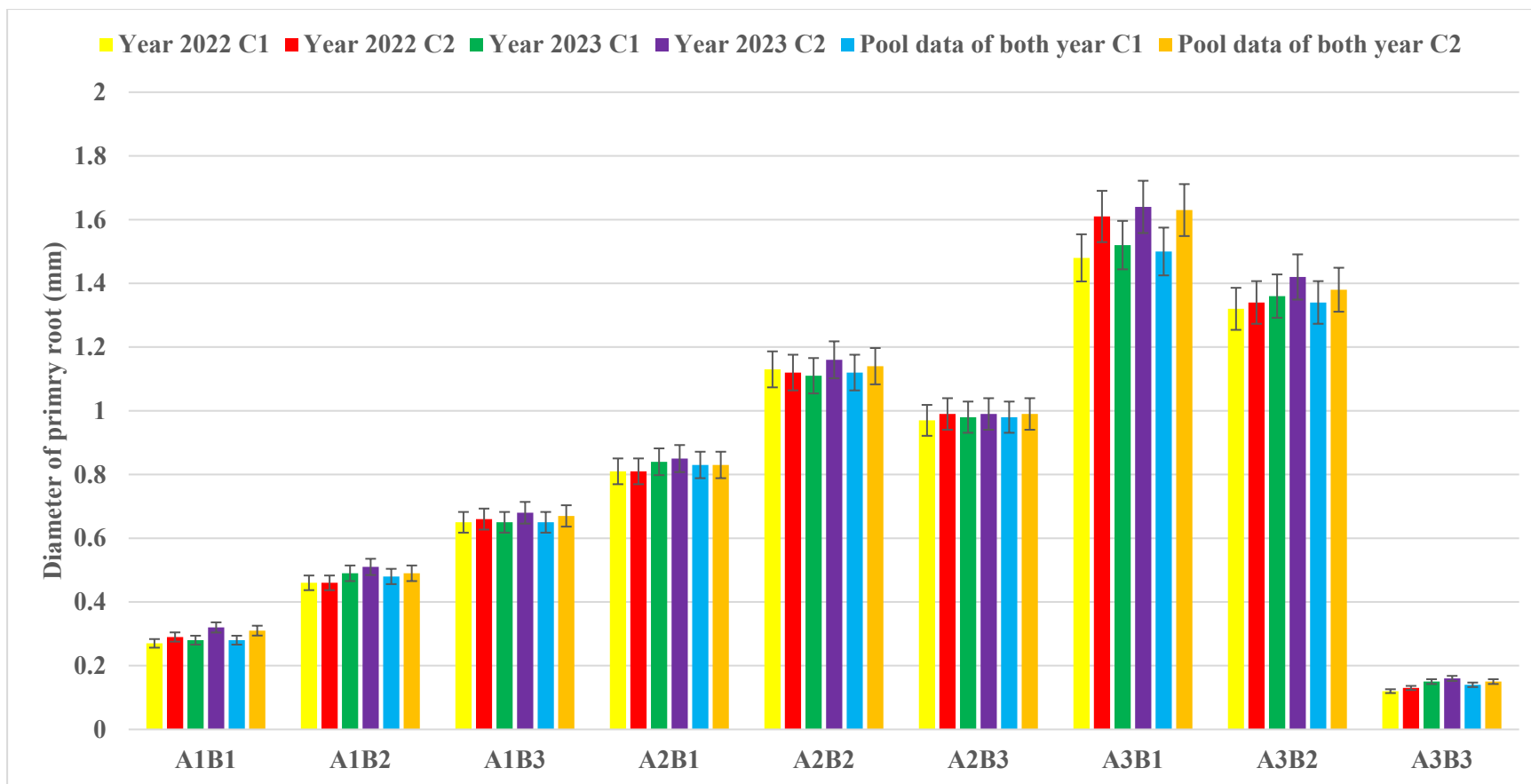


Figure 4.7 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of primary roots (cm) in guava cuttings at different days.

At 60 days, the pooled data showed that A₁B₃ (0.75%) resulted in the longest secondary roots at 1.05 cm, while A₁B₁ (0.25%/tree) had the shortest at 0.84 cm. Among pre-cutting basal zinc treatments, A₂B₂ (1.30 cm) consistently had the longest roots, while A₂B₁ (1.13 cm) had the shortest. Post-cutting treatment with 5000-ppm IBA maintained the longest secondary roots with a pooled mean value of 2.82 cm, and the control group had the shortest at 0.28 cm (Figure 4.7).

Secondary root length in cuttings was similarly affected by the timing of pre-cutting zinc treatments or the dormant stage. Cuttings collected after 60 days showed longer secondary roots (1.34 cm) than those taken after 30 days (1.31 cm). The application method and interactions (AxB, BxC, AxC, AxBxC) were also significant. The longest secondary root length (2.82 cm) was recorded in the A₃B₁C₂ treatment, involving cuttings collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

4.1.8 Diameter of primary root (mm)

In 2022, zinc foliar application significantly affected the diameter of primary roots. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) resulted in the maximum primary root diameter at 0.65 mm, whereas A₁B₁ (0.25%) had the minimum at 0.27 mm, reflecting significant differences across zinc foliar treatments (Table 4.8, Figure 4.8). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the maximum primary root diameter at 1.13 mm, with A₂B₁ showing the minimum at 0.81 mm. For post-cutting treatment of 5000-ppm concentration produced the maximum primary root diameter at 1.48 mm, while the control group had the minimum at 0.12 mm.

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) again had the maximum primary root diameter at 0.66 mm, while A₁B₁ (0.25%) had the minimum at 0.29 mm, demonstrating clear differences among zinc basal applications. A₂B₂ (75 g/tree) was the top performer with a primary root diameter of 1.12 mm, whereas A₂B₁ (50 g/tree) had the minimum at 0.81 mm. For post-cutting treatment of 5000-ppm concentration showed the maximum primary root diameter at 1.61 mm, and the control group the minimum at 0.13 mm (Figure 4.8).

In 2023, the influence of zinc foliar application on the diameter of primary roots remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) had the maximum primary root diameter at 0.65 mm, while A₂B₂ (75 g/tree) had the minimum at 0.28 mm. Among zinc basal treatments, A₂B₂ (75 g/tree) had the maximum primary root diameter at 1.11 mm, with A₂B₁ (50 g/tree) showing the minimum at 0.84 mm. post-cutting treatment of 5000-ppm concentration led to the maximum primary root diameter at 1.52 mm, while the control group had the minimum at 0.15 mm (Table 4.8, Figure 4.8).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75% /tree) recorded the maximum primary root diameter at 0.68 mm, and A₁B₁ (0.25 g/tree) the minimum at 0.32 mm. Among various levels of zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) had the maximum primary root diameter at 1.16 mm, and A₂B₁ (50 g/tree) had the minimum at 0.85 mm. For post-cutting treatment of 5000-ppm concentration had the maximum primary root diameter at 1.64 mm, with the control group having the minimum at 0.16 mm (Table 4.8, Figure 4.8).

Combining data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the maximum primary root diameter at 0.65 mm, while A₁B₁ (0.25%) recorded the minimum at 0.28 mm, demonstrating consistent trends (Table 4.8, Figure 4.8). Among basal treatments, A₂B₂ (75 g/tree) achieved the maximum primary root diameter at 1.12 mm, while A₂B₁ (50 g/tree) had the minimum at 0.83 mm. post-cutting treatment at 5000-ppm IBA concentration produced the maximum primary root diameter with a mean value of 1.50 mm, while the control group had the minimum at 0.14 mm.

At 60 days, pooled data indicated that A₁B₃ (0.75%) recorded the maximum primary root diameter at 0.67 mm, while A₁B₁ (0.25 %/) had the minimum at 0.31 mm. Among basal treatments, A₂B₂ (75 g/tree) (1.14 mm) had the maximum primary root diameter, while A₂B₁ (0.83 mm) had the minimum. For post-cutting treatment of 5000-ppm concentration maintained the maximum primary root diameter with a pooled mean value of 1.63 mm, while the control group had the minimum at 0.15 mm (Figure 4.8).

Table 4.9 Effect of zinc (Zn) and IBA treatments on diameter of secondary root (mm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.08	0.11	0.09	0.14	0.17	0.16	0.11	0.14	0.13
A ₁ B ₂	0.17	0.22	0.21	0.23	0.23	0.23	0.19	0.23	0.22
A ₁ B ₃	0.28	0.31	0.29	0.35	0.35	0.35	0.32	0.33	0.33
A ₂ B ₁	0.41	0.41	0.41	0.43	0.44	0.44	0.42	0.43	0.43
A ₂ B ₂	0.64	0.66	0.65	0.69	0.71	0.7	0.67	0.69	0.68
A ₂ B ₃	0.52	0.54	0.53	0.56	0.57	0.57	0.54	0.56	0.55
A ₃ B ₁	0.88	0.99	0.94	0.96	0.99	0.98	0.92	0.99	0.96
A ₃ B ₂	0.79	0.82	0.81	0.84	0.89	0.87	0.82	0.86	0.84
A ₃ B ₃	0.02	0.02	0.02	0.04	0.04	0.04	0.03	0.03	0.03
Mean	0.42	0.45		0.47	0.49		0.45	0.47	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.012	0.004	0.008	0.003	0.007	0.002
Factor B	0.012	0.004	0.008	0.003	0.007	0.002
Factor C	0.007	0.002	0.005	0.002	0.004	0.001
Interaction A X B	0.021	0.007	0.014	0.005	0.012	0.004
Interaction A X C	0.011	0.004	0.008	0.003	0.008	0.003
Interaction B X C	0.011	0.004	0.008	0.003	0.008	0.003
Interaction A X B X C	0.02	0.007	0.015	0.005	0.013	0.004

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

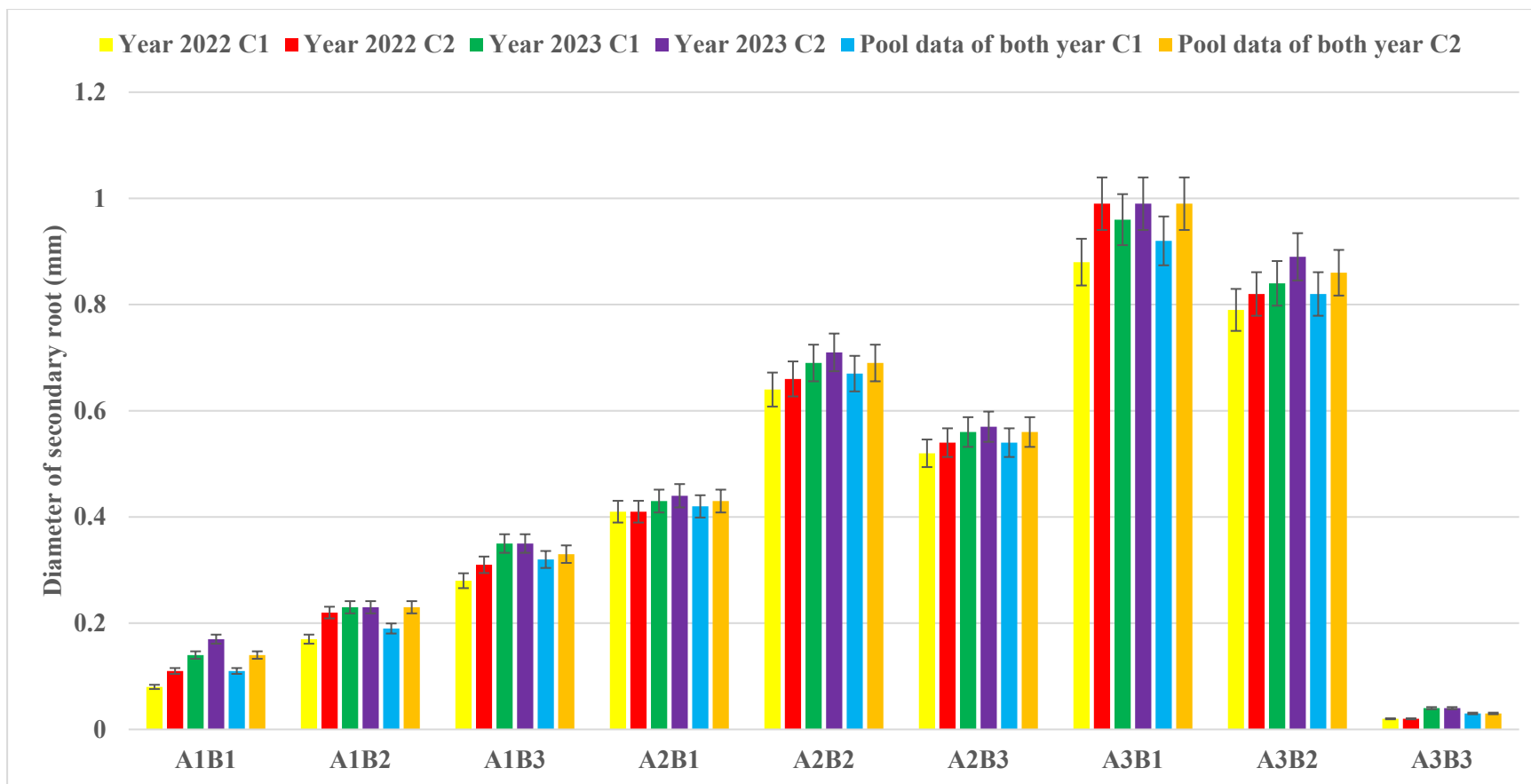


Figure 4.9 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of secondary roots (cm) in guava cuttings at different days.

Table 4.10 Effect of zinc (Zn) and IBA treatments on fresh weight of primary root (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.71	0.73	0.72	0.82	0.82	0.82	0.77	0.78	0.78
A ₁ B ₂	0.82	0.82	0.82	0.87	0.87	0.87	0.85	0.85	0.85
A ₁ B ₃	0.90	0.90	0.90	0.94	0.94	0.94	0.92	0.92	0.92
A ₂ B ₁	0.99	1.03	1.01	1.01	1.02	1.02	0.99	1.02	1.01
A ₂ B ₂	1.15	1.19	1.17	1.21	1.24	1.23	1.19	1.24	1.23
A ₂ B ₃	1.06	1.11	1.09	1.11	1.13	1.12	1.09	1.12	1.11
A ₃ B ₁	2.20	2.33	2.27	2.41	2.44	2.43	2.31	2.39	2.35
A ₃ B ₂	2.04	2.08	2.06	2.25	2.29	2.27	2.15	2.19	2.17
A ₃ B ₃	0.25	0.27	0.26	0.27	0.27	0.27	0.26	0.27	0.27
Mean	1.13	1.16		1.21	1.22		1.17	1.20	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(M)	CD	SE(M)	CD	SE(M)
Factor A	0.015	0.005	0.008	0.003	0.011	0.004
Factor B	0.015	0.005	0.008	0.003	0.011	0.004
Factor C	0.004	0.001	0.005	0.002	0.002	0.001
Interaction A X B	0.027	0.009	0.014	0.005	0.018	0.006
Interaction A X C	0.007	0.002	0.008	0.003	0.004	0.001
Interaction B X C	0.007	0.002	0.008	0.003	0.004	0.001
Interaction A X B X C	0.012	0.004	0.014	0.005	0.007	0.002

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

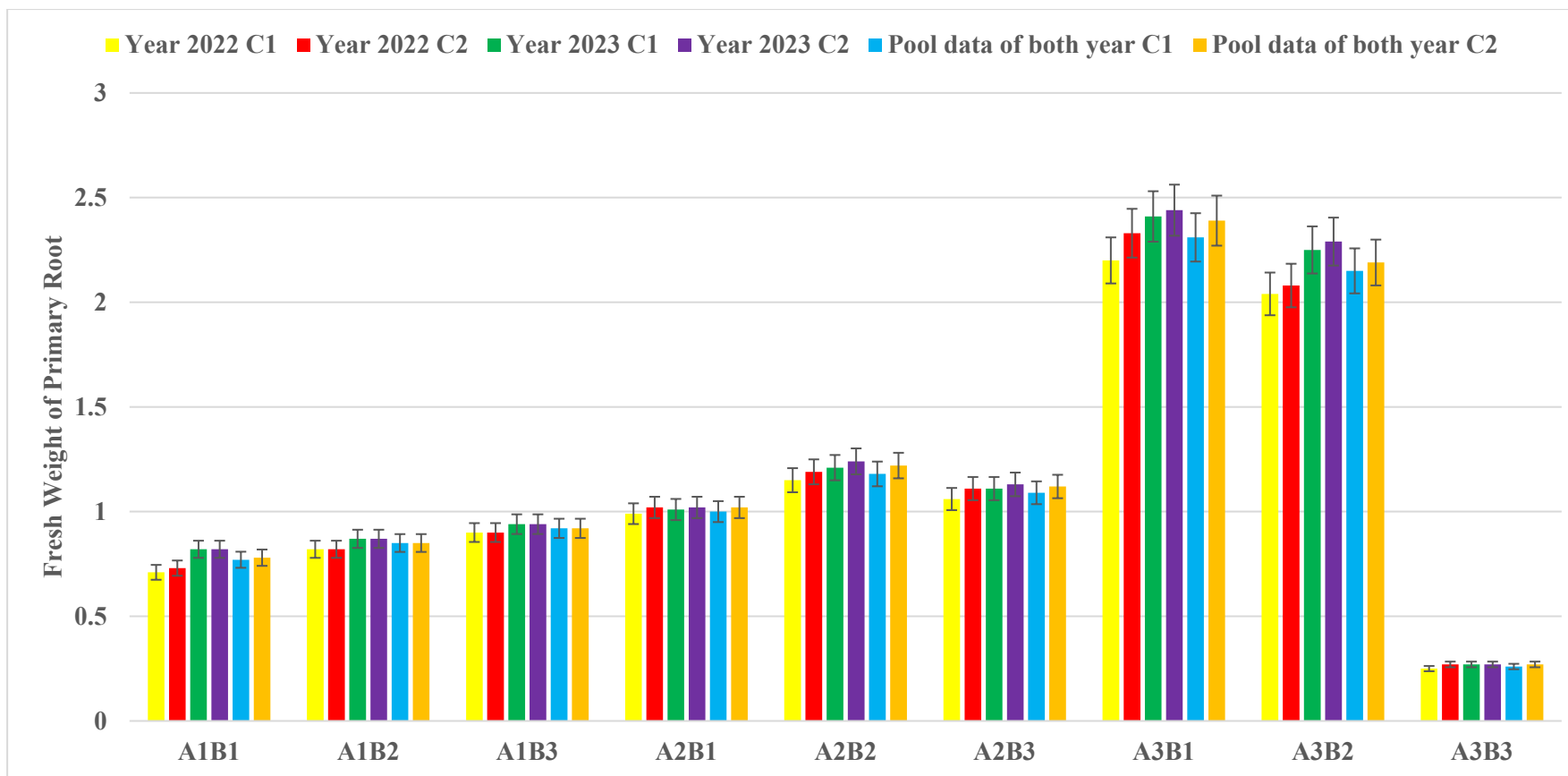


Figure 4.10 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of primary root (g) in guava cuttings at different days.

Primary root diameter in cuttings was significantly influenced by the timing of pre-cutting zinc treatments or the dormant stage of guava. Cuttings collected after 30 days exhibited a larger root diameter (0.81 mm) compared to those collected after 60 days (0.85 mm). The application method and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The largest primary root diameter (1.63 mm) was recorded in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.9 Diameter of Secondary Roots (mm)

In 2022, zinc foliar application significantly affected the diameter of secondary roots. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) resulted in a maximum secondary root diameter of 0.28 mm, whereas A₁B₁ (0.25%) showed a minimum at 0.08 mm (Table 4.9, Figure 4.9). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) exhibited the maximum secondary root diameter at 0.64 mm, with A₂B₁ having the minimum at 0.41 mm. post-cutting treatment of 5000-ppm concentration led to a maximum secondary root diameter of 0.88 mm, while the control group had a minimum of 0.02 mm.

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) maintained the maximum secondary root diameter at 0.31 mm, and A₁B₁ (0.25%) the minimum at 0.11 mm, highlighting significant differences among zinc basal applications. A₂B₂ (75 g/tree) recorded the maximum secondary root diameter at 0.66 mm, whereas A₂B₁ (50 g/tree) had the minimum at 0.43 mm. For post-cutting treatment of 5000-ppm concentration showed the maximum secondary root diameter at 0.99 mm, with the control group showing the minimum at 0.02 mm (Table 4.9, Figure 4.9).

In 2023, zinc foliar application continued to influence the diameter of secondary roots significantly. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the maximum secondary root diameter at 0.35 mm, while A₁B₁ (0.25%) had the minimum at 0.14 mm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the maximum secondary root diameter at 0.69 mm, and A₂B₁ (50 g/tree) the minimum at 0.43 mm. post-cutting treatment of 5000-ppm IBA

concentration resulted in the maximum secondary root diameter at 0.96 mm, while the control group had a minimum of 0.04 mm (Table 4.9, Figure 4.9).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the maximum secondary root diameter at 0.35 mm, and A₁B₁ (0.25%) the minimum at 0.17 mm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum secondary root diameter at 0.71 mm, while A₂B₁ had the minimum at 0.44 mm. For post-cutting treatment of 5000-ppm concentration maintained the maximum secondary root diameter at 0.99 mm, with the control group showing the minimum at 0.04 mm (Figure 4.9).

When pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the maximum secondary root diameter at 0.32 mm, while A₁B₁ (0.25%) had the minimum at 0.11 mm (Table 4.9, Figure 4.9). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum secondary root diameter at 0.67 mm, and A₂B₁ (50 g/tree) had the minimum at 0.42 mm. post-cutting treatment of 5000-ppm concentration consistently resulted in the maximum secondary root diameter with a mean value of 0.92 mm, while the control group had the minimum at 0.03 mm.

At 60 days, pooled data indicated that treatment A₁B₃ (0.75%) had the maximum secondary root diameter at 0.33 mm, while A₁B₁ (0.25%) had the minimum at 0.14 mm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) (35.1 mm) maintained the maximum secondary root diameter, and A₂B₁ (50 g/tree) (28.7 mm) was the minimum. For post-cutting treatment of 5000-ppm concentration continued to show the maximum secondary root diameter with a pooled mean value of 0.99 mm, while the control group had the minimum at 0.03 mm (Figure 4.9).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced secondary root diameter in cuttings. Cuttings collected after 60 days showed maximum root diameter (0.47 mm) than those collected after 30 days (0.45 mm). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the time taken for root initiation. The earliest root

initiation (0.99 mm) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

The length and diameter of primary and secondary roots are crucial parameters that determine the efficiency of nutrient and water uptake. This study found that basal zinc application at 75 g/tree (A₂B₂) significantly increased the length and diameter of both primary and secondary roots. The enhanced root length and diameter provide a larger surface area for nutrient and water absorption, thereby improving the overall efficiency of the root system. These improvements in root length and diameter highlight the critical role of zinc in enhancing root structural integrity and functional capacity, consistent with the findings of Blum (2011). Present findings are fully supported by the results of Somkuwar *et al.* (2013) in dog ridge rootstock and Alizadeh and Dumanoglu (2022) in olive.

4.1.10 Fresh Weight of Primary Root (g)

In 2022, zinc foliar application significantly influenced the fresh weight of the primary root. At 30 days after pre-cutting treatment, the highest fresh weight (0.90g) was recorded in the A₁B₃ treatment (0.75%), whereas the lowest (0.71g) was observed in the A₁B₁ treatment (0.25%), indicating a notable difference among the zinc foliar application levels (Table 4.10, Figure 4.10). For pre-cutting basal zinc treatments A₂B₂ (75 g/tree) resulted in the maximum fresh weight of the primary root (1.15g), while A₂B₁ (50 g/tree) showed the minimum (0.99g). For post-cutting treatment of 5000-ppm concentration produced in the highest fresh weight (2.20g), contrasting with the control group, which exhibited the lowest fresh weight (0.25g).

At 60 days after pre-cutting treatment, the highest fresh weight was again recorded in A₁B₃ (0.75%) (0.90g), while the lowest was observed in the A₁B₁ (0.25%) (0.73g), highlighting significant differences among the zinc foliar application levels. Among the basal treatments, A₂B₂ (75 g/tree) achieved the highest fresh weight (1.19g), while A₂B₁ (50 g/tree) had the lowest (1.02g). For post-cutting treatment of 5000-ppm concentration continued to exhibit the highest fresh weight (2.33g), with the control group remaining the lowest (0.27g).

In 2023, similar trends were observed at 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest fresh weight (0.94g), while A₁B₁ (0.25%) had the lowest (0.82g), again showing significant differences among the zinc foliar application levels (Table 10). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) led with 1.21g, while A₂B₁ (50 g/tree) was at the bottom (1.01g). For post-cutting treatment of 5000-ppm concentration resulted in the highest fresh weight (2.41g), whereas the control group had the lowest (0.27g).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) again recorded the highest fresh weight (0.94g), and A₁B₁ (0.25%) had the lowest (0.82g), indicating a significant difference among the various levels of zinc basal application (Table 4.10, Figure 4.10). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest fresh weight (1.24g), while A₂B₁ (50 g/tree) had the lowest (1.02g). For post-cutting treatment of 5000-ppm concentration maintained the highest fresh weight (2.44g), with the control group showing the lowest (0.27g).

When pooling data for both years, the maximum fresh weight at 30 days after pre-cutting was consistently recorded in the A₁B₃ treatment (0.75%) (0.92g), while the minimum was observed in A₁B₁ (0.25%) (0.77g) (Table 4.10, Figure 4.10). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) (1.18g) had the highest pooled fresh weight, and A₂B₁ (50 g/tree) (1g) had the lowest. For post-cutting treatment of 5000-ppm concentration consistently showed the highest fresh weight (2.31g), while the control group had the lowest (0.26g). At 60 days after pre-cutting treatment, pooled data revealed that A₁B₃ (0.75%) maintained the highest fresh weight (0.92g), with A₁B₁ (0.25%) having the lowest (0.78g). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) (1.22g) consistently performed best, while A₂B₁ (50 g/tree) (1.02g) had the minimum fresh weight. For post-cutting treatment of 5000-ppm concentration maintained the highest pooled fresh weight (2.39g), and the control group remained the lowest (0.27g).

Fresh weight of primary roots was also affected by the timing of pre-cutting zinc treatments or the dormant stage. Cuttings collected after 60 days showed higher fresh root weight (1.20 g) compared to those collected after 30 days (1.17 g). Significant effects were noted for the application method and interactions (AxB, BxC, AxC,

AxBxC). The highest fresh weight of primary roots (3.76 g) was observed in the A3B1C2 treatment, where cuttings were taken after 60 days of the dormant stage and dipped in 5000 ppm IBA.

4.1.11 Fresh Weight of Secondary Root (g)

In both 2022 and 2023, zinc foliar application significantly influenced the fresh weight of secondary roots at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest fresh weight of secondary roots, with values of 0.49 g in 2022 and 0.56 g in 2023, while A₁B₁ (0.25%) showed the lowest values, of 0.29 g in 2022 and 0.31 g in 2023 (Table 4.11, Figure 4.11).

Similarly, for zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the highest fresh weight of secondary roots, with values of 0.85 g in 2022 and 0.95 g in 2023, whereas A₂B₁ (50 g/tree) had the lowest, 0.58 g in 2022 and 0.71 g in 2023. Post-cutting treatment with a 5000-ppm concentration produced the maximum fresh weight of secondary roots at 1.12 g in 2022 and 1.22 g in 2023, while the control group consistently recorded the lowest fresh weight with value (0.09 g in 2022 and 0.11 g in 2023).

At 60 days of pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) recorded the maximum fresh weight of secondary roots (0.53 g in 2022 and 0.56 g in 2023), while A₁B₁ (0.25%) had the lowest (0.31 g in 2022 and 0.31 g in 2023). Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) showed the highest fresh weight (0.86 g in 2022 and 0.96 g in 2023), while A₂B₁ (50 g/tree) had the lowest (0.65 g in 2022 and 0.74 g in 2023). For post-cutting treatment with 5000-ppm concentration produced the maximum fresh weight at 1.16 g in 2022 and 1.34 g in 2023, while the control group recorded the lowest values (0.09 g in 2022 and 0.13 g in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum fresh weight of secondary roots at 0.53 g, while A₁B₁ (0.25%) had the lowest at 0.30 g (Table 4.11, Figure 4.11). A₂B₂ (75 g/tree) showed the highest pooled fresh weight at 0.90 g, while

A₂B₁ (50 g/tree) recorded the lowest at 0.65g. Post-cutting treatment with 5000-ppm concentration produced the maximum fresh weight at 1.17 g, while the control group had the lowest value at 0.11 g. At 60 days after pre-cutting treatment, A₁B₃ had the maximum fresh weight at 0.55 g, while A₁B₁ had the lowest at 0.31 g. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments with 0.91 g, and A₂B₁ (50 g/tree) had the lowest fresh weight at 0.70 g. For post-cutting treatment of 5000-ppm concentration maintained the maximum pooled fresh weight at 1.25 g, and the control group remained the lowest at 0.11 g.

The number of days after zinc pre-cutting treatment or during the dormant stage significantly impacted the fresh weight of secondary roots in guava cuttings. Cuttings taken 60 days after treatment exhibited a higher fresh weight of secondary roots (0.91 g) compared to those taken at 30 days (0.83 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The maximum fresh weight of secondary roots (1.25 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

4.1.12 Dry weight of the primary root (g)

In 2022, zinc foliar application had a marked effect on the dry weight of primary roots. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) resulted in the highest dry weight at 0.27 g, whereas A₁B₁ (0.25%) had the lowest at 0.21 g, reflecting significant differences across zinc foliar treatments (Table 4.12, Figure 4.12). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the highest dry weight at 0.35 g, with A₂B₁ showing the lowest at 0.30 g. For post-cutting treatment, IBA 5000-ppm concentration produced the highest dry weight at 0.66 g, while the control group had the lowest at 0.08 g. At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) again had the highest dry weight at 0.27 g, while A₁B₁ (0.25%) had the lowest at 0.22 g, demonstrating clear differences among zinc basal applications. A₂B₂ (75 g/tree) was the top performer with a dry weight of 0.33 g, whereas A₂B₁ (50 g/tree) had the lowest at 0.31 g. For post-cutting treatment of IBA 5000-ppm concentrations, the highest dry weight was at 0.70 g, and the control group had the lowest at 0.08 g (Figure 4.12).

Table 4.11 Effect of zinc (Zn) and IBA treatments on fresh weight of secondary root (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.29	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
A ₁ B ₂	0.41	0.44	0.43	0.43	0.45	0.44	0.42	0.45	0.44
A ₁ B ₃	0.49	0.53	0.51	0.56	0.56	0.56	0.53	0.55	0.54
A ₂ B ₁	0.58	0.65	0.62	0.71	0.74	0.73	0.65	0.71	0.67
A ₂ B ₂	0.85	0.86	0.86	0.95	0.96	0.96	0.91	0.91	0.91
A ₂ B ₃	0.71	0.77	0.74	0.82	0.87	0.85	0.77	0.83	0.81
A ₃ B ₁	1.12	1.16	1.14	1.22	1.34	1.28	1.17	1.25	1.21
A ₃ B ₂	1.02	1.05	1.04	1.02	1.13	1.08	1.02	1.09	1.06
A ₃ B ₃	0.09	0.09	0.09	0.11	0.13	0.12	0.11	0.11	0.11
Mean	0.62	0.65		0.68	0.72		0.65	0.69	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.006	0.002	0.005	0.002
Factor B	0.007	0.002	0.006	0.002	0.005	0.002
Factor C	0.006	0.002	0.006	0.002	0.004	0.001
Interaction A X B	0.012	0.004	0.011	0.004	0.009	0.003
Interaction A X C	0.011	0.003	0.011	0.003	0.007	0.002
Interaction B X C	0.011	0.003	0.011	0.003	0.007	0.002
Interaction A X B X C	0.018	0.006	0.017	0.006	0.012	0.004

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

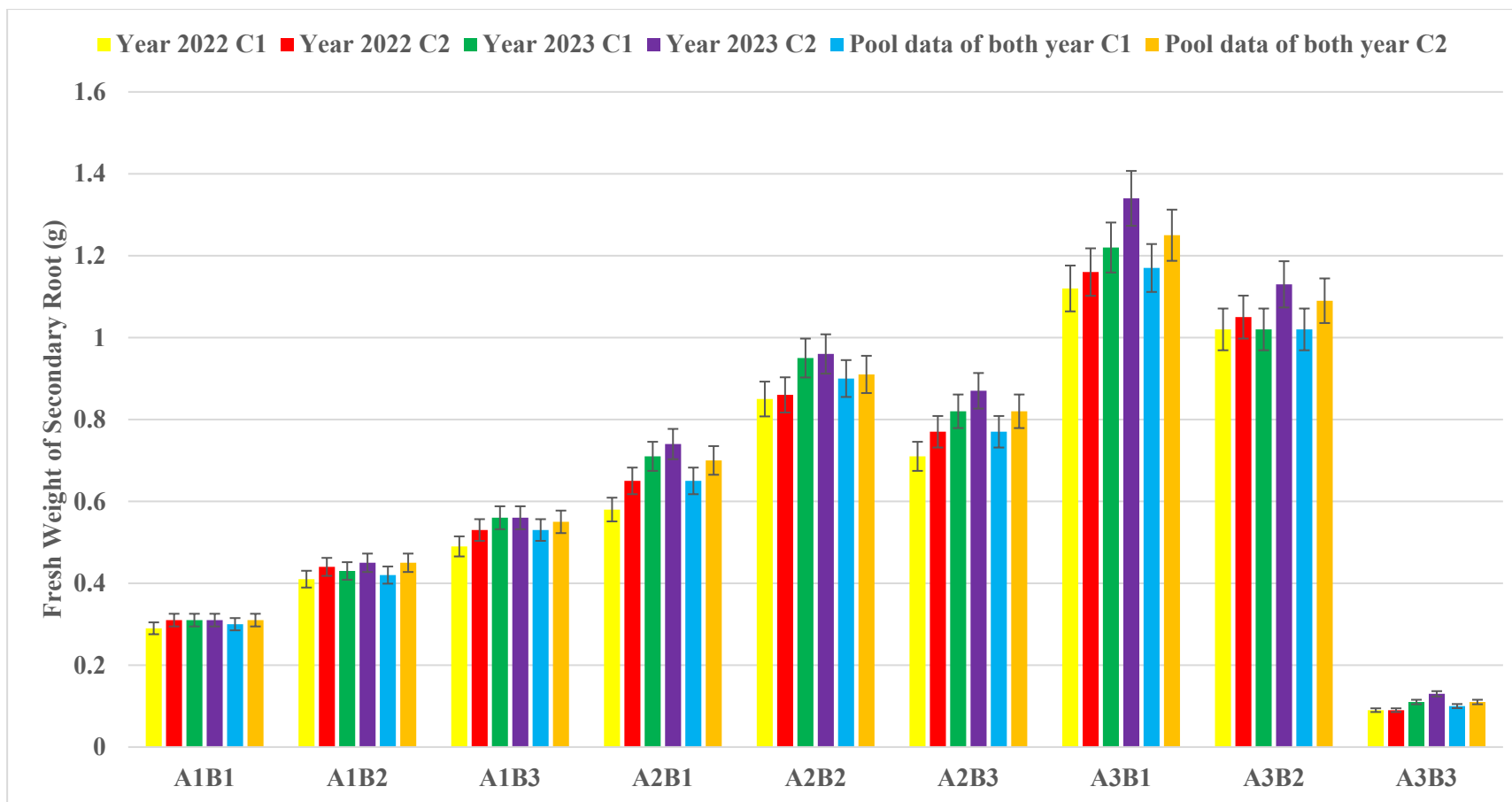


Figure 4.11 Graphical representation of the effect of zinc (Zn) and IBA treatments on fresh weight of secondary root (g) in guava cuttings at different days.

Table 4.12 Effect of zinc (Zn) and IBA treatments on dry weight of primary root (g) in Guava Cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.21	0.22	0.22	0.25	0.25	0.25	0.23	0.23	0.23
A ₁ B ₂	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26
A ₁ B ₃	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28
A ₂ B ₁	0.30	0.31	0.30	0.30	0.31	0.31	0.30	0.31	0.30
A ₂ B ₂	0.35	0.36	0.35	0.36	0.37	0.37	0.35	0.37	0.36
A ₂ B ₃	0.32	0.33	0.33	0.33	0.34	0.34	0.33	0.34	0.33
A ₃ B ₁	0.66	0.70	0.68	0.72	0.73	0.73	0.69	0.72	0.71
A ₃ B ₂	0.61	0.62	0.62	0.68	0.69	0.68	0.65	0.66	0.65
A ₃ B ₃	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Mean	0.34	0.35		0.36	0.37		0.35	0.36	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.006	0.002	0.011	0.004	0.011	0.004
Factor B	0.006	0.002	0.011	0.004	0.011	0.004
Factor C	0.002	0.001	0.004	0.001	0.008	0.003
Interaction A X B	0.011	0.004	0.019	0.006	0.019	0.006
Interaction A X C	0.004	0.001	0.007	0.002	0.014	0.005
Interaction B X C	0.004	0.001	0.007	0.002	0.014	0.005
Interaction A X B X C	0.007	0.002	0.012	0.004	0.015	0.008

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

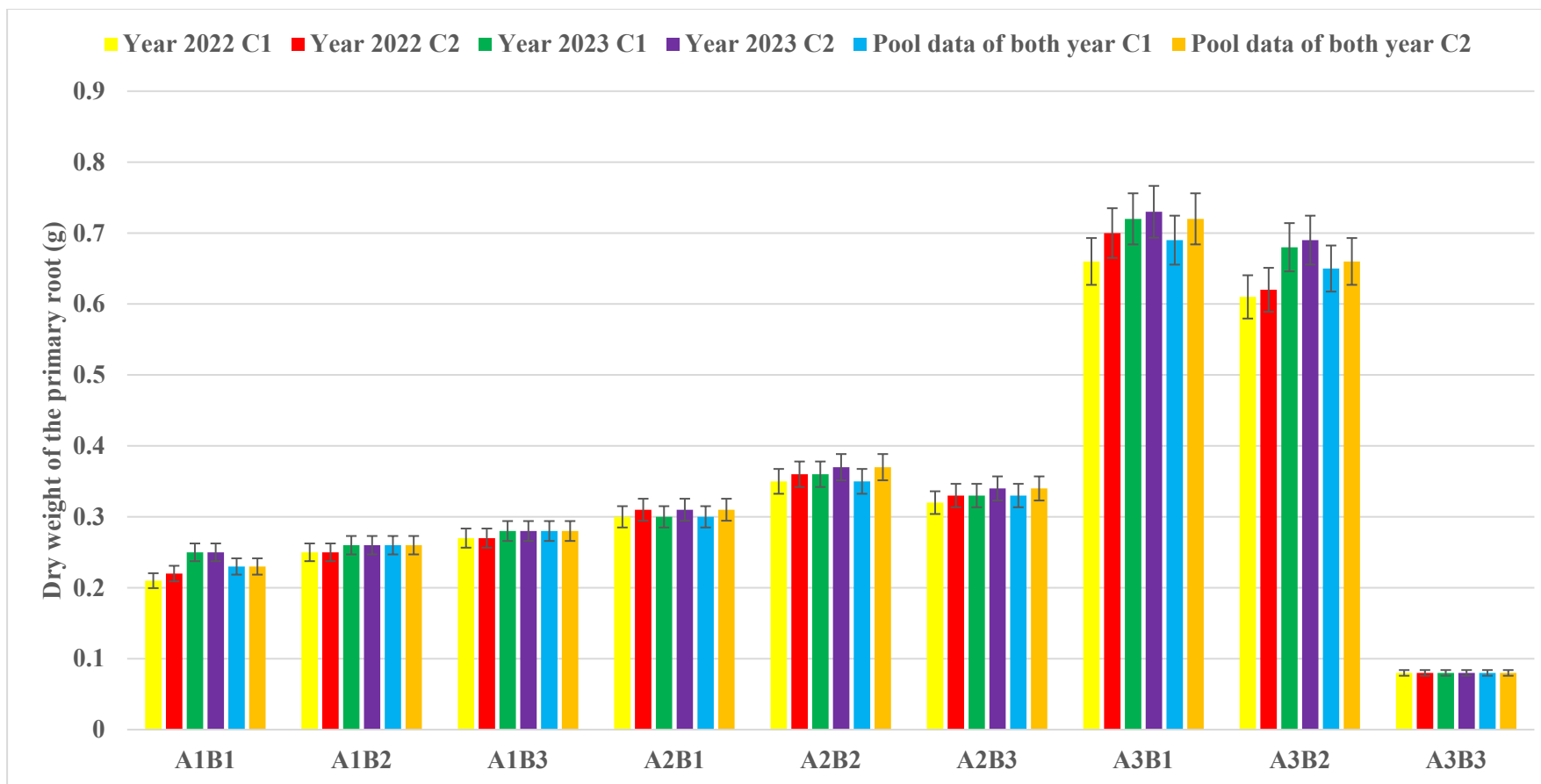


Figure 4.12 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of the primary root (g) in guava cuttings at different days.

In 2023, the influence of zinc foliar application on the dry weight of primary roots remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest dry weight at 0.28 g, while A₁B₁ (0.25%) had the lowest at 0.25 g. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight at 0.36 g, with A₂B₁ (50 g/tree) showing the lowest at 0.30 g. For post-cutting treatment of IBA 5000-ppm concentration led to the highest dry weight at 0.72 g, while the control group had the lowest at 0.08 g (Table 4.12, Figure 4.12).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the highest dry weight at 0.28 g, and A₁B₁ (0.25%) was the lowest at 0.25 g. Among various levels of zinc as pre-cutting as basal treatments showed A₂B₂ (75 g/tree) had the highest dry weight at 0.37 g, and A₂B₁ (50 g/tree) had the lowest at 0.31 g. For post-cutting treatment, IBA 5000-ppm concentration had the highest dry weight at 0.73 g, with the control group having the lowest at 0.08 g (Table 4.12, Figure 4.12).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%/tree) consistently had the highest dry weight at 0.28 g, while A₁B₁ (0.25%/tree) had the lowest at 0.23 g, indicating consistent results (Table12, Figure12). Among various levels of of zinc as pre-cutting basal treatments showed A₂B₂ had the highest dry weight at 0.35 g, and A₂B₁ the lowest at 0.30 g. For post-cutting treatment, IBA 5000-ppm concentration consistently led to the highest dry weight with a mean value of 0.69 g, while the control group had the lowest at 0.08 g.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) had the highest dry weight at 0.28 g, while A₁B₁ (0.25%) had the lowest at 0.23 g. Zinc as pre-cutting basal treatments showed that A₂B₂ (0.37 g) had the highest dry weight, while A₂B₁ (0.31 g) had the lowest. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest dry weight with a pooled mean value of 0.72 g, while the control group had the lowest at 0.08 g (Table 12, Figure 4.12).

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced the dry weight of primary roots in cuttings. Cuttings collected 60 days after treatment exhibited a higher dry weight of primary roots (0.52 g) compared to those collected after 30 days (0.45 g). The method of application and interactions (AxB,

BxC, AxC, AxBxC) also had a significant impact. The maximum dry weight of primary roots (0.68 g) was recorded in the A3B1C2 treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.13 Dry Weight of Secondary Roots (g)

In both 2022 and 2023, zinc foliar application significantly impacted the dry weight of secondary roots at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight, with values of 0.45 g in 2022 and 0.52 g in 2023, while A₁B₁ (0.25%) showed the lowest values, 0.28 g in 2022 and 0.31 g in 2023 (Table 4.13, Figure 4.13). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the highest dry weight, with values of 0.60 g in 2022 and 0.68 g in 2023, while A₂B₁ (50 g/tree) had the lowest, 0.39 g in 2022 and 0.45 g in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the highest dry weight of 0.85 g in 2022 and 0.92 g in 2023, whereas the control group consistently had the lowest dry weight (0.20 g in 2022 and 0.25 g in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the highest dry weight (0.49 g in 2022 and 0.56 g in 2023), while A₁B₁ (0.25%) had the lowest (0.32 g in 2022 and 0.34 g in 2023). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight (0.65 g in 2022 and 0.72 g in 2023), while A₂B₁ (50 g/tree) had the lowest (0.42 g in 2022 and 0.48 g in 2023). For post cutting treatment of 5000-ppm concentration showed the highest dry weight at 0.89 g in 2022 and 0.96 g in 2023, with the control group remaining the lowest (0.22 g in 2022 and 0.27 g in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight at 0.49 g, with A₁B₁ (0.25%) the lowest at 0.30 g (Table 10). A₂B₂ (75 g/tree) showed the highest pooled dry weight at 0.64 g, and A₂B₁ (50 g/tree) had the lowest at 0.42 g. For post cutting treatment of IBA 5000-ppm concentration consistently had the highest dry weight at 0.88 g, while the control group had the lowest at 0.23 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest dry weight at 0.52 g, while A₁B₁ (0.25%) had the lowest at 0.33 g. A₂B₂ (75 g/tree) was the best performer among zinc

basal treatments with 0.69 g, and A₂B₁ (50 g/tree) had the lowest dry weight at 0.45 g. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest pooled dry weight at 0.93 g, and the control group remained the lowest at 0.25 g.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the dry weight of secondary roots in cuttings. Cuttings collected after 60 days recorded a higher dry weight of secondary roots (0.45 g) compared to those collected after 30 days (0.38 g). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly impacted the dry weight of secondary roots. The maximum dry weight (0.62 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

The fresh and dry weight of roots are important indicators of root biomass and overall plant health. In this study, zinc application, particularly through basal methods, significantly increased both fresh and dry root weights. The treatment with basal zinc at 75g/tree (A₂B₂) resulted in the highest fresh and dry root weights, indicating enhanced root biomass and improved nutrient uptake capacity. This increase in root biomass is likely due to the enhanced enzyme activity and hormone regulation facilitated by zinc, leading to better root growth and development, consistent with findings by Marschner (2012).

4.1.14 Days to Sprouting

In both 2022 and 2023, zinc foliar application significantly impacted the days to sprout initiation at both 30- and 60-days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the fewest days to sprout initiation, with values of 28.32 days in 2022 and 26.02 days in 2023, while A₁B₁ (0.25%) showed the most days, 29.28 days in 2022 and 26.91 days in 2023 (Table 4.14, Figure 14). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the fewest days to sprout initiation, with values of 24.61 days in 2022 and 23.46 days in 2023, while A₂B₁ (50 g/tree) had the most, 26.09 days in 2022 and 24.71 days in 2023. For post cutting treatment of IBA 5000-ppm concentration yielded the fewest days to sprout initiation of 20.35 days in 2022

and 18.50 days in 2023, whereas the control group consistently had the most days to sprout initiation (33.16 days in 2022 and 30.67 days in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the fewest days to sprout initiation (28.07 days in 2022 and 25.71 days in 2023), while A₁B₁ (0.25%) had the most (29.14 days in 2022 and 26.74 days in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the fewest days to sprout initiation (24.47 days in 2022 and 23.07 days in 2023), while A₂B₁ (50 g/tree) had the most (26.03 days in 2022 and 24.23 days in 2023). For post-cutting treatment of IBA, 5000-ppm concentration showed the fewest days to sprout initiation at 20.10 days in 2022 and 18.15 days in 2023, with the control group remaining the most (32.24 days in 2022 and 30.05 days in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the fewest days to sprout initiation at 27.17 days, with A₁B₁ (0.25%) the most at 28.10 days (Table 4.14). A₂B₂ (75 g/tree) showed the fewest pooled days to sprout initiation at 24.04 days, and A₂B₁ (50 g/tree) had the most at 25.43 days. For post-cutting treatment of IBA 5000-ppm concentration consistently had the fewest days to sprout initiation at 19.44 days, while the control group had the most at 31.92 days. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the fewest days to sprout initiation at 26.94 days, while A₁B₁ (0.25%) had the most at 27.94 days. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments at 23.77 days, and A₂B₁ had the most days to initiate sprout at 25.13 days. For post-cutting treatment of IBA 5000-ppm concentration maintained the fewest pooled days to sprout initiation at 19.13 days, and the control group remained the most at 31.15 days.

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced sprout initiation in cuttings. Cuttings collected 60 days after treatment exhibited earlier sprout initiation (12.45 days) compared to those collected after 30 days (13.72 days). The application method and interactions (AxB, BxC, AxC, AxBxC) also had a notable effect. The earliest sprout initiation (10.18 days) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Table 4.13 Effect of zinc (Zn) and IBA treatments on dry weight of secondary root (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
A ₁ B ₂	0.12	0.13	0.13	0.13	0.14	0.13	0.13	0.14	0.13
A ₁ B ₃	0.15	0.16	0.15	0.17	0.17	0.17	0.16	0.17	0.16
A ₂ B ₁	0.17	0.20	0.19	0.21	0.22	0.22	0.20	0.21	0.20
A ₂ B ₂	0.26	0.26	0.26	0.29	0.29	0.29	0.27	0.27	0.27
A ₂ B ₃	0.21	0.23	0.22	0.25	0.26	0.26	0.23	0.25	0.24
A ₃ B ₁	0.44	0.49	0.47	0.49	0.58	0.54	0.47	0.54	0.51
A ₃ B ₂	0.33	0.33	0.31	0.34	0.39	0.37	0.34	0.36	0.35
A ₃ B ₃	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03
Mean	0.20	0.21		0.22	0.24		0.21	0.23	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.012	0.004	0.009	0.003	0.011	0.004
Factor B	0.012	0.004	0.009	0.003	0.011	0.004
Factor C	0.008	0.003	0.006	0.002	0.005	0.002
Interaction A X B	0.021	0.007	0.016	0.005	0.019	0.006
Interaction A X C	0.013	0.004	0.011	0.004	0.009	0.003
Interaction B X C	0.013	0.004	0.011	0.004	0.009	0.003
Interaction A X B X C	0.023	0.008	0.019	0.006	0.016	0.005

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

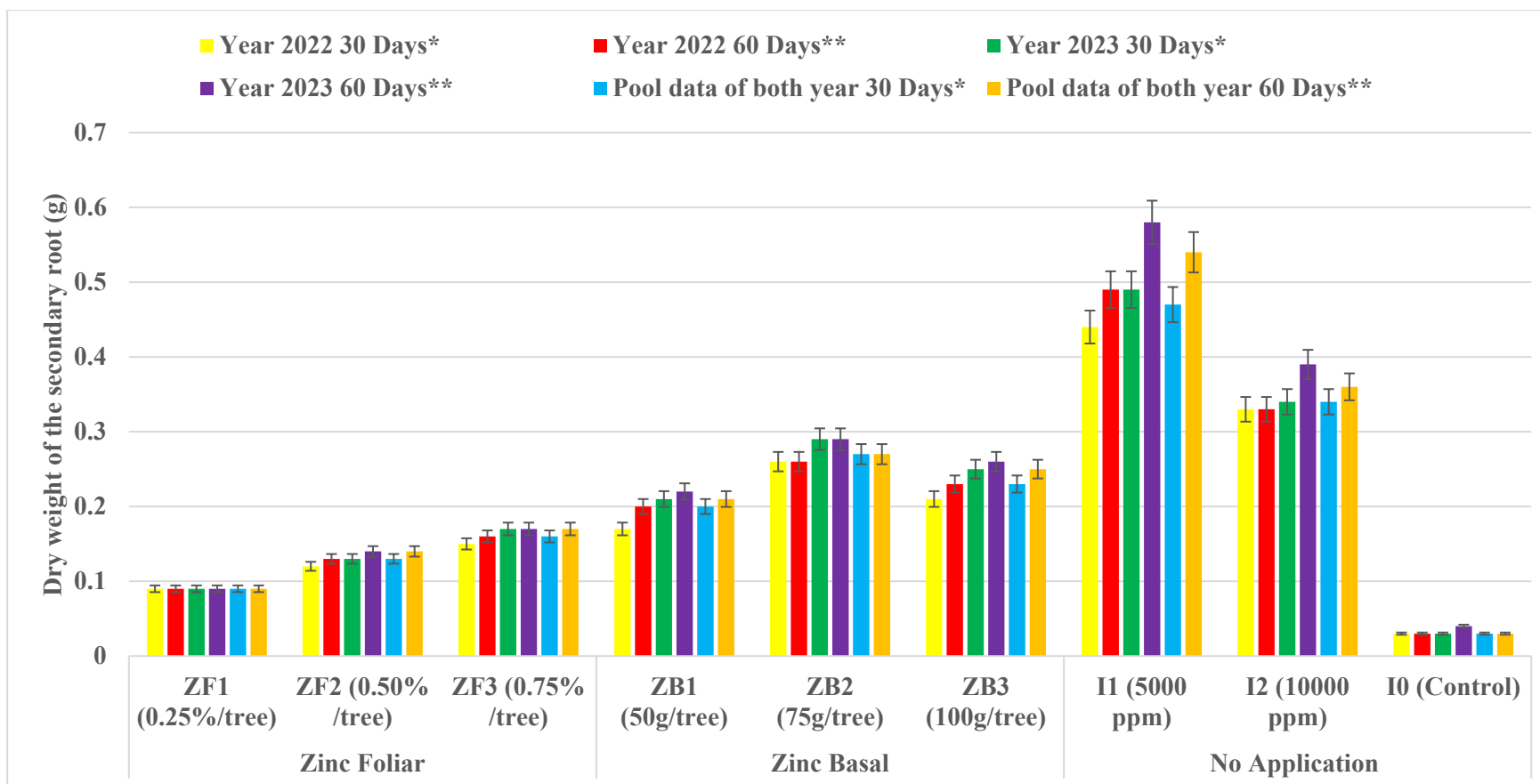


Figure 4.13 Graphical representation of the Effect of Zinc (Zn) and IBA treatments on dry weight of the secondary root (g) in guava cuttings at different days.

Table 4.14 Effect of zinc (Zn) and IBA treatments on days to sprouting in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	29.28	29.14	29.21	26.91	26.74	26.83	28.09	27.94	28.02
A ₁ B ₂	28.76	28.51	28.64	26.32	26.03	26.17	27.53	27.27	27.4
A ₁ B ₃	28.32	28.07	28.22	26.02	25.71	25.87	27.17	26.94	27.06
A ₂ B ₁	26.09	26.03	26.06	24.71	24.23	24.47	25.43	25.13	25.26
A ₂ B ₂	24.61	24.47	24.54	23.46	23.07	23.27	24.04	23.77	23.91
A ₂ B ₃	25.11	24.24	24.62	23.67	23.67	23.84	24.34	24.12	24.23
A ₃ B ₁	20.35	20.13	20.23	18.51	18.15	18.33	19.44	19.13	19.28
A ₃ B ₂	22.67	22.08	22.38	19.64	19.96	19.8	21.16	21.02	21.09
A ₃ B ₃	33.16	32.24	32.71	30.67	30.05	30.36	31.92	31.15	31.54
Mean	26.47	26.11		24.43	24.22		25.45	25.16	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.003	0.007	0.002	0.028	0.009
Factor B	0.011	0.003	0.007	0.002	0.028	0.009
Factor C	0.006	0.002	0.008	0.003	0.006	0.002
Interaction A X B	0.017	0.006	0.011	0.004	0.048	0.016
Interaction A X C	0.011	0.004	0.014	0.005	0.011	0.003
Interaction B X C	0.011	0.004	0.014	0.005	0.011	0.003
Interaction A X B X C	0.019	0.006	0.024	0.008	0.017	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

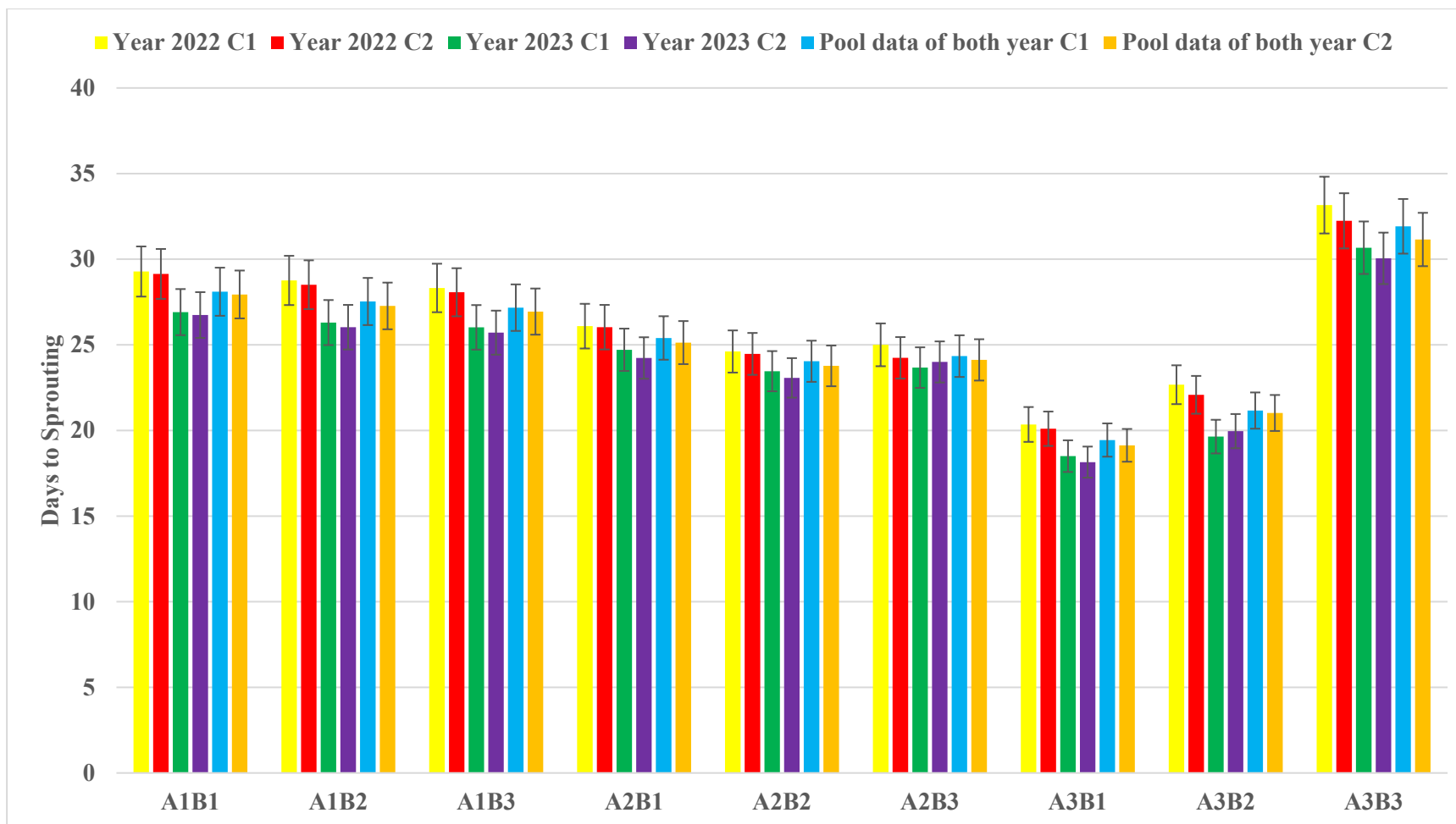


Figure 4.14 Graphical representation of the Effect of Zinc (Zn) and IBA treatment on days to sprouting in Guava Cuttings at different days.

Table 4.15 Effect of Zinc (Zn) and IBA treatments on sprouting (%) in Guava Cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	33.26	33.33	33.30	37.08	37.05	37.07	35.19	35.18	35.19
A ₁ B ₂	35.21	35.73	35.48	36.92	37.10	37.01	36.06	36.42	36.24
A ₁ B ₃	35.99	36.42	36.21	37.71	37.74	37.73	36.86	37.08	36.98
A ₂ B ₁	36.48	37.01	36.75	38.84	38.87	38.85	37.67	38.09	37.88
A ₂ B ₂	38.72	39.03	38.88	39.38	39.80	39.59	39.05	39.42	39.24
A ₂ B ₃	38.34	38.49	38.42	38.39	38.79	38.60	38.37	38.64	38.51
A ₃ B ₁	66.60	67.37	66.99	69.18	69.35	69.27	67.89	68.36	68.13
A ₃ B ₂	65.88	66.00	65.94	66.68	67.04	66.86	66.27	66.53	66.41
A ₃ B ₃	22.89	22.97	22.94	25.73	25.65	25.70	24.32	24.32	24.32
Mean	41.49	41.82		43.32	43.49		42.41	42.68	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.023	0.008	0.040	0.013
Factor B	0.007	0.002	0.023	0.008	0.040	0.013
Factor C	0.008	0.003	0.007	0.002	0.009	0.003
Interaction A X B	0.013	0.004	0.039	0.013	0.070	0.023
Interaction A X C	0.013	0.004	0.012	0.004	0.015	0.005
Interaction B X C	0.013	0.004	0.012	0.004	0.015	0.005
Interaction A X B X C	0.023	0.008	0.021	0.007	0.027	0.009

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

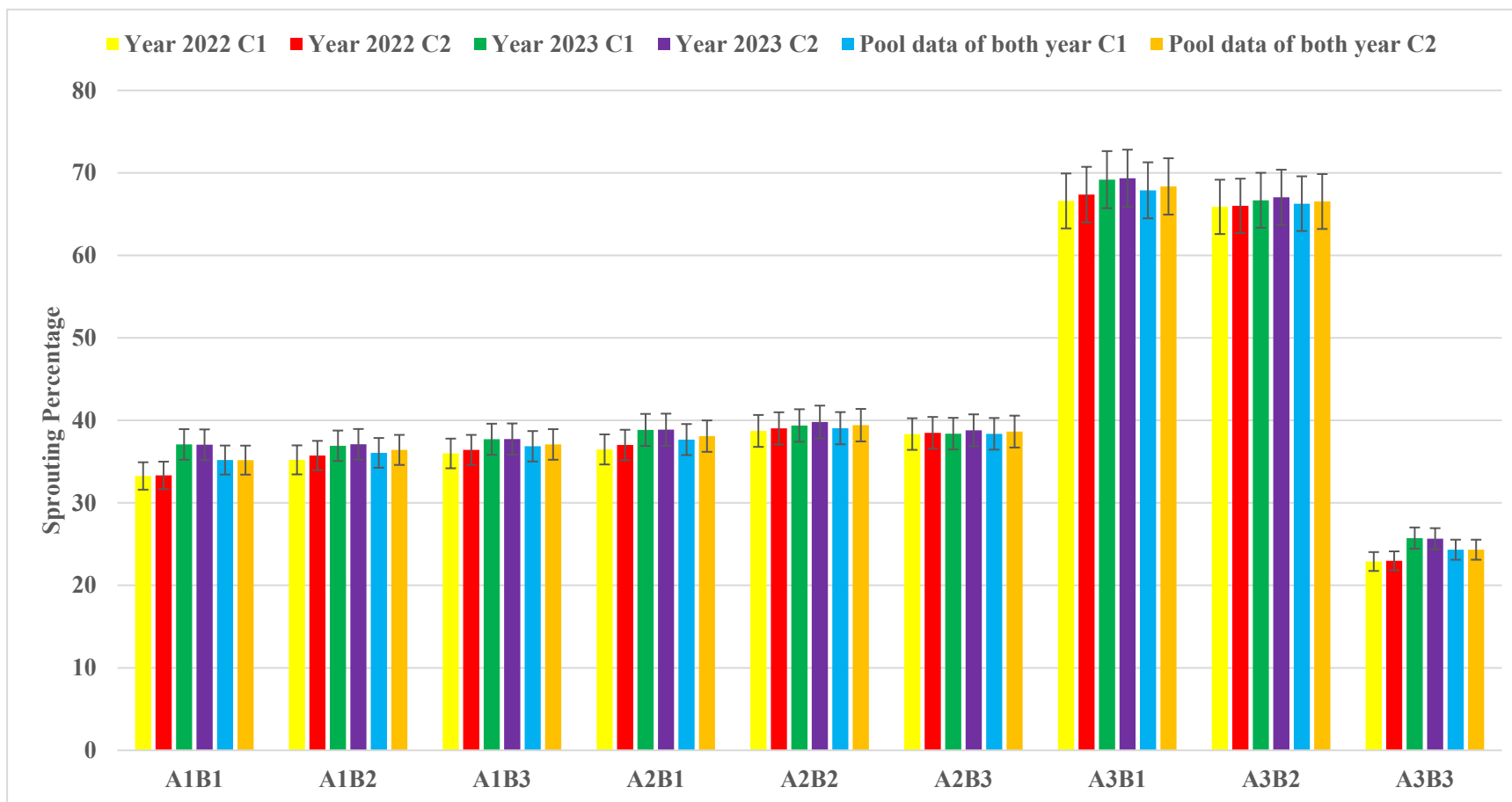


Figure 4.15 Graphical representation of the effect of Zinc (Zn) and IBA on Sprouting percentage in guava cuttings at different days.

4.1.15 Sprouting Percentage

In both 2022 and 2023, zinc foliar application significantly impacted the sprouting percentage at both 30- and 60-days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest sprouting percentage, with values of 35.99% in 2022 and 37.71% in 2023, while A₁B₁ (0.25%) showed the lowest values, 33.26% in 2022 and 37.08% in 2023 (Table 4.15, Figure 4.15). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the highest sprouting percentage, with values of 38.72% in 2022 and 39.38% in 2023, while A₂B₁ (50 g/tree) had the lowest, 36.48% in 2022 and 38.84% in 2023. For post cutting treatment of IBA 5000-ppm concentration yielded the highest sprouting percentage of 96% in 2022 and 98% in 2023, whereas the control group consistently had the lowest sprouting percentage (60% in 2022 and 62% in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the highest sprouting percentage (88% in 2022 and 90% in 2023), while A₁B₁ (0.25%) had the lowest (78% in 2022 and 80% in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest sprouting percentage (94% in 2022 and 96% in 2023), while A₂B₁ (50 g/tree) had the lowest (84% in 2022 and 86% in 2023). For post cutting treatment of IBA 5000-ppm concentration showed the highest sprouting percentage at 98% in 2022 and 99% in 2023, with the control group remaining the lowest (65% in 2022 and 67% in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest sprouting percentage at 36.86%, with A₁B₁ (0.25%) the lowest at 35.19% (Table 4.15, Figure 4.15). A₂B₂ (75 g/tree) showed the highest pooled sprouting percentage at 39.05%, and A₂B₁ (50 g/tree) had the lowest at 37.67%. For post cutting treatment of IBA 5000-ppm concentration consistently had the highest sprouting percentage at 67.89%, while the control group had the lowest at 24.32%.

At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest sprouting percentage at 37.08%, while A₁B₁ (0.25%) had the lowest at 35.18%. A₂B₂ (75 g/tree)

was the best performer among various levels of zinc as pre-cutting treatment basal treatments with 39.42%, and A₂B₁ (50 g/tree) had the lowest sprouting percentage at 38.09%. For post cutting treatment of IBA 5000-ppm concentration maintained the highest pooled sprouting percentage at 68.36%, and the control group remained the lowest at 24.32%.

The timing of zinc pre-cutting treatments or the dormant stage significantly influenced the sprouting percentage in guava cuttings. Cuttings collected 60 days after treatment exhibited a higher sprouting percentage (85.67%) compared to those collected after 30 days (78.45%). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The highest sprouting percentage (92.18%) was recorded in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and treated with 5000 ppm IBA.

Zinc's role as a cofactor in enzyme systems involved in auxin metabolism and protein synthesis is crucial for sprout initiation. Auxins, which are plant hormones that promote cell division and elongation, are essential for the formation of new shoots. This study found that basal zinc application at 75 g/tree (A₂B₂) significantly enhanced sprout initiation and increased the sprouting percentage compared to foliar applications and the control group. These findings align with previous research by Broadley *et al.* (2007), indicating that adequate zinc levels are necessary for optimal hormone function and shoot initiation. Present findings are fully supported by the results of Yamashita *et al.* (2006) in mango and Sourati *et al.* (2022) in mulberry.

4.1.16 Number of sprouts at 30 days

In both 2022 and 2023, the zinc foliar application significantly impacted the number of sprouts at both 30- and 60-days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts, with values of 0.81 in 2022 and 0.96 in 2023, while A₁B₁ (0.25%) showed the minimum values, 0.52 in 2022 and 0.58 in 2023 (Table 4.16, Figure 4.16).

Table 4.16 Effect of zinc (Zn) and IBA treatments on number of sprouts at 30 days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.52	0.53	0.53	0.58	0.59	0.59	0.55	0.56	0.56
A ₁ B ₂	0.69	0.69	0.69	0.77	0.75	0.76	0.73	0.72	0.73
A ₁ B ₃	0.81	0.81	0.81	0.96	1.06	1.01	0.89	0.93	0.91
A ₂ B ₁	0.94	0.96	0.95	1.12	1.19	1.16	1.03	1.08	1.06
A ₂ B ₂	1.06	1.09	1.23	1.42	1.53	1.48	1.32	1.39	1.36
A ₂ B ₃	1.22	1.24	1.08	1.22	1.32	1.27	1.22	1.26	1.18
A ₃ B ₁	2.25	2.32	2.29	2.53	2.56	2.55	2.39	2.44	2.42
A ₃ B ₂	2.02	2.12	2.07	2.31	2.34	2.33	2.19	2.23	2.21
A ₃ B ₃	0.13	0.15	0.14	0.15	0.17	0.16	0.14	0.16	0.15
Mean	1.07	1.11		1.23	1.28		1.15	1.19	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.006	0.002	0.011	0.004	0.008	0.003
Factor B	0.006	0.002	0.011	0.004	0.008	0.003
Factor C	0.005	0.002	0.008	0.003	0.004	0.001
Interaction A X B	0.011	0.004	0.019	0.006	0.013	0.004
Interaction A X C	0.009	0.003	0.013	0.005	0.007	0.002
Interaction B X C	0.009	0.003	0.013	0.005	0.007	0.002
Interaction A X B X C	0.015	0.005	0.023	0.008	0.012	0.004

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

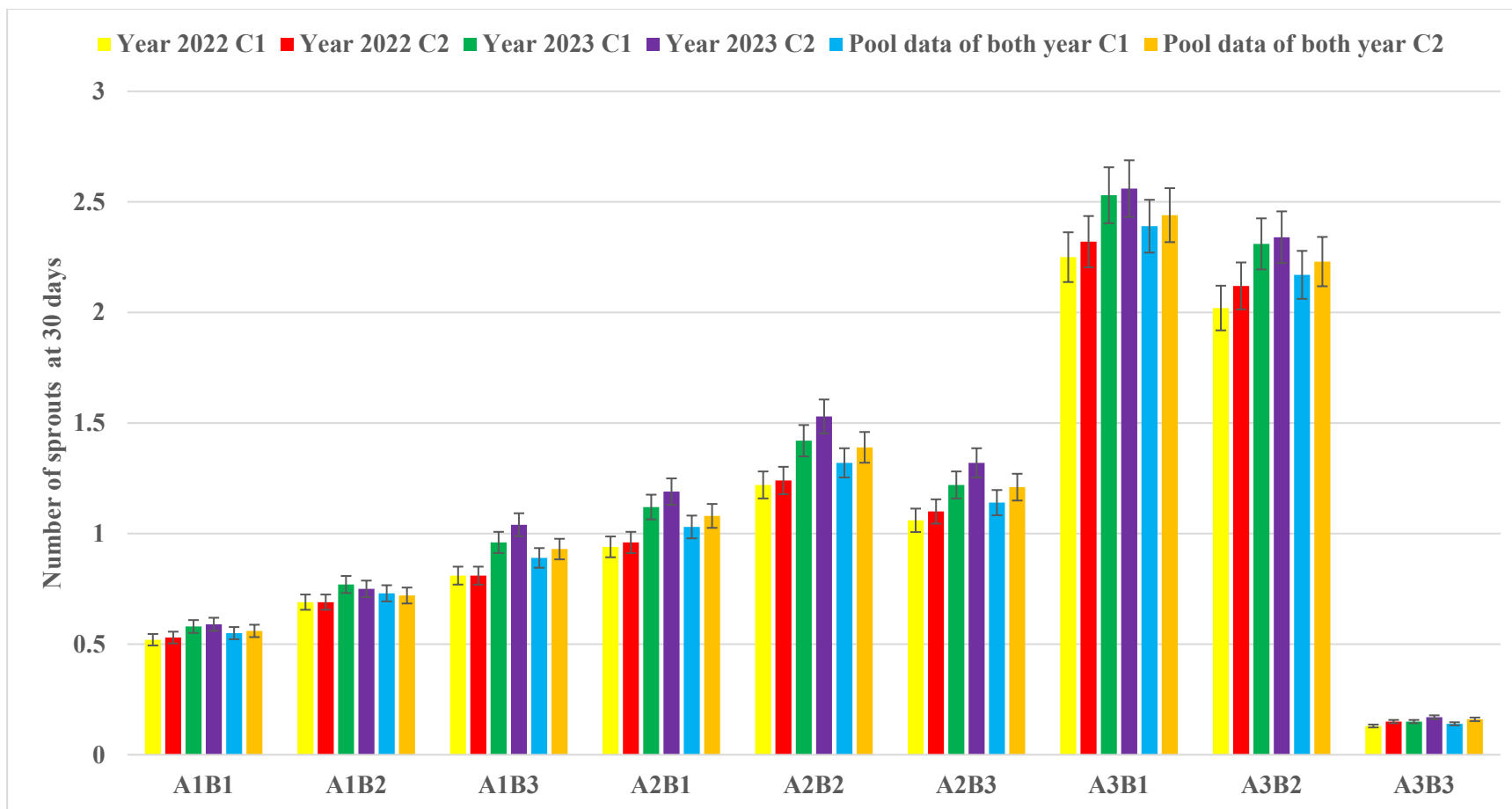


Figure 4.16 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts at 30 days in guava cuttings at different days.

Similarly, for various levels of zinc as pre-cutting basal treatments, A₁B₃ (100 g/tree) showed the maximum number of sprouts at 30 days, with values of 1.22 in 2022 and 1.22 in 2023, while A₁B₁ (50 g/tree) had the minimum, 0.94 in 2022 and 1.12 in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the maximum number of sprouts at 30 days, with 2.25 in 2022 and 2.53 in 2023, whereas the control group consistently had the minimum number of sprouts (0.13 in 2022 and 0.15 in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum number of sprouts (0.81 in 2022 and 1.06 in 2023), while A₁B₁ (0.25%) had the minimum (0.53 in 2022 and 0.59 in 2023). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest number of sprouts (1.24 in 2022 and 1.32 in 2023), while A₂B₁ (50 g/tree) had the lowest (0.96 in 2022 and 1.19 in 2023). For post-cutting treatment of IBA, 5000-ppm concentration showed the maximum number of sprouts at 60 days, with 2.32 in 2022 and 2.56 in 2023, with the control group remaining the minimum (0.15 in 2022 and 0.17 in 2023).

Pooled data from both years change these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts at 0.89, with A₁B₁ (0.25%) the minimum at 0.55 (Table 4.16 Figure 4.16). A₂B₂ (75 g/tree) showed the maximum number of sprouts at 1.32 g, and A₂B₁ (50 g/tree) had the minimum at 1.03. For post-cutting treatment of IBA 5000-ppm concentration consistently had the maximum number of sprouts at 2.29, while the control group had the minimum at 0.14. At 60 days after pre-cutting treatment, A₁B₃ had the highest dry weight at 0.93, while A₁B₁ had the lowest at 0.56. A₂B₂ (75 g/tree) was the best performer among various zinc levels as pre-cutting basal treatments with 1.39, and A₂B₁ (50 g/tree) had the lowest dry weight at 1.08. For post-cutting treatment of IBA, 5000-ppm concentration maintained the maximum pooled number of sprouts at 2.44, and the control group maintained the minimum at 0.16.

The timing of pre-cutting treatments significantly affected the number of sprouts at 30 days. Cuttings collected after 60 days had more sprouts (1.19) compared to those collected after 30 days (1.15). The highest number of sprouts (2.42) was recorded in

the A3B1C2 treatment, combining cuttings taken after 60 days of the dormant stage with 5000 ppm IBA treatment.

4.1.17 Number of sprouts at 60 days

In 2022 and 2023, the zinc foliar application significantly impacted the number of sprouts at 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts, with values of 1.35 in 2022 and 1.39 in 2023, while A₁B₁ (0.25%) showed minimum values, of 1.03 in 2022 and 1.05 in 2023 (Table 4.17, Figure 4.17).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum number of sprouts at 30 days after pre-cutting treatment, with values of 1.99 in 2022 and 1.99 in 2023, while A₂B₁ (50 g/tree) had the minimum, 1.52 in 2022 and 1.61 in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the maximum number of sprouts at 30 days, with 3.06 in 2022 and 3.32 in 2023, whereas the control group consistently had the minimum number of sprouts (0.16 in 2022 and 0.18 in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum number of sprouts (1.39 in 2022 and 1.42 in 2023), while A₁B₁ (0.25%) had the minimum (1.07 in 2022 and 1.11 in 2023). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight (2.02 in 2022 and 2.04 in 2023), while A₂B₁ had the lowest (1.55 in 2022 and 1.59 in 2023). For post-cutting treatment of IBA, 5000-ppm concentration showed the maximum number of sprouts at 60 days, with 3.15 in 2022 and 3.55 in 2023, with the control group remaining the minimum (0.18 in 2022 and 0.19 in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts at 1.37, with A₁B₁ (0.25%) the minimum at 1.04 (Table 4.17). A₂B₂ (75 g/tree) showed the maximum number of sprouts at 1.99, and A₂B₁ (50 g/tree) had the minimum at 1.57. For post-cutting treatment of IBA 5000-ppm concentration consistently had the maximum number of sprouts at 3.19 g, while the control group had the minimum at 0.17. At 60 days after pre-cutting treatment, A₁B₃ had the highest dry weight at 1.41,

while A₁B₁ had the lowest at 1.09. A₂B₂ (75 g/tree) was the best performer among various levels of zinc as pre-cutting basal treatments with 2.02, and A₂B₁ (50 g/tree) had the lowest dry weight at 1.57. For post-cutting treatment of IBA, 5000-ppm concentration maintained the maximum pooled number of sprouts at 3.35, and the control group maintained the minimum at 0.19.

The number of sprouts at 60 days was influenced by these treatments. Cuttings collected after 60 days produced more sprouts (1.75) compared to those collected after 30 days (1.71). The maximum number of sprouts (3.27) was noted in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.18 Number of sprouts at 90 days

In both 2022 and 2023, zinc foliar application significantly affected the number of sprouts at 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently exhibited the highest number of sprouts, recording 2.01 in 2022 and 2.09 in 2023, while A₁B₁ (0.25%) had the lowest values, with 1.67 in 2022 and 1.81 in 2023 (Table 4.18, Figure 4.18).

Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the maximum number of sprouts at 30 days, with values of 2.48 in 2022 and 2.67 in 2023, whereas A₂B₁ (50 g/tree) recorded a minimum, with 2.19 in 2022 and 2.27 in 2023. For post-cutting treatment of IBA 5000-ppm concentration produced the highest number of sprouts at 30 days, with 4.77 in 2022 and 5.02 in 2023, while the control group had the lowest, at 0.31 in 2022 and 0.34 in 2023.

At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to lead with the highest number of sprouts (2.02 in 2022 and 2.13 in 2023), while A₁B₁ (0.25%) had the lowest (1.69 in 2022 and 1.84 in 2023). Zinc basal treatments showed similar trends, with A₂B₂ (75 g/tree) having the highest dry weight (2.53 g in 2022 and 2.72 in 2023) and A₂B₁ (50 g/tree) the lowest (2.21 in 2022 and 2.29 in 2023). For post-cutting treatment of IBA, 5000-ppm concentration maintained the maximum number of sprouts at 60 days, with 4.89 in 2022 and 5.11 in 2023, while the control group remained the lowest, at 0.31 in 2022 and 0.36 in 2023.

Table 4.17 Effect of zinc (Zn) and IBA treatments on number of sprout at 60 days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.03	1.07	1.05	1.05	1.11	1.08	1.04	1.09	1.07
A₁B₂	1.19	1.24	1.22	1.22	1.27	1.25	1.21	1.25	1.23
A₁B₃	1.35	1.39	1.37	1.39	1.42	1.41	1.37	1.41	1.39
A₂B₁	1.52	1.55	1.54	1.61	1.59	1.61	1.57	1.57	1.57
A₂B₂	1.99	2.02	2.02	1.99	2.04	2.01	1.99	2.02	2.01
A₂B₃	1.75	1.77	1.76	1.82	1.85	1.84	1.79	1.84	1.82
A₃B₁	3.06	3.15	3.11	3.32	3.55	3.43	3.19	3.35	3.27
A₃B₂	2.77	2.91	2.84	3.13	3.15	3.14	2.95	3.03	2.99
A₃B₃	0.16	0.18	0.17	0.18	0.19	0.19	0.17	0.19	0.18
Mean	1.64	1.71		1.75	1.82		1.71	1.75	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.007	0.002	0.007	0.002
Factor B	0.007	0.002	0.007	0.002	0.007	0.002
Factor C	0.007	0.002	0.007	0.002	0.004	0.001
Interaction A X B	0.012	0.004	0.012	0.004	0.012	0.004
Interaction A X C	0.011	0.004	0.011	0.004	0.007	0.003
Interaction B X C	0.011	0.004	0.011	0.004	0.007	0.003
Interaction A X B X C	0.022	0.007	0.021	0.007	0.013	0.004

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

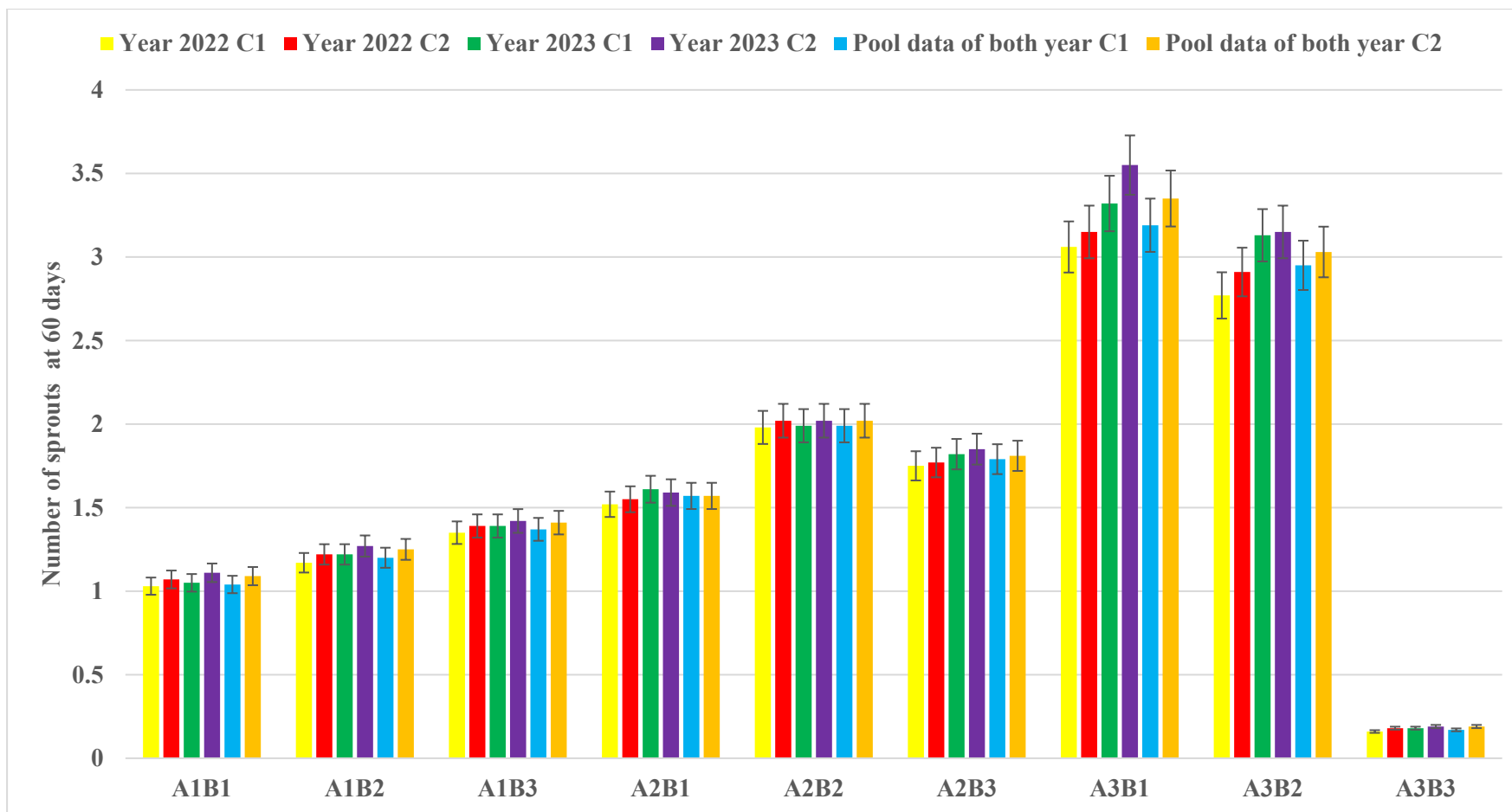


Figure 4.17 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts at 60 days in guava cuttings at different days.

Table 4.18 Effect of zinc (Zn) and IBA treatments on number of sprouts at 90 days in Guava Cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	1.67	1.69	1.68	1.81	1.84	1.83	1.74	1.77	1.75
A ₁ B ₂	1.85	1.86	1.86	1.92	1.97	1.95	1.89	1.92	1.9
A ₁ B ₃	2.01	2.02	2.01	2.09	2.13	2.11	2.05	2.07	2.06
A ₂ B ₁	2.19	2.21	2.20	2.27	2.29	2.28	2.23	2.25	2.24
A ₂ B ₂	2.48	2.53	2.51	2.67	2.72	2.71	2.58	2.63	2.61
A ₂ B ₃	2.27	2.32	2.29	2.41	2.48	2.45	2.34	2.39	2.37
A ₃ B ₁	4.77	4.89	4.83	5.02	5.11	5.07	4.92	5.01	4.95
A ₃ B ₂	4.22	4.43	4.33	4.63	4.73	4.68	4.43	4.58	4.51
A ₃ B ₃	0.31	0.31	0.31	0.34	0.36	0.35	0.32	0.34	0.33
Mean	2.42	2.47		2.57	2.62		2.51	2.55	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.004	0.006	0.002	0.07	0.002
Factor B	0.011	0.004	0.006	0.002	0.007	0.002
Factor C	0.009	0.003	0.006	0.002	0.006	0.002
Interaction A X B	0.018	0.006	0.011	0.004	0.011	0.004
Interaction A X C	0.015	0.005	0.011	0.004	0.011	0.004
Interaction B X C	0.015	0.005	0.011	0.004	0.011	0.004
Interaction A X B X C	0.026	0.009	0.019	0.006	0.018	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

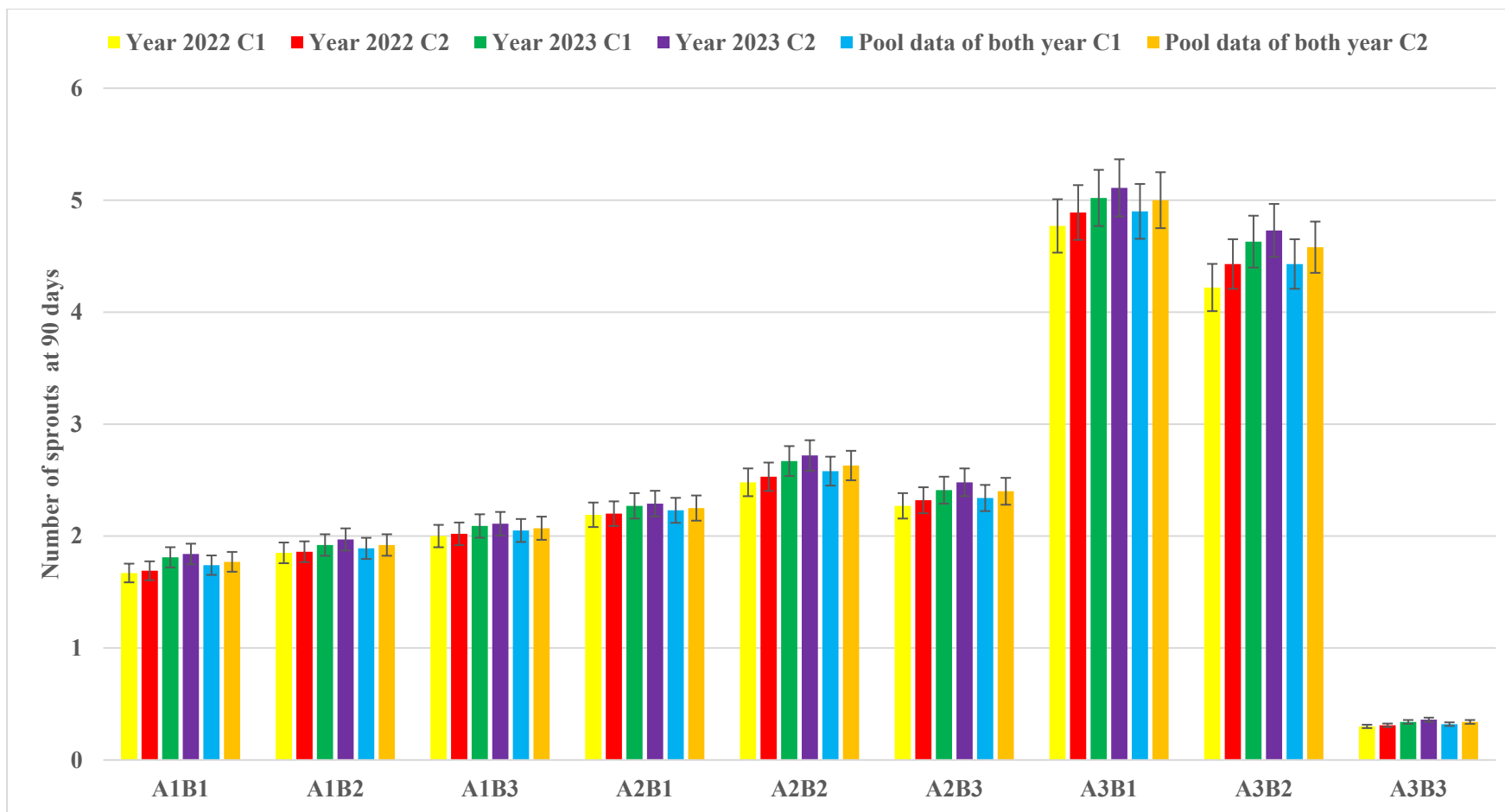


Figure 4.18 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts at 90 days in guava Cuttings at different days.

Pooling data from both years confirmed these patterns. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently had the highest number of sprouts at 2.05 g, with A₁B₁ (0.25%) the lowest at 1.74 g (Table 4.18, Figure 4.18). A₂B₂ (75 g/tree) had the maximum number of sprouts at 2.58 g, whereas A₂B₁ (50 g/tree) had the minimum at 2.23 g. For post-cutting treatment of IBA 5000-ppm concentration consistently yielded the highest number of sprouts at 4.92 g, with the control group recording the lowest at 0.32 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest dry weight at 2.07 g, while A₁B₁ (0.25%) had the lowest at 1.77 g. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the best performance at 2.63 g, and A₂B₁ (50 g/tree) had the lowest dry weight at 2.25 g. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest pooled number of sprouts at 5.01 g, with the control group remaining the lowest at 0.34 g.

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced the number of sprouts at 90 days in cuttings. Cuttings collected 60 days after treatment produced a higher number of sprouts (2.55) compared to those collected after 30 days (2.51). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The maximum number of sprouts (4.95) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and treated with 5000 ppm IBA.

4.1.19 Diameter of sprouts (mm)

In 2022, zinc foliar application significantly influenced the diameter of sprout. At 30 days after pre-cutting treatment, the maximum diameter of the sprout was observed in treatment A₁B₃ (0.75%) at 0.28 mm, while the minimum diameter was recorded in treatment A₁B₃ (0.25%) at 0.08 cm, indicating a significant difference among the various levels of zinc foliar application (Table 4.19, Figure 4.19). Among the zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) produced the maximum diameter of the sprout at 0.64 mm, whereas A₂B₁ (50 g/tree) showed the minimum at 0.41 mm. For post-cutting IBA treatments, a concentration of 5000 ppm resulted in the maximum diameter of the sprout at 0.88 mm, while the control group exhibited the minimum at 0.02 mm.

Table 4.19 Effect of zinc (Zn) and IBA treatments on diameter of sprout (mm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.08	0.09	0.09	0.14	0.17	0.16	0.11	0.14	0.13
A₁B₂	0.17	0.22	0.21	0.23	0.23	0.23	0.19	0.23	0.22
A₁B₃	0.28	0.33	0.32	0.35	0.35	0.35	0.32	0.33	0.33
A₂B₁	0.41	0.41	0.41	0.43	0.44	0.44	0.42	0.43	0.43
A₂B₂	0.64	0.66	0.65	0.69	0.71	0.71	0.67	0.69	0.68
A₂B₃	0.52	0.54	0.53	0.56	0.57	0.57	0.54	0.56	0.55
A₃B₁	0.88	0.99	0.94	0.96	0.99	0.98	0.92	0.99	0.96
A₃B₂	0.79	0.82	0.81	0.84	0.89	0.87	0.82	0.86	0.84
A₃B₃	0.02	0.02	0.02	0.04	0.04	0.04	0.03	0.03	0.03
Mean	0.42	0.45		0.47	0.49		0.45	0.47	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.016	0.005	0.012	0.004	0.015	0.005
Factor B	0.016	0.005	0.012	0.004	0.015	0.005
Factor C	0.009	0.003	0.005	0.002	0.005	0.002
Interaction A X B	0.028	0.009	0.021	0.007	0.025	0.008
Interaction A X C	0.016	0.005	0.009	0.003	0.009	0.003
Interaction B X C	0.016	0.005	0.009	0.003	0.009	0.003
Interaction A X B X C	0.027	0.009	0.016	0.005	0.015	0.005

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

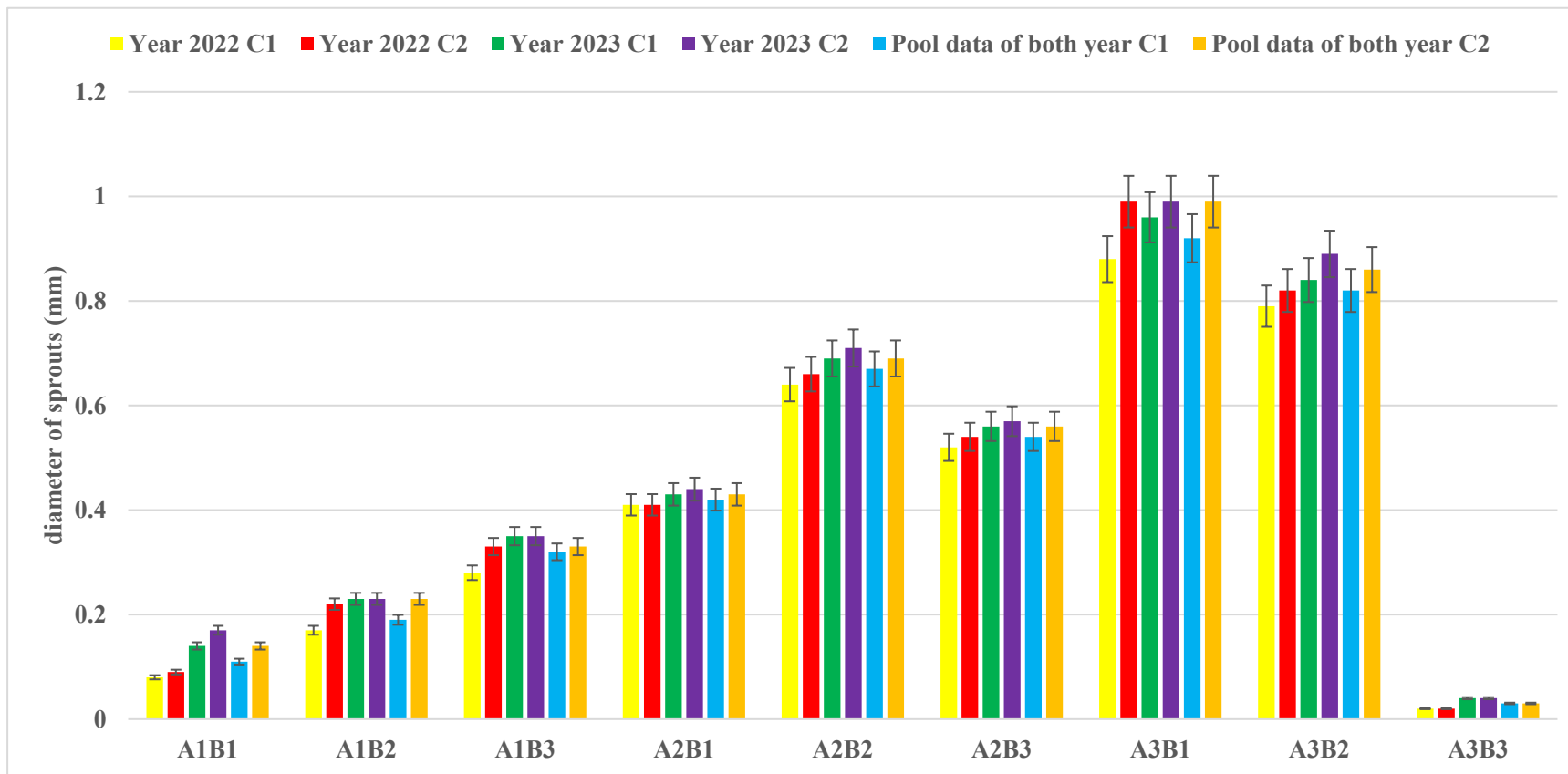


Figure 4.19 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of sprouts (mm) in guava cuttings at different days.

At 60 days after pre-cutting treatment in 2022, the maximum diameter of the sprout was recorded in treatment A₁B₃ (0.75%) at 2.56 mm, and the minimum in A₁B₁ (0.25%) at 2.01 mm, highlighting significant differences among the zinc basal treatments. Similarly, A₂B₂ (75 g/tree) had the maximum diameter of the sprout at 3.23 mm, whereas A₂B₁ (50 g/tree) had the minimum at 2.82 mm. post-cutting treatment with 5000-ppm IBA showed the maximum diameter of the sprout at 4.21 mm, while the control group exhibited the minimum at 1.67 mm (Table 19, Figure 19)

In 2023, zinc foliar application continued to significantly affect the maximum diameter of the sprout. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) recorded the maximum diameter of the sprout at 2.67 mm, while A₂B₁ (0.25%) had the minimum at 2.06 cm. Among the zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) produced the maximum diameter of the sprout at 3.72 mm, while A₂B₁ (50 g/tree) had the minimum at 2.89 mm. For post-cutting treatment, 5000-ppm IBA treatment resulted in the maximum diameter of the sprout at 4.51 cm, while the control group exhibited the minimum at 1.93 mm (Table 4.19, Figure 4.19).

At 60 days after pre-cutting treatment in 2023, the maximum diameter of the sprout was recorded in treatment A₁B₃ (0.75%) at 2.73 mm, while the minimum in treatment A₁B₁ (0.25%) at 2.11 mm. For zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently resulted in the maximum diameter of the sprout at 3.76 mm, whereas A₂B₁ (50 g/tree) had the minimum at 2.91 mm. post-cutting treatment with 5000-ppm IBA led to the maximum diameter of the sprout at 4.53 mm, while the control group had the minimum at 1.96 mm.

When analysing pooled data for both years, the maximum diameter of the sprout at 30 days after pre-cutting treatment was recorded in treatment A₁B₃ (0.75%) at 0.32 mm, while the minimum was in treatment A₁B₁ (0.25%) at 0.11 mm, showing consistent results across years (Table 4.19, Figure 4.19). Among the zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently produced the maximum diameter of the sprout at 0.67 cm, and A₂B₁ had the minimum at 0.42 mm. post-cutting treatment with 5000 ppm IBA consistently resulted in the maximum diameter of the sprout with a mean value of 0.92 mm, while the control group had the minimum at 0.03 mm.

At 60 days after pre-cutting treatment, the pooled data indicated that treatment A₁B₃ (0.75%) had the maximum diameter of the sprout at 0.33 mm, while A₁B₁ (0.25%) had the minimum at 0.14 mm. Among zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently resulted in the maximum diameter of the sprout at (0.69 mm), whereas A₂B₁ (50 g/tree) had the minimum at 0.43 mm. post-cutting treatment with 5000 ppm IBA produced the maximum diameter of the sprout with a pooled mean value of 0.99 mm, while the control group recorded the minimum at 0.43 mm.

The number of days after zinc pre-cutting treatment or during the dormant stage significantly impacted the diameter of sprouts in guava cuttings. Cuttings taken 60 days after treatment exhibited a greater sprout diameter (0.47 mm) compared to those taken at 30 days (0.45 mm). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The maximum sprout diameter (0.96 mm) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

Following the analysis of the results, it is evident that the number of sprouts and their diameter are critical indicators of shoot vigor and overall plant health. Zinc supplementation, particularly through basal application, significantly increased the number of sprouts and their diameter. The treatment with basal zinc at 75 g/tree (ZB₂) produced the highest number of sprouts with larger diameters, indicating more robust shoot development. This improvement can be attributed to zinc's role in enhancing cellular processes and structural integrity (Alloway, 2008). The present findings are fully supported by the results of Yamashita *et al.* (2006) in mango and Sourati *et al.* (2022) in mulberry.

4.1.20 Length of sprouts

In both 2022 and 2023, zinc foliar application significantly impacted the length of sprouts at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the minimum length of sprout, with values increasing to 7.87 cm in 2022 and 7.50 cm in 2023, while A₁B₁ (0.25%) showed the maximum length, reaching 8.48 cm in 2022 and 8.27 cm in 2023 (Table 4.20).

Table 4.20 Effect of zinc (Zn) and IBA treatments on length of sprout (cm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	8.48	8.39	8.44	8.27	8.09	8.18	8.37	8.14	8.26
A₁B₂	7.96	7.67	7.81	7.75	7.58	7.67	7.85	7.67	7.76
A₁B₃	7.87	7.75	7.81	7.50	7.40	7.45	7.68	7.58	7.63
A₂B₁	7.68	7.61	7.64	7.32	7.24	7.28	7.5	7.42	7.46
A₂B₂	7.25	7.19	7.23	6.81	6.75	6.79	7.03	6.97	7.01
A₂B₃	7.46	7.38	7.42	7.03	6.99	7.02	7.24	7.19	7.22
A₃B₁	5.34	5.45	5.40	5.58	5.60	5.59	5.47	5.53	5.50
A₃B₂	5.64	5.73	5.69	5.69	6.18	5.94	5.67	5.95	5.81
A₃B₃	11.34	11.43	11.39	10.82	10.95	10.88	11.14	11.19	11.17
Mean	7.66	7.62		7.42	7.42		7.55	7.51	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.004	0.001	0.009	0.003	0.012	0.004
Factor B	0.004	0.001	0.009	0.003	0.012	0.004
Factor C	0.008	0.003	0.008	0.003	0.007	0.002
Interaction A X B	0.007	0.002	0.016	0.005	0.020	0.007
Interaction A X C	0.013	0.004	0.014	0.005	0.011	0.004
Interaction B X C	0.013	0.004	0.014	0.005	0.011	0.004
Interaction A X B X C	0.023	0.008	0.024	0.008	0.020	0.007

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

Similarly, for zinc basal treatments, A₂B₂, (75 g/tree) consistently showed the minimum length of sprouts, with values increasing to 7.25 cm in 2022 and 6.81 cm in 2023, while A₂B₁ (50 g/tree) had the maximum length of sprouts, 7.68 cm in 2022 and 7.32 cm in 2023. Among the IBA treatments, the 5000-ppm concentration yielded the maximum shift in sprout diameter of 16.8 in 2022 and 17.7 in 2023. In contrast, the control group consistently had the lowest change in sprout diameter (5.4 in 2022 and 6.2 in 2023).

At 60 days post-treatment, the trends remained consistent. A₁B₃ continued to have the minimum length of sprouts (7.75 cm in 2022 and 7.40 cm in 2023), while A₁B₃ had the maximum length (8.39 cm in 2022 and 8.09 cm in 2023). For zinc basal treatments, A₂B₂ had the minimum length of sprouts (7.19 cm in 2022 and 6.75 cm in 2023), while A₂B₁ had the maximum length (7.61 cm in 2022 and 7.24 cm in 2023). The post-cutting treatment of 5000 ppm IBA treatment showed the minimum length of sprouts at 5.45 cm in 2022 and 5.60 cm in 2023, with the control group remaining with the maximum change (11.43 cm in 2022 and 10.95 cm in 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ consistently recorded the minimum length of sprouts at 7.58 cm, with A₁B₁ showing the maximum length at 8.14 cm. A₂B₂ showed the minimum length of sprouts at 6.97 cm, and A₂B₁ had the maximum length at 7.42 cm. The 5000 ppm IBA treatment consistently had the minimum length of sprouts at 5.53 cm, while the control group had the maximum length at 11.19 cm. At 60 days after pre-cutting treatment, A₁B₃ had the minimum length of sprouts at 12.5 cm, while A₁B₁ had the maximum at 9.6. A₂B₂ was the minimum length among zinc basal treatments at 15.0, and A₂B₁ had the maximum sprout length at 11.5. The 5000 ppm IBA treatment maintained the minimum pooled change in length of sprout diameter at 18.0, and the control group remained with the change at 6.3.

The number of days after zinc pre-cutting treatment or during the dormant stage significantly impacted the diameter of sprouts in guava cuttings. Cuttings taken 60 days after treatment exhibited a greater sprout diameter (7.55 cm) than those taken at 30 days (7.51 cm). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The maximum sprout diameter (5.50 cm) was observed

in the A3B1C2 treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

4.1.21 Diameter of Shoots (mm)

In both 2022 and 2023, zinc foliar application significantly impacted the diameter of shoots at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum change in shoot diameter, with values increasing to 5.57 mm in 2022 and 5.85 mm in 2023, while A₁B₁ (0.25%) showed the minimum change, reaching 5.19 mm in 2022 and 5.53 mm in 2023 (Table 4.21, Figure 4.21). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum change in shoot diameter, with values increasing to 6.22 mm in 2022 and 6.45 mm in 2023, while A₂B₁ (50 g/tree) had the lowest change, reaching 5.69 mm in 2022 and 5.96 mm in 2023. For post cutting treatment of IBA 5000-ppm concentration yielded the maximum change in shoot diameter of 7.31 mm in 2022 and 7.69 mm in 2023, whereas the control group consistently had the lowest change in shoot diameter (2.32 mm in 2022 and 2.64 mm in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum change in shoot diameter (5.63 mm in 2022 and 5.91 mm in 2023), while A₁B₁ (0.25%) had the lowest change (5.24 mm in 2022 and 5.58 mm in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum change in shoot diameter (6.36 mm in 2022 and 6.52 mm in 2023), while A₂B₁ (50 g/tree) had the lowest change (5.69 mm in 2022 and 6.05 mm in 2023). For post-cutting treatment of IBA, 5000-ppm concentration showed the maximum change in shoot diameter at 7.49 mm in 2022 and 7.81 cm in 2023, with the control group remaining the lowest (2.42 mm in 2022 and 2.80 mm in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum change in shoot diameter at 5.71 mm, with A₁B₁ showing the lowest change at 5.36 mm (Table 4.21, Figure 4.21). A₂B₂ (75 g/tree) showed the maximum pooled change in shoot diameter at 6.26 mm, and A₂B₁ (50 g/tree) had the lowest change at 5.83 mm. For post-cutting

treatment of IBA 5000-ppm concentration consistently had the maximum change in shoot diameter at 7.50 mm, while the control group had the lowest at 2.48 mm. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the maximum change in shoot diameter at 5.77 mm, while A₁B₁ (0.25%) had the lowest at 5.41 mm. A₂B₂ (75 g/tree) was the best performer among various levels of zinc as pre-cutting basal treatments with 6.44 cm, and A₂B₁ (50 g/tree) had the lowest change in shoot diameter at 5.91 mm. For post-cutting treatment of IBA, 5000-ppm concentration maintained the maximum pooled change in shoot diameter at 7.65 mm, and the control group remained the lowest at 2.61 mm.

The diameter of the shoot was also significantly impacted by the timing of zinc treatments and the dormant stage. Cuttings collected after 60 days showed a greater shoot diameter (5.85 mm) compared to those collected after 30 days (5.72 mm). The largest shoot diameter (7.57 mm) was recorded in the A₃B₁C₂ treatment.

These results highlight the importance of zinc in promoting shoot growth. The length of sprouts and the overall shoot diameter are crucial parameters that determine the growth potential and structural stability of the plant. The study found that basal zinc application at 75 g/tree (A₂B₂) resulted in the longest sprouts and the thickest shoot diameters. This enhancement in shoot length and diameter underscores zinc's role in promoting cell elongation and division, which are crucial for shoot growth (Marschner, 2012). The present findings are fully supported by the results of Yamashita *et al.* (2006) in mango and Sourati *et al.* (2022) in mulberry.

4.1.22 Fresh weight of shoot (g)

In both 2022 and 2023, zinc foliar application significantly influenced the fresh weight of shoots at both 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting, treatment A₁B₃ (0.75%) consistently exhibited the maximum fresh weight of shoots, with values of 1.09 g in 2022 and 1.17 g in 2023, while A₁B₁ (0.25%) showed minimum values, of 0.71 g in 2022 and 0.81 g in 2023.

Similarly, among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently demonstrated the maximum fresh weight of shoots, with values of 1.54 g in 2022 and 1.62 g in 2023, while A₂B₁ (50 g/tree) had the minimum, 1.22 g in

2022 and 1.33 g in 2023. Post cutting treatment of IBA 5000-ppm concentration consistently yielded the highest fresh weight of shoots at 2.59 g in 2022 and 2.78 g in 2023, whereas the control group consistently showed the lowest fresh weight (0.23 g in 2022 and 0.28 g in 2023). At 60 days after pre-cutting treatment, similar trends persisted. A₁B₃ maintained the maximum fresh weight of shoots (1.16 g in 2022 and 1.21 g in 2023), while A₁B₁ had the minimum (0.73 g in 2022 and 0.83 g in 2023). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) again showed the highest fresh weight (1.65 g in 2022 and 1.78 g in 2023), whereas A₂B₁ (50 g/tree) had the lowest (1.33 g in 2022 and 1.42 g in 2023). For post-cutting treatment IBA 5000-ppm concentration exhibited the highest fresh weight of shoots at 2.59 g in 2022 and 2.77 g in 2023, with the control group maintaining the lowest (0.24 g in 2022 and 0.29 g in 2023).

Pooling data from both years reaffirmed these trends. At 30 days, ZF₃ consistently recorded the maximum fresh weight of shoots at 1.13 g, with ZF₁ recording the minimum at 0.76 g (Table 4.22, figure 4.22). ZB₃ demonstrated the highest pooled fresh weight at 1.58 g, whereas ZB₁ had the lowest at 1.28 g. The 5000 ppm IBA treatment consistently showed the highest fresh weight of shoots at 2.69 g, while the control group had the lowest at 0.26 g. At 60 days, ZF₃ maintained the maximum fresh weight at 1.19 g, while ZF₁ had the minimum at 0.78 g. Among zinc basal treatments, ZB₃ continued to perform the best with 1.72 g, whereas ZB₁ had the minimum fresh weight at 1.38 g. The 5000 ppm IBA treatment also maintained the highest pooled fresh weight at 2.68 g, with the control group remaining at a minimum of 0.27 g. The fresh weight of shoots in guava cuttings was significantly influenced by the timing of pre-cutting zinc treatments and the dormant stage. Cuttings collected 60 days after treatment produced higher fresh shoot weight (1.44 g) compared to those collected after 30 days (1.39 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The highest fresh shoot weight (2.68 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and treated with 5000 ppm IBA.

Table 4.21 Effect of zinc (Zn) and IBA treatments on diameter of shoot (mm) at days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	5.19	5.24	5.22	5.53	5.58	5.56	5.36	5.41	5.39
A ₁ B ₂	5.38	5.41	5.4	5.68	5.74	5.71	5.53	5.57	5.55
A ₁ B ₃	5.57	5.63	5.6	5.85	5.91	5.88	5.71	5.77	5.74
A ₂ B ₁	5.69	5.77	5.73	5.96	6.05	6.01	5.83	5.91	5.87
A ₂ B ₂	6.22	6.36	6.29	6.45	6.52	6.49	6.26	6.44	6.35
A ₂ B ₃	5.83	5.96	5.9	5.9	6.12	6.01	5.9	6.04	5.97
A ₃ B ₁	7.31	7.49	7.4	7.69	7.81	7.75	7.5	7.65	7.57
A ₃ B ₂	6.75	7.08	6.92	7.11	7.34	7.23	6.93	7.21	7.07
A ₃ B ₃	2.32	2.42	2.37	2.64	2.8	2.72	2.48	2.61	2.55
Mean	5.58	5.71		5.87	5.99		5.72	5.85	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.006	0.002	0.015	0.005
Factor B	0.009	0.003	0.006	0.002	0.015	0.005
Factor C	0.007	0.002	0.009	0.003	0.011	0.004
Interaction A X B	0.016	0.005	0.011	0.004	0.025	0.008
Interaction A X C	0.012	0.004	0.015	0.005	0.019	0.006
Interaction B X C	0.012	0.004	0.015	0.005	0.019	0.006
Interaction A X B X C	0.021	0.007	0.026	0.009	0.033	0.011

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

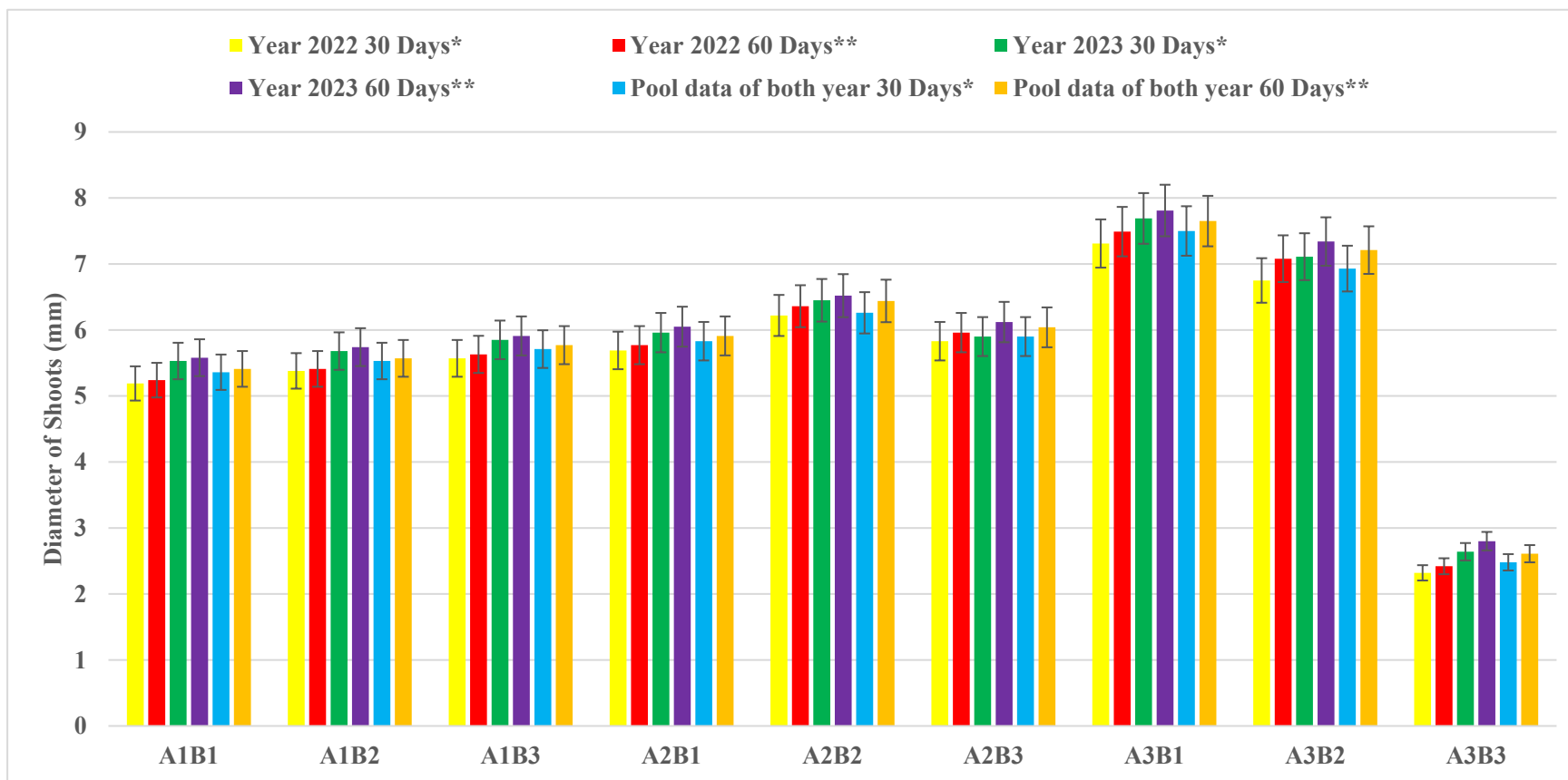


Figure 4.21 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of shoots (mm) in guava cuttings at different days.

Table 4.22 Effect of zinc (Zn) and IBA treatments on fresh weight of shoot (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.71	0.73	0.72	0.81	0.83	0.82	0.76	0.78	0.77
A₁B₂	0.92	0.96	0.94	0.99	1.01	1.01	0.96	0.99	0.97
A₁B₃	1.09	1.16	1.13	1.17	1.21	1.19	1.13	1.19	1.16
A₂B₁	1.22	1.33	1.28	1.33	1.42	1.38	1.28	1.38	1.33
A₂B₂	1.39	1.49	1.44	1.49	1.59	1.54	1.44	1.54	1.49
A₂B₃	1.54	1.65	1.6	1.62	1.78	1.71	1.58	1.72	1.65
A₃B₁	2.59	2.59	2.59	2.78	2.77	2.78	2.69	2.68	2.69
A₃B₂	2.29	2.35	2.32	2.51	2.51	2.51	2.4	2.43	2.42
A₃B₃	0.23	0.24	0.24	0.28	0.29	0.29	0.26	0.27	0.26
Mean	1.33	1.39		1.44	1.49		1.39	1.44	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.004	0.009	0.003	0.008	0.003
Factor B	0.011	0.004	0.009	0.003	0.008	0.003
Factor C	0.009	0.003	0.007	0.002	0.006	0.002
Interaction A X B	0.019	0.006	0.016	0.05	0.014	0.005
Interaction A X C	0.016	0.005	0.012	0.004	0.011	0.004
Interaction B X C	0.016	0.005	0.012	0.04	0.011	0.004
Interaction A X B X C	0.027	0.009	0.021	0.007	0.018	0.006

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

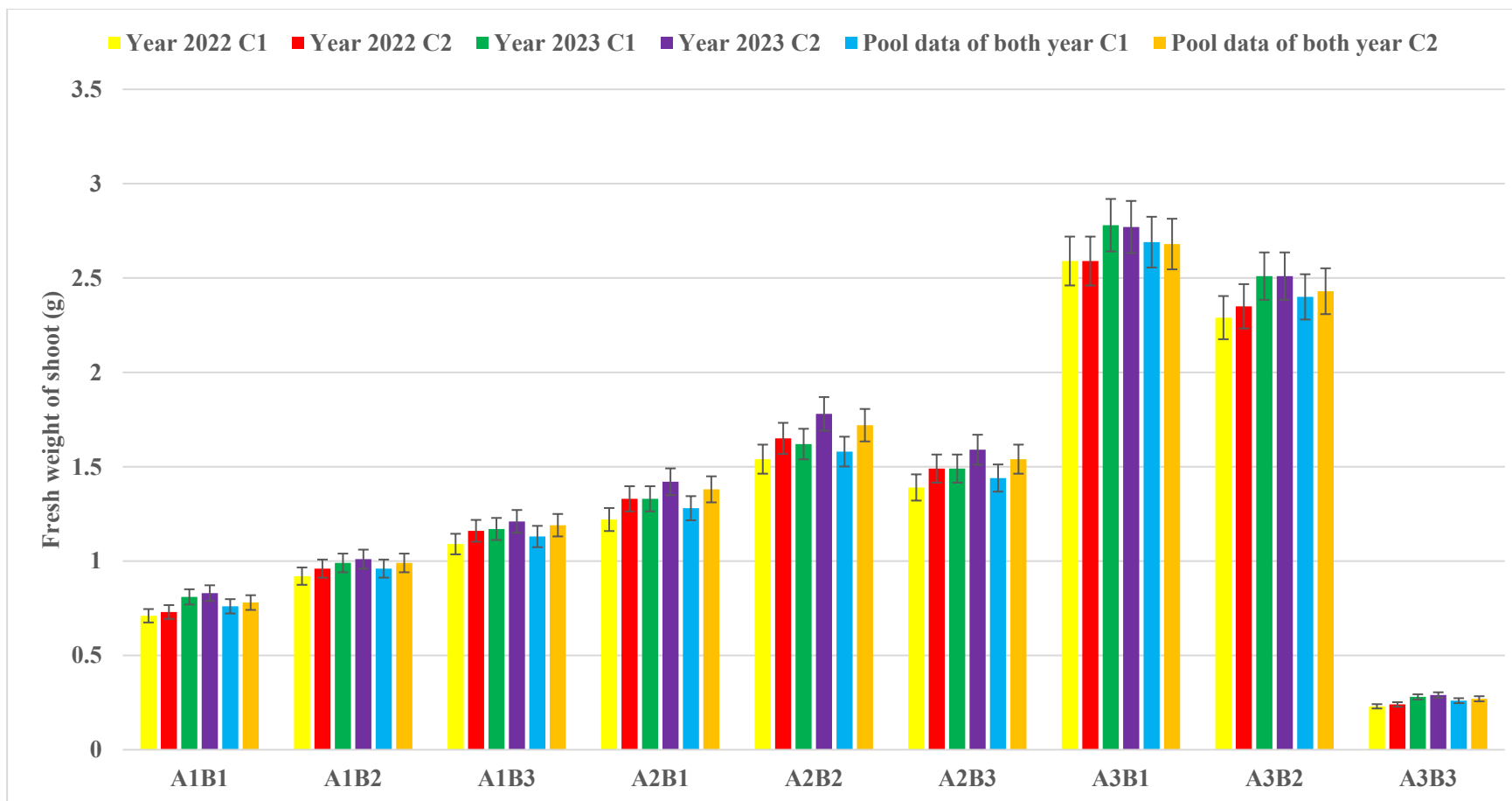


Figure 4.22 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of shoot (g) in guava cuttings at different days.

Table 4.23 Effect of zinc (Zn) and IBA treatments on dry weight of shoot (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.26	0.28	0.27	0.28	0.31	0.30	0.27	0.3	0.29
A ₁ B ₂	0.44	0.47	0.46	0.45	0.49	0.47	0.45	0.48	0.47
A ₁ B ₃	0.61	0.68	0.65	0.62	0.68	0.65	0.62	0.68	0.65
A ₂ B ₁	0.82	0.85	0.84	0.82	0.85	0.84	0.82	0.85	0.84
A ₂ B ₂	0.97	1.02	0.99	1.02	1.04	1.03	0.99	1.03	1.02
A ₂ B ₃	1.15	1.23	1.19	1.23	1.26	1.25	1.19	1.25	1.22
A ₃ B ₁	1.62	1.81	1.72	1.66	1.85	1.76	1.65	1.83	1.74
A ₃ B ₂	1.44	1.47	1.46	1.47	1.57	1.52	1.46	1.52	1.49
A ₃ B ₃	0.08	0.11	0.10	0.11	0.11	0.11	0.09	0.13	0.11
Mean	0.82	0.88		0.85	0.91		0.84	0.9	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.006	0.002	0.008	0.003	0.006	0.002
Factor B	0.006	0.002	0.008	0.003	0.006	0.002
Factor C	0.008	0.003	0.009	0.003	0.007	0.002
Interaction A X B	0.011	0.003	0.014	0.005	0.011	0.003
Interaction A X C	0.014	0.005	0.015	0.005	0.012	0.004
Interaction B X C	0.014	0.005	0.015	0.005	0.012	0.004
Interaction A X B X C	0.024	0.008	0.026	0.009	0.02	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

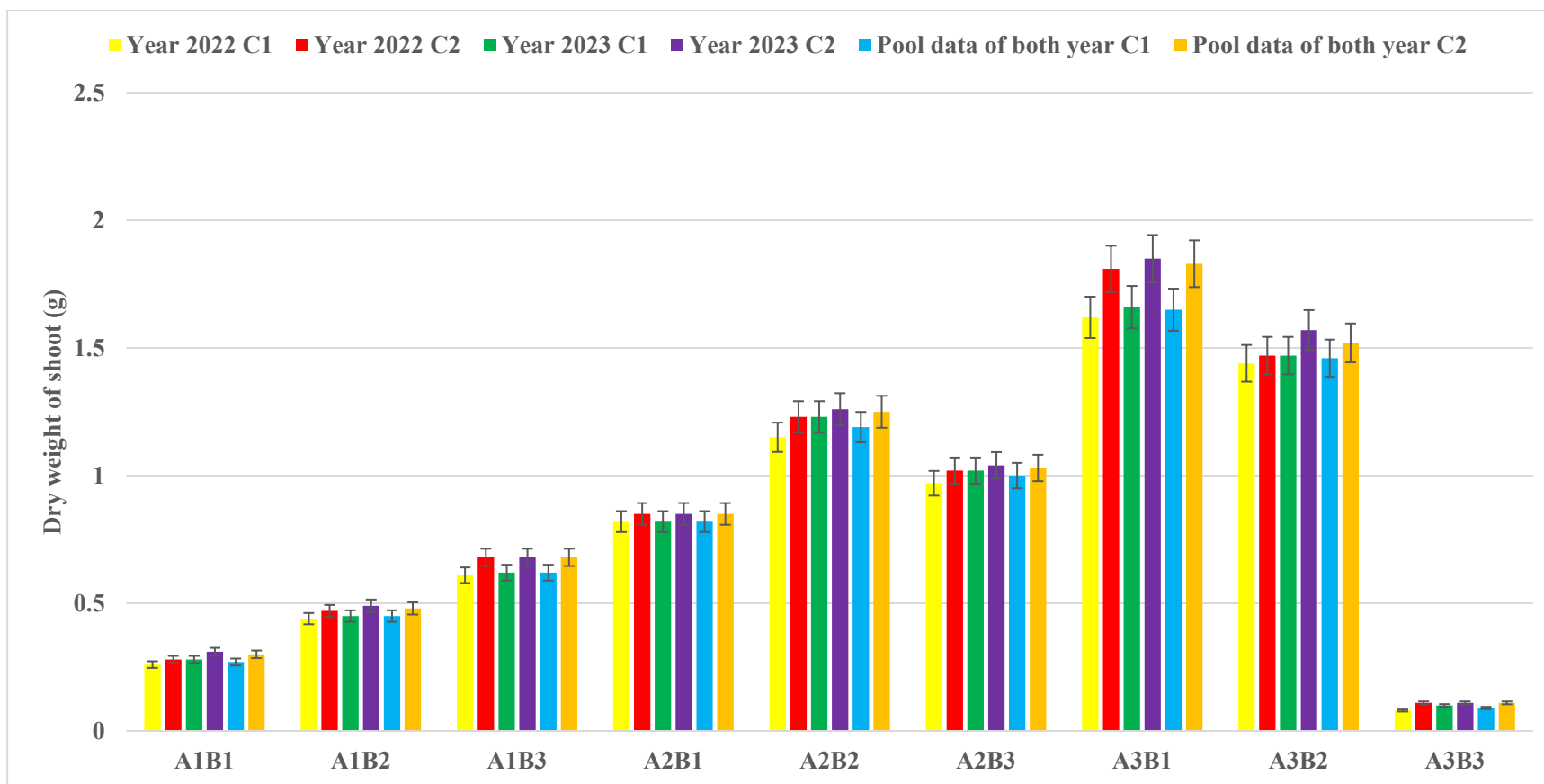


Figure 4.23 Graphical representation of the effect of Zinc (Zn) IBA treatments on dry weight of shoot (g) in guava cuttings at different days.

4.1.23 Dry weight of shoot (g)

In both 2022 and 2023, zinc foliar application had a significant impact on the maximum dry weight of shoots at both 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum dry weight, with values of 0.61 g in 2022 and 0.62 g in 2023, while A₁B₁ (0.25%) showed the minimum values, of 0.26 g in 2022 and 0.28 g in 2023. Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum dry weight, with values of 1.15 g in 2022 and 1.23 g in 2023, while A₂B₁ (50 g/tree) had minimum, 0.82 g in 2022 and 0.82 g in 2023. For post cutting treatment of IBA 5000-ppm concentration yielded the maximum dry weight of shoots at 1.62 g in 2022 and 1.66 g in 2023, whereas the control group consistently had the minimum dry weight (0.08 g in 2022 and 0.10 g in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum dry weight (0.68 g in 2022 and 0.68 g in 2023), while A₁B₁ (0.25%) had the minimum (0.28 g in 2022 and 0.31 g in 2023). For the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum dry weight (1.23 g in 2022 and 1.26 g in 2023), whereas A₂B₁ (50 g/tree) had the minimum (0.85 g in 2022 and 0.85 g in 2023). For post-cutting treatment, IBA 5000-ppm concentration showed the maximum dry weight at 1.81 g in 2022 and 1.85 g in 2023, with the control group maintaining the minimum (0.11 g in 2022 and 0.11 g in 2023).

Pooling data from both years reinforced these trends. At 30 days, A₁B₃ (0.75%) consistently recorded the maximum dry weight at 0.62 g, with A₁B₁ (0.25%) recording the minimum at 0.27 g (Table 4.23, Figure 4.23). A₂B₂ (75 g/tree) showed the maximum pooled dry weight at 1.19 g, whereas (50 g/tree) had the minimum at 0.82 g. The 5000 ppm IBA treatment consistently exhibited the maximum dry weight at 1.65 g, while the control group had the minimum at 0.09 g. At 60 days, A₁B₃ (0.75%) maintained the maximum dry weight at 0.68 g, while A₁B₁ (0.25%) had the minimum at 0.30 g. Among zinc basal treatments, A₂B₂ (75 g/tree) performed the best with 1.25 g, whereas (50 g/tree) had the minimum dry weight at 0.85 g. The 5000 ppm IBA treatment continued to show the maximum pooled dry weight at 1.83 g, with the control group remaining at a minimum of 0.13 g.

The dry weight of shoots was also significantly impacted by the timing of pre-cutting zinc treatments and the dormant stage. Cuttings taken 60 days after treatment recorded a higher dry shoot weight (0.90 g) than those taken after 30 days (0.84 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were significant. The maximum dry shoot weight (1.74 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA.

The observed effects on biomass accumulation further illustrate the impact of zinc supplementation. The fresh and dry weight of shoots are essential measures of biomass accumulation and plant health. Zinc supplementation significantly increased fresh and dry shoot weights, particularly through basal methods. The treatment with basal zinc at 75 g/tree (A₂B₂) resulted in the highest shoot biomass, indicating enhanced growth and development. This increase in shoot biomass is likely due to zinc's role in facilitating nutrient uptake and metabolic processes (Blum, 2011). The present findings are fully supported by the results of Alizadeh and Dumanoglu (2022) in olive and Somkuwar *et al.* (2013) in dog ridge rootstock.

4.1.24 Number of leaves

In 2022, the application of zinc via foliar treatments significantly influenced the Number of Leaves observed at both 30 and 60 days after pre-cutting treatment. Specifically, treatment A₁B₃ (0.75%) showed the highest number of leaves with 2.25 at 30 days, whereas A₁B₁ (0.25%) exhibited the lowest with 1.82 (Table 4.24, Figure 4.24). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest number of leaves at 2.83, while A₂B₁ (50 g/tree) had the lowest at 2.39. For post-cutting treatment IBA 5000-ppm concentration resulted in the highest number of leaves observed at 7.16, contrasting with the control group, which showed the fewest at 1.02.

By 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) continued to demonstrate the highest leaf count at 2.41, whereas A₁B₁ (0.25%) had the lowest at 1.83, underscoring significant variations among the zinc basal applications. A₂B₂ (75 g/tree) showed the highest leaf count at 3.01, while A₂B₁ (50 g/tree) exhibited the

lowest at 2.44. For post-cutting treatment, IBA 5000-ppm concentration maintained a notable lead with 7.96 leaves, while the control group remained markedly lower at 1.07 (Table 4.24, Figure 4.24).

In 2023, the effects of zinc foliar application on the Number of Leaves were similarly pronounced. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) led with 2.44 leaves, contrasting with A₁B₁ (0.25%) which showed the fewest at 2.10. Among the various zinc levels as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest leaf count at 4.11, while A₂B₁ (50 g/tree) displayed the lowest at 3.02. For post-cutting treatment, IBA 5000-ppm concentration produced the most leaves at 8.62, with the control group again presenting the fewest at 1.07. By 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained its lead with 2.50 leaves, whereas A₁B₁ (0.25%) had the fewest at 2.13. Among the various zinc levels as pre-cutting basal treatments, A₂B₂ (75 g/tree) exhibited the highest leaf count at 4.33, with A₂B₁ (50 g/tree) showing the fewest at 3.05. For post-cutting treatment, IBA 5000-ppm concentration continued to lead significantly with 9.02 leaves, while the control group lagged with 1.11 leaves (Table 4.24, Figure 4.24).

Pooling data from both years reaffirmed consistent trends in leaf production. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently exhibited the highest number of leaves at 2.35, whereas A₁B₁ (0.25%) consistently showed the lowest at 1.96 (Table 4.24, Figure 4.24). Among various levels of zinc as pre-cutting basal treatments demonstrated A₂B₂ (75 g/tree) with the highest leaf count at 3.47, and A₂B₁ (50 g/tree) with the lowest at 2.71. For post-cutting treatment, IBA 5000-ppm concentration consistently resulted in the highest leaf count with an average of 7.89 leaves, while the control group consistently had the lowest at 1.05. At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75% /tree) maintained its lead with 2.41 leaves, while A₁B₁ (0.25%/tree) had the fewest at 1.98. Among the various zinc levels pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest leaf count at 3.67, whereas A₂B₁ (50 g/tree) had the lowest at 2.75. For post-cutting treatment, IBA 5000-ppm concentration consistently produced the highest number of leaves with an average of 8.19, while the control group consistently exhibited the lowest at 1.09 (Table 4.24, Figure 4.24).

Table 4.24 Effect of zinc (Zn) and IBA treatments on number of leaves guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.82	1.83	1.83	2.1	2.13	2.12	1.96	1.98	1.97
A₁B₂	2.07	2.1	2.09	2.22	2.26	2.24	2.15	2.18	2.17
A₁B₃	2.25	2.41	2.33	2.44	2.51	2.47	2.35	2.41	2.38
A₂B₁	2.39	2.44	2.42	3.02	3.05	3.04	2.71	2.75	2.73
A₂B₂	2.83	3.01	2.92	4.11	4.33	4.22	3.47	3.67	3.57
A₂B₃	2.61	2.73	2.67	3.69	3.73	3.71	3.15	3.22	3.19
A₃B₁	7.16	7.96	7.56	8.62	9.02	8.82	7.89	8.19	8.04
A₃B₂	6.41	6.64	6.53	8.02	8.01	8.02	7.22	7.33	7.28
A₃B₃	1.02	1.07	1.05	1.07	1.11	1.09	1.05	1.09	1.07
Mean	3.17	3.36		3.92	4.01		3.55	3.65	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.011	0.003	0.008	0.003
Factor B	0.009	0.003	0.011	0.003	0.008	0.003
Factor C	0.007	0.002	0.011	0.003	0.006	0.002
Interaction A X B	0.015	0.005	0.017	0.006	0.014	0.005
Interaction A X C	0.012	0.004	0.018	0.006	0.011	0.004
Interaction B X C	0.012	0.004	0.018	0.006	0.011	0.004
Interaction A X B X C	0.021	0.007	0.031	0.010	0.019	0.006

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

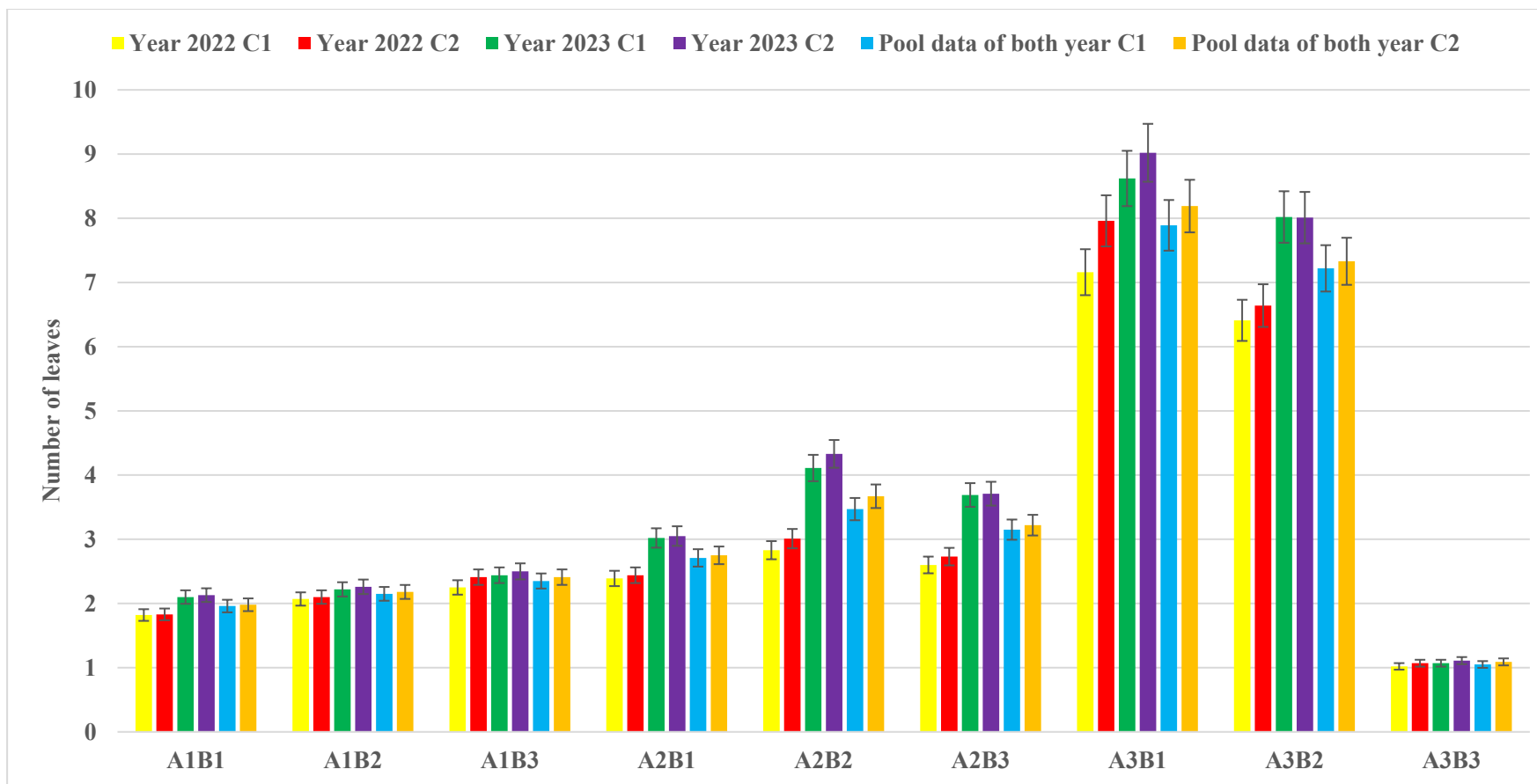


Figure 4.24 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of leaves in guava cuttings at different days.

Table 4.25 Effect of zinc (Zn) and IBA treatments on leaf area (cm²) guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.24	1.32	1.28	1.43	1.55	1.49	1.34	1.44	1.39
A₁B₂	1.41	1.59	1.5	1.77	1.91	1.84	1.59	1.75	1.67
A₁B₃	1.69	1.88	1.79	2.15	2.19	2.17	1.92	2.04	1.98
A₂B₁	1.95	2.03	1.99	2.38	2.31	2.35	2.17	2.17	2.17
A₂B₂	2.17	2.27	2.22	2.52	2.52	2.52	2.33	2.38	2.36
A₂B₃	2.36	2.55	2.46	2.87	2.84	2.86	2.62	2.71	2.66
A₃B₁	5.86	6.56	6.21	8.01	8.03	8.02	6.93	7.3	7.11
A₃B₂	5.48	6.12	5.82	7.31	7.35	7.33	6.4	6.74	6.57
A₃B₃	0.53	0.6	0.57	0.63	0.63	0.63	0.58	0.62	0.6
Mean	2.52	2.77		3.23	3.26		2.88	3.01	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.012	0.004	0.009	0.003
Factor B	0.008	0.003	0.012	0.004	0.009	0.003
Factor C	0.007	0.002	0.008	0.003	0.007	0.002
Interaction A X B	0.013	0.004	0.021	0.007	0.015	0.005
Interaction A X C	0.013	0.004	0.014	0.005	0.012	0.004
Interaction B X C	0.013	0.004	0.014	0.005	0.012	0.004
Interaction A X B X C	0.022	0.007	0.025	0.008	0.021	0.007

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

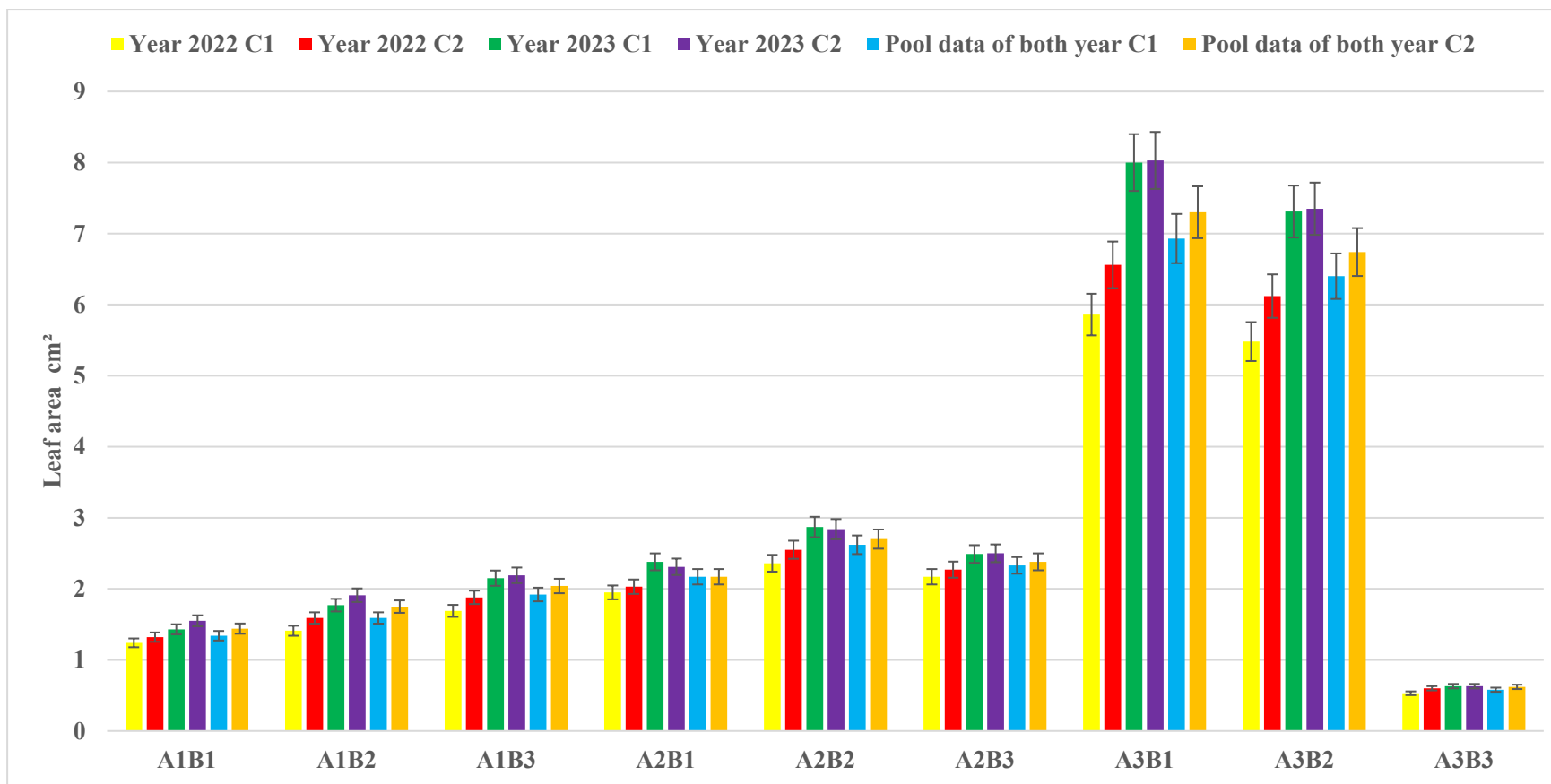


Figure 4.25 Graphical representation of the effect of Zinc (Zn) and IBA treatments on leaf area (cm²) in guava cuttings at different days.

Table 4.26 Effect of zinc (Zn) and IBA treatments on chlorophyll (mg/g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.23	0.26	0.25	0.31	0.33	0.32	0.27	0.3	0.29
A ₁ B ₂	0.38	0.41	0.4	0.46	0.48	0.47	0.42	0.45	0.44
A ₁ B ₃	0.55	0.55	0.55	0.63	0.66	0.65	0.59	0.61	0.6
A ₂ B ₁	0.73	0.69	0.71	0.79	0.84	0.82	0.76	0.77	0.77
A ₂ B ₂	1.08	0.96	1.02	1.08	1.14	1.11	1.08	1.05	1.07
A ₂ B ₃	0.91	0.81	0.86	0.92	0.99	0.96	0.92	0.91	0.91
A ₃ B ₁	1.47	1.51	1.49	1.68	1.65	1.67	1.55	1.60	1.58
A ₃ B ₂	1.22	1.26	1.24	1.47	1.51	1.49	1.35	1.39	1.37
A ₃ B ₃	0.07	0.08	0.08	0.09	0.09	0.09	0.08	0.09	0.09
Mean	0.74	0.73		0.83	0.86		0.78	0.81	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.011	0.003	0.008	0.003
Factor B	0.009	0.003	0.011	0.003	0.008	0.003
Factor C	0.009	0.003	0.006	0.002	0.005	0.002
Interaction A X B	0.016	0.005	0.017	0.006	0.014	0.005
Interaction A X C	0.015	0.005	0.012	0.003	0.008	0.003
Interaction B X C	0.015	0.005	0.012	0.003	0.008	0.003
Interaction A X B X C	0.026	0.009	0.017	0.006	0.014	0.005

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

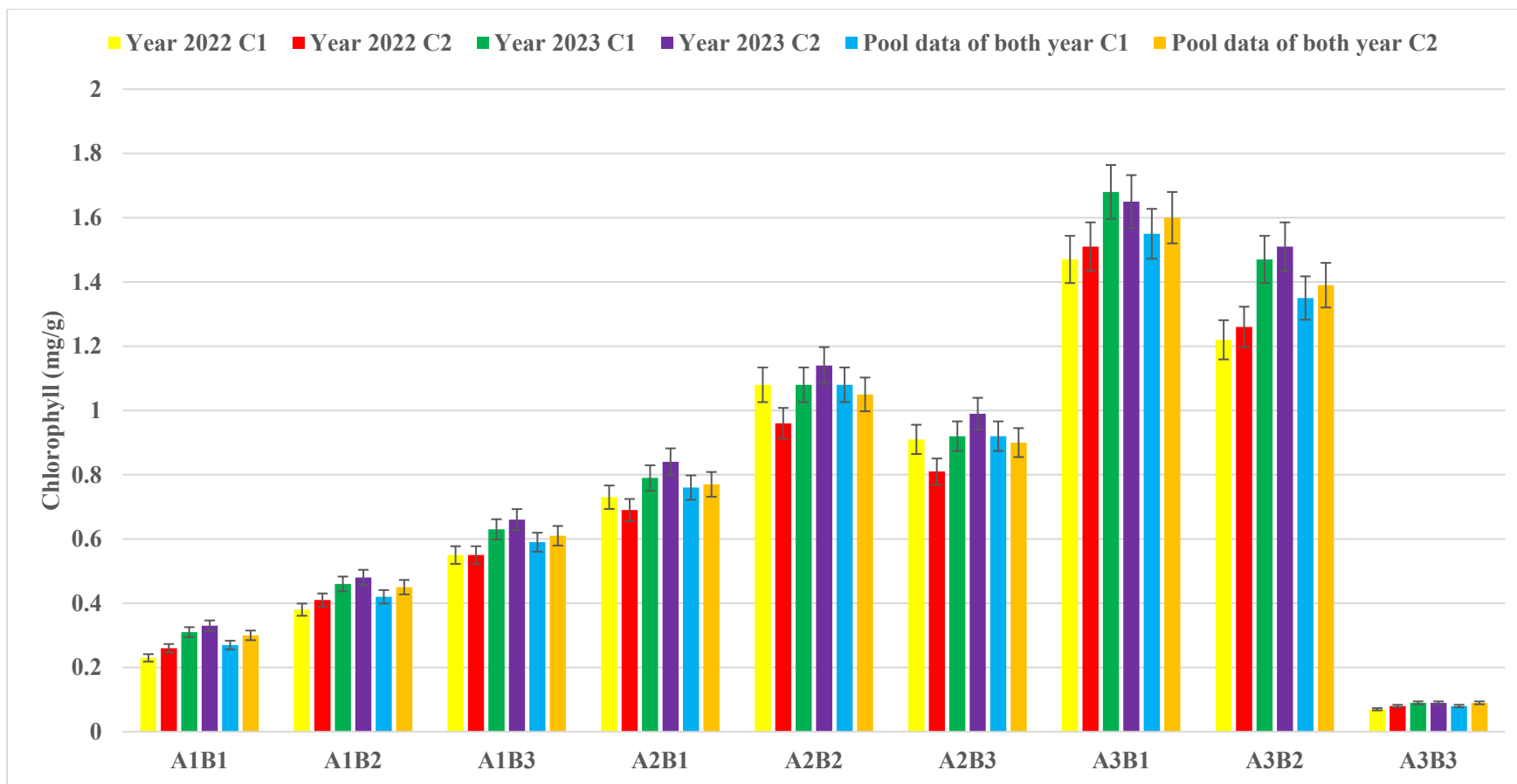


Figure 4.26 Graphical representation of the effect of Zinc (Zn) and IBA treatments on chlorophyll (mg/g) in guava cuttings at different days.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of leaves in guava cuttings. Cuttings collected after 60 days produced a higher number of leaves (3.65) compared to those collected after 30 days (3.55). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected leaf production. The highest number of leaves (8.04) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.25 Leaf area (cm²)

In 2022, zinc foliar application significantly influenced the Leaf Area at both 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) exhibited the largest increase in leaf area, measuring a maximum of 1.69 cm², while A₁B₁ (0.25% /tree) showed the smallest increase with a minimum of 1.24 cm² (Table 4.25, Figure 4.25). Among the various levels of zinc as pre-cutting basal treatments, A₂B₃ (100 g/tree) showed the maximum leaf area at 2.36 cm², with A₂B₁ displaying the minimum at 1.95 cm². Post-cutting treatment of IBA 5000-ppm concentration led to a maximum leaf area of 5.86 cm², whereas the control group had a minimum of 0.53 cm².

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) maintained the maximum leaf area at 1.88 cm², while A₁B₁ (0.25%) had the minimum at 1.32 cm², demonstrating significant differences among zinc basal applications. A₂B₃ (100g/tree) again showed the maximum leaf area of 2.55 cm², whereas A₂B₁ (50 g/tree) exhibited the minimum at 2.03 cm². For post-cutting treatment of IBA, 5000-ppm concentration demonstrated the maximum leaf area of 6.56 cm², with the control group showing a minimum at 0.60 cm² (Figure 4.25).

In 2023, the impact of zinc foliar application on Leaf Area remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the maximum leaf area at 2.15 cm², while A₁B₁ (0.25%) had the minimum at 1.43 cm². Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) exhibited the maximum leaf area at 2.87 cm², whereas A₂B₁, (50 g/tree) showed the minimum at 2.38 cm². For post-cutting treatment of IBA, 5000-ppm concentration resulted in a maximum leaf

area of 8 cm², while the control group had a minimum at 0.63 cm² (Table 4.25, Figure 4.25).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the maximum leaf area at 2.19 cm², and A₂B₁ (0.25%) exhibited the minimum at 2.19 cm². Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the maximum leaf area at 2.84 cm², and A₂B₁ with the minimum at 2.31 cm². For post-cutting treatment, IBA 5000-ppm concentration demonstrated a maximum leaf area of 8.03 cm², while the control group exhibited a minimum at 0.63 cm² (Figure 4.25, Figure 4.25).

Pooling data from both years revealed consistent trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) consistently displayed the maximum leaf area at 1.92 cm², whereas A₁B₁ (0.25%/tree) had the minimum at 1.34 cm² (Table 4.25, Figure 4.25). Zinc as pre-cutting basal treatments showed ZB₃ with the maximum pooled leaf area at 2.62 cm², and ZB₁ with the minimum at 2.17 cm². The 5000 ppm IBA treatment consistently led to the maximum leaf area with a mean value of 6.93 cm², while the control group consistently had the minimum at 0.58 cm².

At 60 days, pooled data indicated that ZF₃ (0.75% /tree) had the maximum leaf area at 2.04 cm², while ZF₁ (0.25%/tree) had the minimum at 1.44 cm². Zinc basal treatments showed ZB₃ with the maximum pooled leaf area at 2.70 cm², whereas ZB₁ had the minimum at 2.17 cm². The 5000 ppm IBA treatment maintained the maximum pooled leaf area with a mean value of 7.30 cm², while the control group had the minimum at 0.62 cm² (Figure 4.25).

4.1.26 Chlorophyll (mg/g)

In both 2022 and 2023, zinc foliar application significantly influenced the Chlorophyll content at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the maximum Chlorophyll content, with values of 0.55 mg/g in 2022 and 0.63 mg/g in 2023, while A₁B₁ (0.25%) exhibited the minimum values, 0.23 mg/g in 2022 and 0.31 mg/g in 2023 (Table 4.26, Figure 4.26).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently displayed the maximum Chlorophyll content, with values of 1.08 mg/g in 2022 and 1.08 mg/g in 2023, while A₂B₁ (50 g/tree) had the minimum, 0.73 mg/g in 2022 and 0.79 mg/g in 2023. For post cutting treatment of IBA 5000-ppm concentration yielded the maximum Chlorophyll content of 1.47 mg/g in 2022 and 1.68 mg/g in 2023, whereas the control group consistently had the minimum Chlorophyll content, of 0.07 mg/g in 2022 and 0.09 mg/g in 2023.

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to exhibit the maximum Chlorophyll content (0.55 mg/g in 2022 and 0.66 mg/g in 2023), while A₁B₁ (0.25%) showed the minimum (0.26 mg/g in 2022 and 0.33 mg/g in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the maximum Chlorophyll content (0.96 mg/g in 2022 and 1.14 mg/g in 2023), while A₂B₁ (50 g/tree) had the minimum (0.69 mg/g in 2022 and 0.84 mg/g in 2023). For post-cutting treatment of IBA 5000-ppm concentration displayed the maximum Chlorophyll content at 1.51 mg/g in 2022 and 1.65 mg/g in 2023, with the control group remaining at the minimum (0.08 mg/g in 2022 and 0.09 mg/g in 2023).

Pooled data from both years reinforced these trends. At 30 days, ZF₃ consistently recorded the maximum Chlorophyll content at 0.59 mg/g, with ZF₁ showing the minimum at 0.27 mg/g (Table 4.26). ZB₂ displayed the maximum pooled Chlorophyll content at 1.08 mg/g, and ZB₁ had the minimum at 0.76 mg/g. The 5000 ppm IBA treatment consistently exhibited the maximum Chlorophyll content at 1.55 mg/g, while the control group had the minimum at 0.08 mg/g. At 60 days, ZF₃ had the maximum Chlorophyll content at 0.61 mg/g, while ZF₁ had the minimum at 0.30 mg/g. ZB₂ performed the best among zinc basal treatments with 1.05 mg/g, and ZB₁ had the minimum Chlorophyll content at 0.77 mg/g. The 5000 ppm IBA treatment maintained the maximum pooled Chlorophyll content at 1.60 mg/g, with the control group remaining at the minimum of 0.09 mg/g.

The significant increase in chlorophyll content observed in this study underscores the crucial role of zinc in photosynthesis. The chlorophyll content is a vital parameter that determines the photosynthetic efficiency of the plant. Zinc is known to influence

chlorophyll synthesis and stability. The study found that zinc supplementation, particularly through basal application, significantly increased chlorophyll content in the leaves. Higher chlorophyll levels are associated with enhanced photosynthetic activity, leading to improved plant growth and productivity. This finding is consistent with research indicating that zinc deficiency can lead to chlorosis and reduced chlorophyll synthesis (Broadley *et al.*, 2007). The present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Alizadeh and Dumanoglu (2022) in olive.

4.1.27 Fresh weight of leaves (g)

The fresh weight of leaves was significantly affected by zinc foliar application in both 2022 and 2023, at 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently displayed the maximum fresh weight of leaves, with values of 0.87 g in 2022 and 0.87 g in 2023, while A₁B₁ (0.25%) showed minimum values, of 0.41 g in 2022 and 0.46 g in 2023 (Table 4.27, Figure 4.27).

Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum fresh weight of leaves, with values of 1.45 g in 2022 and 1.47 g in 2023, while A₂B₁ (50 g/tree) had the minimum, 1.09 g in 2022 and 1.04 g in 2023. Post cutting treatment of IBA 5000-ppm concentration consistently yielded the highest fresh weight of leaves at 2.75 g in 2022 and 2.83 g in 2023, whereas the control group consistently had the lowest fresh weight (0.18 g in 2022 and 0.25 g in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum fresh weight of leaves (0.98 g in 2022 and 1.29 g in 2023), while A₁B₁ (0.25%) had the minimum (0.74 g in 2022 and 0.83 g in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest fresh weight (1.60 g in 2022 and 2.05 g in 2023), while A₂B₁ (50 g/tree) had the lowest (1.18 g in 2022 and 1.42 g in 2023). For post-cutting treatment, IBA 5000-ppm concentration showed the highest fresh weight of leaves at 2.40 g in 2022 and 2.62 g in 2023, with the control group maintaining the lowest (0.48 g in 2022 and 0.73 g in 2023).

Pooling data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum fresh weight of leaves at 0.87 g, with A₁B₁ (0.25%) the lowest at 0.44 g (Table 4.27, Figure 4.27). A₂B₂ (75 g/tree) showed the highest pooled fresh weight at 1.46 g, and A₂B₁ (50 g/tree) had the lowest at 1.07 g. For post-cutting treatment of IBA 5000-ppm concentration consistently exhibited the highest fresh weight of leaves at 2.79 g, while the control group had the lowest at 0.22 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the maximum fresh weight at 0.90 g, while A₁B₁ (0.25%) had the minimum at 0.45 g. Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) performed the best with 1.54 g, whereas A₂B₁ (50 g/tree) had the minimum fresh weight at 1.08 g. For post-cutting treatment, IBA 5000-ppm concentration also maintained the highest pooled fresh weight at 2.83 g, with the control group remaining at a minimum of 0.22 g.

The fresh weight of leaves varied significantly with the timing of pre-cutting zinc treatments or dormant-stage collection. Cuttings collected after 60 days exhibited higher fresh leaf weight (1.29 g) compared to those collected after 30 days (1.26 g). The highest fresh weight of leaves (2.81 g) was obtained in the A₃B₁C₂ treatment, where cuttings were taken after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.28 Dry weight of leaves (g)

In both 2022 and 2023, the zinc foliar application significantly impacted the dry weight of leaves at both 30- and 60-days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight, with values of 0.52g in 2022 and 0.55g in 2023, while A₁B₁ (0.25%) showed the lowest values, 0.21g in 2022 and 0.24g in 2023 (Table 4.28). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the highest dry weight, with values of 0.97g in 2022 and 1.01g in 2023, while A₂B₁ (50 g/tree) had the lowest, 0.69g in 2022 and 0.72g in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the highest dry weight of 1.49g in 2022 and 1.81g in 2023, whereas the control group consistently had the lowest dry weight (0.07g in 2022 and 0.09g in 2023).

Table 4.27 Effect of zinc (Zn) and IBA treatments on fresh weight of leaves (g) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.41	0.43	0.42	0.46	0.47	0.47	0.44	0.45	0.44
A ₁ B ₂	0.65	0.65	0.65	0.68	0.71	0.7	0.67	0.68	0.67
A ₁ B ₃	0.87	0.87	0.87	0.87	0.92	0.9	0.87	0.90	0.88
A ₂ B ₁	1.09	1.11	1.1	1.04	1.04	1.04	1.07	1.08	1.07
A ₂ B ₂	1.45	1.52	1.49	1.47	1.55	1.51	1.46	1.54	1.50
A ₂ B ₃	1.26	1.31	1.29	1.23	1.29	1.26	1.25	1.30	1.27
A ₃ B ₁	2.75	2.78	2.77	2.83	2.87	2.85	2.79	2.83	2.81
A ₃ B ₂	2.47	2.54	2.51	2.55	2.58	2.57	2.51	2.56	2.54
A ₃ B ₃	0.18	0.19	0.19	0.25	0.25	0.25	0.22	0.22	0.22
Mean	1.24	1.27		1.27	1.31		1.26	1.29	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.009	0.003	0.009	0.003
Factor B	0.008	0.003	0.009	0.003	0.009	0.003
Factor C	0.014	0.002	0.006	0.002	0.006	0.002
Interaction A X B	0.006	0.005	0.015	0.005	0.015	0.005
Interaction A X C	0.011	0.004	0.01	0.003	0.01	0.003
Interaction B X C	0.011	0.004	0.01	0.003	0.01	0.003
Interaction A X B X C	0.019	0.006	0.017	0.006	0.017	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

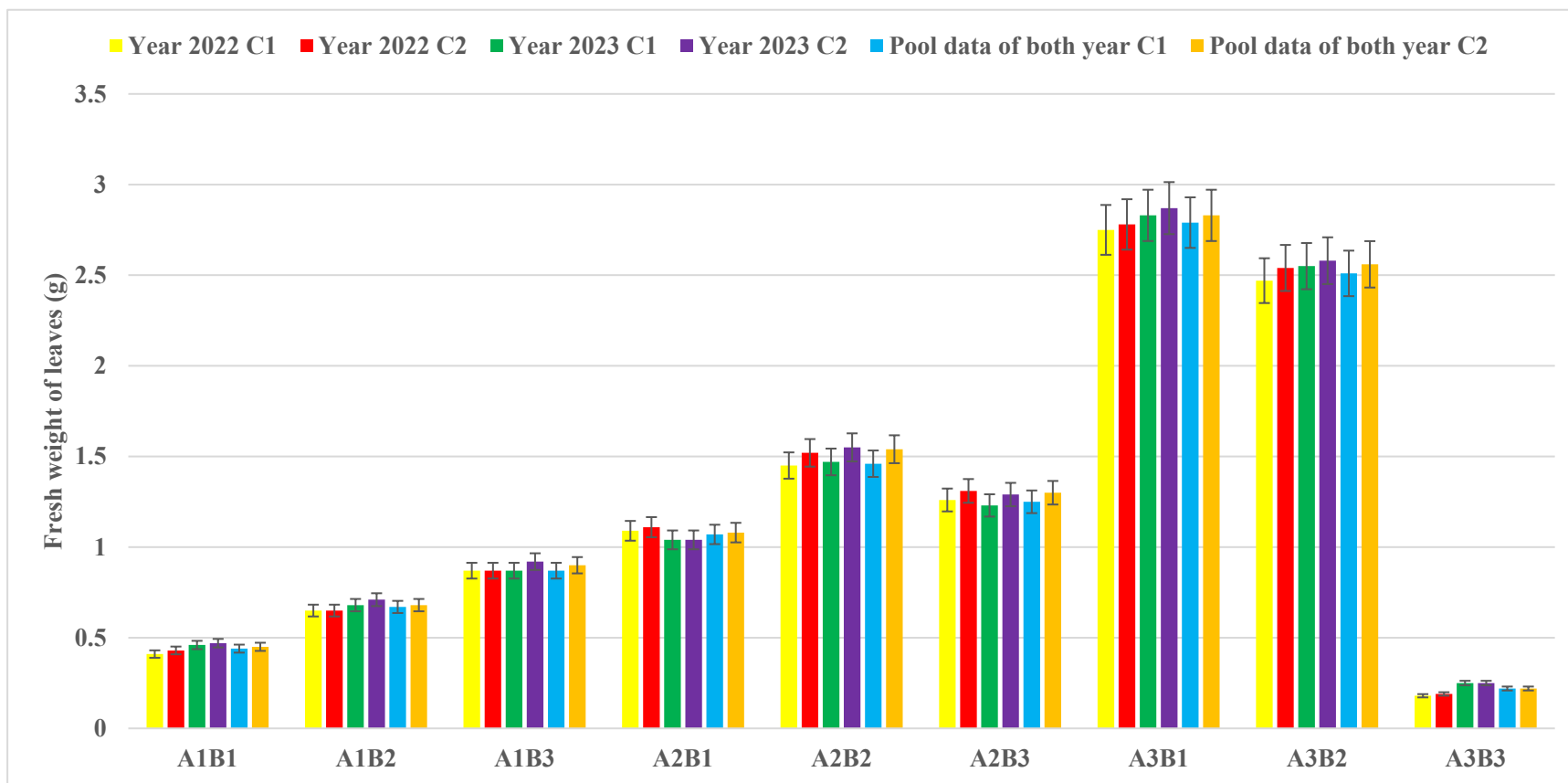


Figure 4.27 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of leaves (g) in guava cuttings at different days.

Table 4.28 Effect of zinc (Zn) and IBA treatments on dry weight of leaves (g) in Guava Cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.21	0.22	0.22	0.24	0.24	0.24	0.23	0.23	0.23
A ₁ B ₂	0.37	0.37	0.37	0.39	0.39	0.39	0.38	0.38	0.38
A ₁ B ₃	0.52	0.52	0.52	0.55	0.58	0.57	0.54	0.55	0.55
A ₂ B ₁	0.69	0.71	0.7	0.72	0.75	0.74	0.71	0.73	0.72
A ₂ B ₂	0.97	0.99	0.98	1.01	1.09	1.05	0.99	1.04	1.02
A ₂ B ₃	0.81	0.82	0.82	0.86	0.93	0.9	0.84	0.88	0.86
A ₃ B ₁	1.49	1.58	1.54	1.81	1.81	1.81	1.65	1.75	1.7
A ₃ B ₂	1.32	1.38	1.35	1.54	1.54	1.54	1.43	1.46	1.45
A ₃ B ₃	0.07	0.06	0.07	0.09	0.1	0.1	0.08	0.08	0.08
Mean	0.72	0.74		0.80	0.83		0.76	0.79	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.012	0.004	0.009	0.003	0.008	0.003
Factor B	0.012	0.004	0.009	0.003	0.008	0.003
Factor C	0.006	0.002	0.005	0.002	0.004	0.001
Interaction A X B	0.02	0.007	0.015	0.005	0.014	0.005
Interaction A X C	0.01	0.003	0.009	0.003	0.006	0.002
Interaction B X C	0.01	0.003	0.009	0.003	0.006	0.002
Interaction A X B X C	0.018	0.006	0.016	0.005	0.011	0.004

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

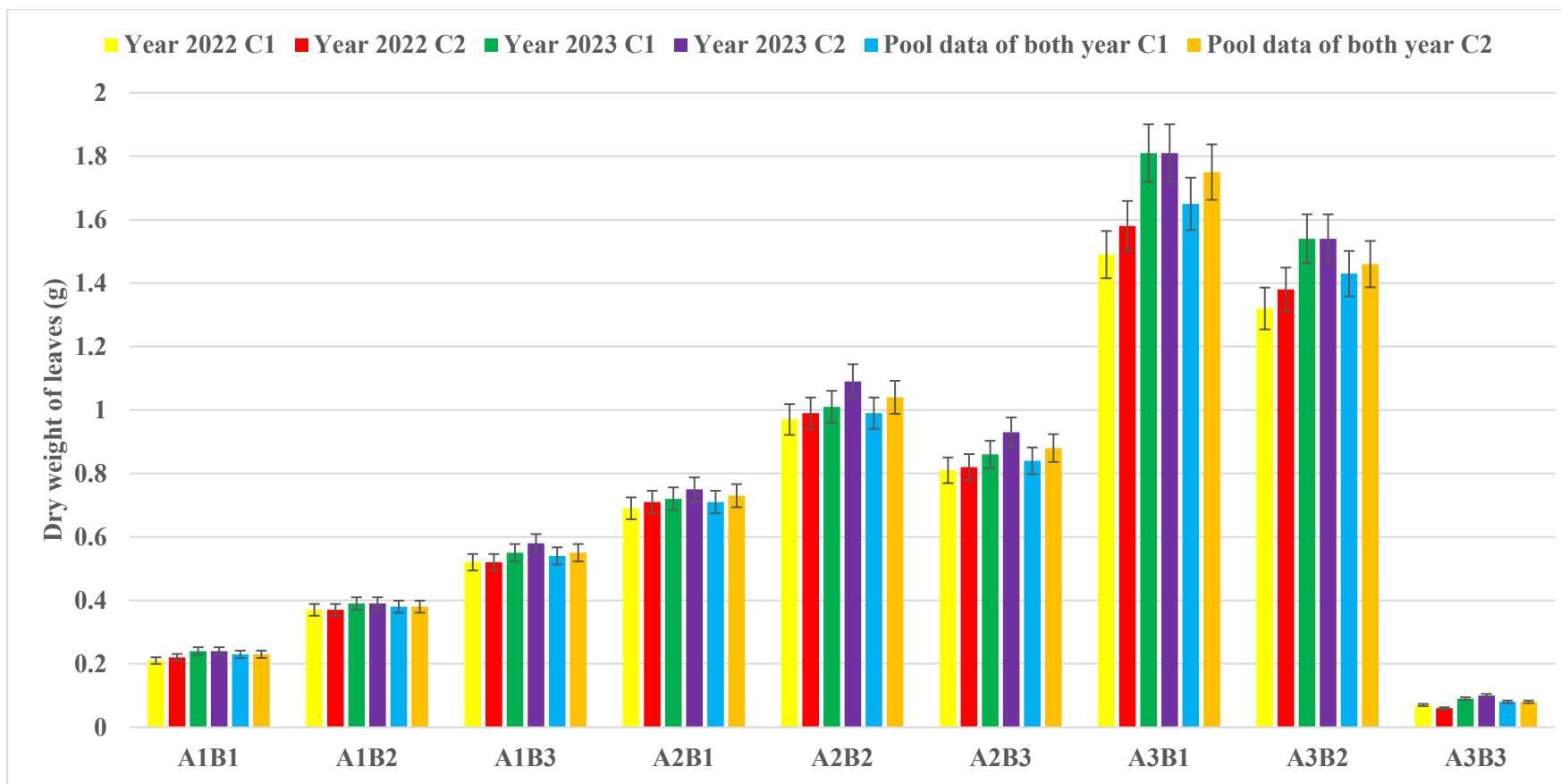


Figure 4.28 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of leaves (g) in guava cuttings at different days.

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the highest dry weight (0.52 in 2022 and 0.58g in 2023), while A₁B₁ (0.25%) had the lowest (0.22g in 2022 and 0.24g in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight (0.99g in 2022 and 1.09g in 2023), while A₂B₁ (50 g/tree) had the lowest (0.71g in 2022 and 0.73g in 2023). For post-cutting treatment, IBA 5000-ppm concentration showed the highest dry weight at 1.58g in 2022 and 1.81g in 2023, with the control group remaining the lowest (0.06g in 2022 and 0.10g in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight at 0.54g, with A₁B₁ (0.25%) the lowest at 0.23g (Table 4.28). A₂B₂ (75 g/tree) showed the highest pooled dry weight at 0.99 g, and A₂B₁ (50 g/tree) had the lowest at 0.71g. For post-cutting treatment, IBA 5000-ppm concentration consistently had the highest dry weight at 1.65g, while the control group had the lowest at 0.08g. At 60 days after pre cutting treatment, A₁B₃ (0.75%) had the highest dry weight at 0.55g, while A₁B₁ (0.25%) had the lowest at 0.23g. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments with 1.04g, and A₂B₁ (50 g/tree) had the lowest dry weight at 0.73g. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest pooled dry weight at 1.75g, and the control group remained the lowest at 0.08g.

The results highlight the impact of zinc on leaf development and overall plant vigor. The number of leaves, along with their fresh and dry weights, are critical indicators of photosynthetic capacity and overall plant health. Basal zinc application at 75 g/tree (A₂B₂) significantly increased the number of leaves, their fresh and dry weights, and leaf area. These enhancements suggest that zinc improves leaf development and expansion, leading to a more substantial photosynthetic area and improved plant growth. Increased leaf area and biomass are indicative of better nutrient and water absorption, contributing to overall plant health (Alloway, 2008). The present findings are fully supported by the results of Yamashita *et al.* (2006) in mango and Sourati *et al.* (2022) in mulberry.

Table 4.29 Effect of zinc (Zn) and IBA treatments on root to shoot ratio in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.00	1.00	1.00	1.01	0.99	1.00	1.01	0.99	1.00
A₁B₂	0.89	0.85	0.87	0.88	0.86	0.87	0.89	0.85	0.87
A₁B₃	0.83	0.78	0.80	0.80	0.77	0.79	0.82	0.77	0.80
A₂B₁	0.81	0.76	0.79	0.76	0.72	0.74	0.78	0.74	0.76
A₂B₂	0.75	0.72	0.74	0.75	0.70	0.72	0.75	0.71	0.73
A₂B₃	0.77	0.75	0.76	0.75	0.71	0.73	0.76	0.73	0.74
A₃B₁	0.85	0.90	0.88	0.87	0.88	0.87	0.86	0.89	0.87
A₃B₂	0.89	0.88	0.89	0.90	0.91	0.90	0.89	0.90	0.90
A₃B₃	1.07	1.13	1.10	0.97	0.93	0.95	1.02	1.03	1.03
Mean	0.87	0.86		0.85	0.83		0.86	0.85	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.014	0.005	0.023	0.008	0.018	0.006
Factor B	0.014	0.005	0.023	0.008	0.018	0.006
Factor C	0.012	0.008	0.011	0.004	0.010	0.003
Interaction A X B	0.025	0.007	0.040	0.013	0.031	0.010
Interaction A X C	0.036	0.012	0.019	0.006	0.017	0.006
Interaction B X C	0.036	0.012	0.019	0.006	0.017	0.006
Interaction A X B X C	0.042	0.021	0.023	0.011	0.019	0.010

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

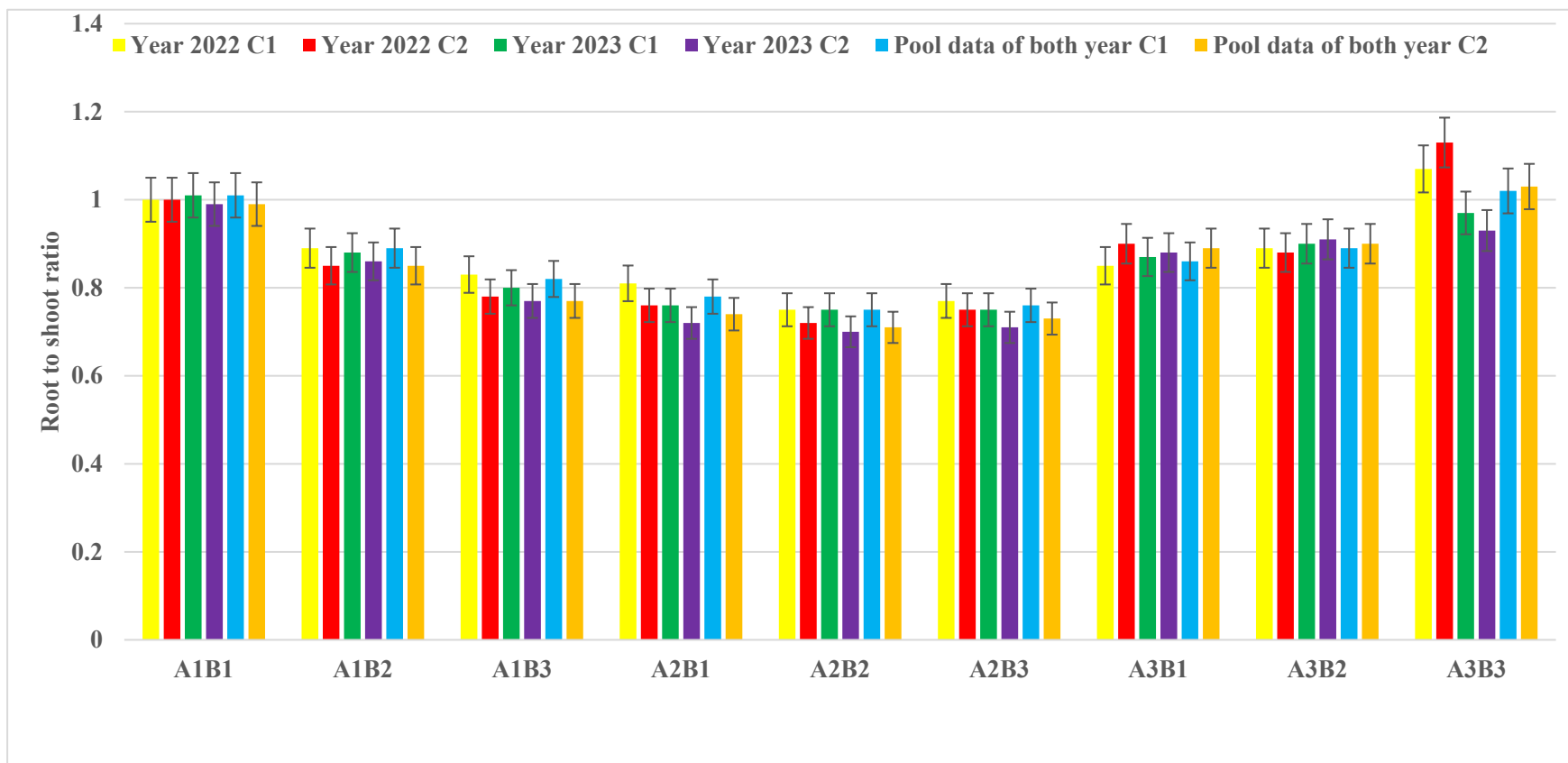


Figure 4.29 Graphical representation of the effect of Zinc (Zn) and IBA treatments on root to shoot ratio in guava cuttings at different days.

4.1.29 Root to shoot ratio

In both 2022 and 2023, zinc foliar application significantly influenced the root to shoot ratio at both 30- and 60 days after pre-cutting treatment. At 30 days after pre cutting treatment, A₁B₃ (0.75%) consistently recorded the minimum root to shoot ratio, with values of 0.83 in 2022 and 0.80 in 2023, while A₁B₁ (0.25%) showed the maximum ratios, 1.01 in 2022 and 1.01 in 2023 (Table 4.29, Figure 4.29).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the minimum root to shoot ratio, with values of 0.75 in 2022 and 0.75 in 2023, while A₂B₁ (50 g/tree) had the maximum, 0.81 in 2022 and 0.76 in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the minimum root to shoot ratio of 0.85 in 2022 and 0.87 in 2023, whereas the control group consistently had the maximum ratios (1.07 in 2022 and 0.97 in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the minimum root to shoot ratio (0.78 in 2022 and 0.77 in 2023), while A₁B₁ (0.25%) had the maximum (1.01 in 2022 and 0.99 in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the minimum root to shoot ratio (0.76 in 2022 and 0.72 in 2023), while A₂B₁ (50 g/tree) had the maximum (1.00 in 2022 and 1.15 in 2023). For post-cutting treatment of IBA, 5000-ppm concentration showed the minimum root to shoot ratio at 0.90 in 2022 and 0.88 in 2023, with the control group remaining the maximum (1.13 in 2022 and 0.93 in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the minimum root to shoot ratio at 0.82, with A₁B₁ (0.25%) the maximum at 1.01 (Table 29). A₂B₂ (75 g/tree) showed the minimum pooled root to shoot ratio at 0.75, and A₂B₁ (50 g/tree) had the maximum at 0.78. For post-cutting treatment of IBA 5000-ppm concentration consistently had the minimum root to shoot ratio at 0.86, while the control group had the maximum at 1.02. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the minimum root to shoot ratio at 0.77, while A₁B₁ (0.25%) had the maximum at 0.99. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments at 0.71, and

A₂B₁ (50 g/tree) had the maximum root to shoot ratio at 0.74. For post-cutting treatment of IBA, 5000-ppm concentration maintained the minimum pooled root to shoot ratio at 0.89, and the control group remained the maximum at 1.03.

The findings demonstrate that zinc supplementation, particularly with basal application at 75 g/tree, significantly improved the root-to-shoot ratio. The increased root growth relative to shoot growth under this treatment highlights zinc's pivotal role in maintaining an optimal balance between root and shoot development. This balance is crucial for the plant's ability to efficiently absorb water and nutrients from the soil. Zinc's influence on root development is supported by its involvement in key physiological processes such as cell division and elongation, which directly impact root growth. Research by Alloway (2008) and Marschner (2012) corroborates these results, indicating that adequate zinc levels enhance root growth and result in a more balanced root-to-shoot ratio. This improvement in the root-to-shoot ratio under basal zinc application suggests a more effective uptake of nutrients and water, ultimately contributing to better overall plant health and growth.

4.1.30 Root index

In 2022, zinc foliar application significantly influenced the Root Index. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) resulted in the highest Root Index with a value of 5.12, whereas A₁B₁ (0.25%) showed the lowest at 3.18, indicating notable differences across zinc foliar treatments (Table 4.30, Figure 4.30). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the highest Root Index at 14.23, while A₂B₁ (50 g/tree) had the lowest at 8.56. For post-cutting treatment, IBA 5000-ppm concentration exhibited the highest Root Index at 43.26, whereas the control group had the lowest at 1.56.

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) maintained the highest Root Index at 5.78, while A₁B₁ (0.25%) had the lowest at 3.52, highlighting clear distinctions among zinc basal applications. A₂B₂ (75 g/tree) performed the best with a Root Index of 15.02, whereas A₂B₁ (50 g/tree) had the lowest at 9.31. For post-cutting treatment, IBA 5000-ppm concentration showed the highest Root Index at 44.37, with the control group having the lowest at 1.88 (Figure 4.30).

Table 4.30 Effect of zinc (Zn) and IBA treatments on root index in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	3.18	3.52	3.35	5.48	5.82	5.65	4.33	4.67	4.5
A ₁ B ₂	3.78	4.35	4.07	6.59	7.21	6.9	5.18	5.78	5.48
A ₁ B ₃	5.12	5.78	5.45	7.88	8.28	8.08	6.5	7.03	6.77
A ₂ B ₁	8.56	9.31	8.94	12.13	12.91	12.52	10.34	11.11	10.73
A ₂ B ₂	14.23	15.82	15.02	19.79	22.8	21.3	17.01	19.31	18.16
A ₂ B ₃	10.16	11.05	10.61	14.63	16.41	15.52	12.39	13.73	13.06
A ₃ B ₁	43.26	44.37	43.81	56.15	57.4	56.78	49.7	50.89	50.3
A ₃ B ₂	38.31	40.22	39.27	50.31	52.4	51.36	44.31	46.31	45.31
A ₃ B ₃	1.56	1.88	1.72	2.67	2.86	2.77	2.12	2.37	2.25
Mean	14.24	15.14		19.51	20.67		16.88	17.91	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.105	0.035	0.199	0.066	0.142	0.048
Factor B	0.105	0.035	0.199	0.066	0.142	0.048
Factor C	0.018	0.006	0.039	0.013	0.019	0.006
Interaction A X B	0.183	0.061	0.345	0.115	0.247	0.082
Interaction A X C	0.032	0.011	0.067	0.023	0.033	0.011
Interaction B X C	0.032	0.011	0.067	0.023	0.033	0.011
Interaction A X B X C	0.055	0.019	0.117	0.039	0.058	0.019

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

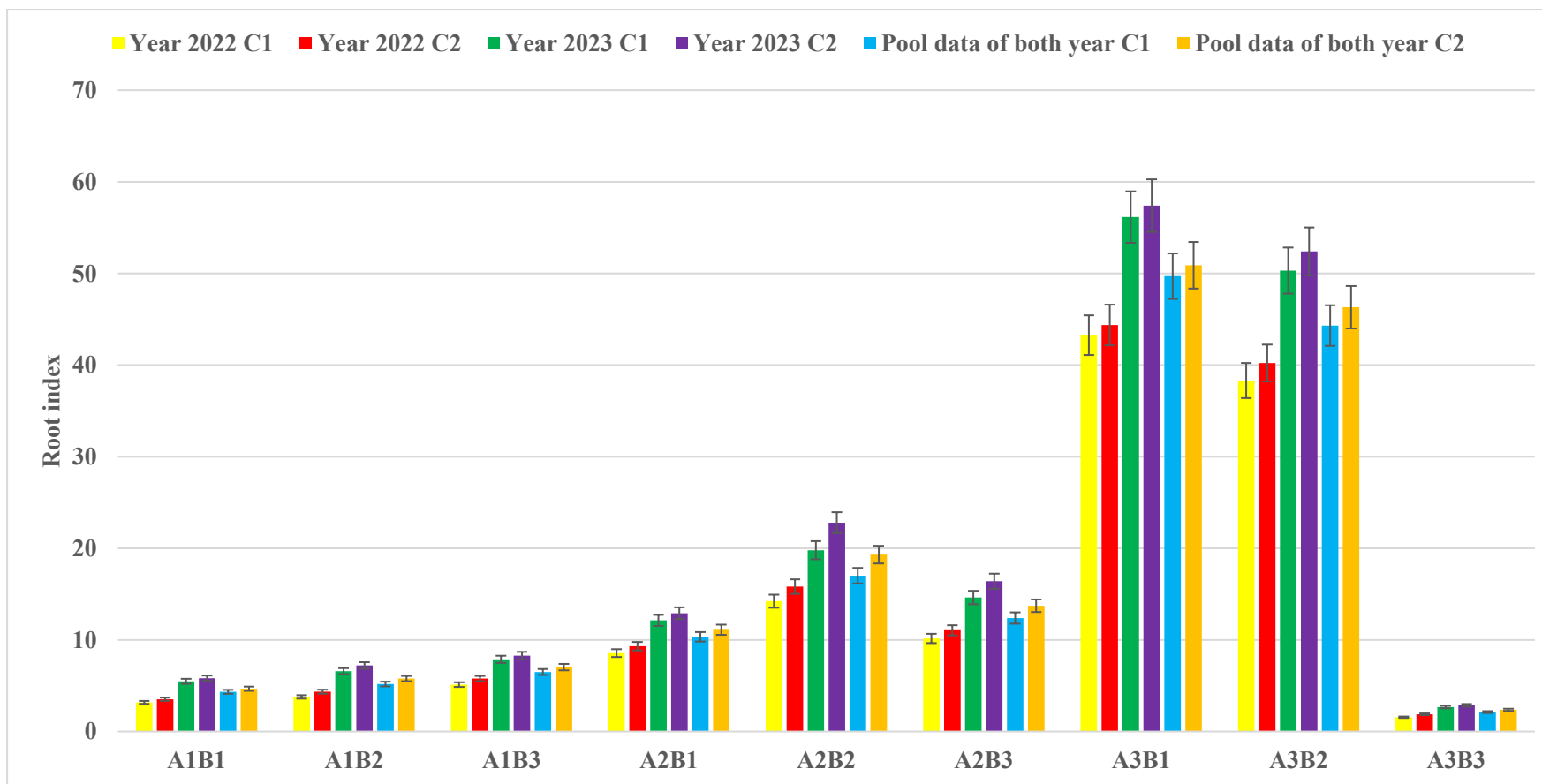


Figure 4.30 Graphical representation of the Effect of Zinc (Zn) and IBA treatments on root index in guava cuttings at different days.

Table 4.31 Effect of zinc (Zn) and IBA treatments on Survival Rate in Guava Cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	21.95	21.44	21.69	23.51	23.9	23.7	22.18	22.67	22.42
A ₁ B ₂	23.23	24.75	23.99	27.91	28.61	28.26	26.02	26.73	26.37
A ₁ B ₃	24.52	25.86	25.19	31.75	32.82	32.28	30.13	30.89	30.51
A ₂ B ₁	26.08	27.61	26.84	35.89	36.19	36.04	34.48	35.95	35.21
A ₂ B ₂	28.68	29.13	28.9	37.84	38.11	37.97	37.36	37.62	37.49
A ₂ B ₃	29.36	29.89	29.62	38.9	39.23	39.06	38.11	38.56	38.33
A ₃ B ₁	54.89	55.05	54.97	56.11	59.89	58	55.05	59.47	57.26
A ₃ B ₂	56.32	57.57	56.94	58.82	60.32	59.57	57.57	58.94	58.25
A ₃ B ₃	7.11	7.31	7.21	9.15	9.28	9.21	8.33	9.19	8.76
Mean	30.24	30.96		35.54	36.48		34.36	35.56	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.010	0.003	0.011	0.004	0.010	0.003
Factor B	0.010	0.003	0.011	0.004	0.010	0.003
Factor C	0.004	0.001	0.006	0.002	0.002	0.001
Interaction A X B	0.017	0.006	0.019	0.006	0.018	0.006
Interaction A X C	0.007	0.002	0.01	0.003	0.003	0.001
Interaction B X C	0.007	0.002	0.01	0.003	0.003	0.001
Interaction A X B X C	0.012	0.004	0.018	0.006	0.006	0.002

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

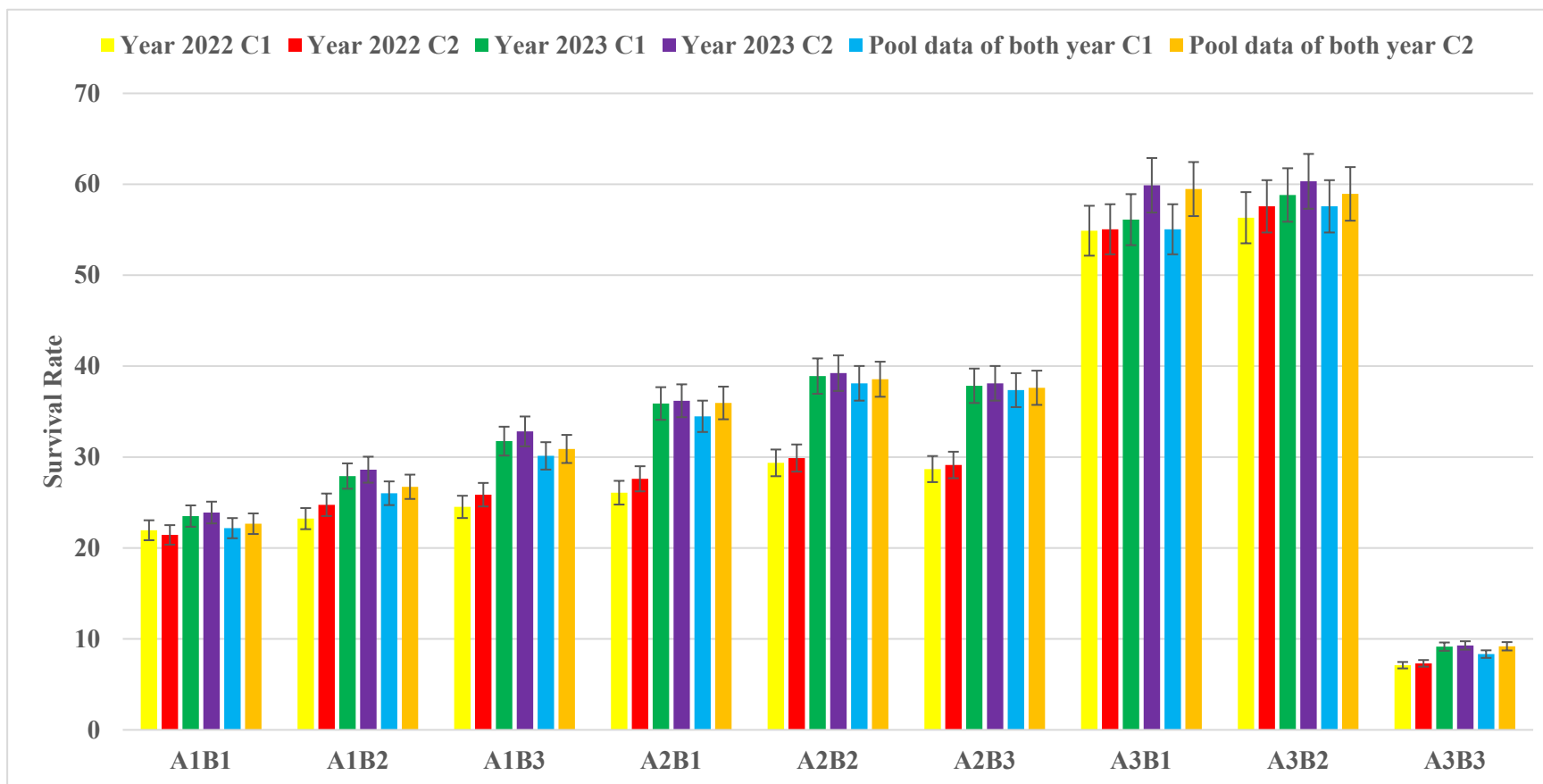


Figure 4.31 Graphical representation of the effect of Zinc (Zn) and IBA treatments on survival rate in guava cuttings at different days.

In 2023, the impact of zinc foliar application on the Root Index remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the highest Root Index at 7.88, while A₁B₁ (0.25%) had the lowest at 5.48. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest Root Index at 19.79, with A₂B₁ (50 g/tree) showing the lowest at 12.13. For post-cutting treatment, IBA 5000-ppm concentration resulted in the highest Root Index at 56.15, while the control group had the lowest at 2.67 (Table 4.30, Figure 4.30).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the highest Root Index at 8.28, and A₁B₁ (0.25%) had the lowest at 5.82. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest Root Index at 22.80, with A₂B₁ (50 g/tree) having the lowest at 12.91. For post-cutting treatment, IBA 5000-ppm concentration demonstrated the highest Root Index at 57.40, while the control group had the lowest at 2.86 (Figure 4.30).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the highest Root Index at 6.50, while A₁B₁ (0.25%) had the lowest at 4.33, indicating consistent results (Table 4.30, Figure 4.30). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest Root Index at 17.01, and A₂B₁ (50 g/tree) had the lowest at 10.34. For post-cutting treatment of IBA 5000-ppm concentration consistently led to the highest Root Index with a mean value of 49.70, while the control group had the lowest at 2.12.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) had the highest Root Index at 7.03, while A₁B₁ (0.25%) had the lowest at 4.67. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest Root Index at 19.31, whereas A₂B₁ (50 g/tree) had the lowest at 11.11. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest Root Index with a pooled mean value of 50.89, while the control group had the lowest at 2.37 (Figure 4.30).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the root index of cuttings. Cuttings collected after 60 days exhibited a higher root index (17.91) compared to those collected after 30 days

(16.88). The method of application and interactions (AxB, BxC, AxC, AxBxC) also had a significant impact. The highest root index (50.31) was recorded in the A₃B₁C₂ treatment, where cuttings were taken after 60 days of the dormant stage and treated with 5000 ppm IBA.

In our study, zinc application led to a notable increase in the root index. Basal application at 75 g/tree resulted in a higher root index compared to other treatments, reflecting improved root development. This enhancement is likely due to zinc's influence on root growth regulators and its impact on cellular processes involved in root formation (Blum, 2011). The present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Alizadeh and Dumanoglu (2022) in olive.

4.1.31 Survival Rate

In 2022, zinc foliar application had a marked effect on the survival rate. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) resulted in the highest survival rate at 24.52%, whereas A₁B₁ (0.25%) had the lowest at 21.95%, reflecting significant differences across zinc foliar treatments (Table 4.31, Figure 4.31). For various levels of zinc as pre-cutting basal treatments, A₂B₃ (100 g/tree) showed the highest survival rate at 29.36%, with A₂B₁ exhibiting the lowest at 26.08%. For post-cutting treatment, IBA 10000-ppm concentration achieved a survival rate of 56.32%, while the control group had the lowest at 7.11%.

At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) again showed the highest survival rate at 25.86%, while A₁B₁ (0.25%) had the lowest at 21.44%, demonstrating clear differences among zinc basal applications. A₂B₃ (100 g/tree) performed the best with a survival rate of 29.89%, whereas A₂B₁ (50 g/tree) had the lowest at 27.61%. For post-cutting treatment, IBA 10000-ppm concentration achieved a survival rate of 57.57%, while the control group had the lowest at 7.31% (Table 4.31, Figure 4.31).

In 2023, the influence of zinc foliar application on survival rate remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest survival rate at 31.75%, while A₁B₁ (0.25%) had the lowest at 23.51%. Among the various levels of

zinc as pre-cutting basal treatments, A₂B₃ (100 g/tree) recorded the highest survival rate at 38.90%, with A₂B₁ (50 g/tree) showing the lowest at 35.89%. Post-cutting treatment of IBA 5000-ppm concentration led to the highest survival rate at 58.82%, while the control group had the lowest at 9.15%. At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the highest survival rate at 32.82%, and A₁B₁ (0.25%) had the lowest at 23.90%. Zinc as pre-cutting basal treatments showed A₂B₃ (100 g/tree) with the highest survival rate at 39.23%, and A₂B₁ (50 g/tree) with the lowest at 36.19%. For post-cutting treatment, IBA 10000-ppm concentration achieved the highest survival rate at 60.32%, with the control group having the lowest at 9.28% (Table 4.31, Figure 4.31).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the highest survival rate at 30.13%, while A₁B₁ (0.25%) had the lowest at 22.18%, indicating consistent results (Table 4.31, Figure 4.31). Zinc s pre-cutting basal treatments showed A₂B₃ (100 g/tree) with the highest survival rate at 38.11%, and A₂B₁ (50 g/tree) with the lowest at 34.48%. For post-cutting treatment, IBA 10000-ppm concentration consistently led to the highest survival rate with a mean value of 57.57%, while the control group had the lowest at 8.33%.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) had the highest survival rate at 30.89%, while A₁B₁ (0.25%) had the lowest at 22.67%. Among various levels of zinc pre-cutting basal treatments showed A₂B₃ (100 g/tree) with the highest survival rate 38.56%, whereas A₂B₁ (50 g/tree) had the lowest 35.95%. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest survival rate with a pooled mean value of 59.47%, while the control group had the lowest at 9.19% (Table 4.31, Figure 4.31).

Survival percentage is an important indicator of plant resilience and adaptability. Adequate zinc levels contribute to improved plant health, which can enhance survival rates. Zinc deficiency often leads to reduced plant Vigor, lower survival rates, and increased susceptibility to stress (Alloway, 2008). Our study found that zinc supplementation, particularly through basal application, significantly increased survival percentage. For example, basal zinc application at 75 g/tree resulted in a higher survival rate compared to the control and other treatments. This improvement

in survival percentage is attributed to zinc's role in strengthening plant tissues and enhancing stress tolerance (Marschner, 2012). The present findings are fully supported by the results of Sourati *et al.* (2022) in mulberry and Somkuwar *et al.* (2013) in dog ridge rootstock.

4.1.32 Mortality rate

In both 2022 and 2023, the zinc foliar application significantly influenced the mortality rate at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the lowest mortality rate, with values of 75.48% in 2022 and 68.25% in 2023, while A₁B₁ (0.25%) had the highest values, 78.05% in 2022 and 76.49% in 2023 (Table 4.32, Figure 4.32). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₃ (100 g/tree) consistently had the lowest mortality rate, with values of 70.64% in 2022 and 61.11% in 2023, while A₂B₁ (50 g/tree) had the highest, 73.92% in 2022 and 64.11% in 2023. For post-cutting treatment of IBA, 10000-ppm concentration yielded the lowest mortality rate of 43.68% in 2022 and 41.18% in 2023, whereas the control group consistently showed the highest mortality rate (92.89% in 2022 and 90.85% in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ continued to have the lowest mortality rate (74.14% in 2022 and 67.18% in 2023), while A₁B₁ had the highest (78.56% in 2022 and 76.10% in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₃ had the lowest mortality rate (70.11% in 2022 and 60.94% in 2023), while A₂B₁ had the highest (72.39% in 2022 and 63.81% in 2023). For post-cutting treatment of IBA, 10000-ppm concentration showed the lowest mortality rate at 42.43% in 2022 and 39.68% in 2023, with the control group remaining the highest (92.69% in 2022 and 90.72% in 2023).

Pooled data from both years reinforced these trends. At 30 days, ZF₃ consistently showed the lowest mortality rate at 69.87%, with ZF₁ the highest at 77.82% (Table 4.32). ZB₃ had the lowest pooled mortality rate at 61.89%, and ZB₁ had the highest at 65.52%. The 10000 ppm IBA treatment consistently had the lowest mortality rate at 42.43%, while the control group had the highest at 91.67%. At 60 days, ZF₃ had the lowest mortality rate at 69.11%, while ZF₁ had the highest at 77.33%. ZB₃ performed the best among zinc basal treatments with a pooled mortality rate of 61.44%, and ZB₁

had the highest at 64.05%. The 10000 ppm IBA treatment maintained the lowest pooled mortality rate at 41.06%, and the control group remained the highest at 90.81%.

The mortality percentage of cuttings was significantly influenced by the timing of pre-cutting treatments and interactions. Cuttings collected after 60 days exhibited a lower mortality rate (64.44%) compared to those collected after 30 days (65.64%). The application method and interactions (AxB, BxC, AxC, AxBxC) further impacted mortality. The lowest mortality percentage (41.75%) was observed in the A₃B₁C₂ treatment, where cuttings were taken after 60 days of the dormant stage and treated with 5000 ppm IBA.

Conversely, the mortality percentage reflects the number of plants that fail to thrive under given conditions. Zinc deficiency is known to increase mortality rates due to impaired growth and reduced resistance to environmental stresses (Blum, 2011). The study observed a significant reduction in mortality percentage with zinc application. Basal zinc at 75 g/tree resulted in a lower mortality rate compared to other treatments. This reduction is linked to zinc's role in improving plant health, enhancing growth, and increasing resilience to stress, thereby reducing the likelihood of plant death (Broadley *et al.*, 2007). The present findings are fully supported by the results of Alizadeh and Dumanoglu (2022) in olive and Yamashita *et al.* (2006) in mango.

4.2 Experiment 2 Studies on the performance of stem cutting under Shed net conditions as affected by Zinc application on Guava Plants.

4.2.1 Callus formation

In 2022, zinc foliar application had a significant impact on callus formation. At 30 days after pre-cutting, treatment A₁B₃ (0.75%) exhibited the highest callus formation score of 7.36mm, while A₁B₁ (0.25%) showed the lowest at 6.66 mm (Table 1). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest callus formation score of 8.57 mm, with A₂B₁ (50 g/tree) achieving the lowest at 8.02 mm. In contrast, post-cutting treatment of IBA 5000-ppm concentration induced the highest callus formation score of 14.27 mm, whereas the control group displayed minimal formation at 5.39.

Table 4.32 Effect of zinc (Zn) and IBA treatments on mortality percentage in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	78.05	78.56	78.31	76.49	76.1	76.3	77.82	77.33	77.58
A₁B₂	76.77	75.25	76.01	72.09	71.39	71.74	73.98	73.27	73.63
A₁B₃	75.48	74.14	74.81	68.25	67.18	67.72	69.87	69.11	69.49
A₂B₁	73.92	72.39	73.16	64.11	63.81	63.96	65.52	64.05	64.79
A₂B₂	71.32	70.87	71.1	62.16	61.89	62.03	62.64	62.38	62.51
A₂B₃	70.64	70.11	70.38	61.1	60.77	60.94	61.89	61.44	61.67
A₃B₁	45.11	44.95	45.03	43.89	40.11	42.07	44.95	40.53	42.74
A₃B₂	43.68	42.43	43.06	41.18	39.68	40.43	42.43	41.06	41.75
A₃B₃	92.89	92.69	92.79	90.85	90.72	90.79	91.67	90.81	91.24
Mean	69.76	69.04		64.46	63.52		65.64	64.44	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.021	0.007	0.023	0.008	0.026	0.009
Factor B	0.021	0.007	0.023	0.008	0.026	0.009
Factor C	0.017	0.006	0.018	0.006	0.016	0.006
Interaction A X B	0.037	0.013	0.039	0.014	0.044	0.015
Interaction A X C	0.031	0.01	0.032	0.011	0.028	0.011
Interaction B X C	0.031	0.01	0.032	0.011	0.028	0.011
Interaction A X B X C	0.052	0.018	0.055	0.019	0.049	0.017

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

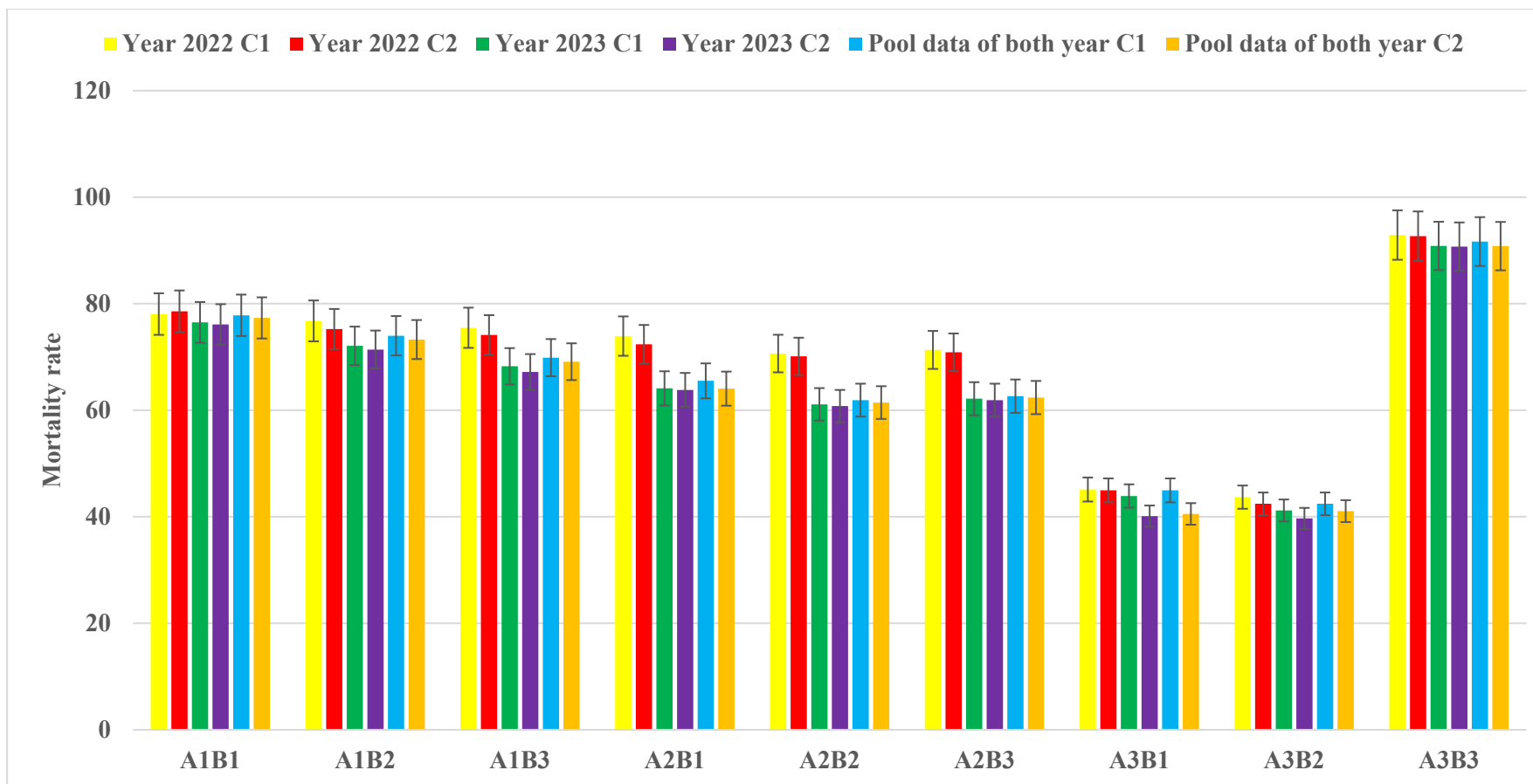


Figure 4.32 Graphical representation of the effect of Zinc (Zn) and IBA treatments on mortality rate in guava cuttings at different days.

Table 4.33 Effect of zinc (Zn) and IBA treatments on callus formation (mm) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	6.66	7.26	6.96	7.28	7.36	7.32	6.97	7.31	7.14
A ₁ B ₂	6.05	6.61	6.33	6.86	7.84	7.35	6.46	7.23	6.84
A ₁ B ₃	7.36	7.78	7.57	8.28	8.75	8.52	7.82	8.27	8.05
A ₂ B ₁	6.57	6.69	6.63	7.69	8.01	7.85	7.13	7.36	7.24
A ₂ B ₂	8.02	8.62	8.32	9.14	9.33	9.24	8.58	8.98	8.78
A ₂ B ₃	7.62	7.84	7.73	8.64	9.27	8.96	8.13	8.56	8.34
A ₃ B ₁	14.27	14.78	14.52	15.29	16.11	15.7	14.78	15.45	15.12
A ₃ B ₂	13.15	13.24	13.2	14.58	14.47	14.53	13.87	13.86	13.87
A ₃ B ₃	5.39	5.51	5.45	6.12	6.73	6.43	5.76	6.12	5.94
Mean	8.34	8.71		9.32	9.76		6.83	9.24	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.016	0.005	0.01	0.003
Factor B	0.007	0.002	0.016	0.005	0.01	0.003
Factor C	0.007	0.002	0.012	0.004	0.007	0.002
Interaction A X B	0.012	0.004	0.027	0.009	0.017	0.006
Interaction A X C	0.012	0.004	0.02	0.007	0.011	0.004
Interaction B X C	0.012	0.004	0.02	0.007	0.011	0.004
Interaction A X B X C	0.021	0.007	0.035	0.012	0.02	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

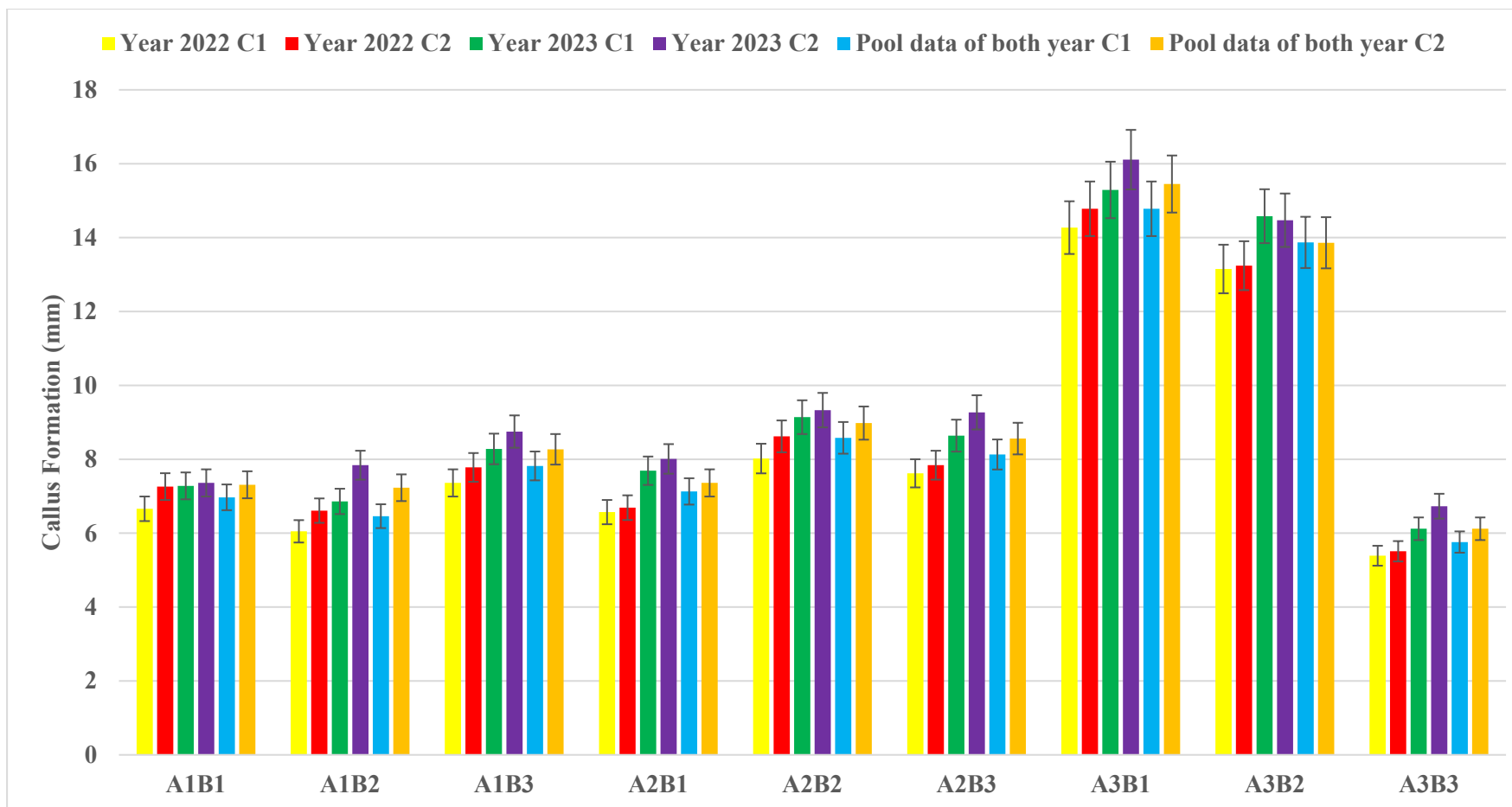


Figure .4.33 Graphical representation of the effect of Zinc (Zn) and IBA treatments on callus formation (mm) in guava cuttings at different days.

By 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) maintained its lead in callus formation with a score of 7.78 mm, while A₁B₁ (0.25%) had the lowest at 7.26 mm (Table 1). Among the various levels of zinc pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest callus formation score of 8.62 mm, whereas A₂B₁ (50 g/tree) exhibited the lowest at 6.69 mm. For post-cutting treatment of IBA 5000-ppm concentration continued to excel with 14.78 mm in callus formation, contrasting sharply with the control group's minimal score of 5.51 mm.

In 2023, zinc foliar application again significantly influenced callus formation. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) led with a callus formation score of 3.95 mm, while A₁B₁ (0.25%) showed the lowest score at 2.71 mm (Table 1). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest score of 4.99 mm, with A₂B₁ (50 g/tree) recording the lowest at 4.35 mm. For post-cutting treatment IBA 5000-ppm concentration resulted in the highest callus formation score of 8.91 mm, while the control group had the lowest at 1.05 mm.

By 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained its lead with a callus formation score of 3.95 mm, while A₁B₁ (0.25%) had the lowest at 2.96 mm (Table 1). Zinc as pre-cutting basal treatments again showed A₂B₂ (75 g/tree) with the highest score at 4.99, whereas A₂B₁ (50 g/tree) had the lowest at 4.85 mm. For post-cutting treatment of IBA 5000-ppm concentration continued to promote high callus formation with 8.91 mm, significantly higher than the control group's score of 1.48 mm.

Pooling data from both years confirmed consistent trends in callus formation. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently exhibited the highest callus formation score with an average of 3.95 mm, while A₁B₁ (0.25%) consistently showed the lowest at 2.71 mm (Table 3). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) averaged the highest callus formation score at 5.31 mm, while A₂B₁ (50 g/tree) averaged the lowest at 4.64 mm. Similarly, for post-cutting treatment of IBA 5000-ppm concentration consistently led with an average score of (mean value), while the control group maintained the lowest at (1.46 mm).

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) maintained its lead with an average callus formation score of 4.46 mm, while A₁B₁ (0.25%) had the lowest at 2.96 mm. Among various levels of zinc pre-pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest average callus formation score of 8.56 mm, while A₂B₁ (50 g/tree) had the lowest 7.36 mm. For post-cutting treatment of IBA 5000-ppm concentration consistently promoted the highest callus formation score with an average of (15.45mm), whereas the control group consistently exhibited the lowest at (6.12 mm).

Callus formation in guava cuttings was significantly affected by the timing of pre-cutting treatments with zinc or during the dormant stage. Cuttings collected 60 days after treatment showed better callus formation (9.24 mm) compared to those collected 30 days after treatment (6.83 mm). The method of application and the interactions (AxB, BxC, AxC, AxBxC) also played a significant role in promoting callus formation. The best callus formation (15.12 mm) was recorded in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA

Zinc is a crucial component of many enzymes and proteins that regulate various cellular processes. It acts as a catalytic or structural cofactor in over 300 enzymes, including those involved in DNA synthesis and repair, protein synthesis, and hormonal regulation (Cakmak, 2000). These functions are particularly relevant during the early stages of callus formation, where rapid cell division and differentiation occur. Zn's role in stabilizing the structures of proteins and membranes is critical in maintaining cellular integrity under stress conditions, thereby enhancing callus formation (Broadley *et al.*, 2007). The present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry, Sourati *et al.* (2022) in mulberry, and Somkuwar *et al.* (2013) in dog ridge rootstock.

4.2.2 Days to Root Initiation

In 2022, the zinc foliar application had a notable impact on Days to Root Initiation. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) showed the shortest root initiation period at 24.86 days, while treatment A₁B₁ (0.25%) required the longest at 25.32 days,

illustrating a significant variation across different zinc foliar treatments (Table 4.34, Figure 4.34). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the shortest period at 22.91 days, whereas A₂B₁ (50 g/tree) had the longest at 24.18 days. Post-cutting treatment of IBA 5000-ppm concentration led to the quickest root initiation at 19.64 days, with the control group taking the longest at 33.41 days. At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) again recorded the shortest period at 24.42 days, while A₁B₁ (0.25%) took 24.91 days. Among various levels of zinc cutting basal treatments showed A₂B₃ (100 g/tree) with the shortest initiation time of 23.31 days, while A₂B₁ (50 g/tree) took 23.55 days. For post-cutting treatment of IBA 10000-ppm concentration significantly reduced the days to root initiation to 19, while the control group remained the highest at 29.69 days.

The trend continued in 2023 when zinc foliar applications significantly affected Days to Root Initiation. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) again led with the shortest period at 23.34 days, while A₁B₁ (0.25% /tree) required the longest at 23.85 days. Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the quickest initiation at 21.89 days, and A₂B₁ (50 g/tree) the longest at 23 days. For post-cutting treatment of IBA, 5000-ppm concentration resulted in the shortest root initiation time of 18.73 days, with the control group showing the longest at 30.06 days. At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75% /tree) continued to perform best at 23.31 days, while A₁B₁ (0.25%/tree) took 23.87 days. Among various levels of zinc cutting basal treatments had A₂B₂ (75 g/tree) with the shortest period at 21.72 days, and A₂B₁ with the longest at 22.84 days. For post-cutting treatment of IBA 10000-ppm concentration consistently showed the quickest root initiation at 18.22 days, with the control group taking 28.86 days.

Combining data from both years, the trends remained consistent. At 30 days post-treatment, ZF₃ (0.75% /tree) averaged the shortest days to root initiation at 24.10, while ZF₁ (0.25% /tree) averaged the longest at 24.59 days (Table 4.34, Figure 4.34). Among zinc basal treatments, ZB₂ (75 g/tree) averaged 22.25 days, the shortest period, while ZB₁ (50 g/tree) averaged the longest at 23.59 days. The 5000-ppm IBA treatment consistently showed the minimum days to root initiation with an average of 19.19 days, and the control group had the longest period at 31.74 days.

Table 4.34 Effect of zinc (Zn) and IBA treatments on days to root initiation in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	25.32	24.91	25.12	23.85	23.87	23.86	24.59	24.39	24.49
A ₁ B ₂	25.03	24.51	24.77	23.59	23.51	23.55	24.31	24.01	24.16
A ₁ B ₃	24.86	24.42	24.64	23.34	23.31	23.33	24.10	24.01	24.05
A ₂ B ₁	24.18	23.55	23.87	23.01	22.84	22.92	23.59	23.21	23.4
A ₂ B ₂	23.45	22.91	23.18	21.72	21.89	21.81	22.25	22.4	22.33
A ₂ B ₃	23.84	23.31	23.58	22.51	22.65	22.58	23.18	22.98	23.08
A ₃ B ₁	19.64	19.55	19.6	18.73	18.71	18.72	19.19	19.13	19.16
A ₃ B ₂	20.21	19.01	19.61	19.02	18.22	18.61	19.61	19.44	19.53
A ₃ B ₃	33.41	29.69	31.55	30.06	28.86	29.46	31.74	29.28	30.51
Mean	24.38	23.61		22.89	22.63		23.64	23.19	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.196	0.65	0.013	0.004	0.004	0.001
Factor B	0.196	0.65	0.013	0.004	0.004	0.001
Factor C	0.16	0.54	0.006	0.002	0.006	0.002
Interaction A X B	0.339	0.113	0.023	0.008	0.007	0.002
Interaction A X C	0.277	0.093	0.011	0.004	0.011	0.003
Interaction B X C	0.277	0.093	0.011	0.004	0.011	0.003
Interaction A X B X C	0.479	0.161	0.019	0.006	0.017	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

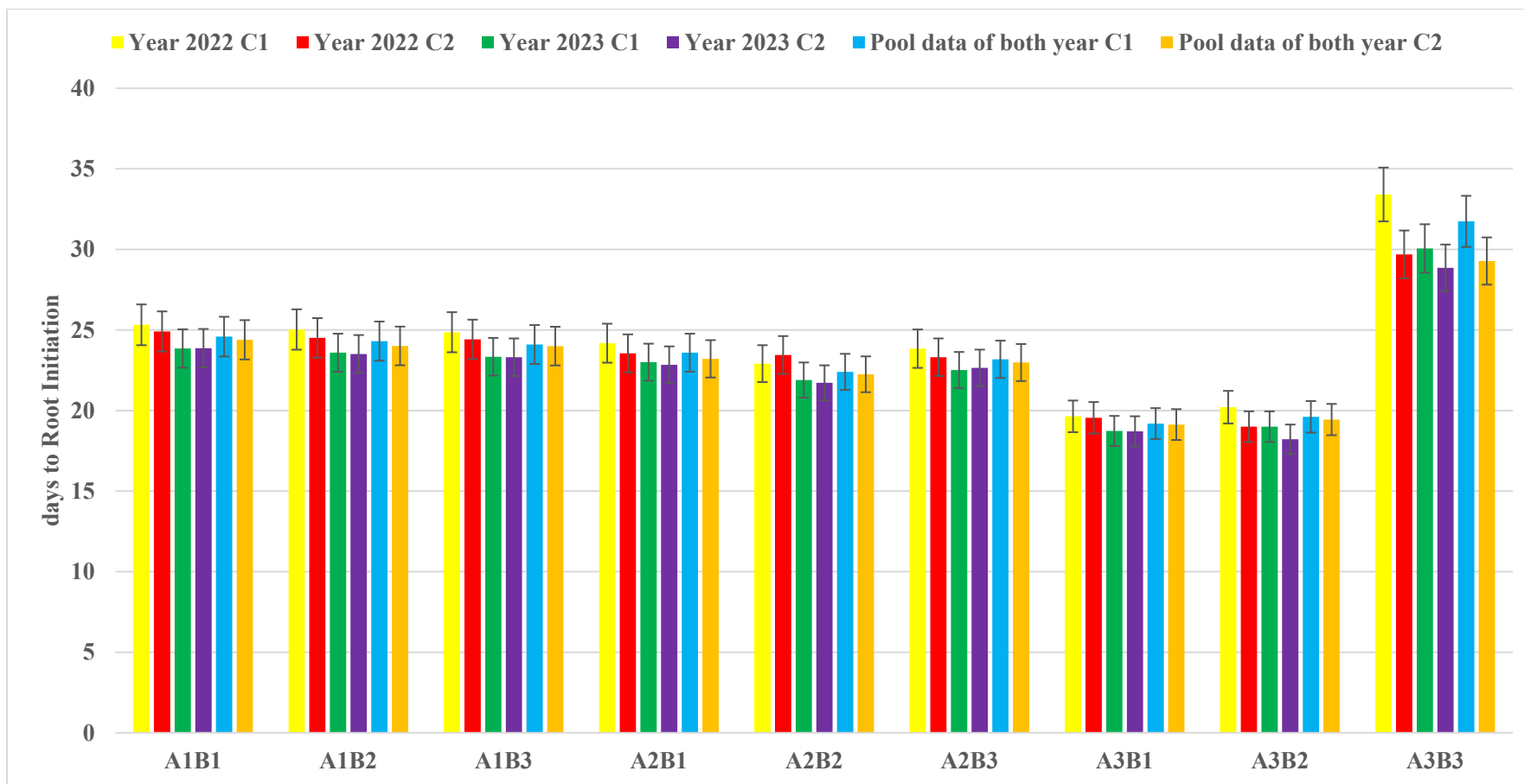


Figure 4.34 Graphical representation of the effect of Zinc (Zn) and IBA treatments on days to root initiation in guava cuttings at different days.

Table 4.35 Effect of zinc (Zn) and IBA treatments on rooting percentage in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	40.69	43.57	42.13	43.11	44.85	43.98	41.90	44.21	43.06
A ₁ B ₂	43.66	46.35	45.01	45.92	47.66	46.79	44.79	47.01	45.90
A ₁ B ₃	44.95	47.40	46.18	47.14	48.67	47.91	46.05	48.04	47.04
A ₂ B ₁	45.02	47.89	46.46	47.24	48.92	48.08	46.13	48.41	47.27
A ₂ B ₂	49.82	51.99	50.91	49.99	52.27	51.13	49.91	52.13	51.02
A ₂ B ₃	48.07	49.92	49.00	49.87	50.35	50.11	48.97	50.14	49.55
A ₃ B ₁	66.59	67.75	67.17	66.98	68.24	67.61	66.79	68.00	67.39
A ₃ B ₂	64.81	66.65	65.73	65.16	66.92	66.04	64.99	66.79	65.89
A ₃ B ₃	28.41	30.45	29.43	29.77	31.76	30.77	29.09	31.11	30.10
Mean	48.00	50.22		49.46	51.07		48.73	50.65	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.007	0.002	0.009	0.003	0.007	0.002
Factor B	0.007	0.002	0.009	0.003	0.007	0.002
Factor C	0.007	0.002	0.009	0.003	0.005	0.002
Interaction A X B	0.012	0.004	0.016	0.005	0.012	0.004
Interaction A X C	0.012	0.004	0.015	0.005	0.009	0.003
Interaction B X C	0.012	0.004	0.015	0.005	0.009	0.003
Interaction A X B X C	0.021	0.007	0.026	0.009	0.016	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

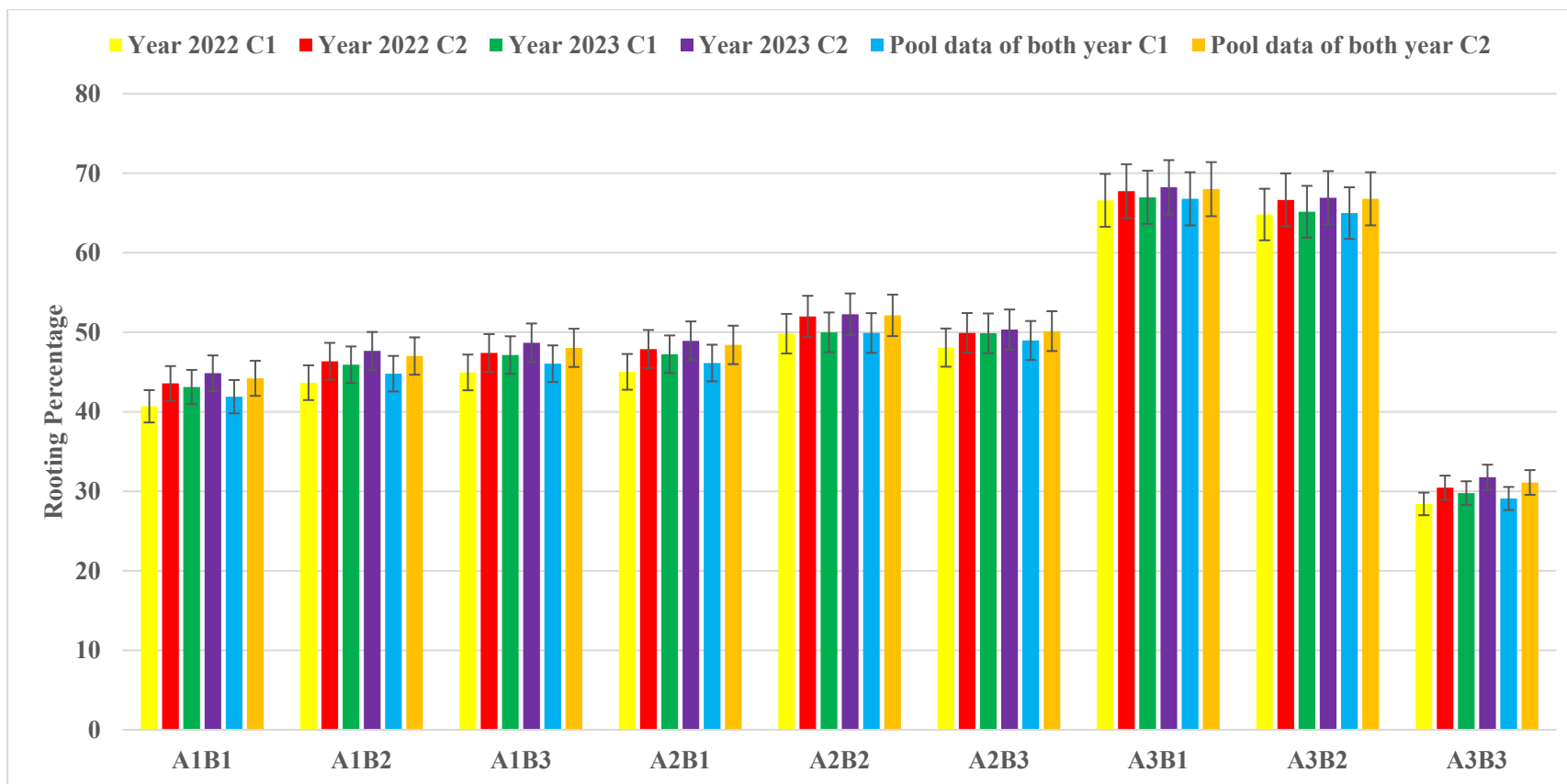


Figure 4.35 Graphical representation of the effect of Zinc (Zn) and IBA treatments on rooting percentage in guava cuttings at different days.

At 60 days, pooled data indicated that ZF₃ (0.75% /tree) consistently resulted in the shortest days to root initiation at 24 days, while ZF₁ (0.25% /tree) took the longest at 24.39 days. For zinc basal treatments, ZB₂ (75 g/tree) was the best performer at 22.40 days, while ZB₁ (50 g/tree) required the longest period at 23.21 days. The 5000-ppm IBA treatment maintained its lead with an average of 19.13 days for root initiation, and the control group required the longest time at 29.28 days.

The number of days after zinc pre-cutting treatment or during the dormant stage significantly impacted root initiation in guava cuttings. Cuttings taken 60 days after treatment-initiated roots earlier (23.19 days) than those taken at 30 days (23.64 days). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The shortest time to root initiation (19.16 days) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA. This indicates that both the timing of the treatment and the application method play crucial roles in enhancing root initiation in guava cuttings.

4.2.3 Rooting (%)

The influence of zinc foliar application on rooting percentage was notable in both 2022 and 2023. In 2022, 30 days after pre-cutting treatment, the highest rooting percentage (44.95%) was achieved with the A₁B₃ treatment (0.75%), whereas the lowest (40.69%) was observed in the A₁B₁ treatment (0.25%), demonstrating a significant variation between different zinc foliar application levels (Table 4.35, Figure 4.35). Zinc as pre-cutting basal treatments showed the highest rooting percentage (49.82%) in A₂B₁ (75 g/tree), while A₂B₁ (50 g/tree) recorded the lowest (45.02%). For post-cutting treatment of IBA, 5000-ppm concentration yielded the highest rooting percentage (66.59%), contrasting sharply with the control group's minimal rooting percentage (28.41%).

At 60 days after pre-cutting treatment, the pattern remained consistent with A₁B₃ (0.75%) leading in rooting percentage (47.40%) and A₁B₁ (0.25%) trailing (43.57%). Among the various levels zinc as pre-cutting basal treatments again saw A₂B₂ (75 g/tree) achieving the highest rooting percentage (51.99%) and A₂B₁ (50 g/tree) the lowest (47.89%). For post-cutting treatment, IBA 5000-ppm concentration continued

to show superior results with a rooting percentage of 67.75%, while the control group remained the lowest at 30.45%.

The trend persisted in 2023, where at 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the highest rooting percentage (47.14%), and A₁B₁ (0.25%) the lowest (43.11%) among zinc foliar applications (Table 4.35, Figure 4.35). Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) at the forefront with a rooting percentage of 49.99%, while A₂B₁ (50 g/tree) had the lowest (47.24%). For post-cutting treatment of IBA 5000-ppm concentration again led with the highest rooting percentage (66.98%), in stark contrast to the control group (29.77%).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) had the highest rooting percentage (48.67%), and A₁B₁ (0.25%) was the lowest (44.85%). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest rooting percentage (52.27%), whereas A₂B₁ (50 g/tree) recorded the lowest (48.92%). For post-cutting treatment of IBA 5000-ppm concentration sustained its performance with a maximum rooting percentage (68.24%), and the control group remained the lowest at 31.76%.

When pooling data from both years, the results consistently showed that at 30 days, after pre-cutting A₁B₃ (0.75%) had the highest average rooting percentage (46.05%), while A₁B₁ (0.25%) had the lowest (41.90%) (Table 4.35, figure 4.35). Among the various levels of zinc as pre-cutting basal treatments reflected similar trends, with A₂B₂ (75 g/tree) having the highest average rooting percentage (49.91%) and A₂B₁ (50 g/tree) the lowest (46.13%). For post-cutting treatment, IBA 5000-ppm concentration consistently exhibited the highest average rooting percentage (66.79%), while the control group remained the lowest at 29.09%.

At 60 days after pre-cutting treatment, the pooled data indicated that A₁B₃ (0.75%) had the highest average rooting percentage (48.04%), with A₁B₁ (0.25%) having the lowest (44.21%). Among the various levels of zinc as pre-cutting basal treatments continued to show A₂B₂ (75 g/tree) with the highest average rooting percentage (52.13%) and A₂B₁ (50 g/tree) with the lowest (48.41%). For post-cutting treatment of

IBA, 5000-ppm concentration maintained the highest average rooting percentage (68%), and the control group had the lowest at 31.11%.

The timing of pre-cutting treatments with zinc or during the dormant stage had a significant effect on the root percentage of guava cuttings. Cuttings collected 60 days after treatment showed a higher root percentage (34.53 days) compared to those collected 30 days after treatment (35.23 days). The method of application and the interactions (AxB, BxC, AxC, AxBxC) also significantly influenced the root percentage. The highest root percentage (26.18 days) was observed in the A3B1C2 treatment, where cuttings were collected after 60 days of dormancy and treated with 5000 ppm IBA.

The findings demonstrate that zinc is a key cofactor for enzymes involved in DNA synthesis and auxin metabolism, both critical for root initiation. Auxins, plant hormones that promote root initiation and elongation, are significantly influenced by zinc's role in auxin metabolism. Adequate zinc levels enhance auxin production and activity, thereby stimulating root initiation. This study found that basal zinc application at 75 g/tree (A₂B₂) resulted in the highest rooting percentage, showing a significant improvement compared to foliar applications and the control group. These results are consistent with previous research indicating that zinc deficiency can lead to poor root initiation and reduced rooting percentages (Broadley *et al.*, 2007). Present findings are fully supported by the results of Yamashita *et al.* (2006) in mango and Sourati *et al.* (2022) in mulberry.

4.2.4 Primary number of roots

The primary number of roots was significantly influenced by zinc foliar application in both 2022 and 2023. At 30 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) exhibited the highest primary number of roots (7.23), whereas A₁B₁ (0.25%) had the lowest (6.02), indicating significant differences among zinc foliar application levels (Table 4.36, Figure 4.36). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the highest primary number of roots (11.24), while A₂B₁ (50 g/tree) had the lowest (9.54). For post-cutting treatment, IBA 5000-

ppm concentration resulted in the highest primary number of roots (16.39), with the control group showing the lowest (3.75).

Similarly, at 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) recorded the highest primary number of roots (7.29), and A₁B₁ (0.25%) the lowest (6.14), demonstrating significant differences among zinc basal application levels. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest primary number of roots (11.32), and A₂B₁ (50g/tree) had the lowest (9.82). For post-cutting treatment, IBA 5000-ppm concentration showed the highest primary number of roots (16.55), with the control group at its lowest (4.03).

Moving to 2023, zinc foliar application again significantly influenced the primary number of roots. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest primary number of roots (8.07), while A₁B₁ (0.25%) had the lowest (6.68). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the highest primary number of roots (12.35), and A₂B₁ (50g/tree) the lowest (10.51). For post-cutting treatment of IBA, 5000-ppm concentration resulted in the highest primary number of roots (17.05), with the control group at its lowest (3.92).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the highest primary number of roots (8.56), and A₁B₁ (0.25%) the lowest (6.81), indicating significant differences among zinc basal application levels. A₂B₂ (75 g/tree) showed the highest primary number of roots (14.21), and A₂B₁ (50 g/tree) was the lowest (10.68). For post-cutting treatment, IBA 5000-ppm concentration maintained its lead with the highest primary number of roots (17.68), while the control group had the lowest (4.54).

Pooling data from both years showed consistent trends. Treatment A₁B₃ (0.75%) had the highest primary number of roots 30 days after application (7.65), with A₁B₁ (0.25%) at the lowest (6.35). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently performed best (11.79), while A₂B₁ (50 g/tree) had the minimum (10.03). For post-cutting treatment of IBA 5000-ppm concentration consistently promoted the highest primary number of roots, averaging (16.72), whereas the control group had the lowest (3.84).

Table 4.36 Effect of zinc (Zn) and IBA treatments on the primary number of roots in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	6.02	6.14	6.08	6.68	6.81	6.75	6.35	6.48	6.42
A₁B₂	6.55	6.66	6.61	7.31	7.46	7.39	6.93	7.06	7
A₁B₃	7.23	7.29	7.26	8.07	8.56	8.32	7.65	7.93	7.79
A₂B₁	9.54	9.82	9.68	10.51	10.68	10.6	10.03	10.25	10.14
A₂B₂	11.24	11.32	11.28	12.35	14.21	13.28	11.79	12.77	12.28
A₂B₃	10.48	10.74	10.61	11.66	13.56	12.61	11.07	12.15	11.61
A₃B₁	16.39	16.55	16.47	17.05	17.68	17.37	16.72	17.12	16.92
A₃B₂	15.87	16.01	15.94	16.57	17.15	16.86	16.22	16.58	16.4
A₃B₃	3.75	4.03	3.89	3.92	4.54	4.23	3.84	4.29	4.06
Mean	9.67	9.84		10.46	11.18		10.07	10.51	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.014	0.005	0.011	0.003	0.011	0.004
Factor B	0.014	0.005	0.011	0.003	0.011	0.004
Factor C	0.017	0.006	0.011	0.004	0.008	0.003
Interaction A X B	0.024	0.008	0.017	0.006	0.02	0.007
Interaction A X C	0.029	0.01	0.02	0.007	0.013	0.004
Interaction B X C	0.029	0.01	0.02	0.007	0.013	0.004
Interaction A X B X C	0.051	0.017	0.034	0.011	0.023	0.008

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

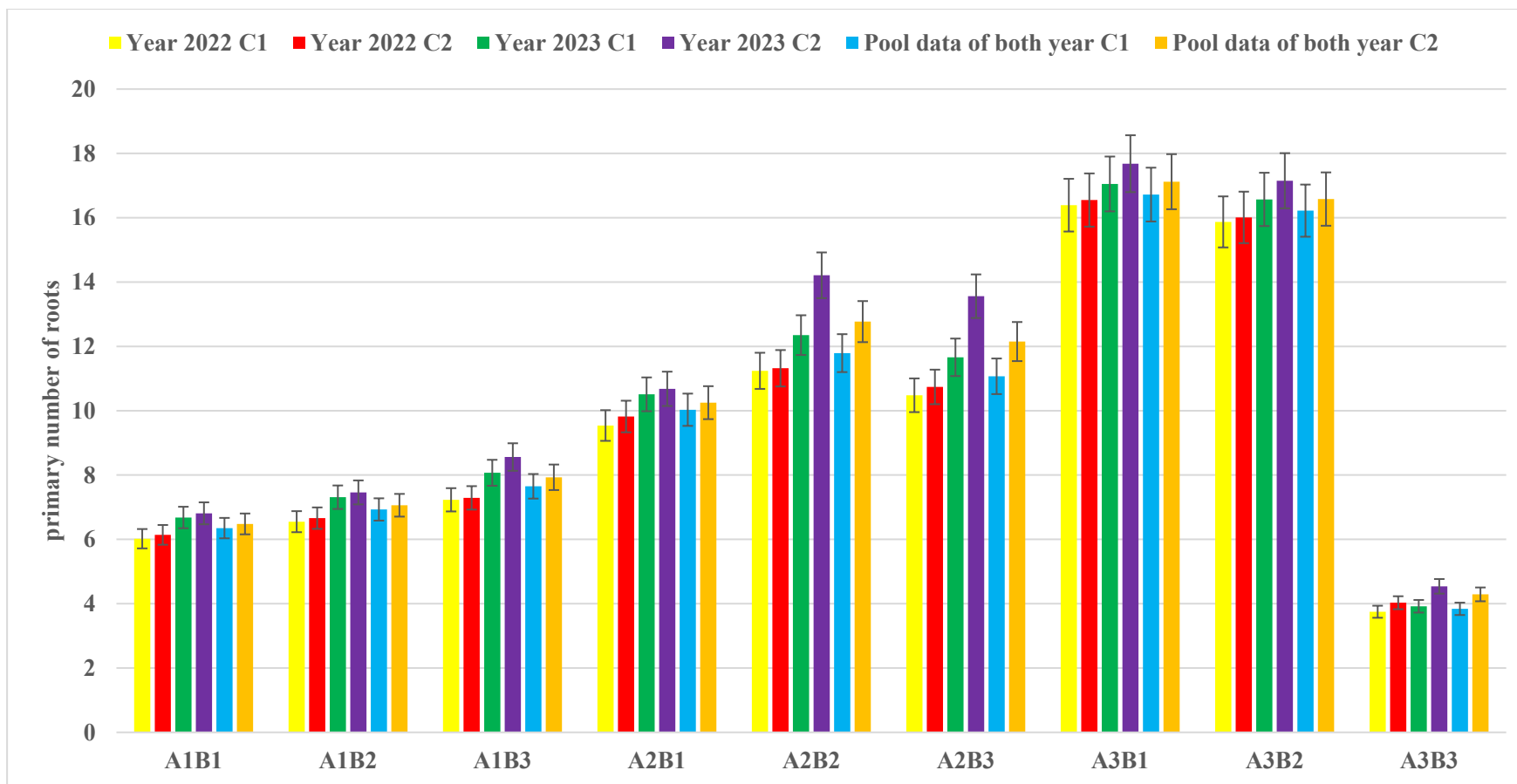


Figure 4.36 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the primary root number in guava cuttings at different days.

Table 4.37 Effect of zinc (Zn) and IBA treatments on the secondary number of roots in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	18.89	19.42	19.16	21.74	21.98	21.86	20.32	20.7	20.51
A₁B₂	19.74	20.21	19.98	22.36	22.45	22.41	21.05	21.33	21.19
A₁B₃	20.47	20.92	20.7	22.72	22.94	22.83	21.6	21.93	21.76
A₂B₁	22.84	23.36	23.1	23.11	23.23	23.17	22.98	23.3	23.14
A₂B₂	24.25	24.74	24.5	24.76	24.97	24.87	24.51	24.86	24.69
A₂B₃	23.15	23.61	23.38	23.95	24.05	24	23.55	23.83	23.69
A₃B₁	29.54	29.78	29.66	30.11	30.52	30.32	29.83	30.15	29.99
A₃B₂	28.48	28.96	28.72	29.76	29.91	29.84	29.12	29.44	29.28
A₃B₃	9.86	10.28	10.07	11.83	12.02	11.93	10.85	11.15	11
Mean	21.91	22.37		23.37	23.56		22.65	22.97	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.015	0.005	0.024	0.008	0.01	0.003
Factor B	0.015	0.005	0.024	0.008	0.01	0.003
Factor C	0.01	0.003	0.004	0.001	0.008	0.003
Interaction A X B	0.026	0.009	0.042	0.014	0.017	0.006
Interaction A X C	0.017	0.006	0.007	0.003	0.014	0.005
Interaction B X C	0.017	0.006	0.007	0.003	0.014	0.005
Interaction A X B X C	0.029	0.011	0.013	0.004	0.024	0.008

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

At 60 days after pre-cutting treatment, A₁B₃ (0.75%) remained the top performer (7.93), with A₁B₁ (0.25%) as the least effective (6.48). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) continued to excel (12.77), while A₂B₁ (50 g/tree) had the lowest prime number of roots (10.25). For post-cutting treatment of IBA 5000-ppm concentration maintained its lead with a pooled mean of (17.12), and the control group had the lowest (4.29).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of secondary roots in guava cuttings. Cuttings collected after 60 days had a higher number of secondary roots (10.51) compared to those collected after 30 days (10.07). Additionally, the method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The highest number of primary roots (16.92) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and treated with 5000 ppm IBA.

4.2.5 Secondary number of roots

Zinc foliar application significantly influenced the secondary number of roots in both 2022 and 2023. At 30 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) had the highest secondary root count (20.47), while A₁B₁ (0.25%) had the lowest (18.89) (Table 36, Figure 4.36). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest secondary root count (24.25), and A₂B₁ (50 g/tree) was the lowest (22.84). For post-cutting treatment of IBA, 5000-ppm concentration resulted in the highest secondary root count (29.54), with the control group showing the lowest (9.86).

At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) again showed the highest secondary root count (20.92), and A₁B₁ (0.25%) the lowest (19.42). Significant differences were observed among zinc basal application levels, with A₂B₂ (75 g/tree) leading in secondary root count (24.74) and A₂B₁ (50g/tree) lagging (23.36). For post-cutting treatment, IBA 5000-ppm concentration showed the highest secondary root count (29.78), while the control group had the lowest (10.28).

In 2023, zinc foliar application continued to significantly impact the secondary number of roots. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the

highest secondary root count (22.72), and A₁B₁ (0.25%) was the lowest (21.74). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) displayed the highest secondary root count (24.76), while A₂B₁ (50g/tree) had the lowest (23.11). For post-cutting treatment of IBA, 5000-ppm concentration resulted in the highest secondary root count (30.11), whereas the control group had the lowest (11.83).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained its lead with the highest secondary root count (22.94), and A₁B₁ (0.25%) had the lowest (21.98). Significant variations among zinc basal application levels were observed, with A₂B₂ (75 g/tree) recording the highest secondary root count (24.97) and A₂B₁ (50 g/tree) the lowest (23.23). For post-cutting treatment, IBA 5000-ppm concentration showed the highest secondary root count (30.52), while the control group had the lowest (12.02).

Pooling data from both years revealed consistent trends. Treatment A₁B₃ (0.75%) consistently had the highest secondary root count at 30 days (21.60), with A₁B₁ (0.25%) consistently showing the lowest (20.32). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently performed best (24.51), while A₂B₁ (50 g/tree) consistently showed the minimum (22.98). For post-cutting treatment of IBA 5000-ppm concentration consistently promoted the highest secondary root count, averaging (a mean of 29.83), whereas the control group consistently showed the lowest (mean of 10.85). At 60 days after pre-cutting treatment, A₁B₃ (0.75%) remained the top performer (21.93), with A₁B₁ (0.25%) demonstrating the least effectiveness (20.70). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) continued to excel (24.86), while A₂B₁ (50 g/tree) exhibited the lowest secondary root count (23.30). For post-cutting treatment of IBA 5000-ppm concentration maintained its lead with a pooled mean of (30.15), whereas the control group recorded the lowest (11.15).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of secondary roots in guava cuttings. Cuttings collected after 60 days had a higher number of secondary roots (22.97) compared to those collected after 30 days (22.65). Additionally, the method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The highest

number of secondary roots (29.99) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and treated with 5000 ppm IBA.

The findings demonstrate that the development of primary and secondary roots is critical for the overall root architecture and health of the plant. Zinc application significantly influenced both primary and secondary root development. The basal application of zinc at 75 g/tree (A₂B₂) led to a substantial increase in the number of primary and secondary roots. Additionally, the primary root length and diameter were notably enhanced, providing a strong foundation for further root growth. Similarly, the secondary roots exhibited increased length and diameter, contributing to a more extensive and robust root system. These improvements in primary and secondary root development underscore the importance of zinc in maintaining optimal root architecture (Alloway, 2008). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Somkuwar *et al.* (2013) in dog ridge rootstock

4.2.6 Length of primary roots (cm)

The length of primary roots was significantly affected by zinc foliar application in 2022. At 30 days after pre-cutting treatment, the highest root length was observed in A₁B₃ (0.75%) at 7.27 cm, whereas A₁B₁ (0.25%) had the shortest (6.65 cm), indicating significant differences among the treatments (Table 4.38, Figure 4.38). Among the various levels of zinc as pre-cutting basal applications, A₂B₂ (75 g/tree) had the longest roots (8.27 cm), while A₁B₁ (50 g/tree) had the shortest (7.44 cm). For post-cutting treatment of IBA 5000-ppm concentration produced the longest roots (9.96 cm), with the control group having the shortest (5.87 cm).

In 2023, zinc foliar application continued to show significant effects on root length. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the longest roots (7.35 cm), while A₁B₁ (0.25%) had the shortest (6.78 cm). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the longest roots (8.48 cm), and A₂B₁ (50 g/tree) the shortest (7.64 cm). For post cutting treatment of IBA 5000-ppm concentration recorded the longest roots (10.21 cm), while the control group had the shortest (6.12 cm).

Table 4.38 Effect of zinc (Zn) and IBA treatments on length of primary roots (cm) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	6.65	6.72	6.69	6.78	6.81	6.8	6.71	6.77	6.74
A ₁ B ₂	6.81	6.86	6.84	6.92	6.96	6.94	6.78	6.85	6.82
A ₁ B ₃	7.27	7.29	7.28	7.35	7.43	7.9	7.31	7.36	7.34
A ₂ B ₁	7.44	7.47	7.46	7.64	7.84	7.74	7.54	7.66	7.6
A ₂ B ₂	8.27	8.51	8.39	8.48	8.79	8.64	8.38	8.65	8.52
A ₂ B ₃	7.83	7.85	7.84	8.02	8.17	8.1	7.93	8.01	7.97
A ₃ B ₁	9.96	9.98	9.97	10.21	10.46	10.34	10.09	10.22	10.16
A ₃ B ₂	9.47	9.63	9.55	9.69	9.91	9.8	9.58	9.77	9.68
A ₃ B ₃	5.87	5.92	5.9	6.12	6.12	6.12	5.92	6	5.96
Mean	7.73	7.81		7.91	8.06		7.81	7.92	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.012	0.004	0.009	0.003
Factor B	0.008	0.003	0.012	0.004	0.009	0.003
Factor C	0.007	0.002	0.006	0.002	0.007	0.002
Interaction A X B	0.014	0.005	0.02	0.007	0.015	0.005
Interaction A X C	0.011	0.004	0.01	0.003	0.012	0.004
Interaction B X C	0.011	0.004	0.01	0.003	0.012	0.004
Interaction A X B X C	0.021	0.007	0.018	0.006	0.021	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

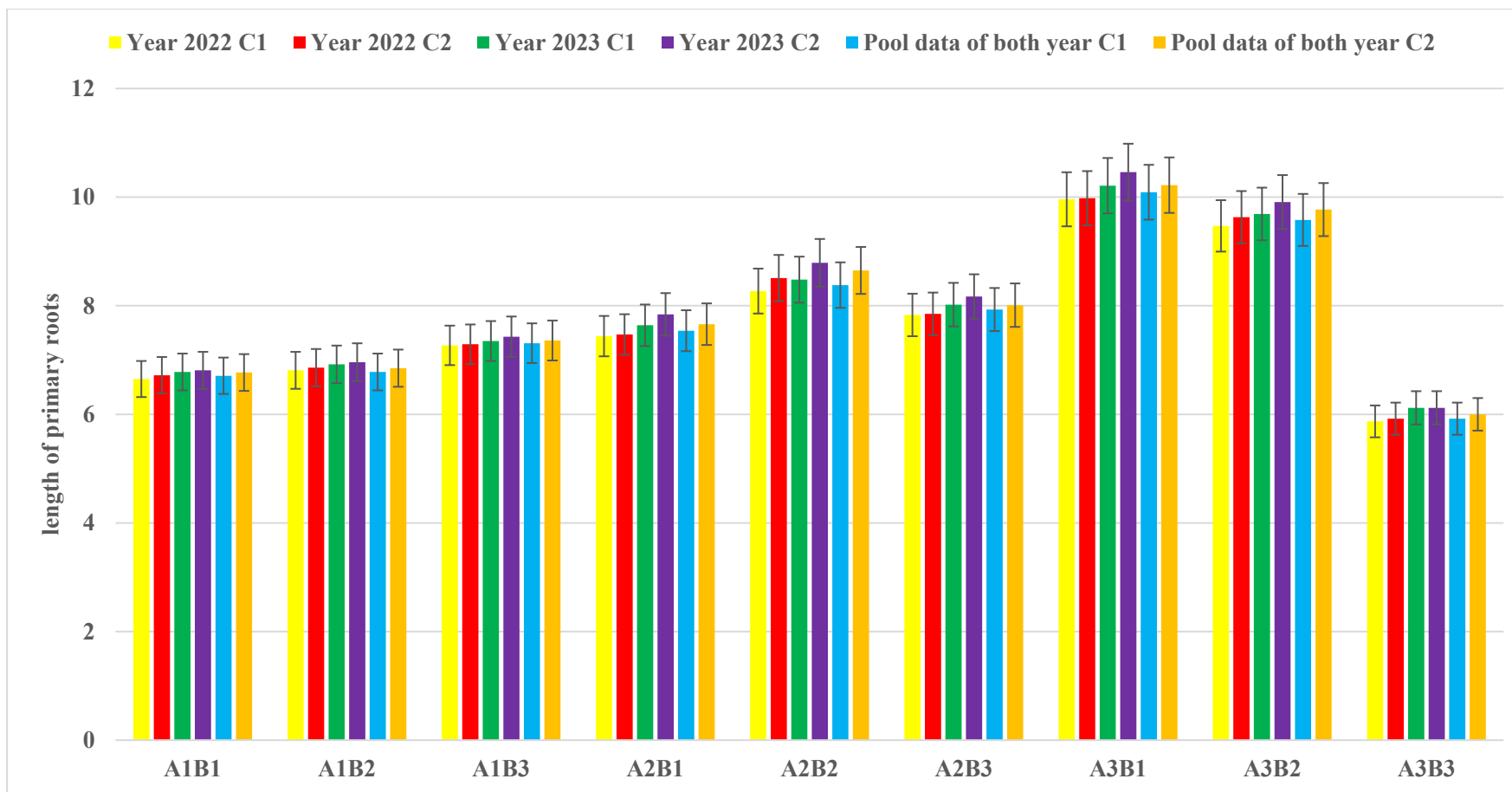


Figure 4.38 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the length of primary roots (cm) in guava cuttings at different days.

Table 4.39 Effect of zinc (Zn) and IBA treatments on the length of secondary roots (cm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	2.61	2.61	2.61	2.75	2.79	2.77	2.68	2.70	2.69
A ₁ B ₂	2.64	2.64	2.64	2.78	2.84	2.81	2.71	2.74	2.73
A ₁ B ₃	2.82	2.86	2.84	3.01	3.01	3.01	2.92	2.94	2.93
A ₂ B ₁	2.9	2.95	2.92	3.11	3.17	3.14	3.01	3.06	3.03
A ₂ B ₂	3.18	3.18	3.18	3.32	3.32	3.32	3.25	3.25	3.25
A ₂ B ₃	3.11	3.29	3.2	3.22	3.43	3.33	3.17	3.36	3.26
A ₃ B ₁	4.02	4.11	4.07	4.23	4.32	4.28	4.13	4.22	4.17
A ₃ B ₂	3.81	3.87	3.84	4.05	4.17	4.11	3.93	4.02	3.98
A ₃ B ₃	2.06	2.09	2.08	2.25	2.32	2.28	2.16	2.21	2.18
Mean	3.02	3.07		3.19	3.26		3.11	3.17	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.004	0.01	0.003	0.008	0.003
Factor B	0.011	0.004	0.01	0.003	0.008	0.003
Factor C	0.003	0.001	0.004	0.001	0.006	0.002
Interaction A X B	0.02	0.007	0.018	0.006	0.014	0.005
Interaction A X C	0.006	0.002	0.007	0.002	0.011	0.004
Interaction B X C	0.006	0.002	0.007	0.002	0.011	0.004
Interaction A X B X C	0.01	0.003	0.012	0.004	0.019	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

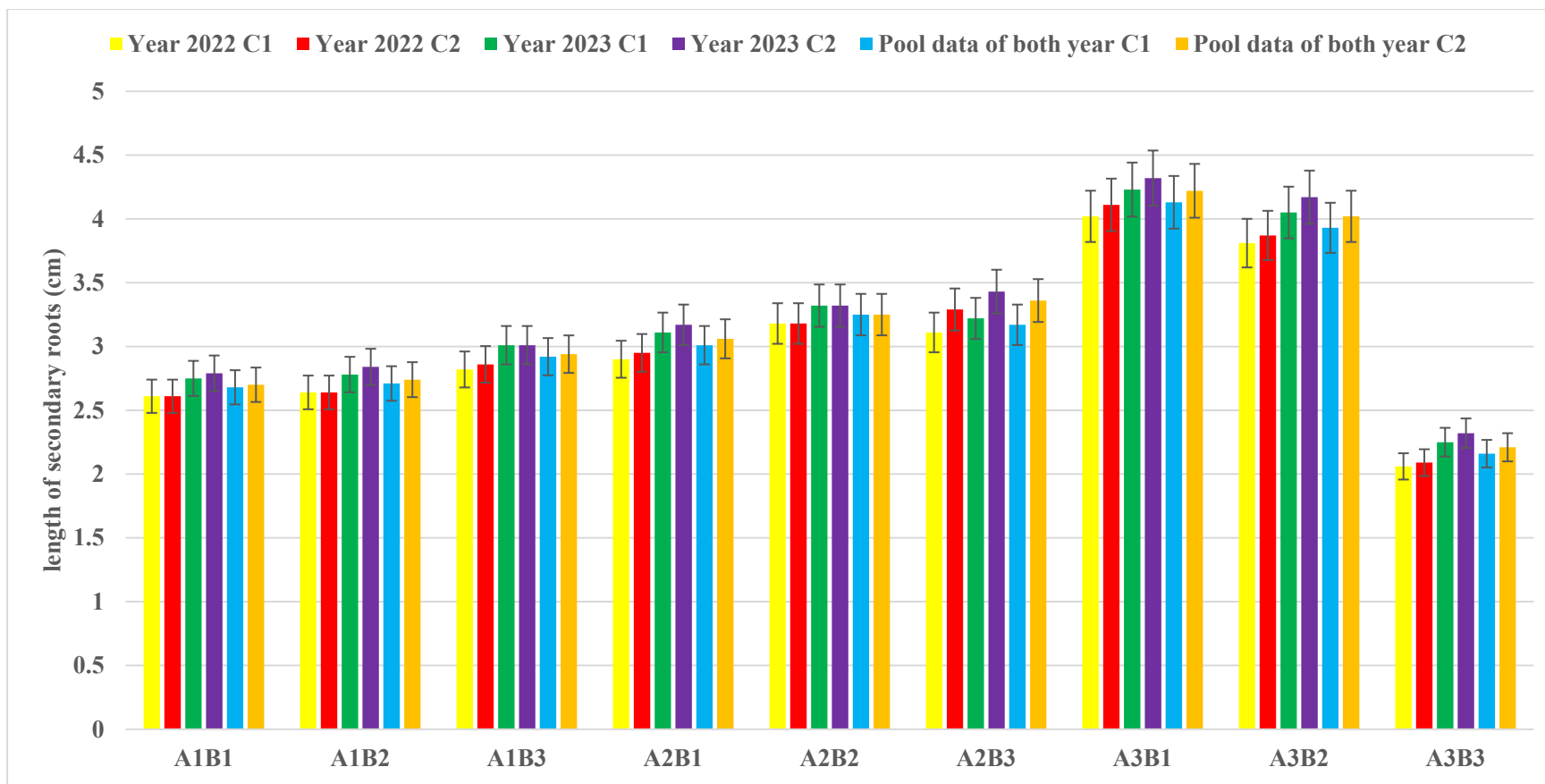


Figure 4.39 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the length of secondary roots (cm) in guava Cuttings at different days.

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) showed the longest roots (7.43 cm), while A₁B₁ (0.25%) had the shortest (6.81 cm). Significant differences were observed among zinc basal treatments, with A₂B₂ (75 g/tree) showing the longest roots (8.79 cm), and A₂B₁ (50 g/tree) the shortest (7.84 cm). For post-cutting treatment of IBA 5000-ppm concentration had the longest roots (10.46 cm), while the control group had the shortest (6.12 cm).

Pooling data from 2022 and 2023, A₁B₃ (0.75%) consistently showed the longest root length at 30 days (7.31 cm), while A₁B₁ (0.25%) had the shortest (6.71 cm). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the longest roots (8.38 cm), with A₂B₁ (50 g/tree) having the shortest (7.54 cm). For post-cutting treatment of IBA 5000-ppm concentration consistently produced the longest roots (10.09 cm), while the control group had the shortest (5.92 cm).

At 60 days after pre-cutting treatment, pooled data showed that A₁B₃ (0.75%) consistently had the longest roots (7.36 cm), while A₁B₁ (0.25%) had the shortest (6.77 cm). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently had the longest roots (8.65 cm), with A₂B₁ (50 g/tree) having the shortest (7.66 cm). For post-cutting treatment of IBA, 5000-ppm concentration maintained the longest root length (10.22 cm), while the control group had the shortest (6 cm).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the length of secondary roots in guava cuttings. Cuttings collected after 60 days exhibited longer secondary roots (34.53 cm) compared to those collected after 30 days (35.23 cm). Furthermore, the application method and interactions (AxB, BxC, AxC, AxBxC) had a significant impact on the length of secondary roots. The longest secondary root length (26.18 cm) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA.

4.2.7 Length of secondary roots (cm)

In 2022, zinc foliar application had a marked effect on the length of secondary roots. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) resulted in the longest

secondary roots at 2.82 cm, whereas A₁B₁ (0.25%) had the shortest at 2.61 cm, reflecting significant differences across zinc foliar treatments (Table 4.39, Figure 4.39). For zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the longest secondary roots at 3.18 cm, with A₂B₁ (50 g/tree) showing the shortest at 2.90 cm. For post-cutting treatment of IBA 5000-ppm concentration produced the longest secondary roots at 4.02 cm, while the control group had the shortest at 2.06 cm.

At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) again had the longest secondary roots at 2.86 cm, while A₁B₁ (0.25%) had the shortest at 2.61 cm, demonstrating clear differences among zinc basal applications. A₂B₂ (75 g/tree) was the top performer with secondary roots at 3.18 cm, whereas A₂B₁ (50 g/tree) was the shortest at 2.95 cm. IBA treatments with 5000 ppm showed the longest secondary roots at 4.11 cm, and the control group the shortest at 2.09 cm (Figure 4.39).

In 2023, the influence of zinc foliar application on the length of secondary roots remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the longest secondary roots at 3.01 cm, while A₁B₁ (0.25%) had the shortest at 2.75 cm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the longest secondary roots at 3.32 cm, with A₂B₁ (50 g/tree) showing the shortest at 3.11 cm. For post cutting treatment of IBA 5000-ppm concentration led to the longest secondary roots at 4.23 cm, while the control group had the shortest at 2.25 cm (Table 4.39, Figure 4.39).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the longest secondary roots at 3.01 cm, and A₁B₁ (0.25%) was the shortest at 2.79 cm. Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) had the longest secondary roots at 3.32 cm, and A₂B₁ (50 g/tree) had the shortest at 3.17 cm. For post-cutting treatment of IBA 5000-ppm concentration had the longest secondary roots at 4.32 cm, with the control group having the shortest at 2.32 cm (Figure 4.39).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently had the longest secondary roots at 2.92 cm, while A₁B₁ (0.25%) had the shortest at 2.68 cm, indicating consistent results. Among the various levels of zinc pre-cutting basal treatments showed that A₂B₂ had the longest secondary roots at 3.25

cm, and A₂B₁ had the shortest at 3.01 cm. For post-cutting treatment of IBA 5000-ppm concentration consistently led to the longest secondary roots with a mean value of 4.13 cm, while the control group had the shortest at 2.16 cm.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) had the longest secondary roots at 2.94 cm, while A₁B₁ (0.25%) had the shortest at 2.70 cm. Zinc as pre-cutting basal treatments showed A₂B₂ (3.25 cm) had the longest secondary roots, while A₂B₁ (3.06 cm) had the shortest. For post-cutting treatment of IBA, 5000-ppm concentration maintained the longest secondary roots with a pooled mean value of 4.22 cm, while the control group had the shortest at 2.21 cm (Figure 4.39).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the length of secondary roots in guava cuttings. Cuttings collected after 60 days exhibited longer secondary roots (3.17 cm) compared to those collected after 30 days (3.11 cm). Furthermore, the application method and interactions (AxB, BxC, AxC, AxBxC) had a significant impact on the length of secondary roots. The longest secondary root length (4.17 cm) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA.

4.2.8 Diameter of primary root (mm)

In 2022, zinc foliar application significantly affected the diameter of primary roots. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) resulted in a maximum primary root diameter of 1.43 mm, whereas A₁B₁ (0.25%) showed a minimum of 1.16 mm (Table 4.40, Figure 4.40). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) exhibited the largest primary root diameter at 1.85 mm, with A₂B₁ (50 g/tree) having the smallest at 1.56 mm. post-cutting treatment of IBA 5000-ppm concentration led to a maximum primary root diameter of 2.06 mm, while the control group had a minimum of 1.02 mm.

At 60 days after pre-cutting in 2022, treatment A₁B₃ (0.75%) maintained the largest primary root diameter at 1.43 mm, and A₁B₁ (0.25%) the smallest at 1.17 mm, highlighting significant differences among zinc basal applications. A₂B₂ (75 g/tree)

recorded the largest primary root diameter at 1.85 mm, whereas A₂B₁ (50 g/tree) had the smallest at 1.56 mm. For post-cutting treatment, IBA 5000-ppm concentration showed the largest primary root diameter at 2.12 mm, with the control group showing the smallest at 1.02 mm (Figure 4.40).

In 2023, zinc foliar application continued to influence the diameter of primary roots significantly. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the largest primary root diameter at 1.53 mm, while A₁B₁ (0.25%) had the smallest at 1.33 mm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the largest primary root diameter at 1.73 mm, and A₂B₁ (50 g/tree) the smallest at 1.62 mm. For post-cutting treatment, IBA 5000-ppm concentration resulted in the largest primary root diameter at 2.12 mm, while the control group had the smallest at 1.18 mm (Table 4.40, Figure 4.40).

At 60 days after pre-cutting treatment in 2023, treatment A₁B₃ (0.75%) recorded the largest primary root diameter at 1.51 mm, and A₁B₁ (0.25%) the smallest at 1.33 mm. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the largest primary root diameter at 1.83 mm, while A₂B₁ (50 g/tree) had the smallest at 1.56 mm. For post-cutting treatment of IBA 5000-ppm concentration the largest primary root diameter at 2.15 mm, with the control group showing the smallest at 1.27 mm (Table 4.40, Figure 4.40).

When pooling data from both years, at 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) consistently showed the largest primary root diameter at 1.48 mm, while A₁B₁ (0.25%) had the smallest at 1.24 mm (Table 4.40, Figure 4.40). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ had the largest primary root diameter at 1.69 mm, and A₂B₁ was the smallest at 1.58 mm. For post-cutting treatment of IBA 5000-ppm concentration consistently resulted in the largest primary root diameter with a mean value of 2.04 mm, while the control group had the smallest at 1.11 mm.

At 60 days after pre-cutting treatment, pooled data indicated that treatment A₁B₃ (0.75%) had the largest primary root diameter at 1.48 mm, while A₁B₁ (0.25%) had the smallest at 1.26 mm. Among the various levels of zinc as pre-cutting basal

treatments, A₂B₂ (1.75 mm) maintained the largest primary root diameter, and A₂B₁ (1.54 mm) the smallest. For post-cutting treatment of IBA, 5000-ppm concentration continued to show the largest primary root diameter with a pooled mean value of 2.06 mm, while the control group had the smallest at 1.17 mm (Figure 4.40).

The timing of zinc pre-cutting treatment or the dormant stage significantly affected the diameter of the primary root in guava cuttings. Cuttings taken 60 days after treatment had a larger primary root diameter (34.53 mm) compared to those collected 30 days after treatment (35.23 mm). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The largest primary root diameter (26.18 mm) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

4.2.9 Diameter of secondary root (mm)

In both 2022 and 2023, the zinc foliar application significantly influenced the Diameter of the secondary root at both 30- and 60-days pre-cutting treatment. At 30 days after pre-cutting, A₁B₃ (0.75% /tree) consistently showed the highest Diameter of secondary root, with values of 0.46 in 2022 and 0.56 in 2023, while A₁B₁ (0.25/tree) had the lowest values, 0.25 in 2022 and 0.41 in 2023 (Table 4.41). Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently had the highest diameter rate, with values of 0.74 in 2022 and 0.84 in 2023, while A₂B₁ (50 g/tree) had the lowest, 0.58 in 2022 and 0.66 in 2023. For post-cutting treatment of IBA, 5000-ppm concentration yielded the highest diameter rate of 0.88 in 2022 and 1 in 2023, whereas the control group consistently showed the lowest diameter (0.12 in 2022 and 0.32 in 2023). At 60 days post-treatment, the trends remained consistent. A₁B₃ continued to have the highest root diameter (0.52 in 2022 and 0.72 in 2023), while A₁B₁ had the lowest (0.29 in 2022 and 0.54 in 2023). For zinc basal treatments, A₂B₂ had the highest diameter (0.70 in 2022 and 0.88 in 2023), while A₂B₁ had the lowest (0.61 in 2022 and 0.79 in 2023). The 5000 ppm IBA treatment showed the highest diameter at 0.88 in 2022 and 1 in 2023, with the control group remaining the highest (0.17 in 2022 and 0.32 in 2023). Pooled data from both years reinforced these trends. At 30 days, ZF₃ consistently showed the largest shoot diameter at 0.51 mm, while ZF₁ had the smallest at 0.33 mm.

Table 4.40 Effect of zinc (Zn) and IBA treatments on diameter of primary root (mm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁ in an		
A₁B₁	1.16	1.17	1.17	1.31	1.33	1.32	1.24	1.26	1.25
A₁B₂	1.29	1.30	1.30	1.45	1.41	1.43	1.37	1.37	1.37
A₁B₃	1.43	1.43	1.43	1.53	1.51	1.52	1.48	1.48	1.48
A₂B₁	1.56	1.56	1.56	1.62	1.56	1.59	1.58	1.54	1.56
A₂B₂	1.85	1.85	1.85	1.73	1.83	1.78	1.69	1.75	1.72
A₂B₃	1.70	1.71	1.71	1.63	1.67	1.65	1.59	1.63	1.61
A₃B₁	2.06	2.12	2.09	2.12	2.15	2.14	2.04	2.06	2.05
A₃B₂	1.93	1.99	1.96	2.01	2.06	2.04	1.92	1.95	1.94
A₃B₃	1.02	1.02	1.02	1.18	1.27	1.23	1.11	1.17	1.14
Mean	1.56	1.57		1.62	1.64		1.56	1.58	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.010	0.003	0.012	0.004	0.017	0.006
Factor B	0.010	0.003	0.012	0.004	0.017	0.006
Factor C	0.005	0.002	0.008	0.003	0.009	0.003
Interaction A X B	0.018	0.006	0.020	0.007	0.029	0.010
Interaction A X C	0.008	0.003	0.013	0.005	0.015	0.005
Interaction B X C	0.008	0.003	0.013	0.005	0.015	0.005
Interaction A X B X C	0.014	0.005	0.023	0.008	0.026	0.009

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

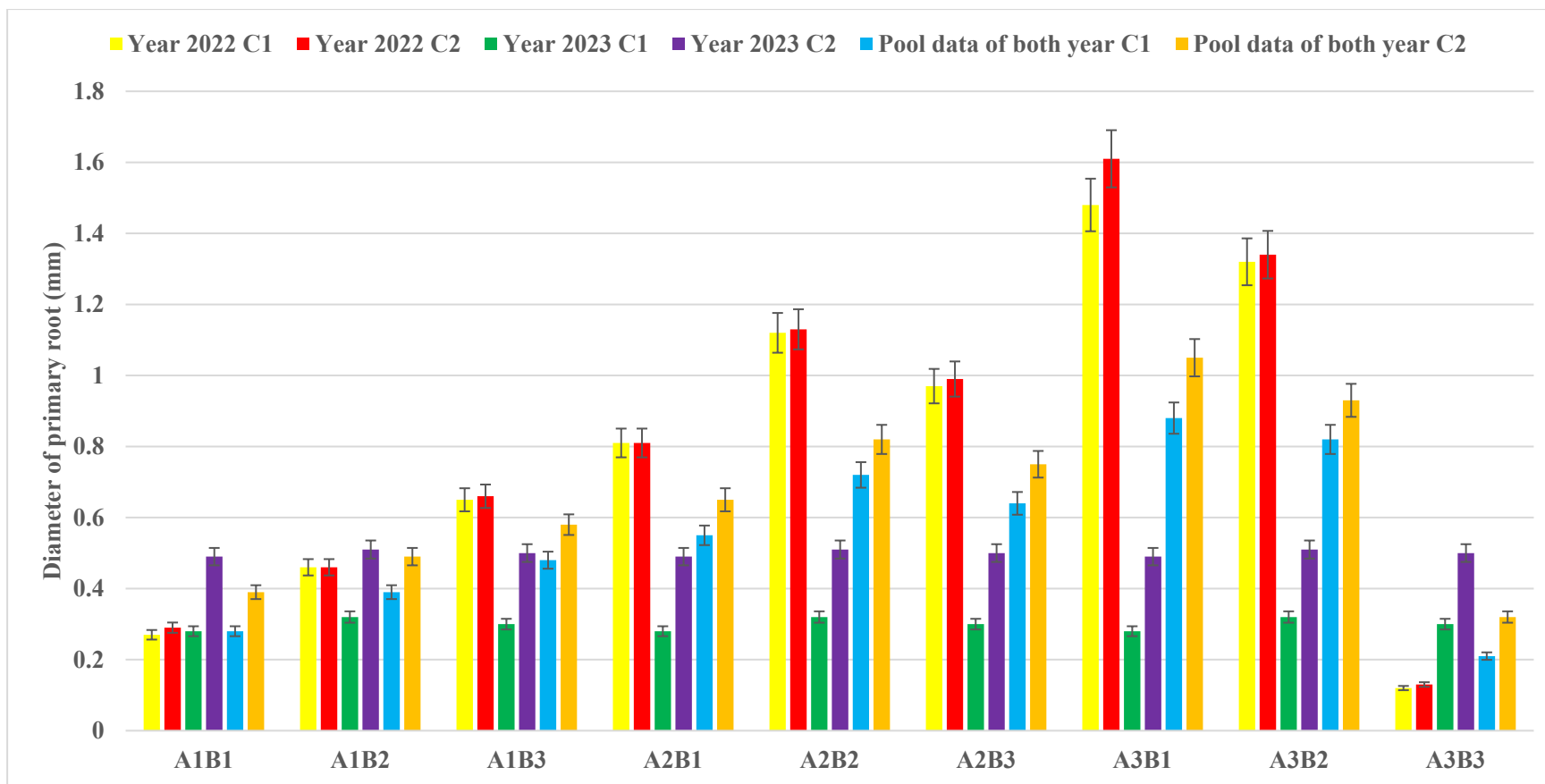


Figure 4.40 Graphical representation of the effect of Zinc (Zn) and IBA treatments on diameter of primary root (mm) in guava cuttings at different days.

Table 4.41 Effect of zinc (Zn) and IBA treatments on diameter of secondary root (mm) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.25	0.29	0.27	0.41	0.54	0.48	0.33	0.42	0.38
A ₁ B ₂	0.35	0.41	0.38	0.49	0.60	0.55	0.42	0.51	0.47
A ₁ B ₃	0.46	0.52	0.49	0.56	0.72	0.64	0.51	0.62	0.57
A ₂ B ₁	0.58	0.61	0.60	0.66	0.79	0.73	0.62	0.70	0.66
A ₂ B ₂	0.74	0.70	0.72	0.84	0.88	0.86	0.79	0.79	0.79
A ₂ B ₃	0.67	0.76	0.72	0.75	0.76	0.76	0.71	0.76	0.74
A ₃ B ₁	0.88	0.88	0.88	1.00	1.00	1.00	0.94	0.94	0.94
A ₃ B ₂	0.80	0.80	0.80	0.92	0.92	0.92	0.86	0.84	0.85
A ₃ B ₃	0.12	0.17	0.15	0.32	0.32	0.32	0.22	0.25	0.24
Mean	0.54	0.57		0.66	0.73		0.60	0.65	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.012	0.004	0.011	0.004	0.009	0.003
Factor B	0.012	0.004	0.011	0.004	0.009	0.003
Factor C	0.006	0.002	0.005	0.002	0.005	0.002
Interaction A X B	0.021	0.007	0.02	0.007	0.015	0.005
Interaction A X C	0.011	0.004	0.009	0.003	0.008	0.003
Interaction B X C	0.011	0.004	0.009	0.003	0.008	0.003
Interaction A X B X C	0.019	0.006	0.016	0.005	0.014	0.005

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

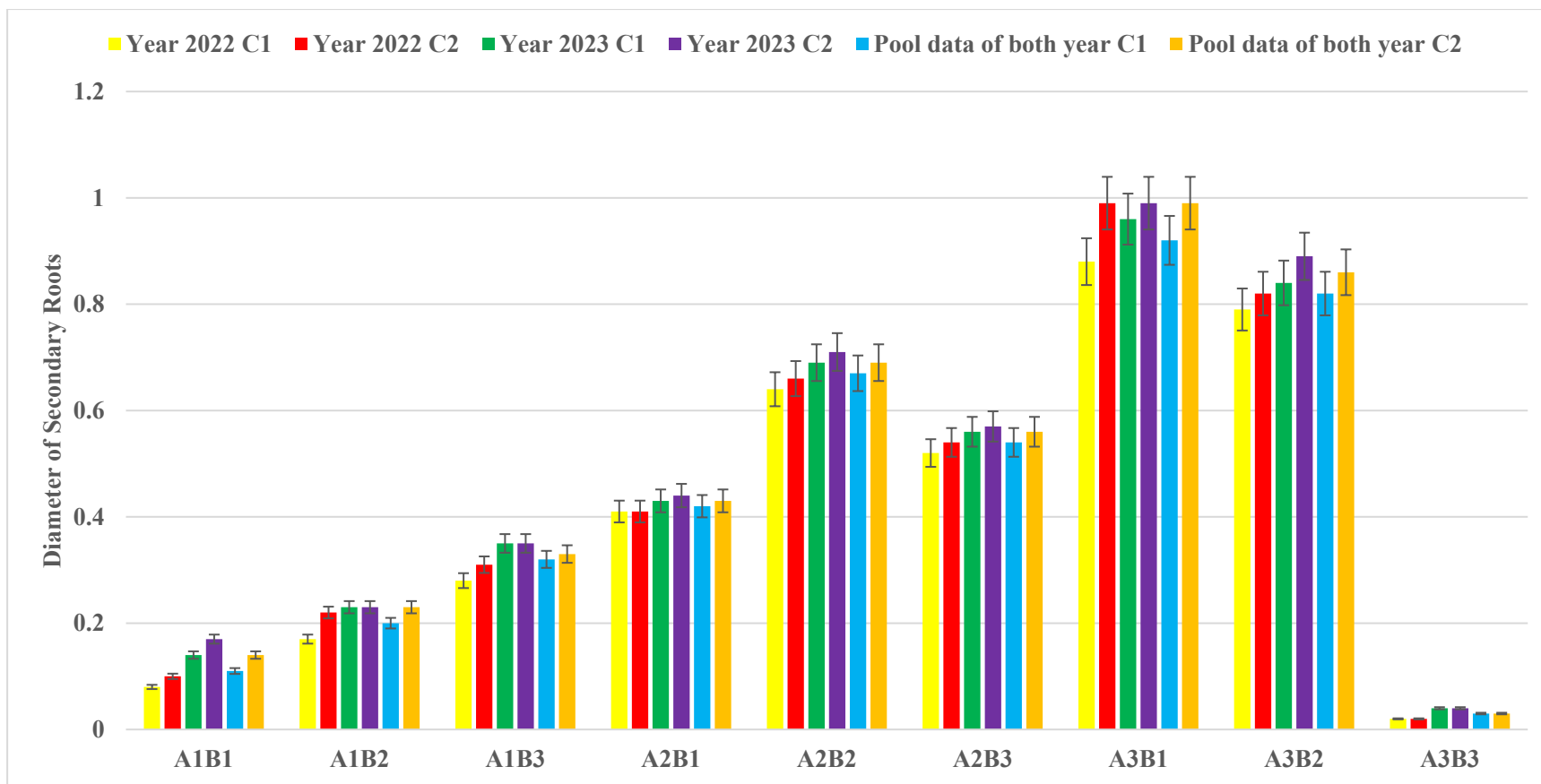


Figure 4.41 Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of secondary (mm) roots in guava cuttings at different days.

Among zinc basal treatments, A₂B₂ had the largest pooled root diameter at 0.79 mm, while A₂B₁ had the smallest at 0.62 mm. The 5000 ppm IBA treatment consistently resulted in the largest shoot diameter at 0.94 mm, whereas the control group had the smallest at 0.22 mm. At 60 days, A₁B₃ had the largest shoot diameter at 0.62 mm, while A₁B₁ had the smallest at 0.42 mm. A₂B₂ had the best performance among zinc basal treatments with a pooled shoot diameter of 0.79 mm, and A₂B₁ had the smallest at 0.70 mm. The 5000 ppm IBA post cutting treatment maintained the largest pooled root diameter at 0.94 mm, while the control group remained the smallest at 0.25 mm.

The timing of pre-cutting zinc treatments or the dormant stage significantly affected the diameter of secondary roots in guava cuttings. Cuttings collected 60 days after treatment had a larger secondary root diameter (34.53 mm) compared to those collected 30 days after treatment (35.23 mm). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The largest secondary root diameter (26.18 mm) was observed in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

The findings from this study underscore the importance of root morphology in overall plant health and nutrient uptake efficiency. The length and diameter of primary and secondary roots are crucial parameters that determine the efficiency of nutrient and water uptake. This study found that basal zinc application at 75 g/tree (ZB₂) significantly increased the length and diameter of both primary and secondary roots. The enhanced root length and diameter provide a larger surface area for nutrient and water absorption, improving the overall efficiency of the root system. The improvements in root length and diameter highlight the critical role of zinc in enhancing root structural integrity and functional capacity (Blum, 2011). Present findings are fully supported by the results of Sourati *et al.* (2022) in mulberry and Somkuwar *et al.* (2013) in dog ridge rootstock.

Table 4.42 Effect of zinc (Zn) and IBA treatments on fresh weight of primary root (g) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	2.27	2.28	2.28	2.41	2.43	2.42	2.34	2.36	2.35
A₁B₂	2.38	2.39	2.39	2.54	2.58	2.56	2.47	2.49	2.48
A₁B₃	2.48	2.5	2.49	2.62	2.63	2.63	2.55	2.57	2.56
A₂B₁	2.59	2.67	2.63	2.76	2.83	2.8	2.68	2.75	2.72
A₂B₂	2.71	2.81	2.76	2.86	2.95	2.91	2.79	2.88	2.84
A₂B₃	2.83	3.04	2.94	3.03	3.17	3.1	2.93	3.11	3.02
A₃B₁	3.37	3.56	3.47	3.69	3.82	3.76	3.53	3.69	3.61
A₃B₂	3.14	3.33	3.24	3.36	3.49	3.43	3.25	3.41	3.33
A₃B₃	1.99	2.09	2.04	2.15	2.23	2.19	2.07	2.16	2.12
Mean	2.64	2.74		2.83	2.9		2.73	2.83	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.008	0.003	0.007	0.002
Factor B	0.009	0.003	0.008	0.003	0.007	0.002
Factor C	0.007	0.002	0.005	0.002	0.008	0.004
Interaction A X B	0.015	0.005	0.014	0.005	0.013	0.004
Interaction A X C	0.012	0.004	0.009	0.003	0.014	0.005
Interaction B X C	0.012	0.004	0.009	0.003	0.014	0.005
Interaction A X B X C	0.021	0.007	0.016	0.005	0.024	0.008

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

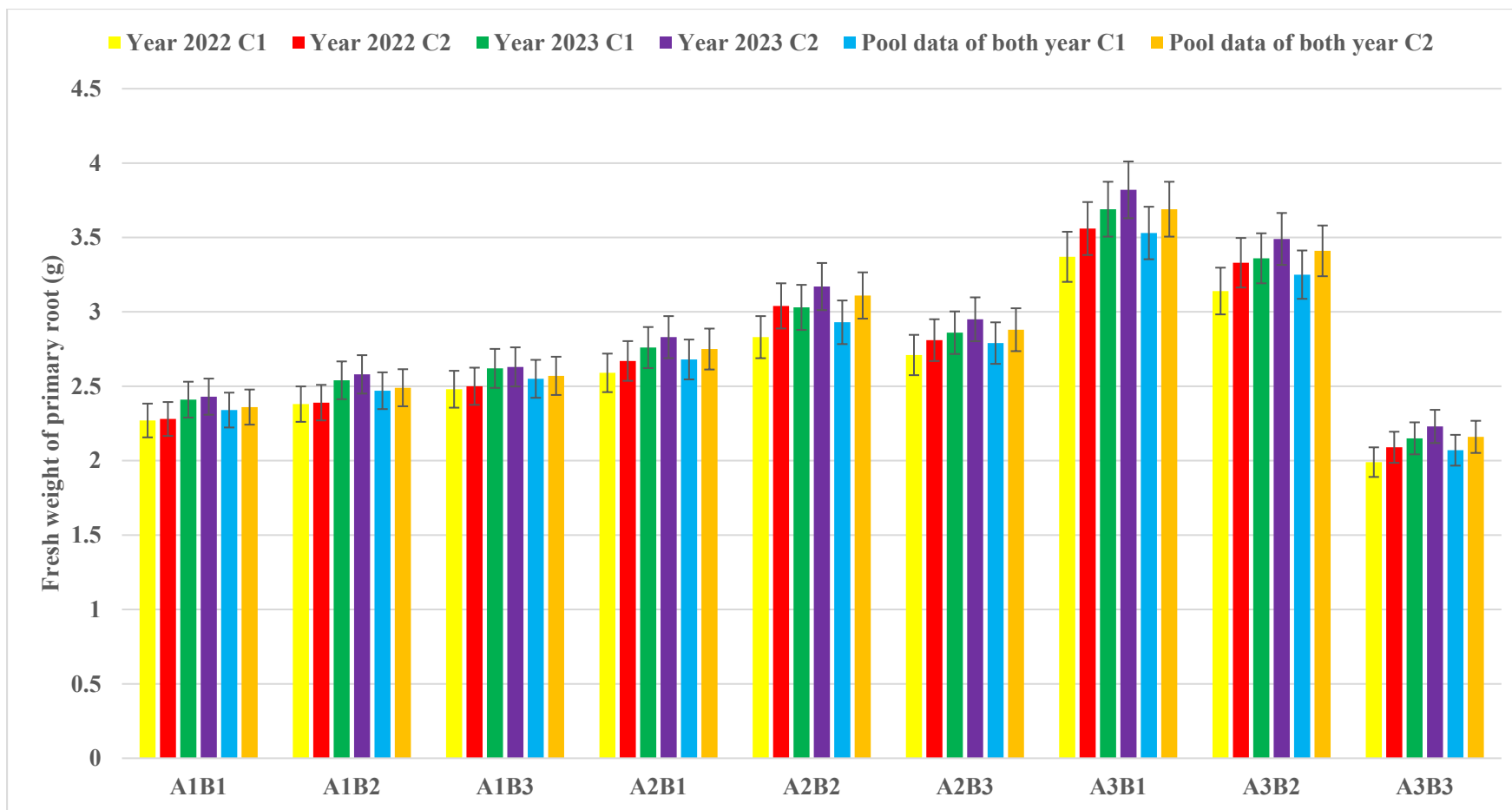


Figure 4.42 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of primary root (g) in guava cuttings at different days.

Table 4.43 Effect of zinc (Zn) and IBA treatments on Fresh weight of secondary root (g) in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.89	0.91	0.9	0.98	0.98	0.98	0.94	0.95	0.95
A₁B₂	1.03	1.01	1.02	1.11	1.11	1.11	1.07	1.06	1.07
A₁B₃	1.16	1.13	1.15	1.22	1.23	1.23	1.19	1.18	1.19
A₂B₁	1.27	1.28	1.27	1.33	1.33	1.33	1.31	1.31	1.31
A₂B₂	1.44	1.49	1.47	1.53	1.55	1.54	1.49	1.52	1.51
A₂B₃	1.35	1.35	1.35	1.42	1.41	1.42	1.39	1.38	1.39
A₃B₁	1.62	1.66	1.64	1.79	1.93	1.86	1.71	1.75	1.73
A₃B₂	1.56	1.62	1.59	1.6	1.64	1.62	1.57	1.63	1.6
A₃B₃	0.68	0.68	0.68	0.83	0.85	0.84	0.76	0.77	0.77
Mean	1.22	1.24		1.31	1.34		1.27	1.28	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.012	0.004	0.011	0.004	0.01	0.003
Factor B	0.012	0.004	0.011	0.004	0.01	0.003
Factor C	0.005	0.002	0.005	0.002	0.006	0.002
Interaction A X B	0.021	0.007	0.02	0.007	0.017	0.006
Interaction A X C	0.008	0.003	0.009	0.003	0.011	0.004
Interaction B X C	0.008	0.003	0.009	0.003	0.011	0.004
Interaction A X B X C	0.014	0.005	0.015	0.005	0.019	0.006

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

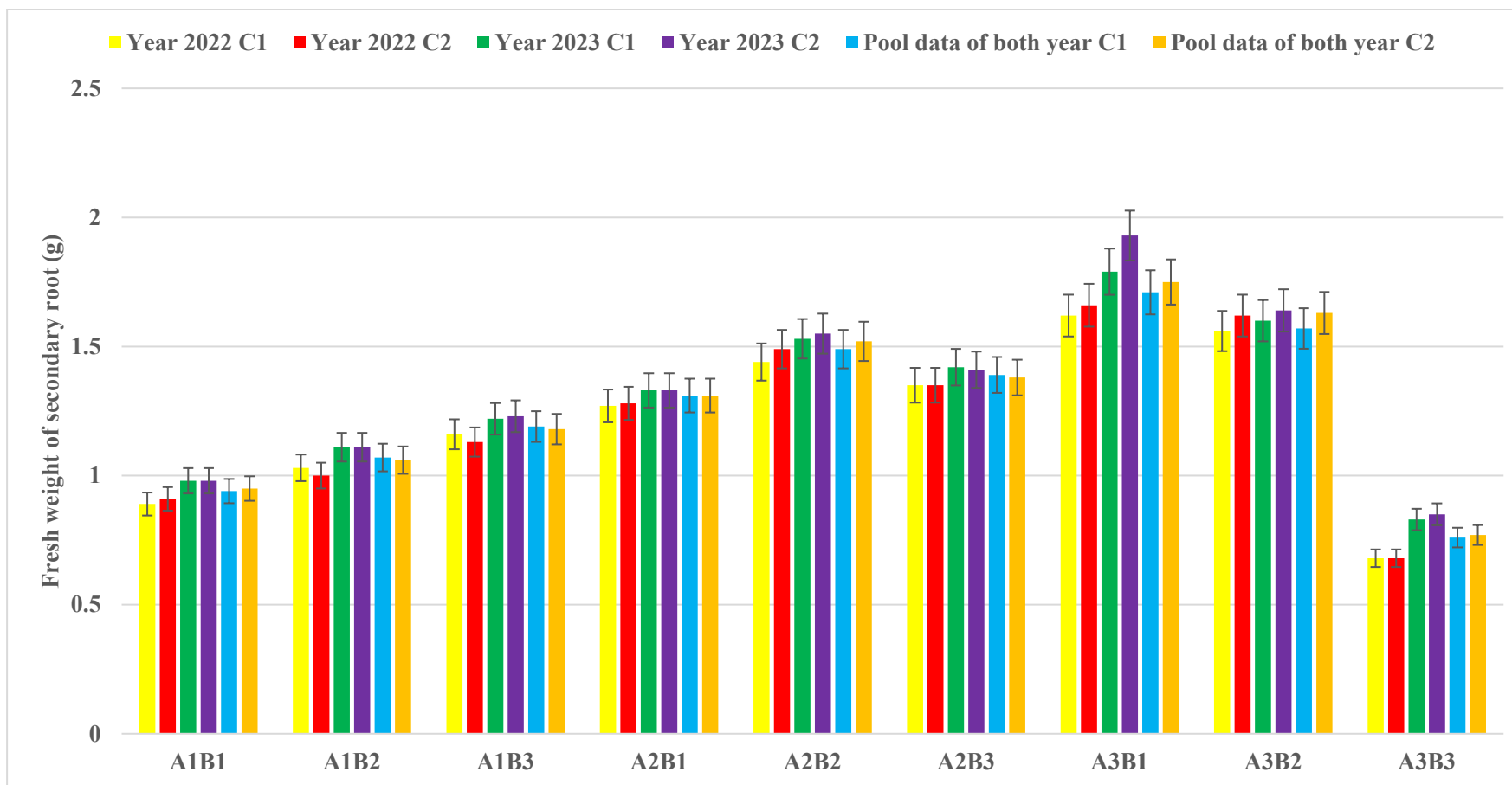


Figure 4.43 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of secondary root (g) in guava cuttings at different days.

4.2.10 Fresh weight of primary root (g)

In both 2022 and 2023, the zinc foliar application significantly influenced the mortality rate at both 30- and 60-days post-treatment. At 30 days, ZF3 (0.75% /tree) consistently showed the lowest mortality rate, with values of 10% in 2022 and 8% in 2023, while ZF1 (0.25%/tree) had the highest values, 26% in 2022 and 22% in 2023 (Table 4.42, Figure 4.42).

Similarly, for zinc basal treatments, ZB2 (75 g/tree) consistently had the lowest mortality rate, with values of 5% in 2022 and 3% in 2023, while ZB1 (100 g/tree) had the highest, 15% in 2022 and 12% in 2023. Among the IBA treatments, the 5000-ppm concentration yielded the lowest mortality rate of 2% in 2022 and 1% in 2023, whereas the control group consistently showed the highest mortality rate (46% in 2022 and 38% in 2023).

At 60 days post-treatment, the trends remained consistent. ZF3 continued to have the lowest mortality rate (7% in 2022 and 5% in 2023), while ZF1 had the highest (28% in 2022 and 24% in 2023). For zinc basal treatments, ZB2 had the lowest mortality rate (4% in 2022 and 2% in 2023), while ZB1 had the highest (16% in 2022 and 11% in 2023). The 5000 ppm IBA treatment showed the lowest mortality rate at 1% in 2022 and 2023, with the control group remaining the highest (50% in 2022 and 42% in 2023).

Pooled data from both years reinforced these trends. At 30 days, ZF3 consistently showed the lowest mortality rate at 12%, with ZF1 the highest at 21% (Table 10). ZB2 had the lowest pooled mortality rate at 7%, and ZB1 had the highest at 14%. The 5000 ppm IBA treatment consistently had the lowest mortality rate at 25%, while the control group had the highest at 6%. At 60 days, ZF3 had the lowest mortality rate at 13%, while ZF1 had the highest at 20%. ZB2 performed the best among zinc basal treatments with a pooled mortality rate of 15%, and ZB1 had the highest at 17%. The 5000 ppm IBA treatment maintained the lowest pooled mortality rate at 26%, and the control group remained the highest at 7%.

The number of days after zinc pre-cutting treatment or during the dormant stage significantly impacted the fresh weight of secondary roots in guava cuttings. Cuttings taken 60 days after treatment exhibited a higher fresh weight of secondary roots (0.91 g) compared to those taken at 30 days (0.83 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The maximum fresh weight of secondary roots (1.25 g) was observed in the A3B1C2 treatment, where cuttings were collected 60 days into dormancy and dipped in 5000 ppm IBA.

4.2.11 Fresh weight of secondary root (g)

In 2022, the fresh weight of the secondary root was significantly influenced by zinc foliar application. At 30 days after pre-cutting treatment, the highest fresh weight of the secondary root (1.16g) was recorded in the A₁B₃ treatment (0.75%), whereas the lowest (0.89g) was observed in the A₁B₁ treatment (0.25%), indicating a notable difference among the zinc foliar application levels (Table 4.43, Figure 4.43). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum fresh weight of the secondary root (1.44g), while A₂B₁ (50 g/tree) had the minimum (1.27g). For post-cutting treatment of IBA, 5000-ppm concentration resulted in the highest fresh weight (1.62g), contrasting with the control group, which had the lowest fresh weight (0.68g).

At 60 days after pre-cutting treatment, the highest fresh weight of the secondary root was again recorded in A₁B₁ (1.13g), while the lowest was seen in A₁B₁ (0.91g), highlighting significant differences among the zinc foliar application levels (Table 4.43, Figure 4.43). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest fresh weight of secondary root (1.49g), while A₂B₁ (50 g/tree) had the lowest (1.28g). For post-cutting treatment of IBA, 5000-ppm concentration continued to show the highest fresh weight (1.66g), with the control group remaining the lowest (0.68g).

In 2023, the fresh weight of the primary root followed a similar pattern. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) had the maximum fresh weight (1.22g), and A₁B₁ (75 g/tree) had the minimum (0.98g), again showing significant

differences among the zinc foliar application levels (Table 4.43, Figure 4.43). For various levels of zinc basal treatments, A₂B₂ (75 g/tree) led with 1.53g, while A₂B₁ (50 g/tree) was at the bottom (1.33g). For post-cutting treatment, IBA 5000-ppm concentration resulted in the highest fresh weight (1.79g), whereas the control group had the lowest (0.83g).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75% /tree) again recorded the highest fresh weight of secondary root (1.23g), and A₁B₁ (0.25% g/tree) had the lowest (0.98g), indicating a significant difference among the various levels of zinc basal application (Table 4.43, Figure 4.43). Among the various levels of zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest fresh weight of secondary root (1.55g), while A₂B₁ (50 g/tree) had the lowest (1.33g). For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest fresh weight of the secondary root (1.93g), with the control group showing the lowest (0.85g).

When pooling data for both years, the maximum fresh weight at 30 days after pre-cutting treatment was consistently recorded in the A₁B₃ treatment (0.75% /tree) (1.19g), while the minimum was observed in A₁B₁ (0.25% g/tree) (0.94g) (Table 4.43, Figure 4.43). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (1.49g) had the highest pooled fresh weight of secondary root, and A₂B₁ (1.31g) had the lowest. For post-cutting treatment, IBA 5000-ppm concentration consistently showed the highest fresh weight (1.71g), while the control group had the lowest (0.76g). At 60 days, pooled data revealed that A₁B₃ (0.75% /tree) maintained the highest fresh weight (1.18g), with A₁B₁ (0.25% g/tree) having the lowest (0.95g). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (1.52g) consistently performed best, while A₂B₁ (1.31g) had the minimum fresh weight. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest pooled fresh weight (1.75g), and the control group remained the lowest (0.77g).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the fresh weight of secondary roots in cuttings. Cuttings collected after 60 days recorded a higher dry weight of secondary roots (1.28 g) compared to those collected after 30 days (1.27 g). Additionally, the application

method and interactions (AxB, BxC, AxC, AxBxC) significantly impacted the dry weight of secondary roots. The maximum dry weight (1.73 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.2.12 Dry weight of the primary root (g)

In 2022, zinc foliar application had a marked effect on the dry weight of primary roots. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75% /tree) resulted in the highest dry weight at 0.36 g, whereas A₁B₁ (0.25/tree) had the lowest at 0.28 g, reflecting significant differences across zinc foliar treatments (Table 36, Figure 10). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the highest dry weight at 0.46 g, with A₂B₁ showing the lowest at 0.40 g. For post-cutting treatment, IBA 5000-ppm concentration produced the highest dry weight at 0.88 g, while the control group had the lowest at 0.10 g. At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75% /tree) again had the highest dry weight at 0.36 g, while A₁B₁ (0.25/tree) had the lowest at 0.29 g, demonstrating clear differences among zinc basal applications. A₂B₂ (75 g/tree) was the top performer with a dry weight of 0.48 g, whereas ZB₁ (50 g/tree) had the lowest at 0.41 g. For post-cutting treatment, IBA 5000-ppm concentration showed the highest dry weight at 0.93 g, and the control group had the lowest at 0.11 g (Figure 10).

In 2023, the influence of zinc foliar application on the dry weight of primary roots remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) had the highest dry weight at 1.75 g, while A₁B₁(75 g/tree) had the lowest at 1.31 g. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight at 2.28 g, with A₂B₁ (50 g/tree) showing the lowest at 1.89 g. For post-cutting treatment of IBA 5000-ppm concentration led to the highest dry weight at 3.01 g, while the control group had the lowest at 1.12 g (Table 36, Figure 10). At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75% /tree) recorded the highest dry weight at 1.79 g, and A₁B₁ (37.5 g/tree) was the lowest at 1.34 g. Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) had the highest dry weight at 2.34 g, and A₂B₁ had the lowest at 1.92 g. For post-cutting treatment, IBA 5000-ppm

concentration had the highest dry weight at 3.08 g, with the control group having the lowest at 1.18 g (Figure 10).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) consistently had the highest dry weight at 0.37 g, while A₁B₁ (0.25/tree) had the lowest at 0.31 g, indicating consistent results (Table 4.44, Figure 4.44). Among the various levels of zinc pre-cutting basal treatments showed A₂B₂ had the highest dry weight at 0.47 g, and ZB1 had the lowest at 0.40 g. For post-cutting treatment, IBA 5000-ppm concentration consistently led to the highest dry weight with a mean value of 0.92 g, while the control group had the lowest at 0.10 g. At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75% /tree) had the highest dry weight at 0.37 g, while A₁B₁ (0.25/tree) had the lowest at 0.31 g. Zinc basal as pre-cutting treatments showed A₂B₂ (0.49 g) had the highest dry weight, while A₂B₁ (0.41 g) had the lowest. For post-cutting treatment of IBA, 5000-ppm concentration maintained the highest dry weight with a pooled mean value of 0.96 g, while the control group had the lowest at 0.11 g (Figure 4.44).

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced the dry weight of primary roots in cuttings. Cuttings collected 60 days after treatment exhibited a higher dry weight of primary roots (0.52 g) compared to those collected after 30 days (0.45 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) also had a significant impact. The maximum dry weight of primary roots (0.68 g) was recorded in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.1.13 Dry Weight of Secondary Roots (g)

In both 2022 and 2023, zinc foliar application significantly impacted the dry weight of secondary roots at both 30- and 60 days post-treatment. At 30 days, ZF₃ (0.75% /tree) consistently recorded the highest dry weight, with values of 0.36 g in 2022 and 0.38 g in 2023, while ZF₁ (0.25% g/tree) showed the lowest values, 0.28 g in 2022 and 0.33 g in 2023 (Table 4.45).

Table 4.44 Effect of zinc (Zn) and IBA treatments on dry weight of the primary root (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.17	0.21	0.19	0.19	0.21	0.20	0.18	0.22	0.20
A₁B₂	0.33	0.33	0.33	0.35	0.35	0.35	0.34	0.34	0.34
A₁B₃	0.45	0.47	0.46	0.51	0.53	0.52	0.48	0.50	0.49
A₂B₁	0.51	0.59	0.55	0.66	0.69	0.68	0.59	0.64	0.62
A₂B₂	0.78	0.80	0.79	0.88	0.94	0.91	0.83	0.87	0.85
A₂B₃	0.64	0.79	0.72	0.75	0.78	0.77	0.70	0.79	0.74
A₃B₁	1.04	1.09	1.06	0.19	0.22	0.21	0.62	0.66	0.64
A₃B₂	0.85	0.89	0.87	1.04	1.05	1.05	0.95	0.98	0.96
A₃B₃	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Mean	0.54	0.59		0.52	0.54		0.53	0.57	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.016	0.005	0.012	0.004	0.012	0.004
Factor B	0.016	0.005	0.012	0.004	0.012	0.004
Factor C	0.010	0.003	0.009	0.003	0.007	0.002
Interaction A X B	0.028	0.009	0.021	0.007	0.02	0.007
Interaction A X C	0.017	0.006	0.015	0.005	0.011	0.004
Interaction B X C	0.017	0.006	0.015	0.005	0.011	0.004
Interaction A X B X C	0.029	0.010	0.026	0.009	0.02	0.007

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

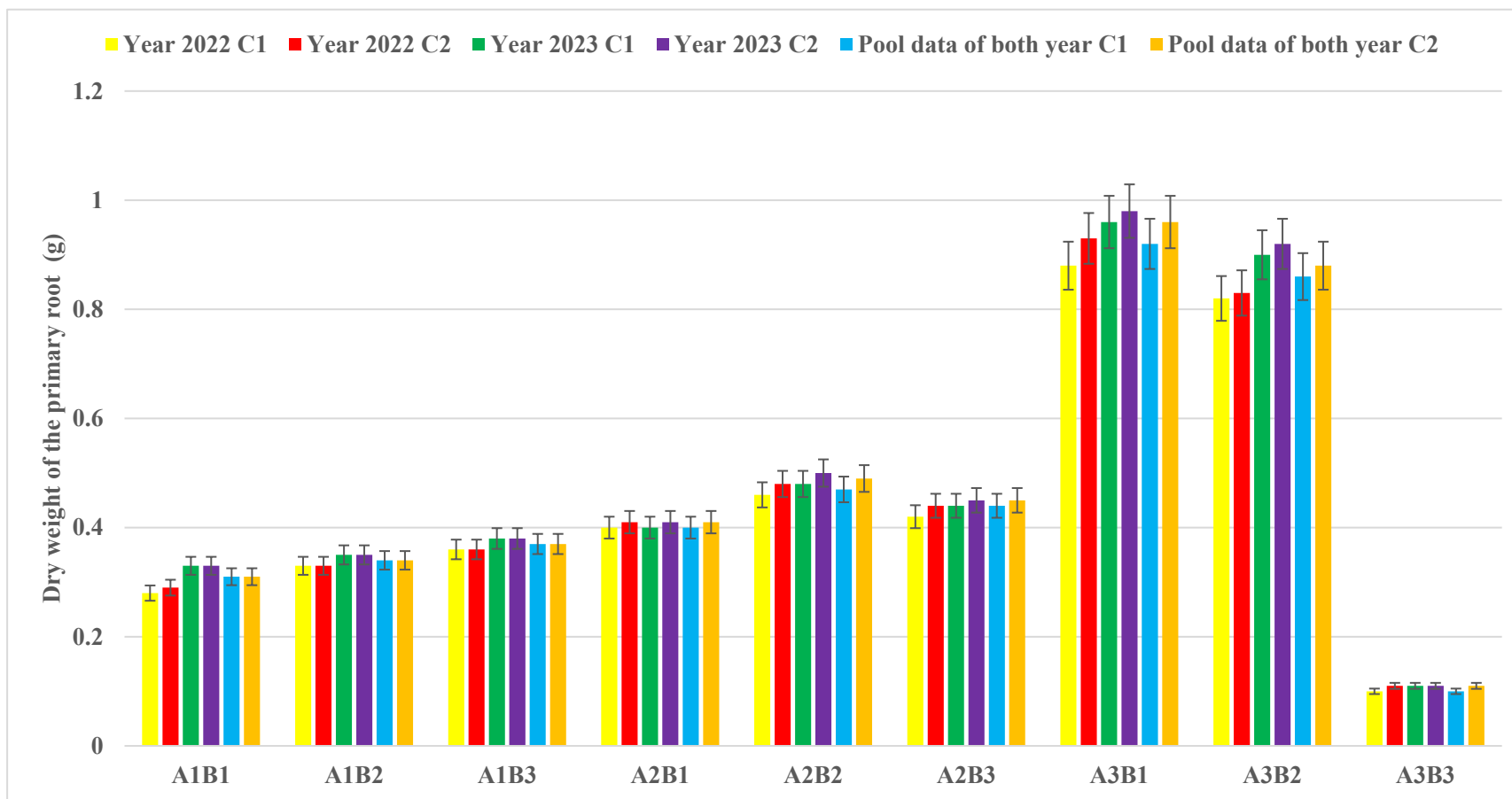


Figure 4.44 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of the primary root (g) in guava cuttings at different days.

Table 4.45 Effect of zinc (Zn) and IBA treatments on Dry weight of the secondary root (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.11	0.12	0.11	0.11	0.12	0.11	0.11	0.12	0.12
A₁B₂	0.23	0.25	0.24	0.23	0.25	0.24	0.23	0.25	0.24
A₁B₃	0.35	0.36	0.36	0.37	0.39	0.38	0.36	0.38	0.37
A₂B₁	0.43	0.47	0.45	0.49	0.52	0.51	0.46	0.50	0.48
A₂B₂	0.68	0.76	0.72	0.75	0.68	0.71	0.72	0.78	0.75
A₂B₃	0.55	0.59	0.57	0.61	0.65	0.63	0.58	0.62	0.60
A₃B₁	0.83	0.95	0.89	0.94	0.99	0.97	0.89	0.97	0.93
A₃B₂	0.71	0.84	0.78	0.82	0.86	0.84	0.77	0.85	0.81
A₃B₃	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.04
Mean	0.44	0.49		0.48	0.50		0.46	0.50	

		Year 2022		Year 2023		Pool data	
Factors		CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A		0.010	0.003	0.018	0.006	0.007	0.002
Factor B		0.010	0.003	0.018	0.006	0.007	0.002
Factor C		0.008	0.003	0.013	0.004	0.005	0.002
Interaction A X B		0.018	0.006	0.031	0.010	0.012	0.004
Interaction A X C		0.013	0.004	0.022	0.007	0.008	0.003
Interaction B X C		0.013	0.004	0.022	0.007	0.008	0.003
Interaction A X B X C		0.023	0.008	0.038	0.013	0.015	0.005
A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal		A ₃ B ₁	Post-cutting 5000 ppm IBA	
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal		A ₃ B ₂	Post-cutting 10000 ppm IBA	
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal		A ₃ B ₃	untreated	
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage		

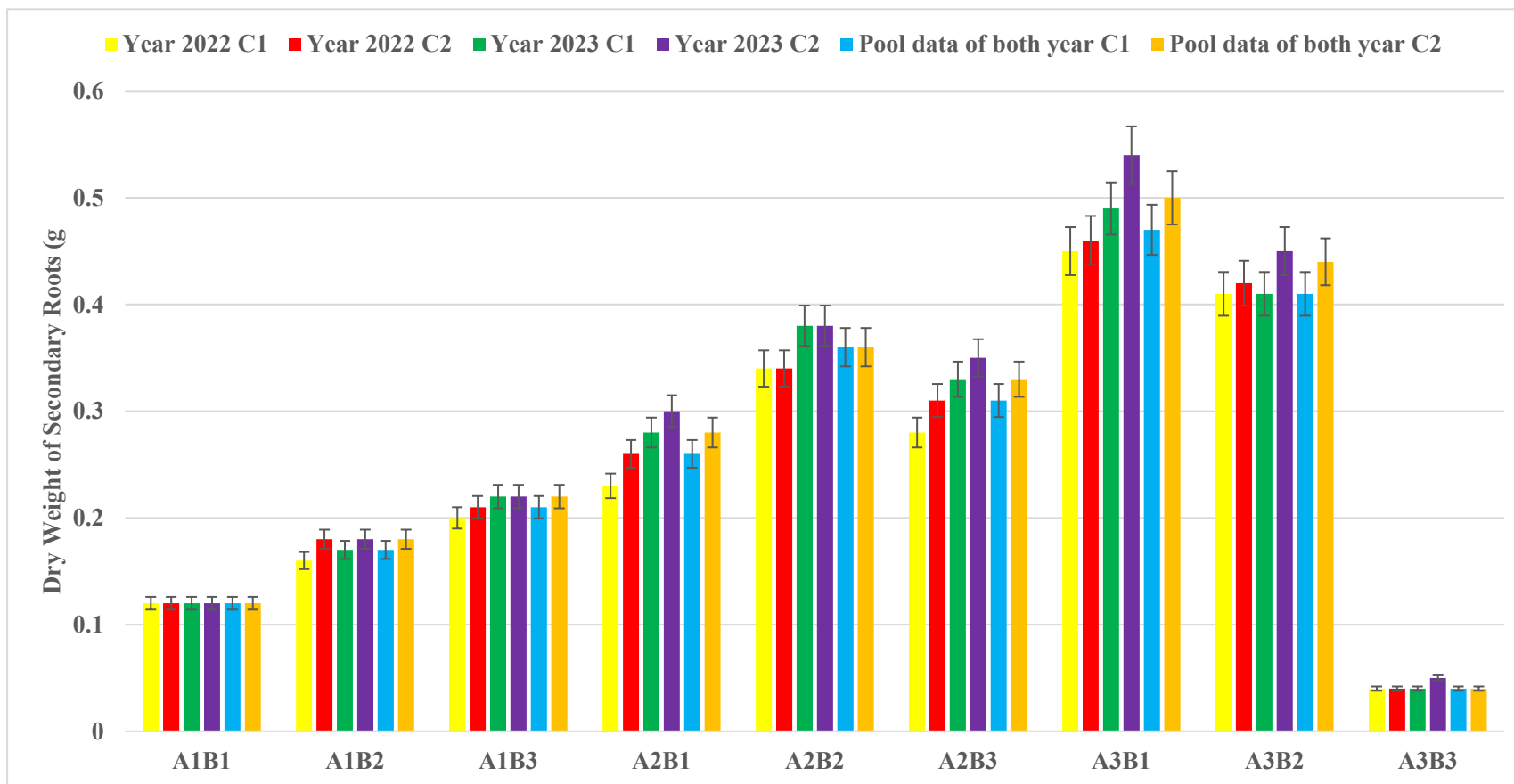


Figure 4.45 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of secondary roots (g) in guava cuttings at different days.

Similarly, for zinc basal treatments, ZB₃ (100 g/tree) consistently showed the highest dry weight, with values of 0.46 g in 2022 and 0.48 g in 2023, while ZB₁ (50 g/tree) had the lowest, 0.40 g in 2022 and 0.40 g in 2023. Among the IBA treatments, the 5000-ppm concentration yielded the highest dry weight of 0.88 g in 2022 and 0.96 g in 2023, whereas the control group consistently had the lowest dry weight (0.10 g in 2022 and 0.11 g in 2023). At 60 days post-treatment, the trends remained consistent. ZF₃ continued to have the highest dry weight (0.36 g in 2022 and 0.38 g in 2023), while ZF₁ had the lowest (0.29 g in 2022 and 0.33 g in 2023). For zinc basal treatments, ZB₃ had the highest dry weight (0.48 g in 2022 and 0.51 g in 2023), while ZB₁ had the lowest (0.41 g in 2022 and 0.41 g in 2023). The 5000 ppm IBA treatment showed the highest dry weight at 0.93 g in 2022 and 0.98 g in 2023, with the control group remaining the lowest (0.11 g in 2022 and 0.11 g in 2023).

Pooled data from both years reinforced these trends. At 30 days, ZF₃ consistently recorded the highest dry weight at 0.37 g, with ZF₁ the lowest at 0.31 g (Table 10). ZB₃ showed the highest pooled dry weight at 0.47 g, and ZB₁ had the lowest at 0.41 g. The 5000 ppm IBA treatment consistently had the highest dry weight at 0.92 g, while the control group had the lowest at 0.10 g. At 60 days, ZF₃ had the highest dry weight at 0.37 g, while ZF₁ had the lowest at 0.31 g. ZB₃ was the best performer among zinc basal treatments with 0.49 g, and ZB₁ had the lowest dry weight at 0.41 g. The 5000 ppm IBA treatment maintained the highest pooled dry weight at 0.96 g, and the control group remained the lowest at 0.11 g.

Sprout initiation in cuttings was significantly affected by the timing of pre-cutting zinc treatments or the dormant stage of guava. Cuttings collected 60 days after treatment-initiated roots sooner (34.53 days) compared to those taken after 30 days (35.23 days). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The fastest root initiation (26.18 days) occurred in the A3B1C2 treatment, involving cuttings collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

The fresh and dry weight of roots are important indicators of root biomass and overall plant health. In this study, zinc application, particularly through basal methods,

significantly increased both fresh and dry root weights. The treatment with basal zinc at 75 g/tree (ZB₂) resulted in the highest fresh and dry root weights, indicating enhanced root biomass and improved nutrient uptake capacity. This increase in root biomass is likely due to the enhanced enzyme activity and hormone regulation facilitated by zinc, leading to better root growth and development, consistent with findings by Marschner (2012). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Yamashita et al. (2006) in mango.

4.2.14 Days to Sprouting

In both 2022 and 2023, zinc foliar application significantly impacted the days to sprout initiation at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting, A₁B₃ (0.75%) consistently recorded the fewest days to sprout initiation, with values of 22.14 days in 2022 and 21.97 days in 2023, while ZF₁ (0.25%) showed the most days, 23.09 days in 2022 and 22.89 days in 2023 (Table 4.46, Figure 4.46). Similarly, for zinc basal treatments, A₂B₃ (100 g/tree) consistently showed the fewest days to sprout initiation, with values of 19.04 days in 2022 and 18.81 days in 2023, while A₂B₁ (50 g/tree) had the most, 20.38 days in 2022 and 20.19 days in 2023. Among the IBA treatments, the 5000-ppm concentration yielded the fewest days to sprout initiation of 15.5 days in 2022 and 15.1 days in 2023, whereas the control group consistently had the most days to sprout initiation (14.42 days in 2022 and 14.21 days in 2023).

At 60 days post-treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the fewest days to sprout initiation (17.8 days in 2022 and 17.6 days in 2023), while A₁B₁ (0.25%) had the most (19.8 days in 2022 and 19.6 days in 2023). For zinc basal treatments, A₂B₂ had the fewest days to sprout initiation (16.8 days in 2022 and 16.5 days in 2023), while A₂B₁ had the most (18.8 days in 2022 and 18.6 days in 2023). The 5000 ppm IBA treatment showed the fewest days to sprout initiation at 14.8 days in 2022 and 14.5 days in 2023, with the control group remaining the most (21.8 days in 2022 and 21.5 days in 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ (0.75%) consistently recorded the fewest days to sprout initiation at 18.4 days, with A₁B₁ (0.25%) the most at 20.2 days (Table 4.47). A₂B₃ showed the fewest pooled days to sprout initiation at 17.3 days, and ZB₁ had the most at 19.3 days. The 5000 ppm IBA treatment consistently had the fewest days to sprout initiation at 15.3 days, while the control group had the most at 22.4 days. At 60 days, A₁B₃ (0.75%) had the fewest days to sprout initiation at 17.7 days, while A₁B₁ (0.25%) had the most at 19.7 days. A₂B₃ was the best performer among zinc basal treatments at 16.7 days, and A₂B₁ had the most days to sprout initiation at 18.7 days. The 5000 ppm IBA post cutting treatment maintained the fewest pooled days to sprout initiation at 14.6 days, and the control group remained the most at 21.6 days.

4.2.15 sprouting percentage

In both 2022 and 2023, zinc foliar application significantly impacted the sprouting percentage at both 30- and 60 days post-treatment. At 30 days, A₁B₃ (0.75%) consistently recorded the highest sprouting percentage, with values of 71.92% in 2022 and 75.42% in 2023, while A₁B₁ (0.25%) showed the lowest values, 65.10% in 2022 and 68.98% in 2023. Similarly, for zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) consistently showed the highest sprouting percentage, with values of 79.21% in 2022 and 79.98% in 2023, while A₂B₁ (50 g/tree) had the lowest, 72.03% in 2022 and 75.58% in 2023. Among the IBA treatments, the 10000-ppm concentration yielded the highest sprouting percentage of 94.54% in 2022 and 95.61% in 2023, whereas the control group consistently had the lowest sprouting percentage (45.46% in 2022 and 47.63% in 2023). (Table 4.47, Figure 4.47).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the highest sprouting percentage (75.84% in 2022 and 77.87% in 2023), while ZF₁ had the lowest (69.71% in 2022 and 71.76% in 2023). For zinc basal treatments, ZB₂ had the highest sprouting percentage (83.18% in 2022 and 83.63% in 2023), while ZB₁ had the lowest (76.62% in 2022 and 78.27% in 2023). The 5000 ppm IBA treatment showed the highest sprouting percentage at 98.12% in 2022 and 97.07% in 2023, with the control group remaining the lowest (48.72% in 2022 and 50.82% in 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ (0.75%) consistently recorded the highest sprouting percentage at 73.67%, with A₁B₁ (0.25%) the lowest at 67.04% (Table 4.47, Figure 4.47). A₂B₂ showed the highest pooled sprouting percentage at 79.85%, and A₂B₁ had the lowest at 73.87%. The 5000 ppm IBA post cutting treatment consistently had the highest sprouting percentage at 95.08%, while the control group had the lowest at 46.54%. At 60 days, A₁B₃ (0.75%) had the highest sprouting percentage at 76.86%, while A₁B₁ (0.25%) had the lowest at 70.74%. A₂B₂ was the best performer among zinc basal treatments at 83.41%, and A₂B₁ had the lowest sprouting percentage at 77.45%. The 5000 ppm IBA post cutting treatment maintained the highest pooled sprouting percentage at 95.47%, and the control group remained the lowest at 49.77%.

The timing of zinc pre-cutting treatments or the dormant stage significantly influenced the sprouting percentage in guava cuttings. Cuttings collected 60 days after treatment exhibited a higher sprouting percentage (81.03%) compared to those collected after 30 days (77.97%). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The highest sprouting percentage (95.27%) was recorded in the A₃B₁C₂ treatment, where cuttings were collected 60 days into dormancy and treated with 5000 ppm IBA.

The role of zinc in plant hormone regulation and enzyme function is paramount for successful sprout initiation. Zinc's role as a cofactor in enzyme systems involved in auxin metabolism and protein synthesis is crucial for sprout initiation. Auxins are plant hormones that promote cell division and elongation, essential for the formation of new shoots. The study found that basal zinc application at 75 g/tree (ZB₂) significantly enhanced sprout initiation and increased the sprouting percentage compared to foliar applications and the control group. This finding aligns with previous research that indicates adequate zinc levels are necessary for optimal hormone function and shoot initiation (Broadley *et al.*, 2007). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Somkuwar *et al.* (2013) in dog ridge rootstock.

Table 4.46 Effect of zinc (Zn) and IBA treatments on Days to Sprouting in Guava Cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	23.09	22.93	23.01	22.89	22.73	22.81	22.99	22.83	22.91
A ₁ B ₂	22.53	22.27	22.4	22.31	22.04	22.18	22.42	22.16	22.29
A ₁ B ₃	22.14	21.94	22.04	21.97	22.71	22.34	22.06	22.33	22.2
A ₂ B ₁	20.38	20.13	20.26	20.19	19.91	20.05	20.29	20.02	20.16
A ₂ B ₂	19.35	19.12	19.24	19.11	18.89	19.01	19.23	19.01	19.12
A ₂ B ₃	19.04	18.77	18.91	18.81	18.54	18.68	18.93	18.66	18.8
A ₃ B ₁	14.42	14.13	14.28	14.21	13.91	14.06	14.32	14.02	14.17
A ₃ B ₂	16.16	16.02	16.09	15.93	15.79	15.86	16.05	15.91	15.98
A ₃ B ₃	26.92	27.67	27.3	26.69	26.45	26.57	26.81	27.06	26.94
Mean	20.45	20.33		20.23	20.10		20.34	20.22	

		Year 2022		Year 2023		Pool data	
Factors		CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A		0.017	0.006	0.009	0.003	0.012	0.004
Factor B		0.017	0.006	0.009	0.003	0.012	0.004
Factor C		0.006	0.002	0.008	0.003	0.005	0.002
Interaction A X B		0.029	0.005	0.016	0.005	0.020	0.007
Interaction A X C		0.010	0.003	0.015	0.005	0.009	0.003
Interaction B X C		0.010	0.003	0.015	0.005	0.009	0.003
Interaction A X B X C		0.017	0.006	0.025	0.008	0.016	0.005
A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal		A ₃ B ₁	Post-cutting 5000 ppm IBA	
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal		A ₃ B ₂	Post-cutting 10000 ppm IBA	
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal		A ₃ B ₃	untreated	
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage		

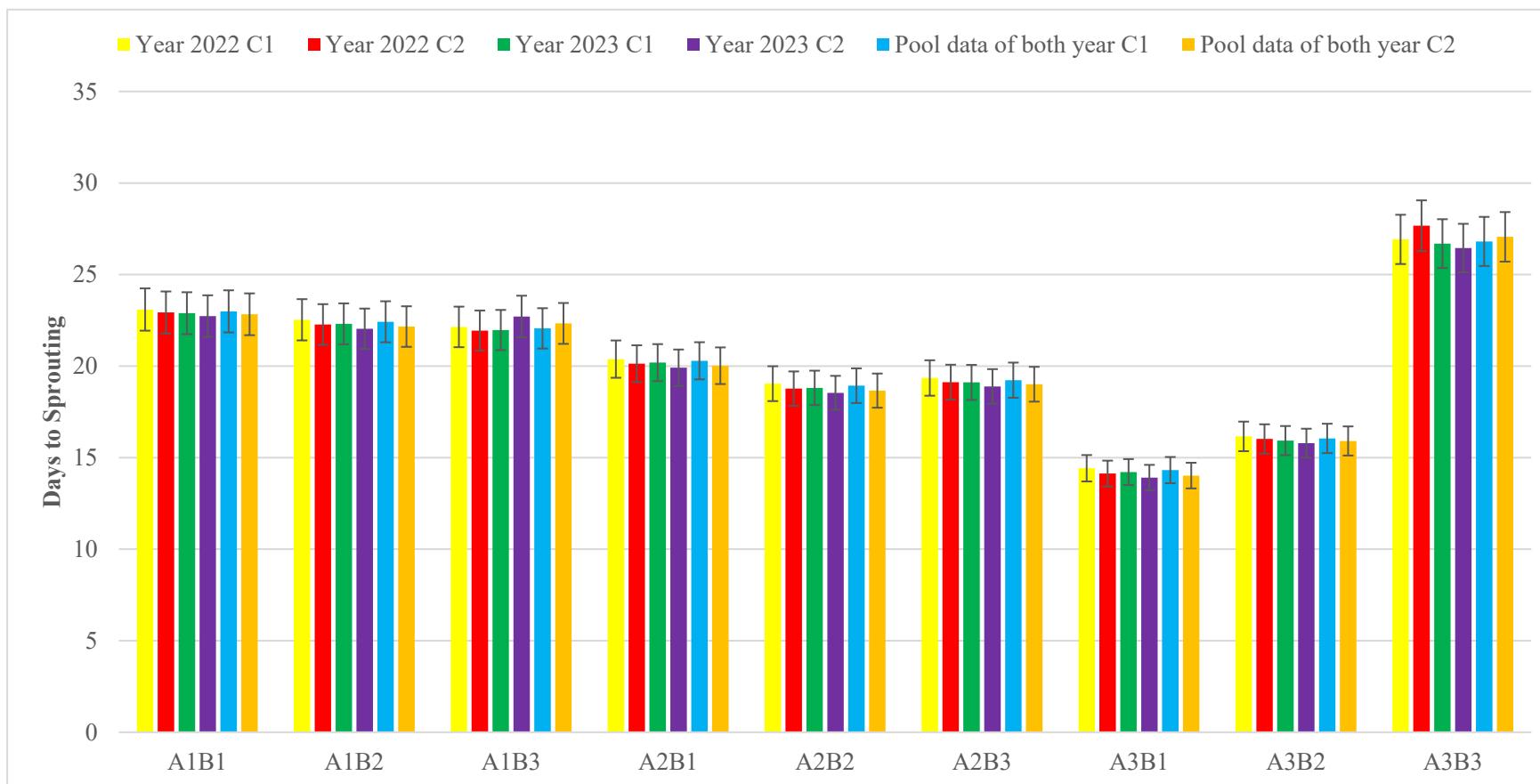


Figure 4.46 Graphical representation of the effect of Zinc (Zn) and IBA treatments on days to sprouting in guava cuttings at different days.

Table 4.47 Effect of zinc (Zn) and IBA treatments on sprouting percentage in guava cuttings taken at different days

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	65.10	69.71	67.41	68.98	71.76	70.37	67.04	70.74	68.89
A₁B₂	69.86	74.16	72.01	73.47	76.26	74.86	71.66	75.21	73.44
A₁B₃	71.92	75.84	73.88	75.42	77.87	76.65	73.67	76.86	75.26
A₂B₁	72.03	76.62	74.33	75.58	78.27	76.93	73.81	77.45	75.63
A₂B₂	79.71	83.18	81.45	79.98	83.63	81.81	79.85	83.41	81.63
A₂B₃	76.91	79.87	78.39	79.79	80.56	80.18	78.35	80.22	79.28
A₃B₁	93.71	96.40	95.06	94.26	97.07	95.67	93.99	94.83	94.41
A₃B₂	94.54	98.12	96.33	95.61	96.12	95.87	95.08	95.47	95.27
A₃B₃	45.46	48.72	47.09	47.63	50.82	49.22	46.54	49.77	48.16
Mean	76.80	80.35		79.14	81.71		77.97	81.03	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.076	0.025	0.042	0.014	0.003	0.001
Factor B	0.076	0.025	0.042	0.014	0.003	0.001
Factor C	0.077	0.026	0.007	0.002	0.011	0.004
Interaction A X B	0.132	0.044	0.074	0.025	0.005	0.002
Interaction A X C	0.133	0.045	0.012	0.004	0.019	0.006
Interaction B X C	0.133	0.045	0.012	0.004	0.019	0.006
Interaction A X B X C	0.231	0.077	0.021	0.007	0.033	0.011

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

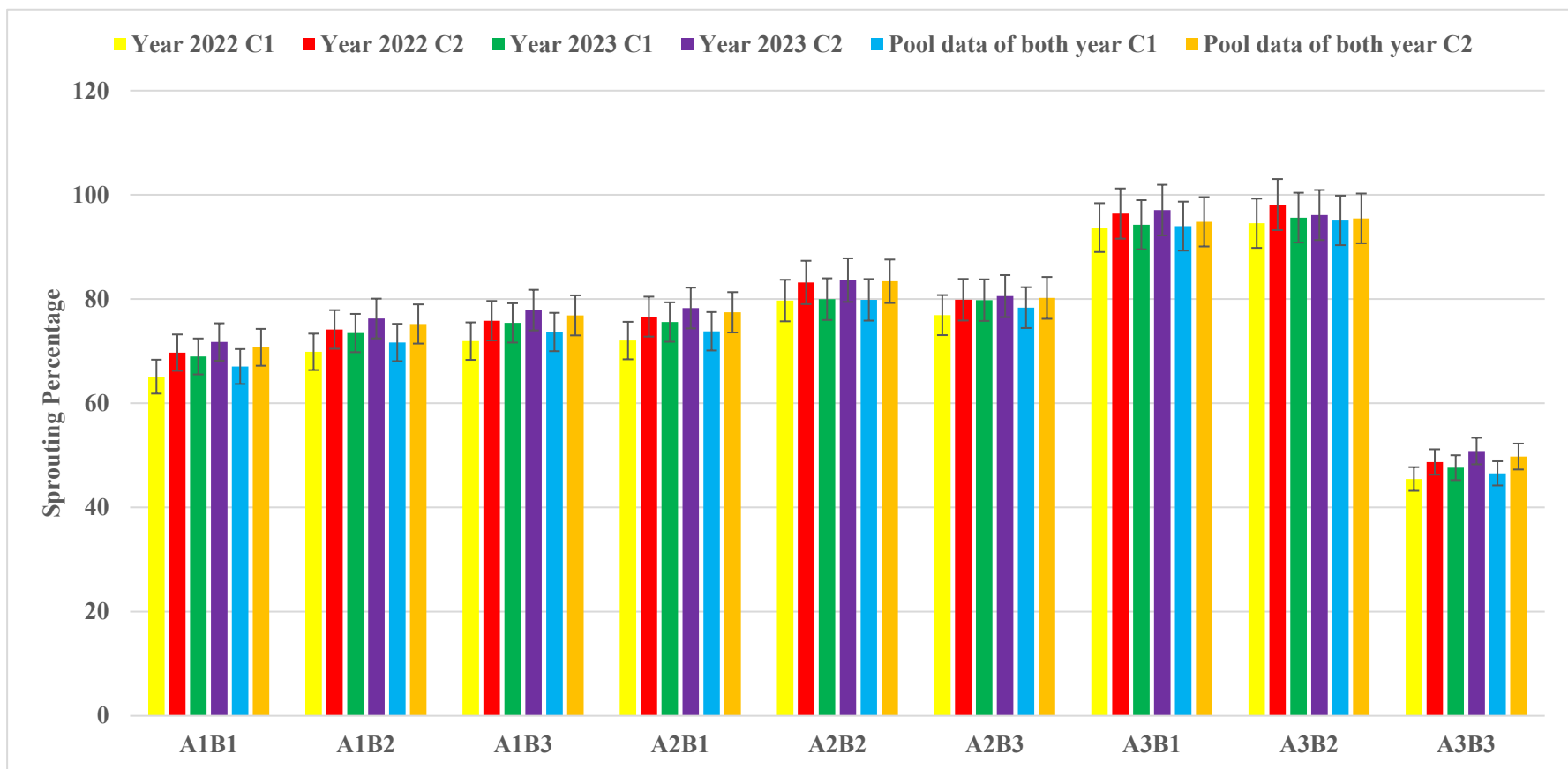


Figure 4.47 Graphical representation of the effect of Zinc (Zn) and IBA treatments on sprouting percentage in guava cuttings at different days.

4.2.16 Number of sprouts at 30 days

In both 2022 and 2023, the zinc foliar application significantly impacted the number of sprouts at both 30- and 60 days post-treatment. At 30 days, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts, with values of 2.18 g in 2022 and 2.28 in 2023, while A₁B₁ (0.25%) showed minimum values, 1.67 in 2022 and 1.81 in 2023 (Table 4.48, Figure 4.48).

Similarly, for zinc basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum number of sprouts at 30 days, with values of 2.86 in 2022 and 2.96 in 2023, while A₂B₁ (50 g/tree) had the minimum, 2.41 in 2022 and 2.53 in 2023. Among the IBA post cutting treatments, the 5000-ppm concentration yielded the maximum number of sprouts at 30 days, with 3.45 in 2022 and 3.43 in 2023, whereas the control group consistently had the minimum number of sprouts (1.04 in 2022 and 1.06 in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ continued to have the maximum number of sprouts (2.25 in 2022 and 2.31 in 2023), while A₁B₁ had the minimum (1.73 in 2022 and 1.81 in 2023). For zinc basal treatments, A₂B₂ had the highest dry weight (2.91 in 2022 and 2.96 in 2023), while A₂B₁ had the lowest (2.44 in 2022 and 2.58 in 2023). The 5000-ppm IBA treatment showed the maximum number of sprouts at 60 days, with 3.63 in 2022 and 3.85 in 2023, with the control group remaining the minimum (1.14 in 2022 and 1.32 in 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ consistently recorded the maximum number of sprouts at 2.23, with A₁B₁ the minimum at 1.74. A₂B₂ showed the maximum number of sprouts at 2.91, and ZB1 had the minimum at 2.47. The 5000-ppm IBA treatment consistently had the maximum number of sprouts at 3.64, while the control group had the minimum at 1.05. At 60 days, A₁B₃ had the highest dry weight at 2.28, while A₁B₁ had the lowest at 1.77. A₂B₂ was the best performer among zinc basal treatments at 2.95, and ZB1 had the lowest dry weight at 2.52. The 5000-ppm IBA post cutting treatment maintained the maximum pooled number of sprouts at 3.74, and the control group maintained the minimum at 1.23.

Table 4.48 Effect of zinc (Zn) and IBA treatments on number of sprouts at 30 days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.67	1.73	1.7	1.81	1.81	1.81	1.74	1.77	1.76
A₁B₂	1.95	1.99	1.97	2.09	2.15	2.12	2.02	2.07	2.05
A₁B₃	2.18	2.25	2.22	2.28	2.31	2.3	2.23	2.28	2.25
A₂B₁	2.41	2.44	2.43	2.53	2.58	2.56	2.47	2.52	2.5
A₂B₂	2.86	2.91	2.89	2.96	2.99	2.98	2.91	2.95	2.93
A₂B₃	2.63	2.66	2.65	2.77	2.82	2.8	2.7	2.75	2.72
A₃B₁	3.45	3.63	3.54	3.83	3.85	3.84	3.64	3.74	3.69
A₃B₂	3.13	3.26	3.2	3.59	3.7	3.65	3.36	3.48	3.42
A₃B₃	1.04	1.14	1.09	1.06	1.32	1.19	1.05	1.23	1.14
Mean	2.37	2.45		2.55	2.62		2.46	2.53	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.01	0.003	0.012	0.004	0.01	0.003
Factor B	0.01	0.003	0.012	0.004	0.01	0.003
Factor C	0.007	0.002	0.008	0.003	0.009	0.003
Interaction A X B	0.018	0.006	0.021	0.007	0.018	0.006
Interaction A X C	0.011	0.004	0.014	0.005	0.015	0.005
Interaction B X C	0.011	0.004	0.014	0.005	0.015	0.005
Interaction A X B X C	0.02	0.007	0.023	0.008	0.026	0.009

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

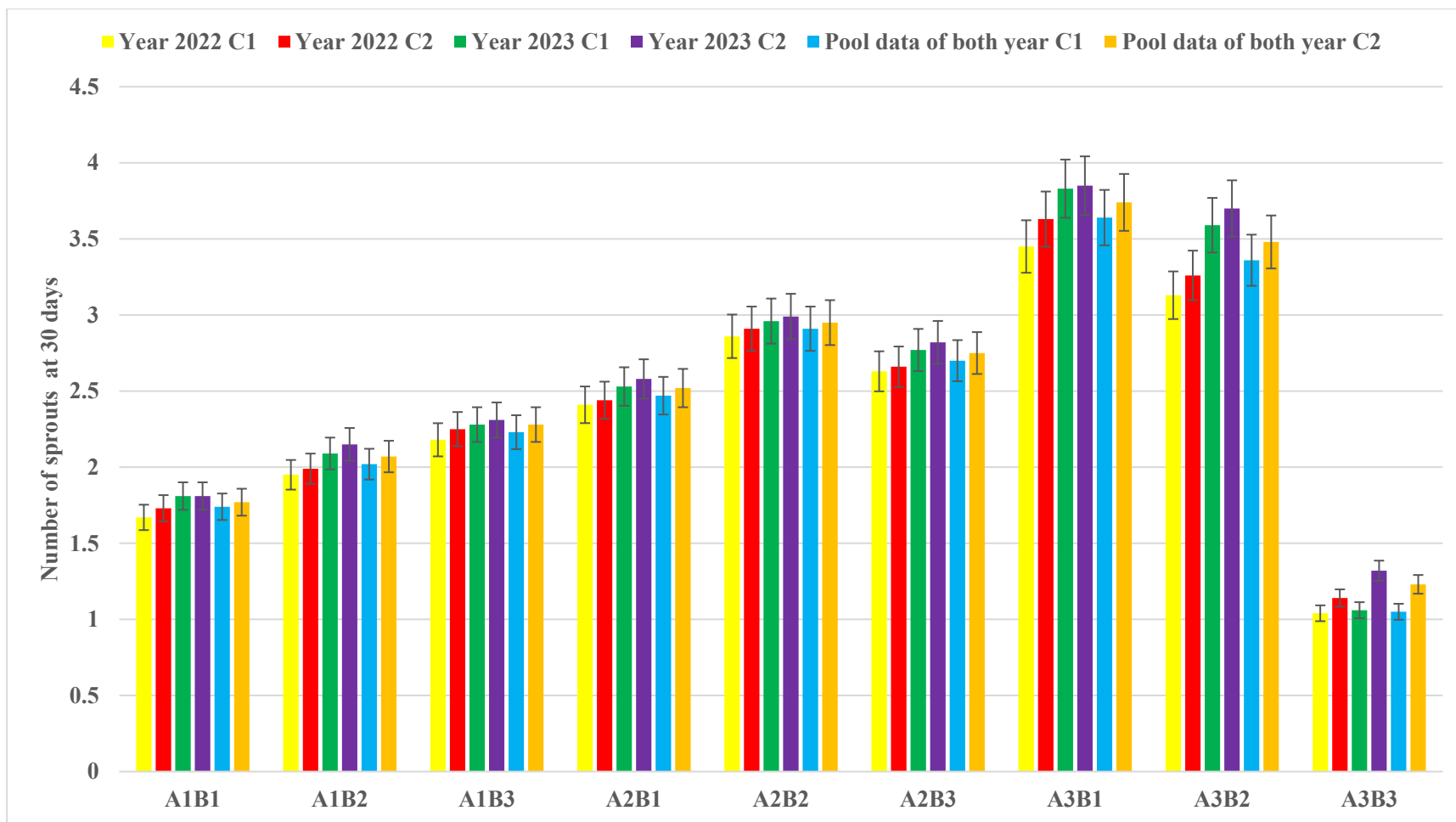


Figure 4.48 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts at 30 days in guava cuttings

Table 4.49 Effect of zinc (Zn) and IBA treatments on Number of sprouts at 60 days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	3.05	3.14	3.1	3.19	3.32	3.26	3.12	3.23	3.18
A ₁ B ₂	3.42	3.48	3.45	3.66	3.66	3.66	3.54	3.57	1.56
A ₁ B ₃	3.58	3.64	3.61	3.84	3.88	3.86	3.71	3.76	3.74
A ₂ B ₁	3.77	3.81	3.79	4.01	4.07	4.04	3.89	3.94	3.92
A ₂ B ₂	4.14	4.17	4.16	4.32	4.47	4.4	4.23	4.32	4.28
A ₂ B ₃	3.96	4.03	4	4.2	4.19	4.2	4.08	4.11	4.1
A ₃ B ₁	4.69	4.75	4.72	4.97	5.13	5.05	4.83	4.94	4.89
A ₃ B ₂	4.43	4.46	4.45	4.75	4.88	4.82	4.59	4.67	4.63
A ₃ B ₃	1.29	1.42	1.36	1.43	1.54	1.49	1.36	1.48	1.42
Mean	3.59	3.66		3.82	3.9		3.71	3.78	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.01	0.003	0.01	0.003	0.008	0.003
Factor B	0.01	0.003	0.01	0.003	0.008	0.003
Factor C	0.006	0.002	0.005	0.002	0.008	0.003
Interaction A X B	0.017	0.006	0.017	0.006	0.013	0.004
Interaction A X C	0.011	0.004	0.009	0.003	0.013	0.004
Interaction B X C	0.011	0.004	0.009	0.003	0.013	0.004
Interaction A X B X C	0.019	0.006	0.015	0.005	0.023	0.008

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

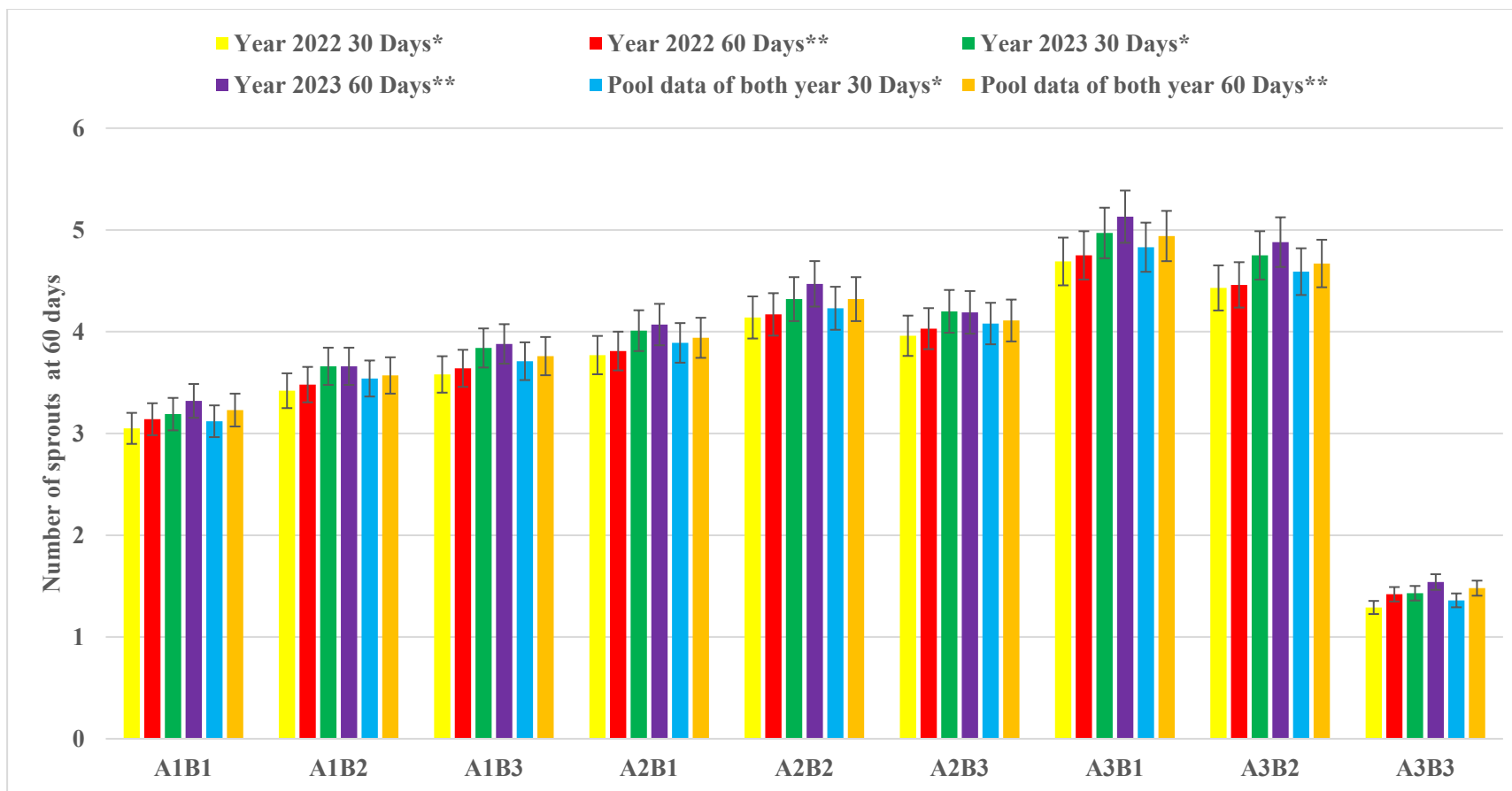


Figure 4.49 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts in guava cuttings at different days.

4.2.17 Number of sprouts at 60 days

In 2022, zinc foliar application had a significant impact on the highest number of sprouts. At 30 days after pre-cutting treatment, the highest number of sprouts were observed in treatment A₁B₃ (0.75%) at 3.58, while the lowest were in treatment A₁B₁ (0.25%) at 3.05, indicating a significant difference among the various levels of zinc foliar application (Table 4.49, Figure 4.49). Among the zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) produced the highest number of sprouts at 4.14, with A₂B₁ (50 g/tree) having the lowest at 3.77. For IBA post-cutting treatments, the 5000-ppm concentration led to the highest number of sprouts at 4.69, while the control group showed the lowest at 1.29.

At 60 days after pre-cutting treatment in 2022, the highest number of sprouts was recorded in treatment A₁B₃ (0.75%) at 3.64, and the lowest in treatment A₁B₁ (0.25%) at 3.14, showing significant differences among the zinc basal treatments. A₂B₂ (75 g/tree) again had the highest number of sprouts at 4.17, with A₂B₁ (50 g/tree) having the lowest at 3.81. For IBA post cutting treatments, the 5000-ppm concentration showed the highest number of sprouts at 4.75, and the control group had the lowest at 1.42.

In 2023, zinc foliar application continued to significantly influence the highest number of sprouts. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) recorded the highest number of sprouts at 3.84, while A₁B₁ (0.25%) had the lowest at 3.19. Among the zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) had the highest number of sprouts at 4.32, with A₂B₁ (50 g/tree) having the shortest at 4.01. The 5000-ppm IBA post-cutting treatment resulted in the highest number of sprouts at 4.97, while the control group had the lowest at 1.43 (Table 4.49, Figure 4.49).

At 60 days after treatment in 2023, the highest number of sprouts was recorded in treatment A₁B₃ (0.75%) at 3.88, and the lowest in treatment A₁B₁ (0.25%) at 3.32. Among the zinc basal treatments, A₂B₂ (75 g/tree) had the highest number of sprouts at 4.47 cm, with A₂B₁ (50 g/tree) having the lowest at 4.07 cm. The 5000-ppm IBA concentration post-cutting treatment showed the highest number of sprouts at 5.13 cm, while the control group had the shortest at 1.54. (Table 4.49, Figure 4.49).

When analyzing pooled data for both years, the highest number of sprouts at 90 days was recorded in treatment A₁B₃ (0.75%) at 3.71, while the lowest was in treatment A₁B₁ (0.25%) at 3.12, demonstrating consistent results (Table 4.49, Figure 4.49). Among the zinc basal treatments, A₂B₂ (75 g/tree) had the highest number of sprouts at 4.23, and A₂B₁ (50 g/tree) had the lowest at 3.89. The 5000 ppm IBA post-cutting treatment consistently showed the highest number of sprouts with a mean value of 4.83, and the control group had the lowest at 1.36. (Table 4.49, Figure 4.49).

At 60 days, the pooled data indicated that treatment A₁B₃ (0.75%) had the number of sprouts at 3.76, while A₁B₁ (0.25%) had the minimum at 3.23. For zinc basal treatments, A₂B₂ (75 g/tree) (4.32) consistently had the maximum number of sprouts, while A₂B₁ (50 g/tree) (3.94) had the minimum number of sprouts. The 5000 ppm IBA post-cutting treatment maintained the maximum number of sprouts with a pooled mean value of 4.94, and the control group had the shortest at 1.48

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of sprouts in guava cuttings. Cuttings collected after 60 days produced a higher number of sprouts (3.78) compared to those collected after 30 days (3.71). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the number of sprouts. The maximum number of sprouts (4.89) at 60 days was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA. At 30 days, the number of sprouts was also influenced by these factors, with A₃B₁C₂ showing a notable improvement.

4.2.18 Number of sprouts at 90 days

In both 2022 and 2023, the zinc foliar application significantly impacted the number of sprouts at both 30- and 60 days after pre-cutting treatment. At 30 days, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts, with values of 5.57 in 2022 and 5.85 in 2023, while A₁B₁ (0.25%) showed minimum values, of 5.19 in 2022 and 5.53 in 2023 (Table 4.50, Figure 4.50).

Similarly, for zinc basal pre-cutting treatments, A₁B₃ (75 g/tree) consistently showed the maximum number of sprouts at 30 days, with values of 6.22 in 2022 and 6.45 in

2023, while A₂B₁ (50 g/tree) had the minimum, 5.69 in 2022 and 5.96 in 2023. Among the IBA post-cutting treatments, the 5000-ppm concentration yielded the maximum number of sprouts 7.31 in 2022 and 7.69 in 2023, whereas the control group consistently had the minimum number of sprouts (2.32 in 2022 and 2.64 in 2023). At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum number of sprouts (5.63 in 2022 and 5.91 in 2023), while A₁B₁ (0.25%) had the minimum (5.24 in 2022 and 5.58 in 2023). For zinc basal treatments, A₂B₂ (75 g/tree) had the highest dry weight (6.36 in 2022 and 6.52 in 2023), while A₂B₁ (50 g/tree) had the lowest (5.77 in 2022 and 6.05 in 2023). The 5000-ppm IBA post-cutting treatment showed the maximum number of sprouts at 60 days, with 7.49 in 2022 and 7.81 in 2023, with the control group remaining the minimum (2.42 in 2022 and 2.80 in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum number of sprouts at 5.71, with A₁B₁ (0.25%) the minimum at 5.36 (Table 4.50). A₂B₂ (75 g/tree) showed the maximum number of sprouts at 6.26, and A₂B₁ (50 g/tree) had the minimum at 5.83. The 5000-ppm IBA post-cutting treatment consistently had the maximum number of sprouts at 7.50, while the control group had the minimum at 2.48. At 60 days after pre-cutting, A₁B₃ (0.75%) had the maximum number of sprouts at 5.77, while A₁B₁ (0.25%) had the minimum at 5.41. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments at 6.44, and A₂B₁ (50 g/tree) had the minimum number of sprouts at 5.91. The 5000-ppm IBA post-cutting treatment maintained the maximum pooled number of sprouts at 7.65, and the control group maintained the minimum at 2.61.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of sprouts at 90 days in guava cuttings. Cuttings collected after 60 days produced more sprouts (5.82) compared to those collected after 30 days (5.72). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the number of sprouts. The highest number of sprouts (7.57) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Table 4.50 Effect of zinc (Zn) and IBA treatments on number of sprouts at 90 days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	5.19	5.24	5.22	5.53	5.58	5.56	5.36	5.41	5.39
A ₁ B ₂	5.38	5.41	5.4	5.68	5.74	5.71	5.53	5.57	5.55
A ₁ B ₃	5.57	5.63	5.6	5.85	5.91	5.88	5.71	5.77	5.74
A ₂ B ₁	5.69	5.77	5.73	5.96	6.05	6.01	5.83	5.91	5.87
A ₂ B ₂	6.22	6.36	6.29	6.45	6.52	6.49	6.26	6.44	6.35
A ₂ B ₃	5.83	5.96	5.9	5.9	6.12	6.01	5.9	6.04	5.97
A ₃ B ₁	7.31	7.49	7.4	7.69	7.81	7.75	7.5	7.65	7.57
A ₃ B ₂	6.75	7.08	6.92	7.11	7.34	7.23	6.93	7.21	7.07
A ₃ B ₃	2.32	2.42	2.37	2.64	2.8	2.72	2.48	2.61	2.55
Mean	5.58	5.71		5.87	5.99		5.72	5.85	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.009	0.003	0.011	0.004
Factor B	0.009	0.003	0.009	0.003	0.011	0.004
Factor C	0.007	0.002	0.008	0.003	0.009	0.003
Interaction A X B	0.016	0.005	0.016	0.005	0.019	0.006
Interaction A X C	0.012	0.004	0.013	0.004	0.015	0.005
Interaction B X C	0.012	0.004	0.013	0.004	0.015	0.005
Interaction A X B X C	0.022	0.007	0.023	0.008	0.027	0.009

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

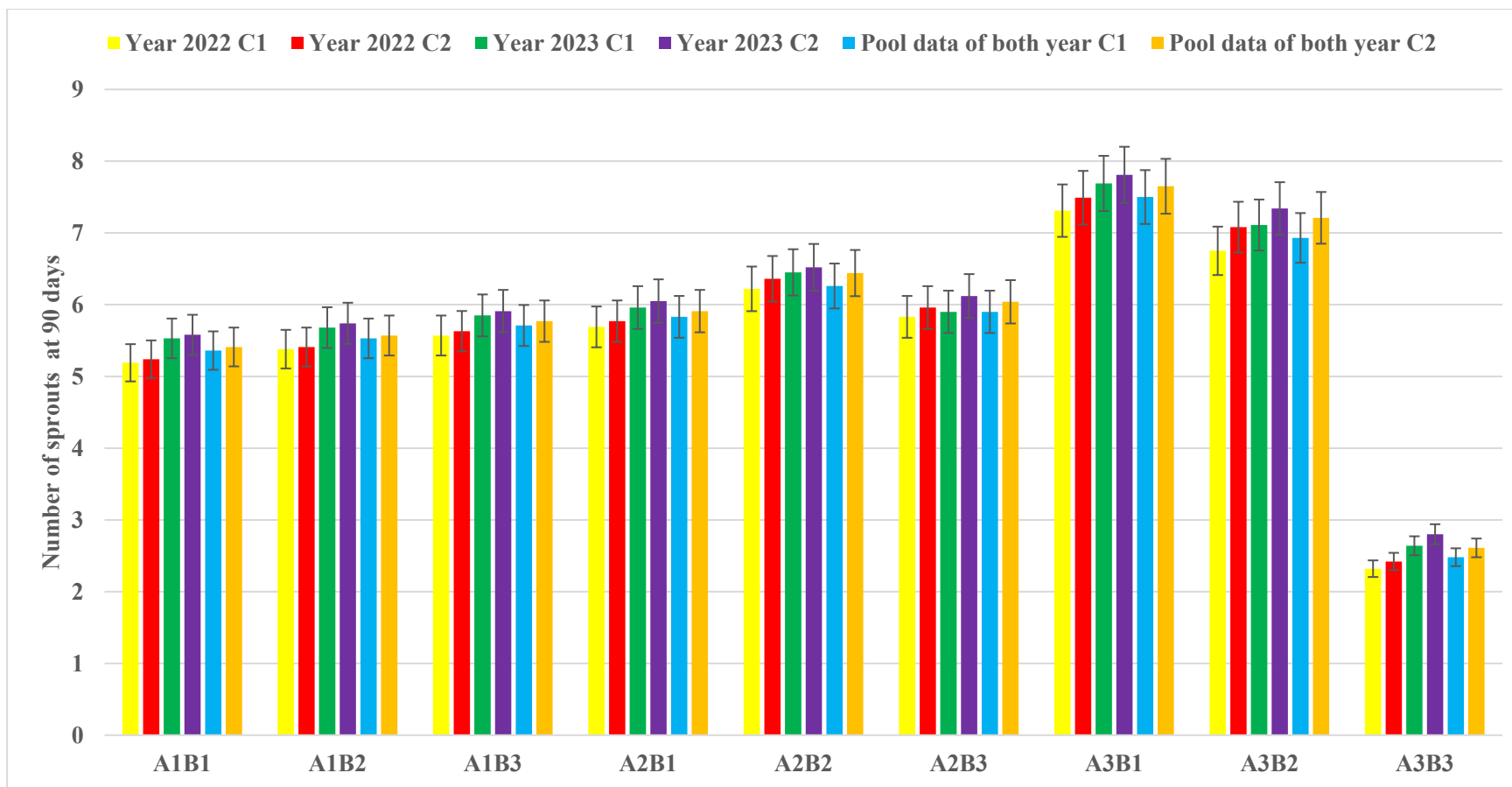


Figure 4.50 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of sprouts at 90 days in guava cuttings at different days.

4.2.19 Diameter of sprouts (mm)

In both 2022 and 2023, zinc foliar application significantly impacted the diameter of sprouts at both 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum diameter of sprouts, with values of 0.84 mm in 2022 and 1.05 mm in 2023, while A₁B₁ (0.25%) showed the lowest values, 0.24 mm in 2022 and 0.42 mm in 2023 (Table 4.51, Figure 4.51).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently had the maximum diameter of sprouts at 30 days, with values of 1.92 mm in 2022 and 2.07 mm in 2023, whereas A₂B₁ (50 g/tree) had the lowest, 1.23 mm in 2022 and 1.29 mm in 2023. For post-cutting treatment with IBA, 5000-ppm concentration yielded the maximum number of sprouts at 30 days, with 2.64 in 2022 and 2.88 mm in 2023, while the control group consistently had the minimum number of sprouts (0.06 mm in 2022 and 0.12 mm in 2023).

At 60 days post-treatment, the trends remained consistent. A₁B₃ continued to have the maximum diameter of sprouts (0.93 mm in 2022 and 1.05 mm in 2023), while A₁B₁ had the lowest (0.30 in 2022 and 0.51 in 2023). For zinc basal treatments, A₂B₂ had the highest number of sprouts (1.98 in 2022 and 2.13 in 2023), while A₂B₁ had the lowest (1.23 in 2022 and 1.32 in 2023). For post-cutting treatment with IBA, 5000-ppm concentration showed the maximum number of sprouts at 60 days, with 2.97 in 2022 and 2.97 in 2023, while the control group remained the lowest (0.06 in 2022 and 0.12 in 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ consistently recorded the maximum diameter of sprouts at 0.96, with A₁B₁ the lowest at 0.33 (Table 4.51). A₂B₂ showed the maximum diameter of sprouts at 2.01, and A₂B₁ had the lowest at 1.26. For post-cutting treatment with IBA, 5000-ppm concentration consistently had the maximum diameter of sprouts at 2.76, while the control group had the lowest at 0.09. At 60 days, A₁B₃ had the highest number of sprouts at 0.99, while A₁B₁ had the lowest at 0.42. A₂B₂ was the best performer among zinc basal treatments with 2.07, and A₂B₁ had the lowest at 1.29. For post-cutting treatment with

IBA, 5000-ppm concentration maintained the highest pooled maximum diameter of sprouts at 2.97 mm, and the control group remained the lowest at 0.09mm.

These findings underscore the critical role of zinc supplementation in promoting shoot vigor and overall plant health. Specifically, the basal application of zinc at 75 g/tree (ZB2) resulted in a significant increase in both the number of sprouts and their diameter, indicating more robust shoot development. This improvement can be attributed to zinc's essential role in enhancing cellular processes and structural integrity (Alloway, 2008). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Yamashita *et al.* (2006) in mango.

4.2.19 Length of sprout

In 2022, zinc foliar applications significantly impacted the length of sprouts. At 30 days post-treatment, the shortest sprouts were observed in treatment A₁B₃ (0.75%) at 6.05 cm, while the longest were in treatment A₁B₁ (0.25%) at 6.52 cm, reflecting substantial differences among the treatments (Table 4.52, Figure 4.52). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the shortest sprouts at 5.58 cm, while A₂B₁ (50 g/tree) recorded the longest at 5.91 cm. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the shortest sprouts at 4.11 cm, with the control group showing the longest at 8.72 cm. At 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) still had the shortest sprouts at 5.90 cm, while A₁B₁ (0.25%) had the shortest at 6.45 cm. Zinc basal treatments showed A₂B₂ (75 g/tree) with the longest sprouts at 5.53 cm, and A₂B₁ (50 g/tree) the shortest at 5.85 cm. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the longest sprouts of 4.41 cm, while the control group had the shortest at 8.79 cm.

In 2023, similar trends were observed. At 30 days post-treatment, A₁B₃ (0.75%) had the shortest sprouts at 5.77 cm, while A₁B₁ (0.25%) had the longest at 6.36 cm. Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the shortest sprouts at 5.24 cm, while A₂B₁ (50 g/tree) had the longest at 5.63 cm. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the shortest sprouts at 4.29 cm, with the control group having the longest at 8.32 cm.

Table 4.51 Effect of zinc (Zn) and IBA treatments on diameter of sprout (mm) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.24	0.3	0.27	0.42	0.51	0.48	0.33	0.42	0.39
A₁B₂	0.51	0.66	0.6	0.69	0.69	0.69	0.6	0.69	0.66
A₁B₃	0.84	0.93	0.9	1.05	1.05	1.05	0.96	0.99	0.99
A₂B₁	1.23	1.23	1.23	1.29	1.32	1.32	1.26	1.29	1.29
A₂B₂	1.92	1.98	1.95	2.07	2.13	2.1	2.01	2.07	2.04
A₂B₃	1.56	1.62	1.59	1.68	1.71	1.71	1.62	1.68	1.65
A₃B₁	2.64	2.97	2.82	2.88	2.97	2.94	2.76	2.97	2.88
A₃B₂	2.37	2.46	2.43	2.52	2.67	2.61	2.46	2.58	2.52
A₃B₃	0.06	0.06	0.06	0.12	0.12	0.12	0.09	0.09	0.09
Mean	1.26	1.35		1.41	1.47		1.35	1.41	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.009	0.003	0.013	0.004
Factor B	0.008	0.003	0.009	0.003	0.013	0.004
Factor C	0.008	0.003	0.005	0.002	0.005	0.002
Interaction A X B	0.014	0.005	0.015	0.005	0.023	0.008
Interaction A X C	0.013	0.004	0.009	0.003	0.009	0.003
Interaction B X C	0.013	0.004	0.009	0.003	0.009	0.003
Interaction A X B X C	0.023	0.008	0.016	0.005	0.016	0.005

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

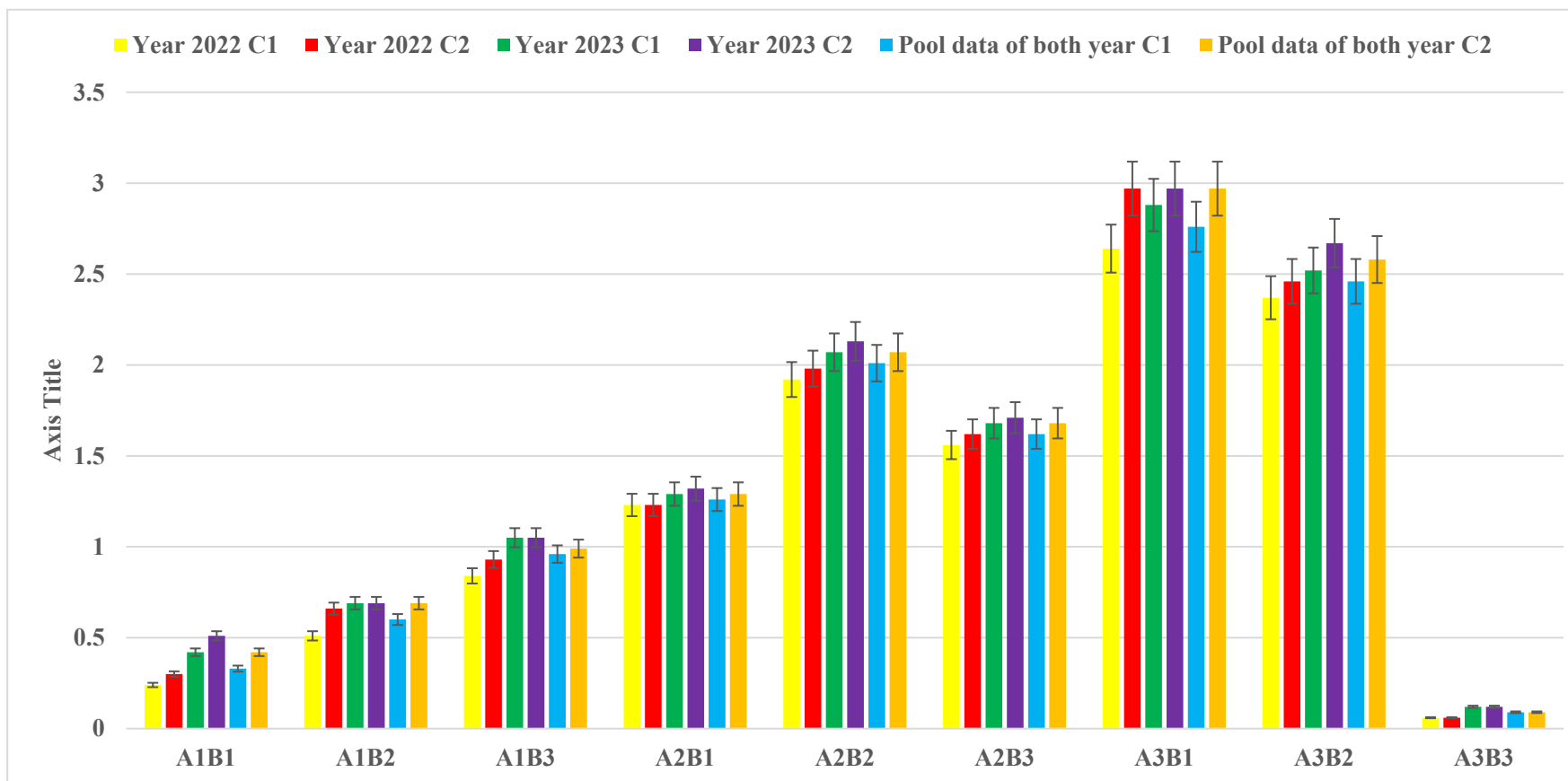


Figure 4.51 - Graphical representation of the effect of Zinc (Zn) and IBA treatments on the diameter of sprouts (mm) in guava cuttings at different days.

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) continued to exhibit the shortest sprouts at 5.69 cm, while A₁B₃ (0.25%) had the longest at 6.22 cm. Zinc basal as pre-cutting treatments had A₂B₂ (75 g/tree) with the longest sprouts at 5.19 cm, and A₂B₁ (50 g/tree) the shortest at 5.57 cm. For post-cutting treatment with IBA, 5000-ppm concentration consistently showed the shortest sprouts at 4.31 cm, with the control group having the shortest at 8.42 cm.

Pooling data from both years, the results remained consistent. At 30 days post-treatment, A₁B₃ (0.75%) consistently had the shortest sprouts at 5.91 cm, while A₁B₁ (0.25%) had the shortest at 5.44 cm (Table 4.52, Figure 4.52). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the shortest sprouts at 5.41 cm, and A₂B₁ (50 g/tree) had the longest at 5.77 cm. For post-cutting treatment with IBA, 5000-ppm concentration consistently resulted in the shortest sprouts with an average of 4.25 cm, while the control group had the longest at 8.61 cm.

At 60 days, pooled data indicated that A₁B₃ (0.75%) resulted in the shortest sprouts at 5.83 cm, while A₁B₁ (0.25%) had the longest at 5.41 cm. Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) as the best performer at 5.36 cm, while A₂B₁ (50 g/tree) had the longest sprouts at 5.71 cm. For post-cutting treatment with IBA, 5000-ppm concentration maintained its lead with an average sprout length of 4.21 cm, and the control group had the shortest at 8.57 cm.

4.2.20 Diameter of Shoots (mm)

In both 2022 and 2023, zinc foliar application significantly impacted the diameter of shoots at both 30- and 60 days post-treatment. At 30 days after pre-cutting, A₁B₃ (0.75%) consistently recorded the maximum change in shoot diameter, with values increasing to 8.13 mm in 2022 and 8.59 mm in 2023, while A₁B₁ (0.25%) showed the minimum change, reaching 7.49 mm in 2022 and 7.82 mm in 2023. Similarly, for zinc basal treatments, A₂B₃ (100 g/tree) consistently showed the maximum change in shoot diameter, with values increasing to 9.44 in 2022 and 9.80 cm in 2023, while A₂B₁ (50 g/tree) had the lowest change, reaching 8.37 in 2022 and 8.77 in 2023. Among the IBA treatments, the 5000-ppm concentration yielded the maximum change in shoot

diameter of 16.08 mm in 2022 and 16.45 mm in 2023, whereas the control group consistently had the lowest change in shoot diameter (5.11 mm in 2022 and 5.67 mm in 2023).

At 60 days post-treatment, the trends remained consistent. A₁B₃ continued to have the maximum change in shoot diameter (1.30 mm in 2022 and 1.45 mm in 2023), while A₁B₁ had the lowest change (1.05 mm in 2022 and 1.12 mm in 2023). For zinc basal treatments, A₂B₃ had the maximum change in shoot diameter (9.33 mm in 2022 and 10.36 mm in 2023), while A₂B₁ had the lowest change (8.37 mm in 2022 and 8.99 mm in 2023). The 5000 ppm IBA post-cutting treatment showed the maximum change in shoot diameter at 1.85 mm in 2022 and 2.00 mm in 2023, with the control group remaining the lowest (0.0.65 mm 2022 and 0.0.78 mm 2023).

Pooled data from both years reinforced these trends. At 30 days, A₁B₃ consistently recorded the maximum change in shoot diameter at 1.28 mm, with A₁B₁ showing the lowest change at 0.98 mm (Table 10). A₂B₃ showed the maximum pooled change in shoot diameter at 1.50 mm, and A₂B₁ had the lowest change at 1.15 mm. The 5000 ppm IBA post-cutting treatment consistently had the maximum change in shoot diameter at 1.83 mm, while the control group had the minimum at 0.76 cm. At 60 days after pre-cutting treatment, A₁B₃ had the maximum change in shoot diameter at 8.46 mm, while A₁B₁ had the lowest at 7.67 mm. A₂B₂ was the best performer among zinc basal treatments at 9.85 mm, and A₁B₁ had the minimum change in shoot diameter at 8.69 mm. The 5000 ppm IBA treatment maintained the maximum pooled change in shoot diameter at 16.78 mm, and the control group remained the lowest at 5.51 mm.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the shoot diameter of guava cuttings. Cuttings collected after 60 days exhibited a greater shoot diameter (9.95 mm) compared to those collected after 30 days (9.79 mm). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the shoot diameter. The maximum shoot diameter (16.53 mm) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

These results highlight the importance of zinc in promoting shoot growth. The length of sprouts and the overall shoot diameter are crucial parameters that determine the growth potential and structural stability of the plant. The study found that basal zinc application at 100 g/tree (ZB3) resulted in the longest sprouts and the thickest shoot diameters. This enhancement in shoot length and diameter underscores zinc's role in promoting cell elongation and division, which are crucial for shoot growth (Marschner, 2012). The present findings are fully supported by the results of Alizadeh and Dumanoglu (2022) in olive and by Yamashita et al. (2006) in mango.

4.2.21 Fresh weight of shoot (g)

In both 2022 and 2023, zinc foliar application significantly influenced the fresh weight of shoots at both 30- and 60-days post-treatment. At 30 days, treatment A₁B₃ (0.75%) consistently exhibited the maximum fresh weight of shoots, with values of 2.55 g in 2022 and 2.81 g in 2023, while A₁B₁ (0.25%) showed minimum values, of 2.09 g in 2022 and 2.43 g in 2023. Similarly, among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently demonstrated the maximum fresh weight of shoots, with values of 3.37 g in 2022 and 3.53 g in 2023, while A₂B₁ (50 g/tree) had the minimum, 2.84 g in 2022 and 3.10 g in 2023. For post-cutting treatment with IBA, 5000-ppm concentration consistently yielded the highest fresh weight of shoots at 3.96 g in 2022 and 4.25 g in 2023, whereas the control group consistently showed the lowest fresh weight (1.83 g in 2022 and 2.21 g in 2023). At 60 days post-treatment, similar trends persisted. A₁B₃ (0.75%) maintained the maximum fresh weight of shoots (2.55 g in 2022 and 2.83 g in 2023), while A₁B₁ (0.25%) had the minimum (2.14 g in 2022 and 2.43 g in 2023). Among the various levels of zinc basal treatments, A₂B₂ (75 g/tree) again showed the highest fresh weight (3.31 g in 2022 and 3.55 g in 2023), whereas A₂B₁ (50 g/tree) had the lowest (2.85 g in 2022 and 3.09 g in 2023). For post-cutting treatment with IBA, 5000-ppm concentration exhibited the highest fresh weight of shoots at 3.96 g in 2022 and 4.28 g in 2023, with the control group maintaining the lowest (1.89 g in 2022 and 2.32 g in 2023). (Table 4.54, Figure 4.54).

Pooling data from both years reaffirmed these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum fresh weight of shoots at

2.68 g, with A₁B₁ (0.25%) recording the minimum at 2.26 g (Table 4.55, Figure 4.55). A₂B₂ (75 g/tree) demonstrated the highest pooled fresh weight at 3.42 g, whereas A₂B₁ (50 g/tree) had the lowest at 2.97g. For post-cutting treatment with IBA, 5000-ppm concentration consistently showed the highest fresh weight of shoots at 4.11 g, while the control group had the lowest at 2.02 g. At 60 days, A₁B₃ (0.75%) maintained the maximum fresh weight at 2.69 g, while A₁B₁ (0.25%) had the minimum at 2.29 g. Among zinc basal treatments, A₂B₂ (75 g/tree) continued to perform the best with 3.43 g, whereas A₂B₁ (50 g/tree) had the minimum fresh weight at 2.97 g. For post-cutting treatment with IBA, 5000-ppm concentration also maintained the highest pooled fresh weight at 4.12 g, with the control group remaining at a minimum of 2.11.

The fresh weight of shoots in guava cuttings was significantly influenced by the timing of pre-cutting zinc treatments and the dormant stage. Cuttings collected 60 days after treatment produced higher fresh shoot weight (3.02 g) compared to those collected after 30 days (3.01 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were also significant. The highest fresh shoot weight (4.12 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and treated with 5000 ppm IBA.

4.2.22 Dry weight of shoot (g)

In both 2022 and 2023, zinc foliar application had a significant impact on the maximum dry weight of shoots at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting, A₁B₃ (0.75%) consistently recorded the maximum dry weight, with values of 1.01 g in 2022 and 1.18 g in 2023, while A₁B₁ (0.25) showed minimum values, of 0.77 g in 2022 and 0.83 g in 2023 (Table 4.55, figure 4.55). Similarly, for various levels of zinc after pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the maximum dry weight, with values of 1.44 g in 2022 and 1.66g in 2023, while A₂B₁ (50 g/tree) had minimum, 1.13 g in 2022 and 1.34 g in 2023. For post-cutting treatment with IBA, 5000-ppm concentration yielded the maximum dry weight of shoots at 1.86 g in 2022 and 1.98 g in 2023, whereas the control group consistently had the minimum dry weight (0.61 g in 2022 and 0.76 g in 2023).

Table 4.52 Effect of zinc (Zn) and IBA treatments on length of sprout at days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	6.52	6.45	6.49	6.36	6.22	6.29	6.44	6.26	6.35
A ₁ B ₂	6.12	5.9	6.01	5.96	5.83	5.9	6.04	5.9	5.97
A ₁ B ₃	6.05	5.96	6.01	5.77	5.69	5.73	5.91	5.83	5.87
A ₂ B ₁	5.91	5.85	5.88	5.63	5.57	5.6	5.77	5.71	5.74
A ₂ B ₂	5.58	5.53	5.56	5.24	5.19	5.22	5.41	5.36	5.39
A ₂ B ₃	5.74	5.68	5.71	5.41	5.38	5.4	5.57	5.53	5.55
A ₃ B ₁	4.11	4.19	4.15	4.29	4.31	4.3	4.21	4.25	4.23
A ₃ B ₂	4.34	4.41	4.38	4.38	4.75	4.57	4.36	4.58	4.47
A ₃ B ₃	8.72	8.79	8.76	8.32	8.42	8.37	8.57	8.61	8.59
Mean	5.89	5.86		5.71	5.71		5.78	5.81	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.011	0.004	0.009	0.003	0.004	0.001
Factor B	0.011	0.004	0.009	0.003	0.004	0.001
Factor C	0.011	0.004	0.007	0.002	0.006	0.002
Interaction A X B	0.019	0.006	0.015	0.005	0.007	0.002
Interaction A X C	0.019	0.006	0.011	0.004	0.010	0.003
Interaction B X C	0.019	0.006	0.011	0.004	0.010	0.003
Interaction A X B X C	0.033	0.011	0.019	0.007	0.018	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

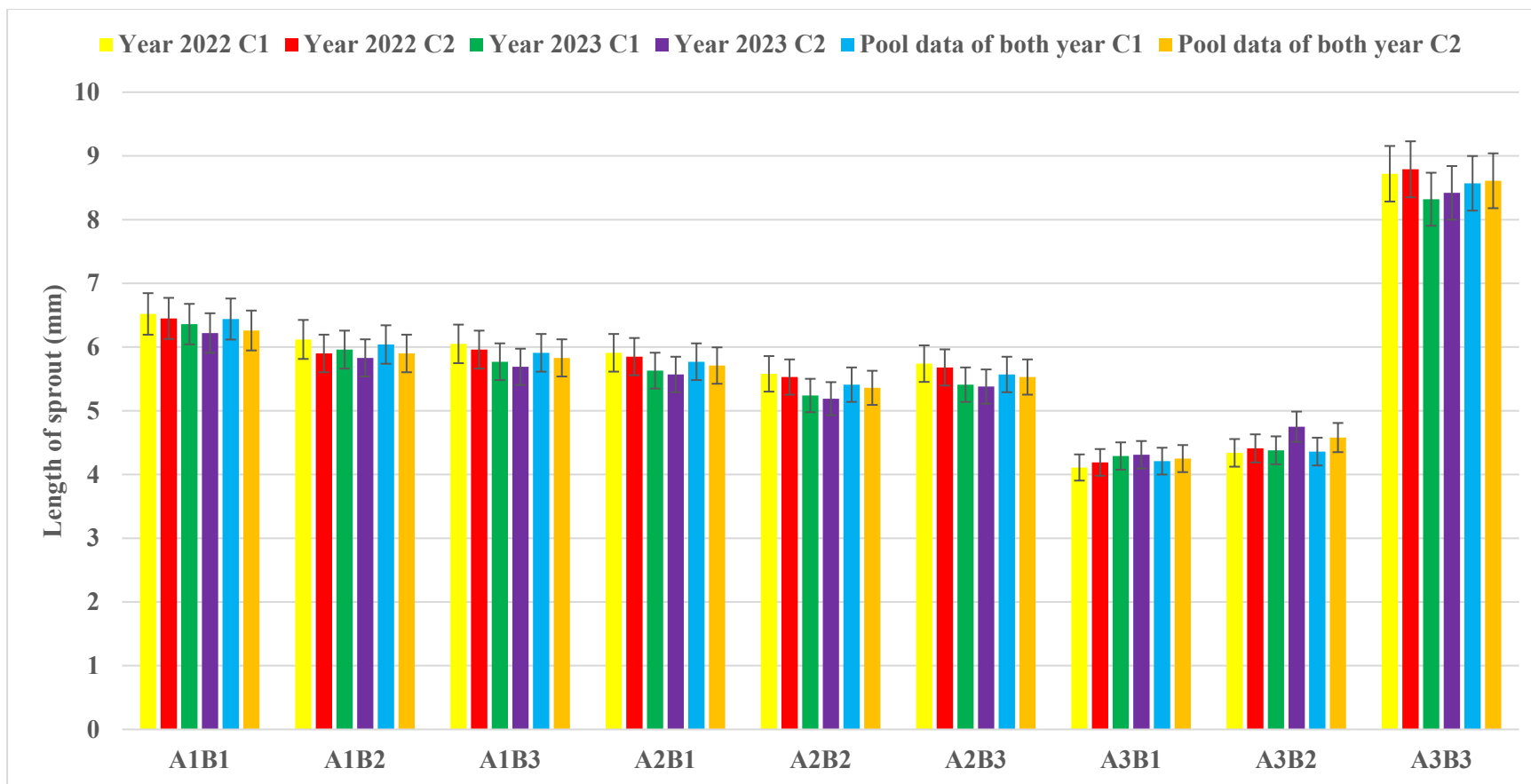


Figure 4.52 Graphical representation of the effect of Zinc (Zn) and IBA treatments on length of sprout (mm) in guava cuttings at different days.

Table 4.53 Effect of zinc (Zn) and IBA treatments on diameter of shoot at days in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	7.49	7.46	7.48	7.82	7.88	7.85	7.66	7.67	7.67
A ₁ B ₂	7.78	7.84	7.81	8.32	8.32	8.32	8.05	8.08	8.07
A ₁ B ₃	8.13	8.06	8.1	8.59	8.85	8.72	8.36	8.46	8.41
A ₂ B ₁	8.37	8.37	8.37	8.77	8.99	8.88	8.57	8.69	8.63
A ₂ B ₂	8.78	8.94	8.86	9.32	9.52	9.42	9.02	9.23	9.13
A ₂ B ₃	9.44	9.33	9.39	9.80	10.36	10.08	9.62	9.85	9.74
A ₃ B ₁	16.08	16.31	16.2	16.45	17.25	16.85	16.27	16.78	16.53
A ₃ B ₂	15.02	15.02	15.02	15.28	15.45	15.37	15.15	15.24	15.2
A ₃ B ₃	5.11	5.25	5.18	5.67	5.76	5.72	5.39	5.51	5.45
Mean	9.58	9.62		10	10.26		9.79	9.95	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.014	0.005	0.009	0.003	0.008	0.003
Factor B	0.014	0.005	0.009	0.003	0.008	0.003
Factor C	0.009	0.003	0.006	0.002	0.007	0.002
Interaction A X B	0.024	0.008	0.016	0.005	0.013	0.004
Interaction A X C	0.016	0.005	0.010	0.003	0.011	0.004
Interaction B X C	0.016	0.005	0.010	0.003	0.011	0.004
Interaction A X B X C	0.028	0.009	0.018	0.006	0.020	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

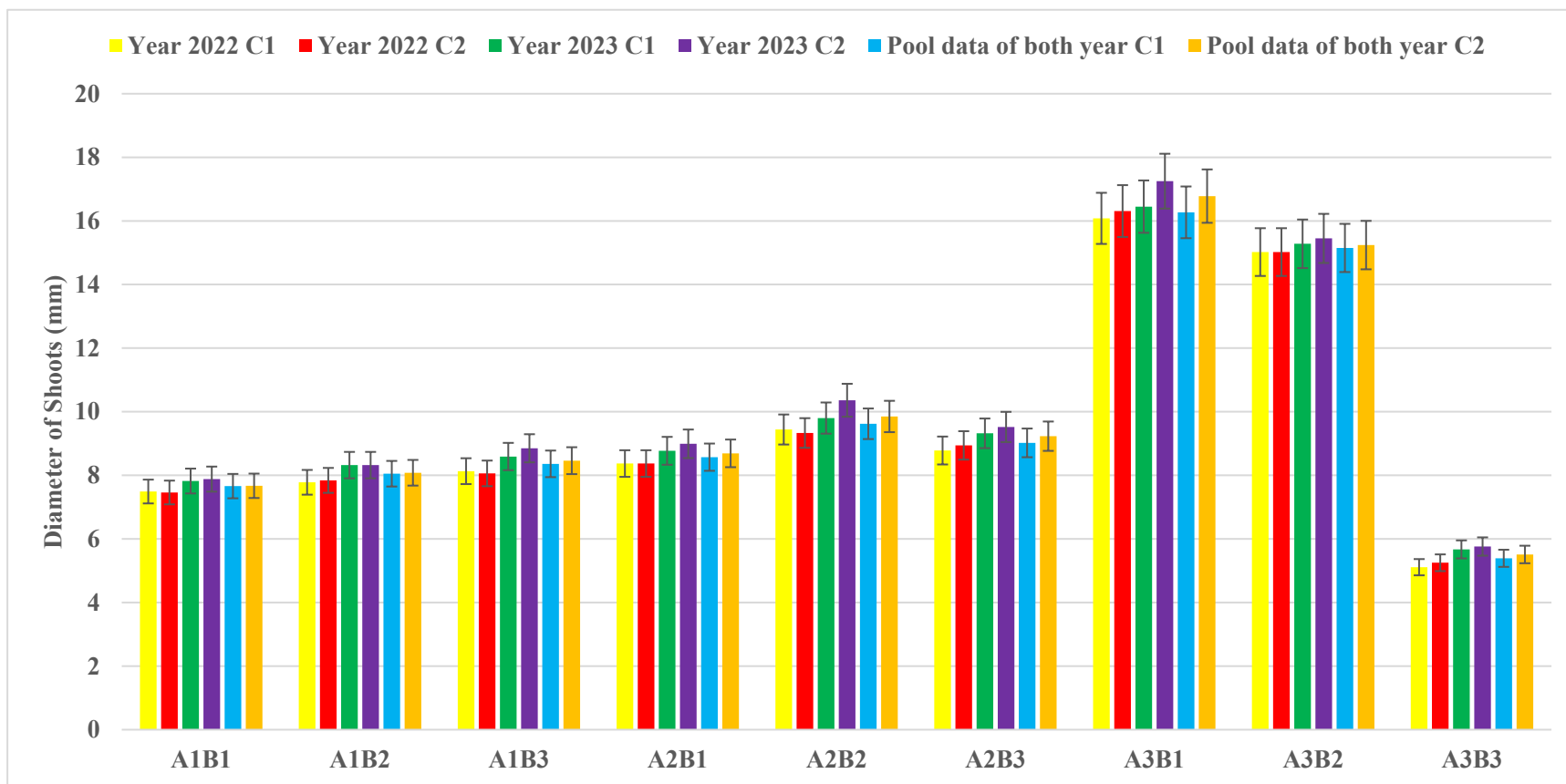


Figure 4.53 Graphical representation of the Effect of Zinc (Zn) and IBA treatment on diameter of shoots (mm) in guava cuttings at different days.

At 60 days after pre-cutting, the trends remained consistent. A₁B₃ (0.75%) continued to have the maximum dry weight (1.05 g in 2022 and 1.22 g in 2023), while A₁B₁ (0.25%) had the minimum (0.81 g in 2022 and 0.91 g in 2023). For zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the maximum dry weight (1.55 g in 2022 and 1.71 g in 2023), whereas A₂B₁ (50 g/tree) had the minimum (1.18 g in 2022 and 1.39 g in 2023). For post-cutting treatment with IBA, 5000-ppm concentration showed the maximum dry weight at 1.86 g in 2022 and 2.09 g in 2023, with the control group maintaining the minimum (0.66 g in 2022 and 0.82 g in 2023).

Pooling data from both years reinforced these trends. At 30 days after pre-cutting, A₁B₃ (0.75%) consistently recorded the maximum dry weight at 1.09 g, with A₁B₁ (0.25%) recording the minimum at 0.83 g (Table 4.55, Figure 4.55). A₂B₂ (75 g/tree) showed the maximum pooled dry weight at 1.55 g, whereas A₂B₁ (50 g/tree) had the minimum at 1.22 g. For post-cutting treatment with IBA, 5000-ppm concentration consistently exhibited the maximum dry weight at 1.92 g, while the control group had the minimum at 0.69 g.

At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the maximum dry weight at 1.11 g, while A₁B₁ (0.25%) had the minimum at 0.87 g. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) performed the best with 1.63 g, whereas A₂B₁ (50 g/tree) had the minimum dry weight at 1.26 g. For post-cutting treatment with IBA, 5000-ppm concentration continued to show the maximum pooled dry weight at 1.95 g, with the control group remaining at a minimum of 0.74 g.

The dry weight of shoots was also significantly impacted by the timing of pre-cutting zinc treatments and the dormant stage. Cuttings taken 60 days after treatment recorded a higher dry shoot weight (1.31 g) than those taken after 30 days (1.26 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) were significant. The maximum dry shoot weight (1.94 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA.

Following the results, it is evident that the fresh and dry weight of shoots serve as critical indicators of biomass accumulation and overall plant health. Zinc

supplementation, particularly through basal application methods, led to significant increases in both fresh and dry shoot weights. Specifically, the treatment with basal zinc at 75 g/tree (A₂B₂) yielded the highest shoot biomass, reflecting enhanced growth and development. This observed increase in shoot biomass is likely attributable to zinc's role in facilitating nutrient uptake and metabolic processes (Blum, 2011). The present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and by Sourati *et al.* (2022) in mulberry.

4.2.23 Number of Leaves

In 2022, the application of zinc via foliar treatments significantly influenced the Number of Leaves observed at both 30- and 60-days after pre-cutting treatment. Specifically, treatment A₁B₃ (0.75%) showed the highest number of leaves with 9.13 at 30 days, whereas A₁B₁ (0.25%) exhibited the lowest with 8.49 (Table 4.56, Figure 4.56). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest number of leaves at 10.44, while A₂B₁ (50 g/tree) had the lowest at 9.37. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the highest number of leaves observed at 17.08, contrasting with the control group, which showed the fewest at 6.11. By 60 days after pre-cutting treatment in 2022, A₁B₃ (0.75%) continued to demonstrate the highest leaf count at 9.06, whereas A₁B₁ (0.25%) had the lowest at 8.46, underscoring significant variations among the zinc basal applications. A₂B₂ (75 g/tree) showed the highest leaf count at 10.33, while A₂B₁ (50 g/tree) exhibited the lowest at 9.37. For post-cutting treatment with IBA, 5000-ppm concentration maintained a notable lead with 17.31 leaves, while the control group remained markedly lower at 6.25 (Figure 4.56).

In 2023, the effects of zinc foliar application on the Number of Leaves were similarly pronounced. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) led with 9.59 leaves, contrasting with A₁B₁ (0.25%) which showed the fewest at 8.82. Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest leaf count at 10.80, while A₂B₁ (50 g/tree) displayed the lowest at 9.77. For post-cutting treatment with IBA, 5000-ppm concentration produced the most leaves at 17.45, with the control group again presenting the fewest at 6.67 (Table 4.56, Figure 4.56).

Table 4.54 Effect of zinc (Zn) and IBA treatments on Fresh weight of shoot (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	2.09	2.14	2.12	2.43	2.43	2.43	2.26	2.29	2.28
A₁B₂	2.31	2.33	2.32	2.65	2.71	2.68	2.48	2.52	2.5
A₁B₃	2.55	2.55	2.55	2.81	2.83	2.82	2.68	2.69	2.69
A₂B₁	2.84	2.85	2.85	3.1	3.09	3.09	2.97	2.97	2.97
A₂B₂	3.31	3.31	3.31	3.53	3.55	3.54	3.42	3.43	3.43
A₂B₃	3.08	3.06	3.07	3.3	3.29	3.3	3.19	3.18	3.19
A₃B₁	3.96	3.96	3.96	4.25	4.28	4.27	4.11	4.12	4.12
A₃B₂	3.66	3.76	3.71	4.01	4.02	4.02	3.84	3.89	3.87
A₃B₃	1.83	1.89	1.86	2.21	2.32	2.27	2.02	2.11	2.07
Mean	2.85	2.87		3.14	3.17		3.01	3.02	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.013	0.004	0.01	0.003
Factor B	0.009	0.003	0.013	0.004	0.01	0.003
Factor C	0.006	0.002	0.009	0.003	0.006	0.002
Interaction A X B	0.016	0.005	0.023	0.008	0.017	0.006
Interaction A X C	0.011	0.003	0.015	0.005	0.011	0.003
Interaction B X C	0.011	0.003	0.015	0.005	0.011	0.003
Interaction A X B X C	0.017	0.006	0.026	0.009	0.018	0.006

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

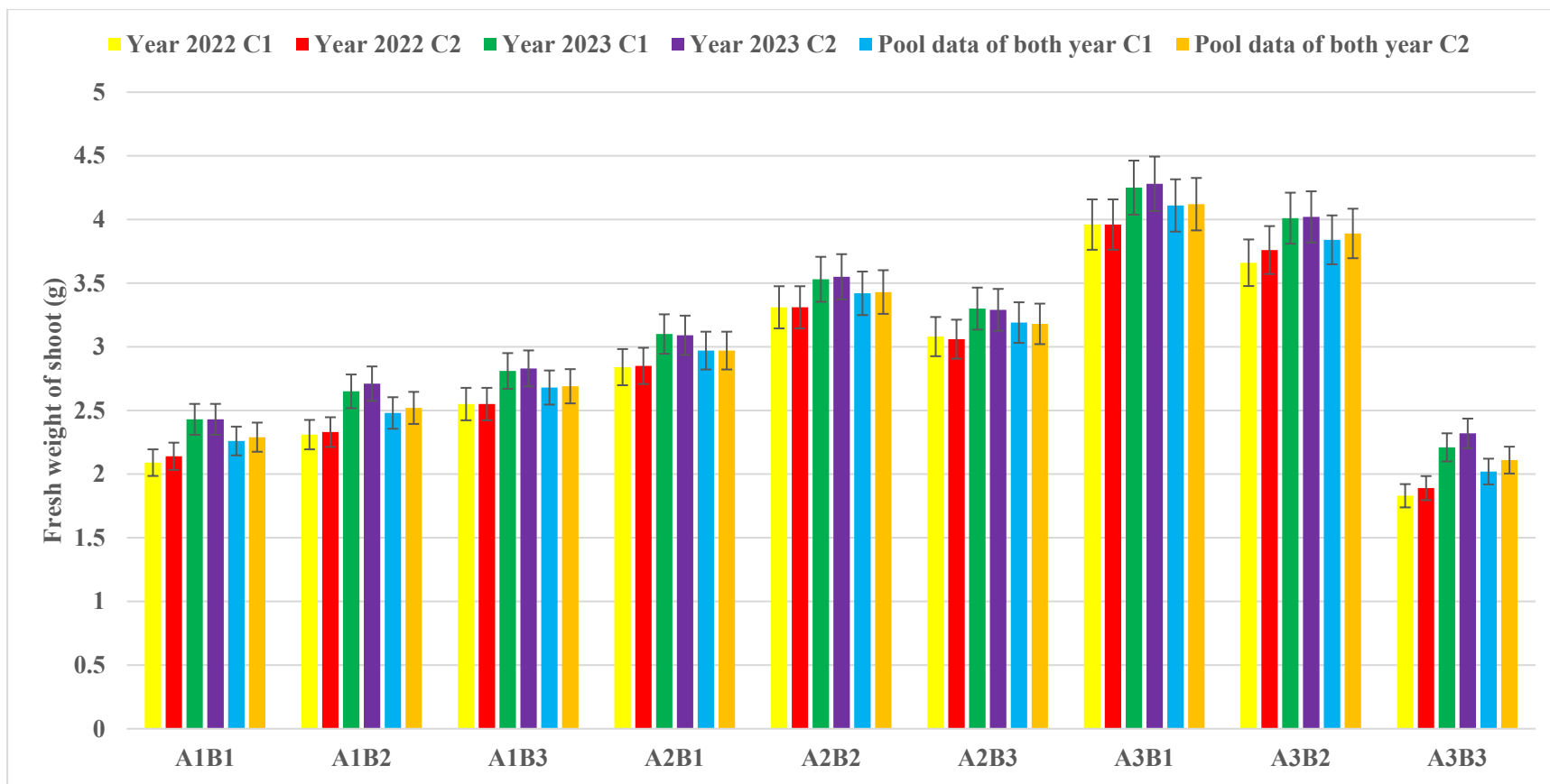


Figure 4.54 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of shoot (g) in guava cuttings at different days.

By 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained its lead with 9.85 leaves, whereas A₁B₁ (0.25%) had the fewest at 8.88. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) exhibited the highest leaf count at 11.36, with A₂B₁ (50 g/tree) showing the fewest at 9.99. For post-cutting treatment with IBA, 5000-ppm concentration continued to lead significantly with 18.25 leaves, while the control group lagged behind with 6.76 leaves (Figure 4.56).

Pooling data from both years reaffirmed consistent trends in leaf production. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently exhibited the highest number of leaves at 9.36, whereas A₁B₁ (0.25%) consistently showed the lowest at 8.66 (Table 4.56, Figure 4.56). Zinc as pre-cutting basal treatments demonstrated A₂B₂ (75 g/tree) with the highest leaf count at 10.62, and A₂B₁ (50 g/tree) with the lowest at 9.57. For post-cutting treatment with IBA, 5000-ppm concentration consistently resulted in the highest leaf count with an average of 17.27 leaves, while the control group consistently had the lowest at 6.39.

At 60 days after pre-cutting, pooled data indicated that A₁B₃ (0.75%) maintained its lead with 9.46 leaves, while A₁B₁ (0.25%) had the fewest at 8.67. Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest leaf count at 10.85, whereas A₂B₁ (50 g/tree) had the lowest at 9.69. For post-cutting treatment with IBA, 5000-ppm concentration consistently produced the highest number of leaves with an average of 17.78, while the control group consistently exhibited the lowest at 6.51 (Figure 4.56).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the number of leaves in guava cuttings. Cuttings collected after 60 days produced a higher number of leaves (10.95) compared to those collected after 30 days (10.79). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected leaf production. The highest number of leaves (17.53) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Table 4.55 Effect of zinc (Zn) and IBA treatments on Dry weight of shoot (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	0.77	0.81	0.79	0.83	0.91	0.87	0.83	0.87	0.85
A₁B₂	0.91	0.94	0.92	1.05	1.07	1.06	0.99	1.01	1
A₁B₃	1.01	1.05	1.03	1.18	1.22	1.2	1.09	1.11	1.1
A₂B₁	1.13	1.18	1.16	1.34	1.39	1.37	1.22	1.26	1.24
A₂B₂	1.44	1.55	1.5	1.66	1.71	1.69	1.55	1.63	1.59
A₂B₃	1.25	1.37	1.31	1.43	1.52	1.48	1.34	1.45	1.4
A₃B₁	1.86	1.86	1.86	1.98	2.09	2.04	1.92	1.95	1.94
A₃B₂	1.56	1.71	1.64	1.78	1.89	1.84	1.68	1.8	1.74
A₃B₃	0.61	0.66	0.64	0.76	0.82	0.79	0.69	0.74	0.72
Mean	1.17	1.24		1.34	1.4		1.26	1.31	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.009	0.003	0.008	0.003
Factor B	0.009	0.003	0.009	0.003	0.008	0.003
Factor C	0.005	0.002	0.007	0.002	0.007	0.002
Interaction A X B	0.016	0.005	0.016	0.005	0.014	0.005
Interaction A X C	0.009	0.003	0.012	0.004	0.012	0.004
Interaction B X C	0.009	0.003	0.012	0.004	0.012	0.004
Interaction A X B X C	0.016	0.005	0.021	0.007	0.02	0.007

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

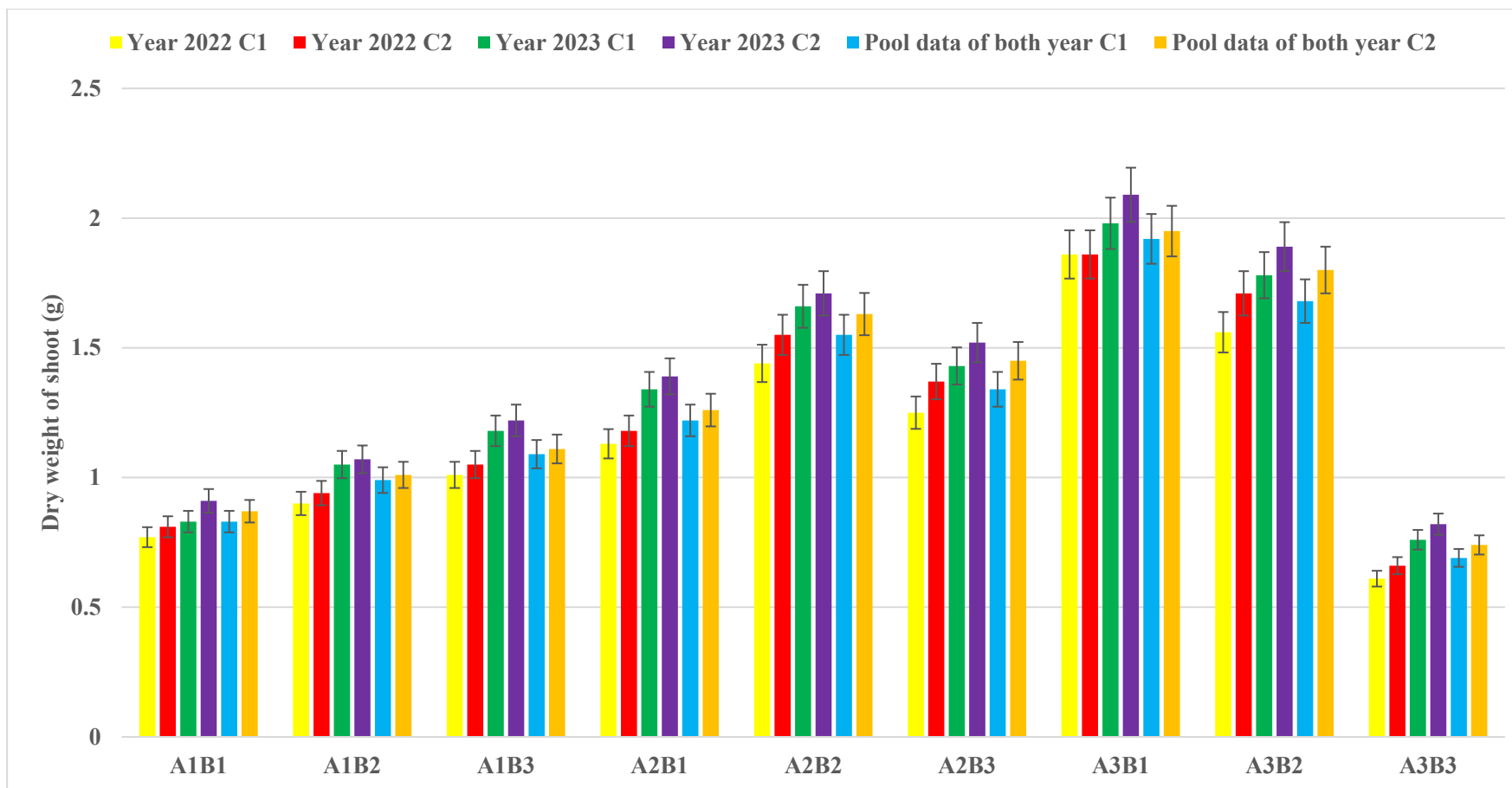


Figure 4.55 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of shoot (g) in guava cuttings at different days.

Table 4.56 Effect of zinc (Zn) and IBA treatments on number of leaves in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	8.49	8.46	8.48	8.82	8.88	8.85	8.66	8.67	8.67
A ₁ B ₂	8.78	8.84	8.81	9.32	9.32	9.32	9.05	9.08	9.07
A ₁ B ₃	9.13	9.06	9.1	9.59	9.85	9.72	9.36	9.46	9.41
A ₂ B ₁	9.37	9.37	9.37	9.77	9.99	9.88	9.57	9.69	9.63
A ₂ B ₂	10.44	10.33	10.39	10.8	11.36	11.08	10.62	10.85	10.74
A ₂ B ₃	9.78	9.94	9.86	10.32	10.52	10.42	10.02	10.23	10.13
A ₃ B ₁	17.08	17.31	17.2	17.45	18.25	17.85	17.27	17.78	17.53
A ₃ B ₂	16.02	16.02	16.02	16.28	16.45	16.37	16.15	16.24	16.2
A ₃ B ₃	6.11	6.25	6.18	6.67	6.76	6.72	6.39	6.51	6.45
Mean	10.58	10.62		11.01	11.26		10.79	10.95	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.007	0.002	0.009	0.003
Factor B	0.008	0.003	0.007	0.002	0.009	0.003
Factor C	0.008	0.003	0.006	0.002	0.007	0.002
Interaction A X B	0.014	0.005	0.011	0.004	0.015	0.005
Interaction A X C	0.014	0.005	0.01	0.003	0.012	0.004
Interaction B X C	0.014	0.005	0.01	0.003	0.012	0.004
Interaction A X B X C	0.024	0.008	0.017	0.006	0.021	0.007

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

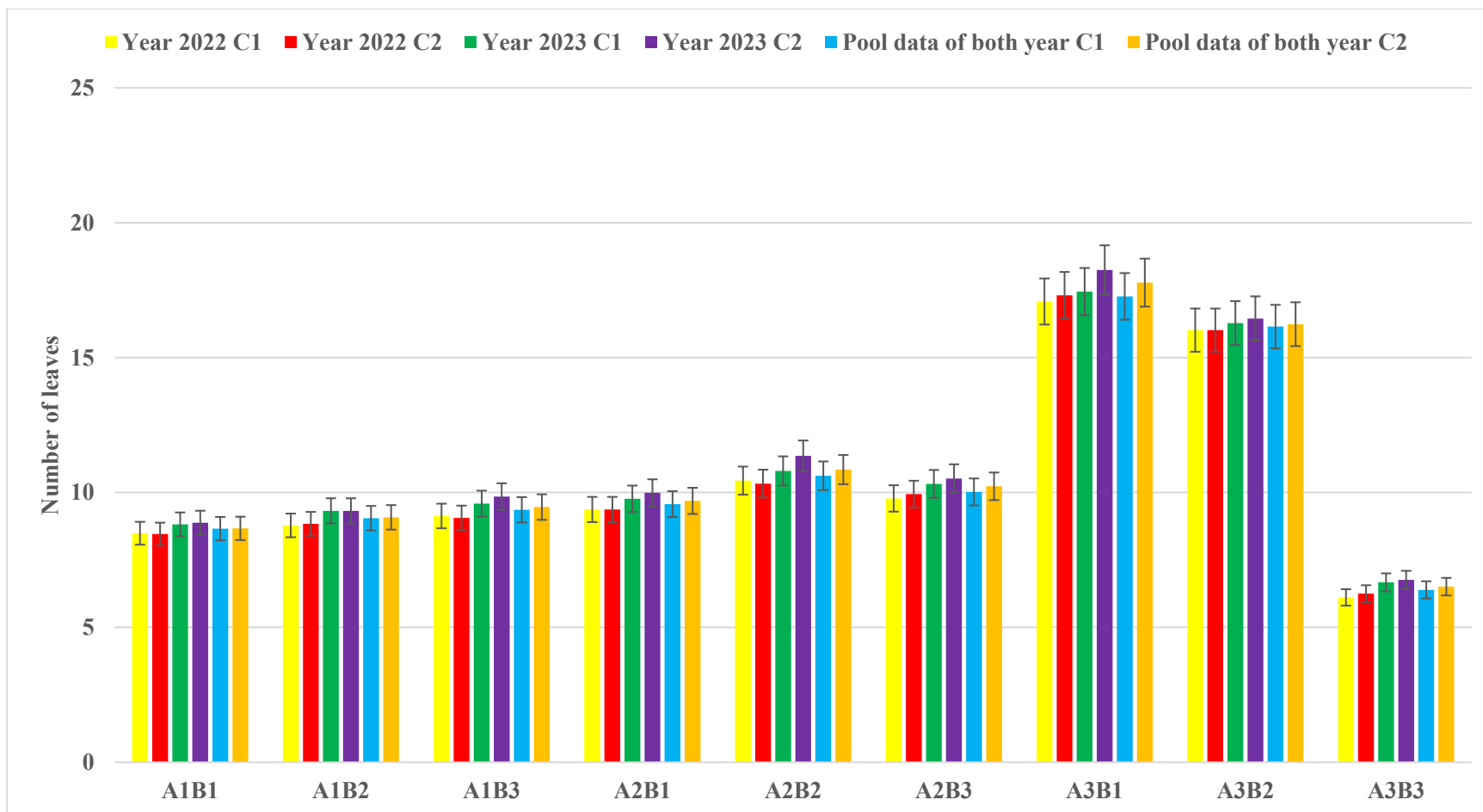


Figure 4.56 Graphical representation of the effect of Zinc (Zn) and IBA treatments on number of leaves in guava cuttings at different days.

4.2.24 Leaf area (cm²)

In 2022, zinc foliar application significantly influenced the Leaf Area at both 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) exhibited the largest increase in leaf area, measuring a maximum of 7.64 cm², while A₁B₁ (0.25%) showed the smallest increase with a minimum of 19.8 cm² (Table 4.57, Figure 4.57). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the maximum leaf area at 8.21 cm², with A₂B₁ (50 g/tree) displaying the minimum at 7.67 cm². For post-cutting treatment with IBA, 5000-ppm concentration led to a maximum leaf area of 15.15 cm², whereas the control group had a minimum of 3.49 cm².

At 60 days after pre-cutting post-treatment in 2022, A₁B₃ (0.75%) maintained the maximum leaf area at 7.99cm², while A₁B₁ (0.25%) had the minimum at 6.29 cm², demonstrating significant differences among zinc basal applications. A₂B₂ (75 g/tree) again showed a maximum leaf area of 8.54 cm², whereas A₂B₁ (50 g/tree) exhibited a minimum at 7.63 cm². For post-cutting treatment with IBA, 5000-ppm concentration demonstrated the maximum leaf area of 15.76 cm², with the control group showing the minimum at 3.83 cm² (Figure 4.57).

In 2023, the impact of zinc foliar application on Leaf Area remained significant. At 30 days post-treatment, A₁B₃ (0.75%) recorded the maximum leaf area at 7.66 cm², while A₁B₁ (0.25%) had the minimum at 5.91 cm². Among zinc basal treatments, A₂B₂ (75 g/tree) exhibited the maximum leaf area at 8.44 cm², whereas A₂B₁ (50 g/tree) showed the minimum at 7.72 cm². For post-cutting treatment with IBA, 5000-ppm concentration resulted in a maximum leaf area of 15.19 cm², while the control group had the minimum at 3.57 cm² (Table 4.57, Figure 4.57).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the maximum leaf area at 8.09 cm², and A₁B₁ (0.25%) exhibited the minimum at 6.32 cm². Zinc basal treatments showed A₂B₂ (75 g/tree) with the maximum leaf area at 8.59 cm², and A₂B₁ with the minimum at 7.67 cm². For post-cutting treatment with IBA, 5000-ppm concentration demonstrated the maximum leaf area of 15.89 cm², while the control group exhibited the minimum at 3.93 cm² (Figure 4.57).

Pooling data from both years revealed consistent trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently displayed the maximum leaf area at 7.65 cm², whereas A₁B₁ (0.25%) had the minimum at 5.90 cm² (Table 4.57, Figure 4.57). Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the maximum pooled leaf area at 8.49 cm², and A₂B₁ (50 g/tree) with the minimum at 7.70 cm². For post-cutting treatment with IBA, 5000-ppm concentration consistently led to the maximum leaf area with a mean value of 15.17 cm², while the control group consistently had the minimum at 3.53 cm².

At 60 days, pooled data indicated that A₁B₃ (0.75%) had the maximum leaf area at 8.04 cm², while A₁B₃ (0.25%) had the minimum at 6.31 cm². Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the maximum pooled leaf area at 8.40 cm², whereas A₂B₁ (50 g/tree) had the minimum at 7.65 cm². For post-cutting treatment with IBA, 5000-ppm concentration maintained the maximum pooled leaf area with a mean value of 15.83 cm², while the control group had the minimum at 3.88 cm² (Figure 4.57, figure 4.57).

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the leaf area of guava cuttings. Cuttings collected after 60 days exhibited a larger leaf area (8.95 cm²) compared to those collected after 30 days (8.58 cm²). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected leaf area expansion. The largest leaf area (15.50 cm²) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.2.25 Chlorophyll (mg/g)

In both 2022 and 2023, zinc foliar application significantly influenced the Chlorophyll content at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the maximum Chlorophyll content, with values of 1.17 mg/g in 2022 and 1.29 mg/g in 2023, while A₁B₁ (0.25%) exhibited the minimum values, 0.81 mg/g in 2022 and 0.91 mg/g in 2023 (Table 4.58, Figure 4.58).

Similarly, for zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently displayed the maximum Chlorophyll content, with values of 1.61 mg/g in 2022 and 1.73 mg/g in 2023, while A₂B₁ (50 g/tree) had a minimum, 1.33 mg/g in 2022 and 1.45 mg/g in 2023. For post-cutting treatment with IBA, 5000-ppm concentration yielded the maximum Chlorophyll content of 2.25 mg/g in 2022 and 2.32 mg/g in 2023, whereas the control group consistently had the minimum Chlorophyll content, 0.58 mg/g in 2022 and 0.71 mg/g in 2023.

At 60 days after pre-cutting post-treatment, the trends remained consistent. A₁B₃ continued to exhibit the maximum Chlorophyll content (1.17 mg/g in 2022 and 1.29 mg/g in 2023), while A₁B₁ showed the minimum (0.85 mg/g in 2022 and 0.94 mg/g in 2023). For zinc basal treatments, A₂B₂ showed the maximum Chlorophyll content (1.66 mg/g in 2022 and 1.78 mg/g in 2023), while A₂B₁ had the minimum (1.36 mg/g in 2022 and 1.45 mg/g in 2023). For post-cutting treatment with IBA, 5000-ppm concentration displayed the maximum Chlorophyll content at 2.22 mg/g in 2022 and 2.32 mg/g in 2023, with the control group remaining at the minimum (0.59 mg/g in 2022 and 0.74 mg/g in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ consistently recorded the maximum Chlorophyll content at 1.23 mg/g, with A₁B₁ showing the minimum at 0.87 mg/g (Table 4.58, figure 4.58). A₂B₂ displayed the maximum pooled Chlorophyll content at 1.67 mg/g, and A₂B₁ had the minimum at 1.39 mg/g. For post-cutting treatment with IBA, 5000-ppm concentration consistently exhibited the maximum Chlorophyll content at 2.29 mg/g, while the control group had the minimum at 0.65 mg/g. At 60 days, A₁B₃ had the maximum Chlorophyll content at 1.23 mg/g, while A₁B₁ had the minimum at 0.90 mg/g. A₂B₂ performed the best among zinc basal treatments with 1.72 mg/g, and A₂B₁ had the minimum Chlorophyll content at 1.41 mg/g. For post-cutting treatment with IBA, 5000-ppm concentration maintained the maximum pooled Chlorophyll content at 2.27 mg/g, with the control group remaining at the minimum at 0.67 mg/g.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the chlorophyll content in cuttings. Cuttings collected after 60 days exhibited higher chlorophyll content (1.44 mg/g) compared to those collected

after 30 days (1.41 mg/g). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the chlorophyll levels. The highest chlorophyll content (2.28 mg/g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

4.2.26 Fresh weight of leaves (g)

In 2022, zinc foliar application significantly influenced the fresh weight of leaves. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest fresh weight (2.51g), while A₁B₃ (0.25%) had the lowest (1.98g), indicating significant variation among the different levels of zinc foliar application (Table 4.59, Figure 4.59). For zinc various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the highest fresh weight (3.23g), and A₂B₁ (50 g/tree) had the lowest (2.76g). For post-cutting treatment with IBA, 5000-ppm concentration yielded the highest fresh weight (4.18g), whereas the control group had the lowest (1.64g).

At 60 days after pre-cutting treatment, the trend continued with A₁B₃ recording the highest fresh weight (2.56g) and A₁B₁ the lowest (2.01g). A₂B₂ again had the highest fresh weight (3.23g) among zinc basal treatments, and A₂B₁ had the lowest (2.82g). The 5000 ppm IBA treatment maintained the highest fresh weight (4.21g), with the control group at the lowest (1.67g).

In 2023, the pattern persisted. At 30 days after pre-cutting treatment, A₁B₃ showed the highest fresh weight (2.67g), while A₁B₁ had the lowest (2.06g). A₂B₂ led among zinc basal treatments with 3.72g, and A₂B₁ was the lowest at 2.89g. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the highest fresh weight (4.51g), with the control group at the lowest (1.93g).

At 60 days after pre-cutting treatment, A₁B₃ had the highest fresh weight (2.73g) and A₁B₁ the lowest (2.11g). A₂B₂ continued to show the highest fresh weight (3.76g) among various levels of zinc as pre-cutting basal treatments, while A₂B₁ had the lowest (2.91g). For post-cutting treatment with IBA, 5000-ppm concentration resulted in the highest fresh weight (4.53g), and the control group remained the lowest (1.96g).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ consistently recorded the highest fresh weight (2.59g), with A₁B₁ the lowest (2.02g) (Table 4.59). A₂B₂ showed the highest pooled fresh weight (3.48g), and A₂B₁ had the lowest (2.83g). For post-cutting treatment with IBA, 5000-ppm concentration consistently had the highest fresh weight (4.35g), while the control group had the lowest (1.79g). At 60 days after pre-cutting treatment, pooled data indicated A₁B₃ had the highest fresh weight (2.65g), and A₁B₁ the lowest (2.06g). A₂B₂ was the best performer among zinc basal treatments with 3.51g, while A₂B₁ had the lowest fresh weight (2.87g). For post-cutting treatment with IBA, 5000-ppm concentration maintained the highest pooled fresh weight (4.35g), and the control group remained the lowest (1.82g).

The timing of pre-cutting zinc treatments or the dormant stage of guava significantly influenced the fresh weight of leaves in cuttings. Cuttings collected 60 days after treatment produced leaves with a higher fresh weight (2.99g) compared to those collected after 30 days (2.96 g). The method of application and interactions (AxB, BxC, AxC, AxBxC) also had a significant impact. The highest fresh weight of leaves (4.35 g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

4.2.27 Dry weight of leaves (g)

In both 2022 and 2023, the zinc foliar application significantly impacted the dry weight of leaves at both 30- and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight, with values of 0.99g in 2022 and 1.24g in 2023, while A₁B₁ (0.25%) showed the lowest values, 0.74g in 2022 and 0.83g in 2023 (Table 4.60, Figure 4.60).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently showed the highest dry weight, with values of 1.55g in 2022 and 1.95g in 2023, while A₂B₁ (50 g/tree) had the lowest, 1.15g in 2022 and 1.36g in 2023. For post-cutting treatment with IBA, 5000-ppm concentration yielded the highest dry weight of 2.28g in 2022 and 2.77g in 2023, whereas the control group consistently had the lowest dry weight (0.54g in 2022 and 0.69g in 2023).

Table 4.57 Effect of zinc (Zn) and IBA treatments leaf area (cm²) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	5.88	6.29	6.09	5.91	6.32	6.12	5.9	6.31	6.1
A ₁ B ₂	6.66	7.22	6.94	6.72	7.32	7.02	6.69	7.27	6.98
A ₁ B ₃	7.64	7.99	7.82	7.66	8.09	7.88	7.65	8.04	7.85
A ₂ B ₁	7.67	7.63	7.65	7.72	7.67	7.7	7.7	7.65	7.68
A ₂ B ₂	8.54	8.21	8.38	8.44	8.59	8.52	8.49	8.40	8.45
A ₂ B ₃	7.74	7.99	7.87	7.98	8.03	8.01	7.86	8.01	7.94
A ₃ B ₁	15.15	15.76	15.46	15.19	15.89	15.54	15.17	15.83	15.5
A ₃ B ₂	14.38	14.93	14.65	14.36	15.09	14.73	14.37	15.01	14.69
A ₃ B ₃	3.49	3.83	3.66	3.57	3.93	3.75	3.53	3.88	3.71
Mean	8.57	8.87		8.62	8.99		8.58	8.95	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.009	0.003	0.022	0.007	0.011	0.004
Factor B	0.009	0.003	0.022	0.007	0.011	0.004
Factor C	0.007	0.002	0.01	0.003	0.006	0.002
Interaction A X B	0.015	0.005	0.018	0.013	0.02	0.007
Interaction A X C	0.011	0.004	0.017	0.006	0.011	0.004
Interaction B X C	0.011	0.004	0.017	0.006	0.011	0.004
Interaction A X B X C	0.02	0.007	0.03	0.01	0.019	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

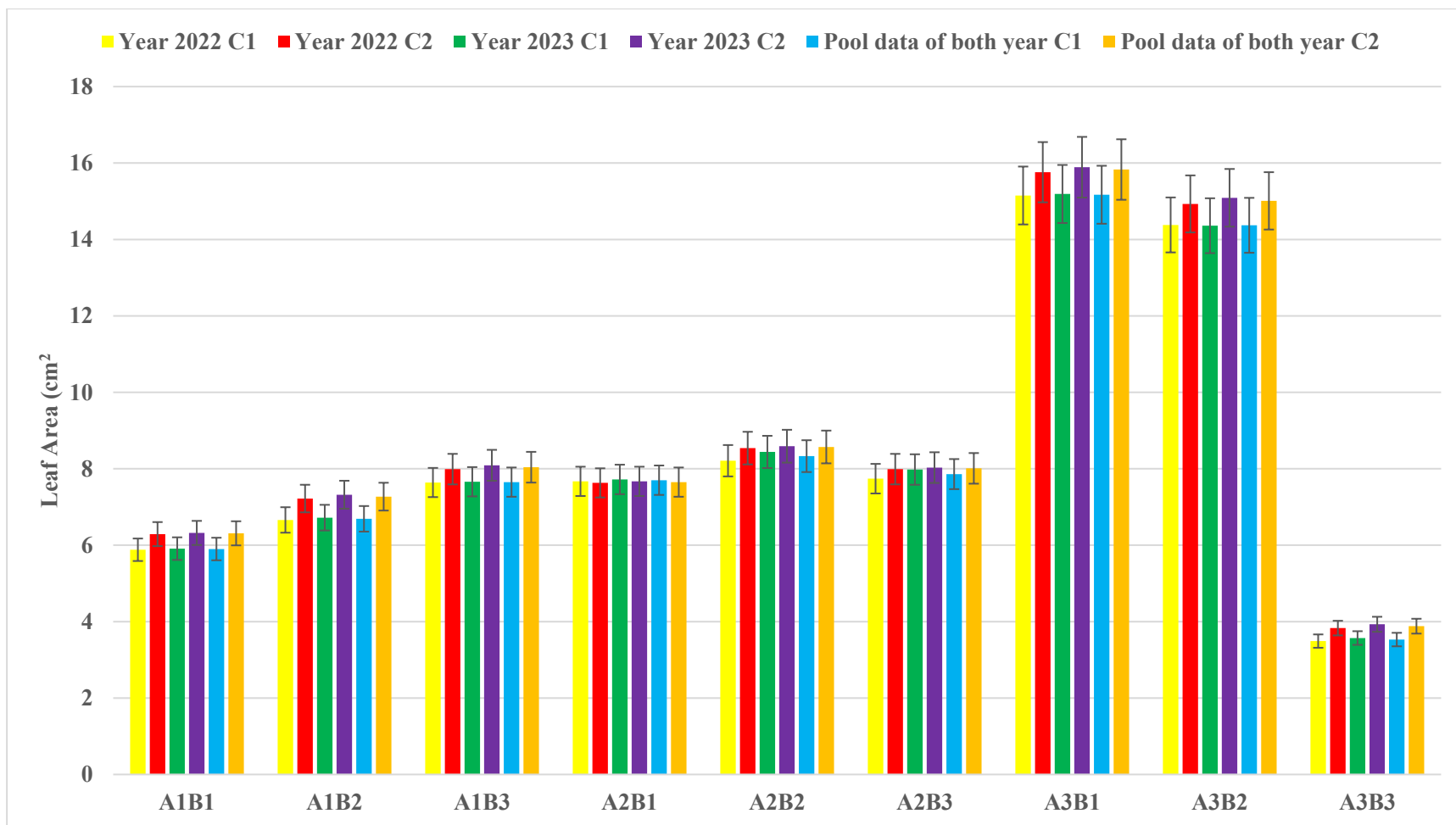


Figure 4.57 Graphical representation of the effect of Zinc (Zn) and IBA treatments on leaf area (cm²) in guava cuttings at different days.

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ (0.75%) continued to have the highest dry weight (1g in 2022 and 1.33g in 2023), while A₁B₁ (0.25%) had the lowest (0.76g in 2022 and 0.85g in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight (1.62g in 2022 and 2.08g in 2023), while A₂B₁ (50 g/tree) had the lowest (1.20g in 2022 and 1.46g in 2023). For post-cutting treatment with IBA, 5000-ppm concentration showed the highest dry weight at 2.42g in 2022 and 2.66g in 2023, with the control group remaining the lowest (0.50g in 2022 and 0.76g in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the highest dry weight of leaves at 1.12g, with A₁B₁ (0.25%) the lowest at 0.79g (Table 4.60, Figure 4.60). A₂B₂ (75 g/tree) showed the highest pooled dry weight at 1.75 g, and A₂B₁ (50 g/tree) had the lowest at 1.26g. For post-cutting treatment with IBA, 5000-ppm concentration consistently had the highest dry weight at 2.53g, while the control group had the lowest at 0.62g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest dry weight at 1.17g, while A₁B₁ (0.25%) had the lowest at 0.81g. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments with 1.85g, and A₂B₁ (50 g/tree) had the lowest dry weight at 1.33g. For post-cutting treatment with IBA, 5000-ppm concentration maintained the highest pooled dry weight at 2.54g, and the control group remained the lowest at 0.63g.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced dry weight of leaves. Cuttings collected after 60 days showed a maximum dry weight of leaves (1.47g) than those collected after 30 days (1.43g). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the dry weight of leaves. The maximum dry weight of leaves (2.54g) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Following the results, it is evident that the number of leaves, along with their fresh and dry weights, are critical indicators of photosynthetic capacity and overall plant vigor. Basal zinc application at 75 g/tree (A₂B₂) significantly increased the number of leaves, as well as their fresh and dry weights, and leaf area. These improvements

suggest that zinc enhances leaf development and expansion, which contributes to a larger photosynthetic area and better plant growth. The increased leaf area and biomass reflect improved nutrient and water absorption, thereby supporting overall plant health (Alloway, 2008). Present findings are fully supported by the results of Yamashita et al. (2006) in mango and *Sourati et al.* (2022) in mulberry

4.2.28 Root-to-shoot ratio

In 2022, the root-to-shoot ratio was significantly influenced by zinc foliar applications. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) recorded the lowest root-to-shoot ratio of 0.97, whereas treatment A₁B₁ (0.25%) showed the highest at 1.09, indicating significant differences among the treatments (Table 4.61, Figure 4.61). Among the zinc basal treatments, A₂B₂ (75 g/tree) had the lowest ratio at 0.86, while A₂B₁ (50 g/tree) recorded the highest at 0.91. For IBA post-cutting treatments, the 5000-ppm concentration resulted in the lowest root-to-shoot ratio of 0.85, with the control group having the highest at 1.09. At 60 days post-treatment in 2022, A₁B₃ (0.75%) continued to have the lowest root-to-shoot ratio at 0.98, while A₁B₁ (0.25%) had the highest at 1.07. Zinc as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the lowest ratio at 0.91 and A₂B₂ (50 g/tree) the highest at 0.93. The IBA post-cutting treatments at 5000 ppm resulted in the lowest root-to-shoot ratio of 0.90, with the control group showing the highest at 1.11

The pattern continued in 2023 when zinc foliar applications significantly affected the root-to-shoot ratio. At 30 days post-treatment, A₁B₃ (0.75% /tree) resulted in the lowest ratio of 0.93, while A₁B₁ (0.25%) had the highest at 0.99. Among zinc basal treatments, A₂B₂ (75 g/tree) had the lowest ratio at 0.86, while A₂B₁ (50 g/tree) showed the highest at 0.89. The 5000-ppm IBA post-cutting treatment resulted in the lowest root-to-shoot ratio at 0.87, with the control group having the highest at 0.97.

At 60 days post-treatment in 2023, A₁B₃ (0.75%) continued to show the lowest ratio at 0.93, while A₁B₁ (0.25%) had the highest at 1. Zinc basal treatments had A₂B₂ (75 g/tree) with the lowest ratio at 0.89, and A₂B₁ (50 g/tree) with the highest at 0.92. The 5000-ppm IBA post-cutting treatment consistently showed the highest root-to-shoot ratio at 0.89, with the control group having the lowest at 0.96.

Table 4.58 Effect of zinc (Zn) and IBA treatments on chlorophyll (mg/g) in guava Cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.81	0.85	0.83	0.91	0.94	0.93	0.87	0.9	0.89
A ₁ B ₂	0.97	1.03	1	1.11	1.12	1.12	1.04	1.08	1.06
A ₁ B ₃	1.17	1.17	1.17	1.29	1.29	1.29	1.23	1.23	1.23
A ₂ B ₁	1.33	1.36	1.35	1.45	1.45	1.45	1.39	1.41	1.4
A ₂ B ₂	1.61	1.66	1.64	1.73	1.78	1.76	1.67	1.72	1.7
A ₂ B ₃	1.49	1.52	1.31	1.59	1.64	1.62	1.54	1.58	1.56
A ₃ B ₁	2.25	2.22	2.24	2.32	2.32	2.32	2.29	2.27	2.28
A ₃ B ₂	1.95	2.01	1.98	2.07	2.09	2.08	2.01	2.05	2.03
A ₃ B ₃	0.58	0.59	0.59	0.71	0.74	0.73	0.65	0.67	0.66
Mean	1.35	1.38		1.47	1.49		1.41	1.44	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.009	0.003	0.011	0.004
Factor B	0.008	0.003	0.009	0.003	0.011	0.004
Factor C	0.005	0.002	0.005	0.002	0.005	0.002
Interaction A X B	0.014	0.005	0.015	0.005	0.019	0.006
Interaction A X C	0.008	0.003	0.009	0.003	0.008	0.003
Interaction B X C	0.008	0.003	0.009	0.003	0.008	0.003
Interaction A X B X C	0.015	0.005	0.015	0.005	0.015	0.005

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

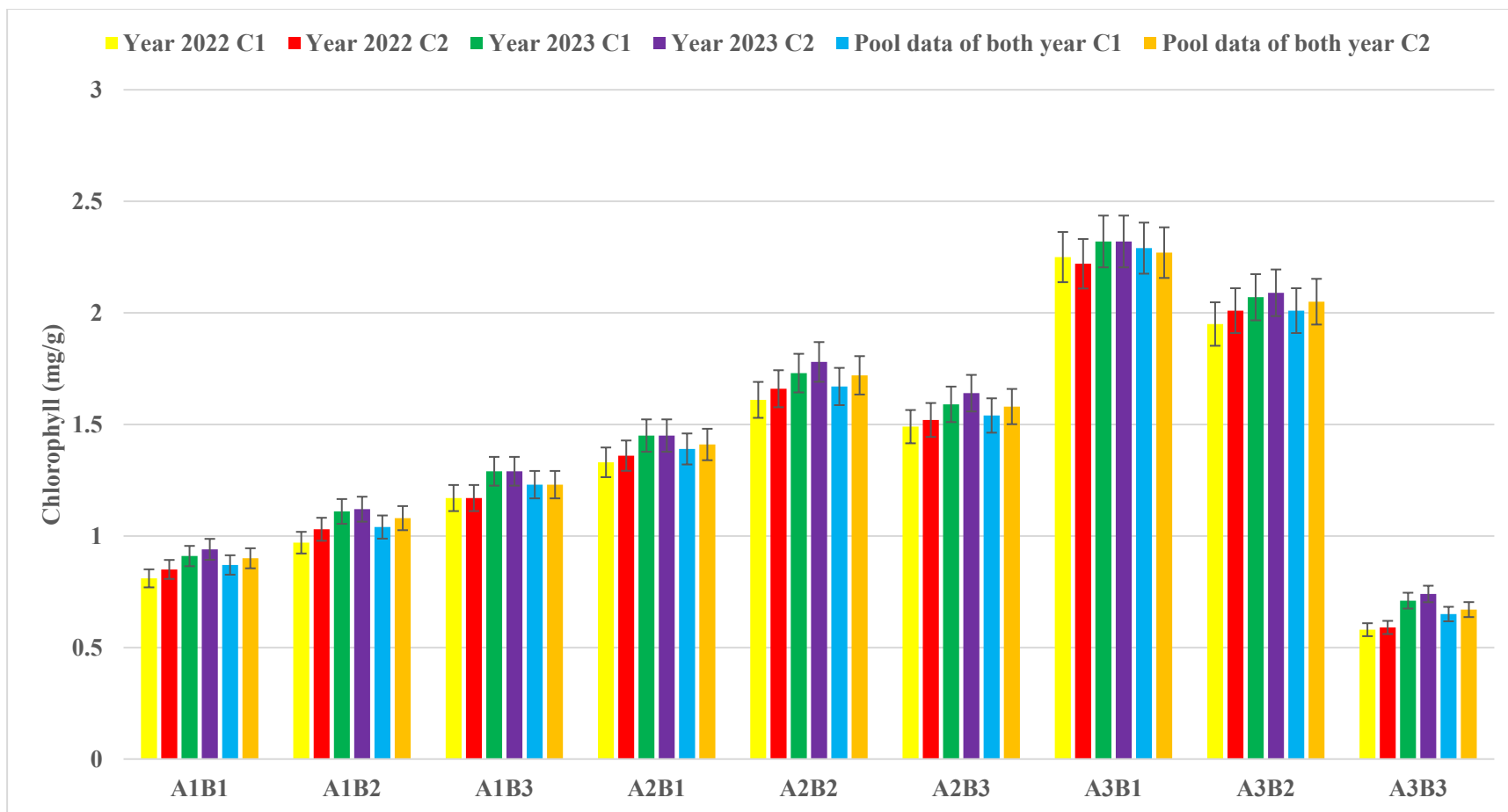


Figure 4.58 Graphical representation of the effect of Zinc (Zn) and IBA treatments on chlorophyll (mg/g) in guava cuttings at different days.

Pooling data from both years, the trends were consistent. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently had the lowest root-to-shoot ratio at 0.95, while A₁B₁ (0.25%) had the highest at 1.04 (Table 4.61, Figure 4.61). Among various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the lowest ratio at 0.86, and A₂B₁ (50 g/tree) had the highest at 0.90. The 5000-ppm IBA post-cutting treatment consistently resulted in the lowest ratio with an average of 0.83, while the control group had the highest at 1.03.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) resulted in the lowest root-to-shoot ratio at 0.95, while A₁B₁ (0.25%) had the highest at 1.03. Zinc basal treatments showed A₂B₂ (75 g/tree) as the best performer with 0.91, while A₂B₁ (50 g/tree) had the highest ratio at 0.93. The 5000-ppm IBA treatment maintained its lead with lowest ratio of 0.90, and the control group had the highest at 1.03.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the root-to-shoot ratio in guava cuttings. Cuttings collected after 60 days exhibited a higher root-to-shoot ratio (0.95) compared to those collected after 30 days (0.93). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the root-to-shoot ratio. The highest root-to-shoot ratio (0.88) was observed in the A₃B₁C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 5000 ppm IBA.

Following the results, it is evident that the root-to-shoot ratio is a critical parameter that reflects the balance between root and shoot growth, influencing a plant's ability to absorb water and nutrients effectively. Zinc plays a pivotal role in maintaining this balance. Zinc deficiency often leads to poor root development, which can negatively affect the root-to-shoot ratio. Research indicates that adequate zinc levels improve root growth, leading to a more balanced root-to-shoot ratio (Alloway, 2008).

In studies where zinc was supplemented, particularly through basal application, an improvement in the root-to-shoot ratio was observed. For example, basal zinc application at 75 g/tree significantly enhanced root development relative to shoot growth, resulting in a more balanced root-to-shoot ratio. This improvement can be

attributed to zinc's role in promoting cell division and elongation in the roots, thereby supporting better nutrient and water uptake (Marschner, 2012).

4.2.29 Root Index

In 2022, zinc foliar application significantly influenced the Root Index. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) resulted in the highest root index with a value of 52.56, whereas A₁B₁ (0.25%) showed the lowest at 41.13, indicating notable differences across zinc foliar treatments (Table 4.62, Figure 4.62). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) yielded the highest root index at 92.95, while A₂B₁ (50 g/tree) had the lowest at 70.98. For post-cutting treatment with IBA, 5000-ppm concentration exhibited the highest root index at 168.24, whereas the control group had the lowest at 22.32.

At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) maintained the highest root index at 53.14, while A₁B₁ (0.25%) had the lowest at 41.26, highlighting clear distinctions among zinc basal applications. A₂B₂ (75 g/tree) performed the best with a root index of 96.33, whereas A₂B₁ (50 g/tree) had the lowest at 73.36. For post-cutting treatment with IBA, 5000-ppm concentration showed the highest root index at 169.17, with the control group having the lowest at 23.86 (Table 4.62, Figure 4.62).

In 2023, the impact of zinc foliar application on the root index remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the highest root index at 59.31, while A₁B₁ (0.25%) had the lowest at 45.29. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest root index at 104.73, with A₂B₁ (50 g/tree) showing the lowest at 80.34. For post-cutting treatment with IBA, 5000-ppm concentration resulted in the highest root index at 174.08, while the control group had the lowest at 23.99 (Table 4.62, Figure 4.62).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) recorded the highest root index at 63.61, and A₁B₁ (0.25%) had the lowest at 46.38. Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) achieved the highest root index at 124.91, with A₂B₁ (50 g/tree) having the lowest at 83.73. For post-cutting treatment with IBA, 5000-ppm concentration demonstrated the highest root index at 184.93, while the control group had the lowest at 27.78 (Table 4.62, Figure 4.62).

Table 4.59 Effect of zinc (Zn) and IBA treatments on fresh weight of leaves (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.98	2.01	2.01	2.06	2.11	2.09	2.02	2.06	2.04
A₁B₂	2.23	2.25	2.24	2.41	2.41	2.41	2.32	2.33	2.33
A₁B₃	2.51	2.56	2.54	2.67	2.73	2.7	2.59	2.65	2.62
A₂B₁	2.76	2.82	2.79	2.89	2.91	2.9	2.83	2.87	2.85
A₂B₂	3.23	3.23	3.23	3.72	3.76	3.74	3.48	3.51	3.5
A₂B₃	3.05	3.02	3.04	3.21	3.34	3.28	3.13	3.17	3.15
A₃B₁	4.18	4.21	4.2	4.51	4.53	4.52	4.35	4.35	4.35
A₃B₂	4.06	4.06	4.06	4.24	4.26	4.25	4.15	4.16	4.16
A₃B₃	1.64	1.67	1.66	1.93	1.96	1.95	1.79	1.82	1.81
Mean	2.85	2.87		3.07	3.11		2.96	2.99	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.006	0.002	0.006	0.002	0.008	0.003
Factor B	0.006	0.002	0.006	0.002	0.008	0.003
Factor C	0.008	0.003	0.006	0.002	0.006	0.002
Interaction A X B	0.011	0.004	0.01	0.003	0.013	0.004
Interaction A X C	0.013	0.004	0.01	0.003	0.01	0.003
Interaction B X C	0.013	0.004	0.01	0.003	0.01	0.003
Interaction A X B X C	0.023	0.008	0.018	0.006	0.017	0.006

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

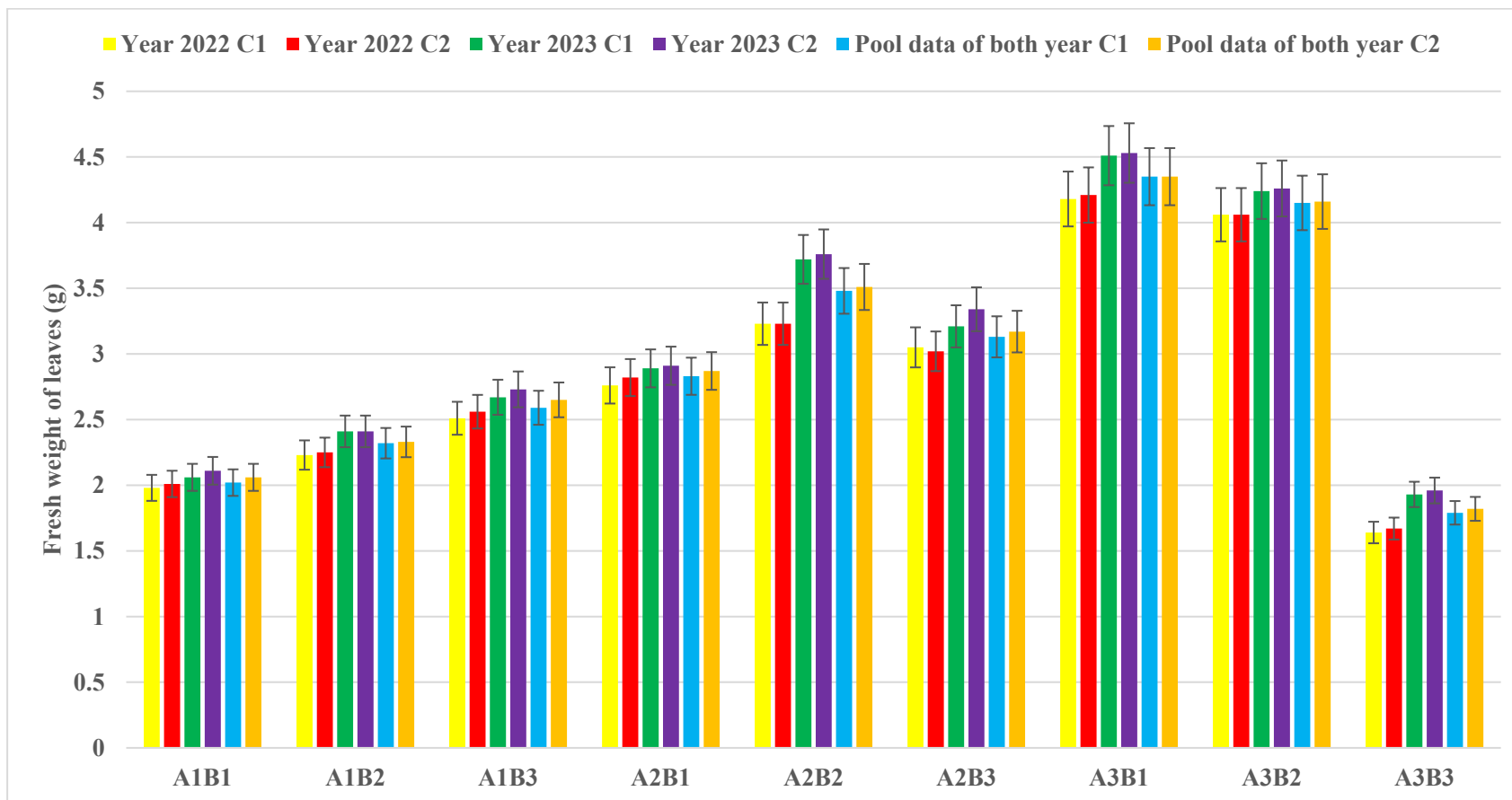


Figure 4.59 Graphical representation of the effect of Zinc (Zn) and IBA treatments on fresh weight of leaves (g) in guava cuttings at different days.

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the highest Root Index at 55.94, while A₁B₁ (0.25%) had the lowest at 42.85, indicating consistent results (Table 4.62, Figure 4.62). Among the various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest Root Index at 98.84, and A₂B₁ (50 g/tree) had the lowest at 75.66. For post-cutting treatment with IBA, 5000-ppm concentration consistently led to the highest Root Index with a mean value of 171.16, while the control group had the lowest at 23.06.

At 60 days, pooled data indicated that ZF₃ (0.75%) had the highest Root Index at 58.37, while ZF₁ (0.25%) had the lowest at 43.82. Among zinc basal treatments, ZB₂ (75 g/tree) achieved the highest Root Index at 110.62, whereas ZB₁ (50 g/tree) had the lowest at 78.55. For post-cutting treatment with IBA, 5000-ppm concentration maintained the highest Root Index with a pooled mean value of 177.05, while the control group had the lowest at 25.82 (Figure 4.62).

Root index in cuttings was significantly affected by the timing of pre-cutting zinc treatments or the dormant stage of guava. Cuttings collected 60 days after treatment root index higher (89.19) compared to those taken after 30 days (84.37). The method of application and interactions (AxB, BxC, AxC, AxBxC) also played a significant role. The highest root index (174.11) occurred in the A₃B₁C₂ treatment, involving cuttings collected after 60 days of the dormant stage and dipped in 5000 ppm IBA.

Following the results, it is evident that the root index, which measures root development and overall root health, is significantly influenced by zinc availability. Zinc acts as a cofactor in various enzymatic processes, which contributes to enhanced root growth and function. Research indicates that zinc application improves the root index by promoting a more robust root architecture and increasing root biomass (Broadley *et al.*, 2007).

Table 4.60 Effect of zinc (Zn) and IBA treatments on dry weight of leaves (g) in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	0.74	0.76	0.75	0.83	0.85	0.84	0.79	0.81	0.8
A ₁ B ₂	0.86	0.91	0.89	1.08	1.11	1.1	0.97	1.01	0.99
A ₁ B ₃	0.99	1.02	1.01	1.24	1.33	1.29	1.12	1.17	1.15
A ₂ B ₁	1.15	1.2	1.18	1.36	1.46	1.41	1.26	1.33	1.3
A ₂ B ₂	1.55	1.62	1.59	1.95	2.08	2.02	1.75	1.85	1.8
A ₂ B ₃	1.38	1.45	1.42	1.64	1.67	1.66	1.51	1.56	1.54
A ₃ B ₁	2.28	2.42	2.35	2.77	2.66	2.72	2.53	2.54	2.54
A ₃ B ₂	2.11	2.2	2.16	2.47	2.41	2.44	2.29	2.31	2.3
A ₃ B ₃	0.54	0.5	0.52	0.69	0.76	0.73	0.62	0.63	0.63
Mean	1.29	1.34		1.56	1.59		1.43	1.47	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.008	0.003	0.008	0.003	0.01	0.003
Factor B	0.008	0.003	0.008	0.003	0.01	0.003
Factor C	0.009	0.003	0.007	0.002	0.006	0.002
Interaction A X B	0.014	0.005	0.014	0.005	0.018	0.006
Interaction A X C	0.015	0.005	0.012	0.004	0.011	0.003
Interaction B X C	0.015	0.005	0.012	0.004	0.011	0.003
Interaction A X B X C	0.026	0.009	0.02	0.007	0.018	0.006

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

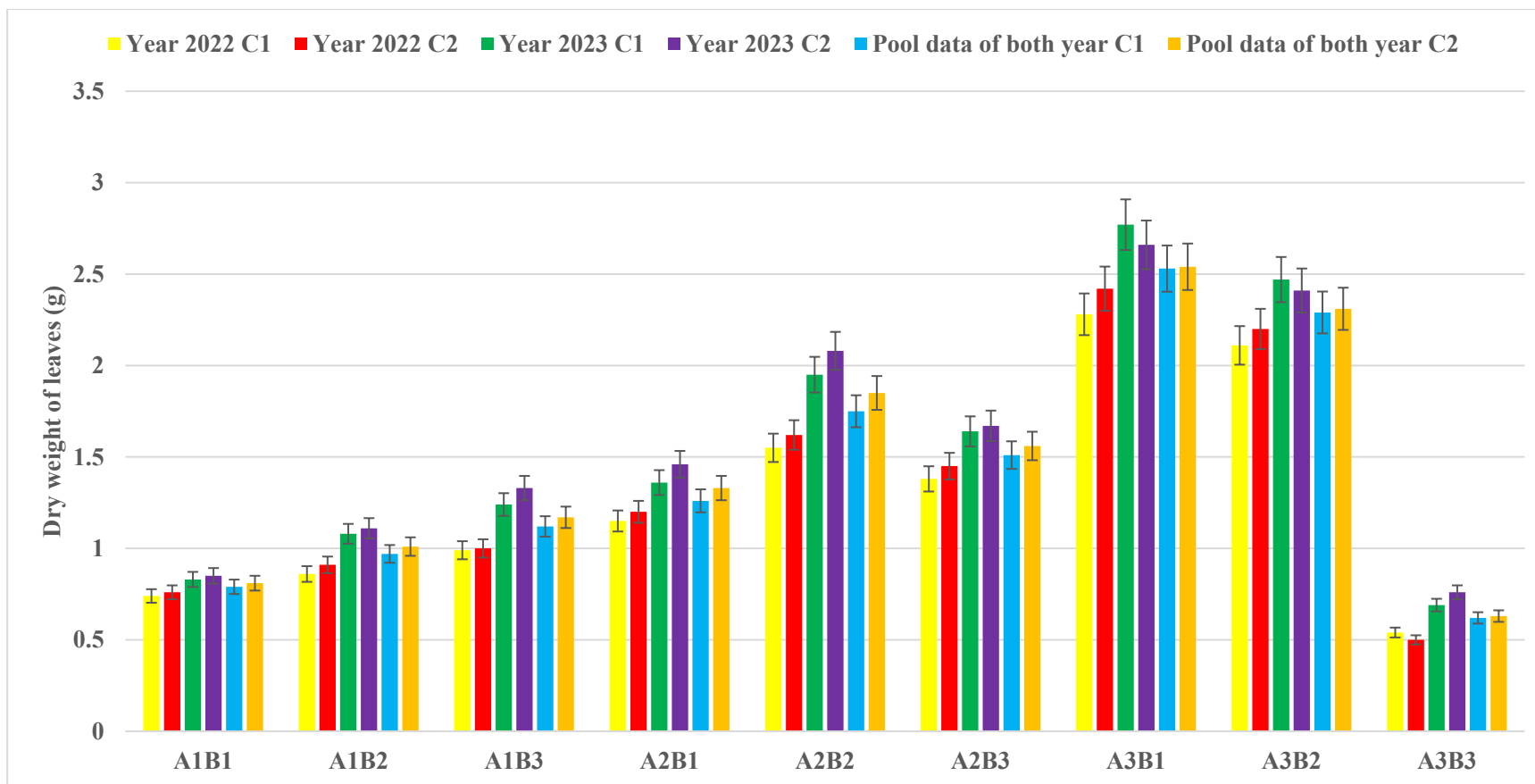


Figure 4.60 Graphical representation of the effect of Zinc (Zn) and IBA treatments on dry weight of leaves (g) in guava cuttings

Table 4.61 Effect of zinc (Zn) and IBA treatments on root to shoot ratio in guava cuttings at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	1.09	1.07	1.08	0.99	1.01	1.01	1.04	1.03	1.03
A₁B₂	1.03	1.03	1.03	0.96	0.95	0.95	0.99	0.99	0.99
A₁B₃	0.97	0.98	0.98	0.93	0.93	0.93	0.95	0.95	0.95
A₂B₁	0.91	0.93	0.92	0.89	0.92	0.91	0.9	0.93	0.92
A₂B₂	0.86	0.91	0.89	0.86	0.89	0.88	0.86	0.91	0.88
A₂B₃	0.88	0.92	0.9	0.87	0.9	0.88	0.88	0.91	0.89
A₃B₁	0.85	0.9	0.88	0.87	0.89	0.88	0.86	0.9	0.88
A₃B₂	0.85	0.89	0.87	0.84	0.87	0.85	0.85	0.87	0.86
A₃B₃	1.09	1.11	1.1	0.97	0.96	0.97	1.03	1.03	1.03
Mean	0.95	0.97		0.91	0.92		0.93	0.95	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.005	0.002	0.005	0.002	0.004	0.001
Factor B	0.005	0.002	0.005	0.002	0.004	0.001
Factor C	0.003	0.001	0.003	0.001	0.003	0.001
Interaction A X B	0.009	0.003	0.009	0.003	0.007	0.002
Interaction A X C	0.006	0.002	0.005	0.002	0.004	0.002
Interaction B X C	0.006	0.002	0.005	0.002	0.004	0.002
Interaction A X B X C	0.01	0.003	0.009	0.003	0.008	0.003

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

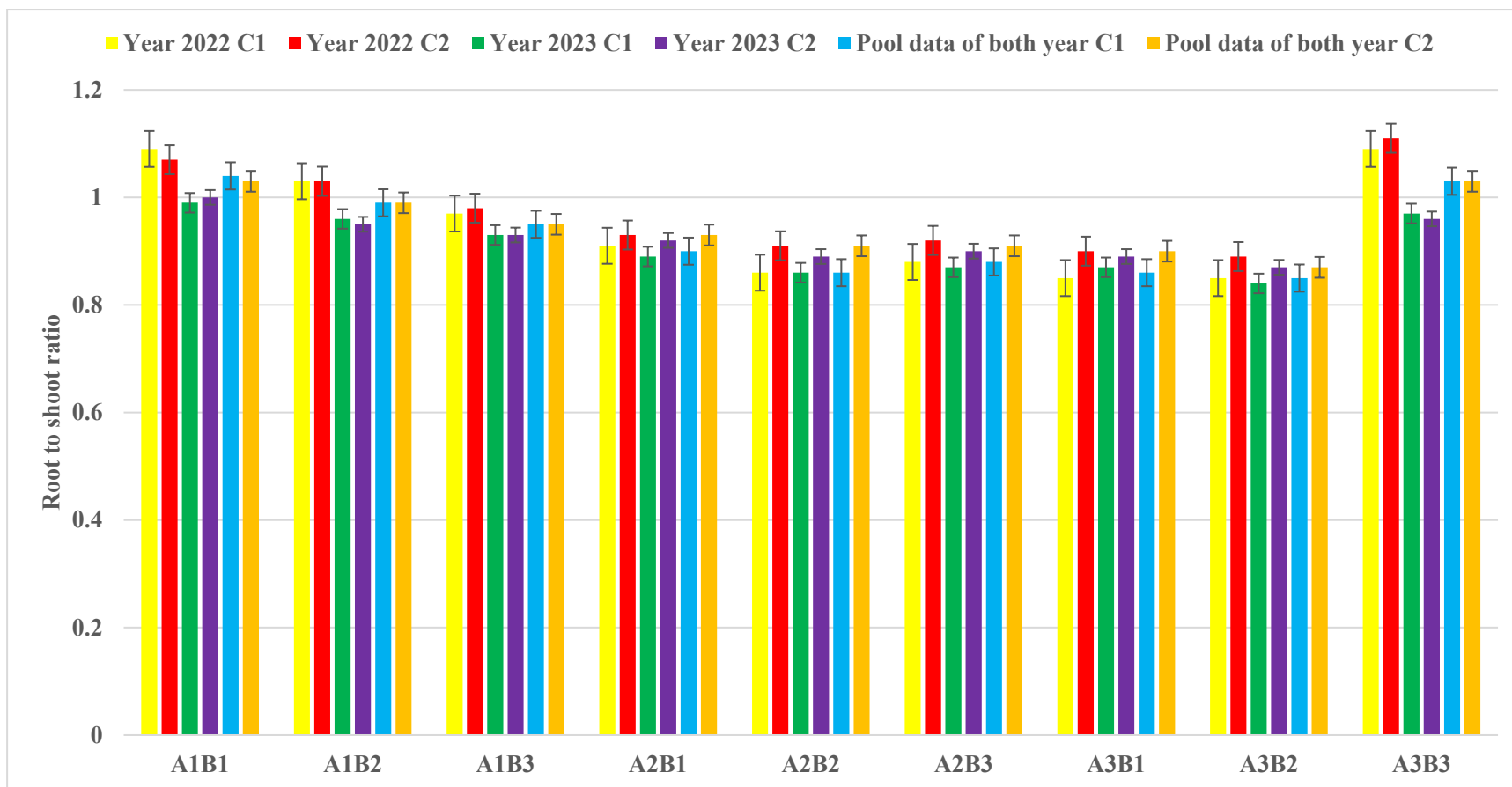


Figure 4.61 Graphical representation of the effect of zinc (Zn) and treatments on root to shoot ratio in guava cuttings at different days.

Table 4.62 Effect of zinc (Zn) and IBA treatments on root index in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A ₁ B ₁	41.13	41.26	41.2	45.29	46.38	45.84	42.85	43.82	43.34
A ₁ B ₂	44.61	45.69	45.15	50.59	51.92	51.86	47.6	48.81	48.21
A ₁ B ₃	52.56	53.14	52.85	59.31	63.61	61.46	55.94	58.37	57.16
A ₂ B ₁	70.98	73.36	72.17	80.34	83.73	82.04	75.66	78.55	77.11
A ₂ B ₂	92.95	96.33	94.64	104.73	124.91	114.82	98.84	110.62	104.73
A ₂ B ₃	82.06	84.31	83.19	93.51	110.79	102.15	87.79	97.55	92.67
A ₃ B ₁	168.24	169.17	168.71	174.08	184.93	179.51	171.16	177.05	174.11
A ₃ B ₂	152.29	154.18	153.24	160.56	169.96	165.26	156.43	162.07	159.25
A ₃ B ₃	22.32	23.86	23.09	23.99	27.78	25.89	23.06	25.82	24.44
Mean	80.79	82.37		88.05	96		84.37	89.19	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.019	0.007	0.07	0.023	0.046	0.015
Factor B	0.019	0.007	0.07	0.023	0.046	0.015
Factor C	0.016	0.006	0.009	0.003	0.043	0.015
Interaction A X B	0.034	0.012	0.121	0.04	0.079	0.026
Interaction A X C	0.027	0.01	0.016	0.006	0.075	0.025
Interaction B X C	0.027	0.01	0.016	0.006	0.075	0.025
Interaction A X B X C	0.047	0.017	0.028	0.01	0.13	0.044

A ₁ B ₁	Pre-cutting 0.25% zinc foliar	A ₂ B ₁	Pre-cutting 50g/tree zinc basal	A ₃ B ₁	Post-cutting 5000 ppm IBA
A ₁ B ₂	Pre-cutting 0.50% zinc foliar	A ₂ B ₂	Pre-cutting 75g /tree zinc basal	A ₃ B ₂	Post-cutting 10000 ppm IBA
A ₁ B ₃	Pre-cutting 0.75% zinc foliar	A ₂ B ₃	Pre-cutting 100g/tree zinc basal	A ₃ B ₃	untreated
C ₁	30 days after the dormant stage			C ₂	60 days after the dormant stage

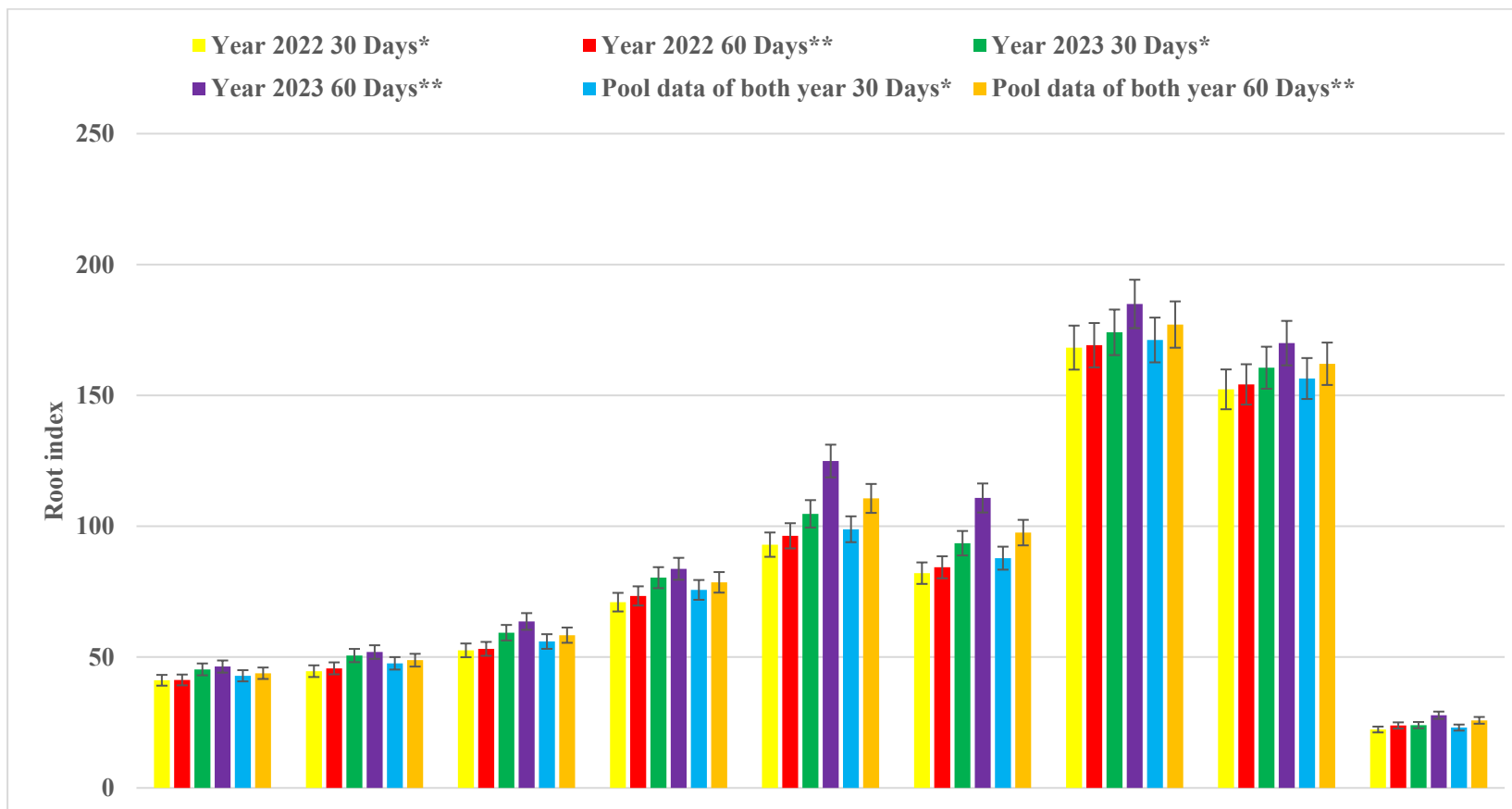


Figure 4.62 Graphical representation of the effect of Zinc (Zn) and IBA treatments on root index in guava cuttings at different days.

Table 4.63 Effect of zinc (Zn) and IBA treatments on survival percentage in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	49.39	51.62	50.5	52.65	53.76	53.2	51.89	52.47	52.18
A₁B₂	51.62	53.07	52.34	54.15	55.11	54.63	53.82	54.53	54.17
A₁B₃	54.86	56.53	55.7	57.09	58.54	57.81	56.86	57.65	57.25
A₂B₁	61.45	62.55	62.01	63.59	64.58	64.08	62.52	63.57	64.02
A₂B₂	63.55	64.78	64.17	65.28	69.11	68.59	64.42	66.95	68.15
A₂B₃	62.78	63.16	62.97	64.73	66.05	65.89	63.76	64.61	64.83
A₃B₁	74.84	76.94	75.89	74.92	74.98	74.95	73.85	74.27	74.06
A₃B₂	75.78	75.99	75.88	77.44	78.03	77.73	76.35	76.74	76.55
A₃B₃	20.27	21.58	20.92	32.31	32.62	32.47	31.13	31.81	31.47
Mean	57.17	58.46		60.24	61.42		59.39	60.29	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.032	0.011	0.021	0.007	0.020	0.007
Factor B	0.032	0.011	0.021	0.007	0.020	0.007
Factor C	0.008	0.003	0.017	0.006	0.016	0.006
Interaction A X B	0.055	0.018	0.036	0.012	0.035	0.012
Interaction A X C	0.014	0.005	0.029	0.010	0.029	0.010
Interaction B X C	0.014	0.005	0.029	0.010	0.029	0.010
Interaction A X B X C	0.024	0.008	0.051	0.018	0.049	0.018

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

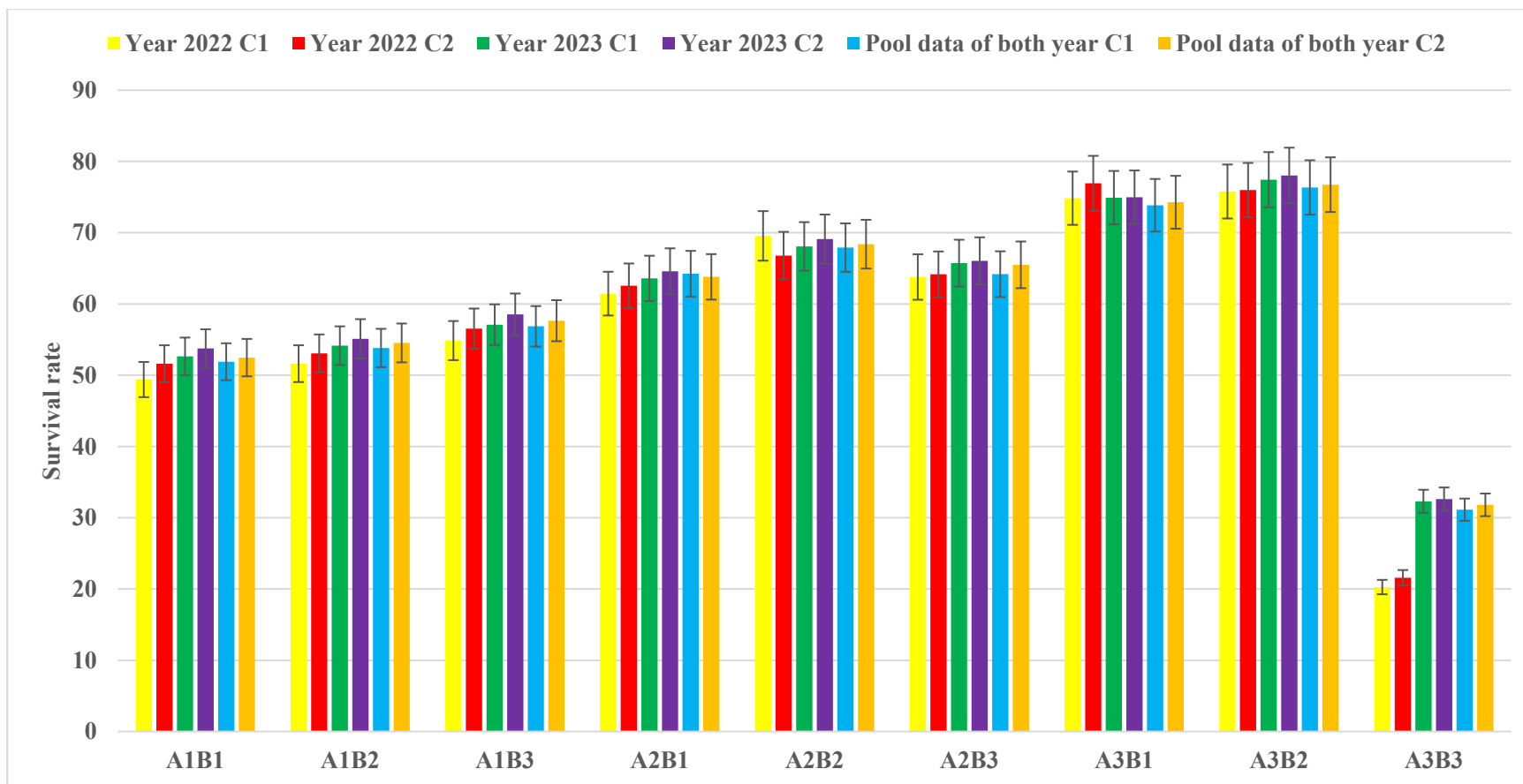


Figure 4.63 Graphical representation of the effect of Zinc (Zn) and IBA supplementation on survival rate in guava cuttings at different days.

4.2.31 Survival rate

In 2022, zinc foliar application had a marked effect on the survival rate. At 30 days after pre-cutting treatment, treatment A₁B₃ (0.75%) resulted in the highest survival rate at 54.86%, whereas A₁B₁ (0.25%) had the lowest at 49.39%, reflecting significant differences across zinc foliar treatments (Table 4.63, Figure 4.63). For various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) showed the highest survival rate at 63.55%, whereas A₂B₁ (50 g/tree) exhibited the lowest at 61.45%. For post-cutting treatment with IBA, 10,000-ppm concentration achieved a survival rate of 75.78%, whereas the control group had the lowest at 31.88%.

At 60 days after pre-cutting treatment in 2022, treatment A₁B₃ (0.75%) again showed the highest survival rate at 56.33%, while A₁B₁ (0.25%) had the lowest at 51.62%, demonstrating clear differences among zinc foliar applications. A₂B₂ (75 g/tree) performed the best with a survival rate of 64.78%, whereas A₂B₁ (50 g/tree) had the lowest at 62.55%. For post-cutting treatment with IBA, 10,000-ppm concentration achieved a survival rate of 76.94%, whereas the control group had the lowest at 21.58% (Table 4.63, Figure 4.63).

In 2023, the influence of zinc foliar application on survival rate remained significant. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) had the highest survival rate at 57.09%, while A₁B₁ (0.50%) had the lowest at 52.65%. Among the various levels of zinc applied as pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the highest survival rate at 65.28%, whereas A₂B₁ (50 g/tree) showed the lowest at 63.59%. For post-cutting treatment with IBA, 10,000-ppm concentration led to the highest survival rate at 77.44%, whereas the control group had the lowest at 32.31% (Table 4.63, Figure 4.63).

At 60 days after pre-cutting treatment in 2023, A₁B₃ (0.75%) maintained the highest survival rate at 58.54%, and A₁B₁ (0.25%) had the lowest at 53.76%. Zinc basal treatments showed A₂B₂ (75 g/tree) with the highest survival rate at 69.11%, and A₂B₁ with the lowest at 64.05%. For post-cutting treatment with IBA, 10,000-ppm concentration achieved the highest survival rate at 78.03%, whereas the control group had the lowest at 74.98% (Table 4.63, Figure 4.63).

Pooling data from both years, at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the highest survival rate at 56.86%, while A₁B₁ (0.25%) had the lowest at 51.89%, indicating consistent results (Table 4.63, Figure 4.63). Zinc applied as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest survival rate at 64.42%, whereas A₂B₁ (50 g/tree) with the lowest at 62.52%. For post-cutting treatment with IBA, 10,000-ppm concentration consistently led to the highest survival rate with a mean value of 76.35%, whereas the control group had the lowest at 31.13%.

At 60 days after pre-cutting treatment, pooled data indicated that A₁B₃ (0.75%) had the highest survival rate at 57.45%, while A₁B₁ (0.25%) had the lowest at 52.47%. Zinc applied as pre-cutting basal treatments showed A₂B₂ (75 g/tree) with the highest survival rate 66.95%, whereas A₂B₁ (50 g/tree) had the lowest 63.57%. For post-cutting treatment with IBA, 10,000-ppm concentration maintained the highest survival rate with a pooled mean value of 76.74%, whereas the control group had the lowest at 31.81% (Table 4.63, Figure 4.63)

Survival percentage in guava cuttings was significantly affected by the timing of pre-cutting zinc treatments or the dormant stage. Cuttings collected 60 days after treatment had a higher survival percentage (60.29%) compared to those taken after 30 days (53.39%). The method of application and interactions (AxB, BxC, AxC, AxBxC) also significantly influenced the survival percentage. The highest survival percentage (76.55%) was observed in the A₃B₃C₂ treatment, where cuttings were collected after 60 days of dormancy and dipped in 5000 ppm IBA.

4.2.32 Mortality rate

In both 2022 and 2023, the zinc foliar application significantly influenced the mortality rate at 30 and 60 days after pre-cutting treatment. At 30 days after pre-cutting treatment, A₁B₃ (0.75% /tree) consistently showed the lowest mortality rate, with values of 45.14% in 2022 and 42.91% in 2023, while A₁B₁ (0.25%/tree) had the highest values, 50.61% in 2022 and 47.35% in 2023 (Table 4.64, Figure 4.64).

Similarly, for various levels of zinc as pre-cutting basal treatments, A₂B₂ (75 g/tree) consistently had the lowest mortality rate, with values of 30.45% in 2022 and 31.92%

in 2023, while A₂B₁ (50 g/tree) had the highest, 38.55% in 2022 and 36.41% in 2023. For post-cutting treatment with IBA, 10000-ppm concentration yielded the lowest mortality rate of 24.22% in 2022 and 22.56% in 2023, whereas the control group consistently showed the highest mortality rate (79.73% in 2022 and 67.69% in 2023).

At 60 days after pre-cutting treatment, the trends remained consistent. A₁B₃ continued to have the lowest mortality rate (43.47% in 2022 and 41.46% in 2023), while A₁B₁ had the highest (48.38% in 2022 and 46.24% in 2023). For various levels of zinc as pre-cutting basal treatments, A₂B₂ had the lowest mortality rate (33.22% in 2022 and 30.90% in 2023), while A₂B₁ had the highest (37.45% in 2022 and 35.42% in 2023). For post-cutting treatment with IBA, 10,000-ppm concentration showed the lowest mortality rate at 23.06% in 2022 and 25.02% in 2023, with the control group remaining the highest (78.42% in 2022 and 67.38% in 2023).

Pooled data from both years reinforced these trends. At 30 days after pre-cutting, A₁B₃ consistently showed the lowest mortality rate at 43.14%, with A₁B₁ the highest at 48.11% (Table 4.64). A₂B₂ had the lowest pooled mortality rate at 32.09%, and A₂B₁ had the highest at 35.76%. For post-cutting treatment with IBA, 10000-ppm concentration consistently had the lowest mortality rate at 23.65%, while the control group had the highest at 68.87%. At 60 days after pre-cutting treatment, A₁B₃ had the lowest mortality rate at 42.35%, while A₁B₁ had the highest at 47.53%. A₂B₂ performed the best among zinc basal treatments with a pooled mortality rate of 31.61%, and A₂B₁ had the highest at 36.20%. For post-cutting treatment with IBA, 10,000-ppm concentration maintained the lowest pooled mortality rate at 23.26%, and the control group remained the highest at 68.19%.

The timing of pre-cutting treatments with zinc or during the dormant stage significantly influenced the mortality percentage in cuttings. Cuttings collected after 60 days showed a lower mortality percentage (39.43%) compared to those collected after 30 days (39.97%). Additionally, the application method and interactions (AxB, BxC, AxC, AxBxC) significantly affected the mortality percentage. The lowest mortality percentage (23.45%) was observed in the A₃B₂C₂ treatment, where cuttings were collected after 60 days of the dormant stage and treated with 10,000 ppm IBA.

Table 4.64 Effect of zinc (Zn) and IBA treatments on mortality percentage in guava cuttings taken at different days.

	Year 2022			Year 2023			Pool data of both year		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
A₁B₁	50.61	48.38	49.5	47.35	46.24	46.8	48.11	47.53	47.82
A₁B₂	48.38	46.93	47.66	45.85	44.89	45.37	46.18	45.47	45.83
A₁B₃	45.14	43.47	44.3	42.91	41.46	42.19	43.14	42.35	42.75
A₂B₁	38.55	37.45	38	36.41	35.42	35.92	35.76	36.2	35.98
A₂B₂	30.45	33.22	31.83	31.92	30.9	31.41	32.09	31.61	31.85
A₂B₃	36.22	35.84	36.03	34.27	33.95	34.11	35.82	34.51	35.17
A₃B₁	25.16	23.06	24.11	25.08	25.02	25.05	26.15	25.73	25.94
A₃B₂	24.22	24.01	24.12	22.56	21.97	22.27	23.65	23.26	23.45
A₃B₃	79.73	78.42	79.08	67.69	67.38	67.53	68.87	68.19	68.53
Mean	42.05	41.2		39.34	38.58		39.97	39.43	

	Year 2022		Year 2023		Pool data	
Factors	CD	SE(m)	CD	SE(m)	CD	SE(m)
Factor A	0.018	0.006	0.013	0.004	0.011	0.004
Factor B	0.018	0.006	0.013	0.004	0.011	0.004
Factor C	0.014	0.005	0.013	0.004	0.008	0.003
Interaction A X B	0.031	0.011	0.022	0.007	0.018	0.006
Interaction A X C	0.025	0.009	0.022	0.007	0.015	0.005
Interaction B X C	0.025	0.009	0.022	0.007	0.015	0.005
Interaction A X B X C	0.043	0.015	0.038	0.013	0.025	0.009

A₁B₁	Pre-cutting 0.25% zinc foliar	A₂B₁	Pre-cutting 50g/tree zinc basal	A₃B₁	Post-cutting 5000 ppm IBA
A₁B₂	Pre-cutting 0.50% zinc foliar	A₂B₂	Pre-cutting 75g /tree zinc basal	A₃B₂	Post-cutting 10000 ppm IBA
A₁B₃	Pre-cutting 0.75% zinc foliar	A₂B₃	Pre-cutting 100g/tree zinc basal	A₃B₃	untreated
C₁	30 days after the dormant stage			C₂	60 days after the dormant stage

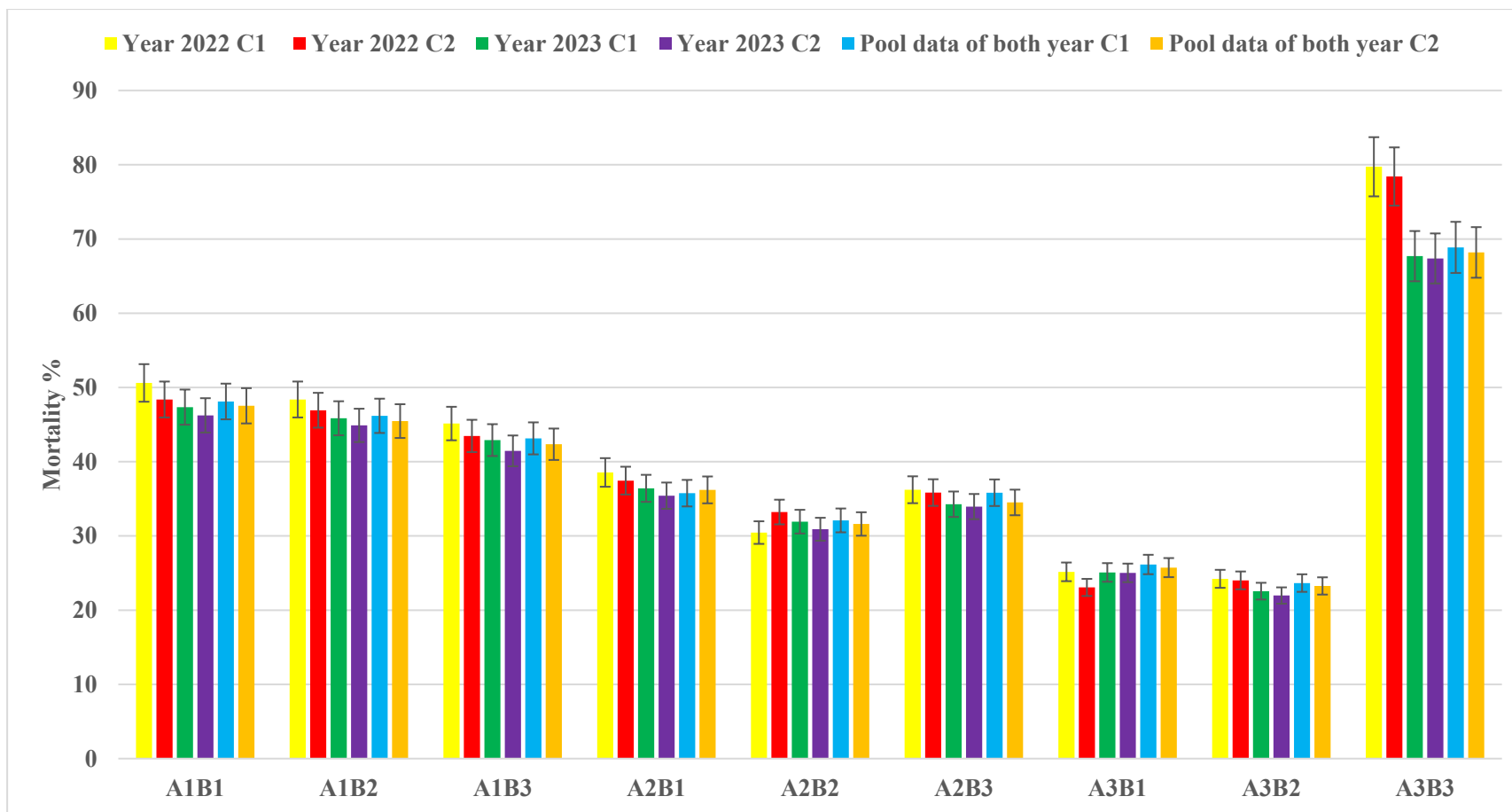


Figure 4.64 Graphical representation of the effect of Zinc (Zn) and IBA treatments on mortality (%) in guava cuttings at different days.

Conversely, the mortality percentage reflects the number of plants that fail to thrive under given conditions. Zinc deficiency is known to increase mortality rates due to impaired growth and reduced resistance to environmental stresses (Blum, 2011).

The study observed a significant reduction in mortality percentage with zinc application. Basal zinc at 100 g/tree resulted in a lower mortality rate compared to other treatments. This reduction is linked to zinc's role in improving plant health, enhancing growth, and increasing resilience to stress, thereby reducing the likelihood of plant death (Broadley et al., 2007). Present findings are fully supported by the results of Khudhur and Abdulhussein (2022) in strawberry and Somkuwar *et al.* (2013) in dog ridge rootstock.

Benefit-Cost (B:C) ratio

Based on the given data, the Zinc Basal 75 g treatment yielded the best results, achieving the highest Benefit-Cost (B:C) ratio of 1.46. This treatment provided a maximum total benefit of ₹29.71 per rooted cutting while maintaining a relatively low total cost of ₹20.29. These findings underscore the effectiveness and cost-efficiency of applying 75 g of zinc sulfate as a basal treatment compared to other treatments. In contrast, the control treatment recorded the lowest B:C ratio of 0.55.

Treatment	Total cost per rooted cuttings	Selling price per cutting	Total benefit	B:C Ratio
A₁B₁	23.90	50	26.10	1.09
A₁B₂	23.75	50	26.25	1.10
A₁B₃	23.11	50	26.89	1.16
A₂B₁	20.88	50	29.12	1.39
A₂B₂	20.29	50	29.71	1.46
A₂B₃	20.61	50	29.39	1.42
A₃B₃	32.07	50	17.93	0.55

SUMMARY AND CONCLUSION

Experiment 1 (Open field condition)**1 Initial stage**

Analysing the pooled data over two years, treatment A₁B₃ (0.75%) consistently exhibited the highest callus formation at 30 days after pre-cutting treatment, measuring 4.32 mm, while A₁B₁ (0.25%) had the lowest at 3.37mm. Among zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) recorded the Maximum callus formation at 5.43mm, whereas A₂B₁ (50 g/tree) had the minimum at 4.64 mm. The 5000 ppm IBA treatment significantly outperformed the control group, which had the lowest at 1.46mm. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) again showed the highest callus formation at 4.46mm, and A₁B₁ (0.25%) was the lowest at 3.37mm. In zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) performed best with 5.31mm, while A₂B₁ (50 g/tree) had the least callus formation. The 5000 ppm IBA treatment consistently promoted the most callus formation, with the control group exhibiting the least at 1.95mm.

2. Rooting Stage

The pooled data over two years revealed that treatment A₁B₃ (0.75%) consistently resulted in the shortest time to root initiation, with 37.42 days 30 days after the pre-cutting treatment and 36.29 days 60 days after the pre-cutting treatment. In contrast, A₁B₁ (0.25%) recorded the longest time to root initiation, at 38.02 days 30 days after the pre-cutting treatment and 37.77 days 60 days after the pre-cutting treatment. Among the zinc basal treatments, A₂B₂ (75 g/tree) had the shortest time to root initiation, with 35.57 days 30 days after the pre-cutting treatment and 34.39 days 60 days after the pre-cutting treatment, whereas A₂B₁ (50 g/tree) had the longest, at 36.84 days and 35.43 days, respectively. The 5000 ppm IBA treatment, applied as a post-cutting treatment, achieved the shortest time to root initiation overall, with a mean of 26.26 days at 30 days and 26.18 days at 60 days. This was significantly better than the control group, which recorded the longest time to root initiation, at 42.19 days and 41.71 days, respectively.

Across both years, A₁B₃ (0.75%) consistently yielded the highest average rooting percentages, with 24.57% 30 days after the pre-cutting treatment and 24.72% 60 days after the pre-cutting treatment. Conversely, A₁B₁ (0.25%) showed the lowest rooting percentages, with 23.46% 30 days after the pre-cutting treatment and 23.45% 60 days after the pre-cutting treatment. Among the zinc basal treatments, A₂B₂ (75 g/tree) recorded the highest rooting percentages, with 26.03% 30 days after the pre-cutting treatment and 26.28% 60 days after the pre-cutting treatment. In comparison, A₂B₁ (50 g/tree) had the lowest at 25.11% and 25.39%, respectively. The 5000 ppm IBA treatment, applied as a post-cutting treatment, achieved the highest rooting percentages overall, with 45.26% 30 days after treatment and 45.57% 60 days after treatment. In contrast, the control group had the lowest rooting percentages at 16.21% for both intervals.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently produced the highest number of primary roots, with 3.52 at 30 days after the pre-cutting treatment and 3.73 at 60 days after the pre-cutting treatment. In contrast, A₁B₁ (0.25%) had the lowest root numbers, with 2.80 at 30 days and 2.97 at 60 days. Among the zinc basal treatments, A₂B₂ (75 g/tree) consistently showed the highest primary root numbers, with 6.43 at 30 days and 7.02 at 60 days after the pre-cutting treatment, whereas A₂B₁ (50 g/tree) had the lowest, at 4.84 and 5.06, respectively. The 5000 ppm IBA treatment, applied as a post-cutting treatment, demonstrated the highest primary root numbers, averaging 10.74 at 30 days and 11 at 60 days, compared to the control group, which had the lowest root numbers, with 2.04 and 2.27, respectively.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently yielded the highest average number of secondary roots, with 5.42 at 30 days after the pre-cutting treatment and 5.58 at 60 days after the pre-cutting treatment. In contrast, A₁B₁ (0.25%) had the lowest number of secondary roots, with 4.61 at 30 days and 4.72 at 60 days. Among the zinc basal treatments, A₂B₂ (75 g/tree) consistently showed the highest average number of secondary roots, with 7.71 at 30 days and 7.84 at 60 days after the pre-cutting treatment, while A₂B₁ (50 g/tree) had the lowest, with 6.53 at 30 days and 6.62 at 60 days. The 5000 ppm IBA treatment, applied as a post-cutting treatment, resulted in the highest average number of secondary roots, with 13.63 at 30

days and 13.91 at 60 days, significantly outperforming the control group, which recorded the lowest secondary root numbers, with 1.78 at 30 days and 1.86 at 60 days.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the longest primary root length at 30 days after pre-cutting (1.83 cm) and 60 days after pre-cutting (1.87 cm), compared to A₁B₁ (0.25%), which had the shortest lengths (1.52 cm and 1.55 cm, respectively). Among zinc basal treatments, A₂B₂ (75 g/tree) consistently demonstrated the longest primary root length, with 2.63 cm at 30 days and 2.73 cm at 60 days after pre-cutting, while A₂B₁ (50 g/tree) had the shortest (2.13 cm and 2.18 cm, respectively). The 5000 ppm IBA as post-cutting treatment consistently showed the longest primary root length at both 30 days (4.61 cm) and 60 days (4.59 cm), significantly outperforming the control group, which had the shortest lengths (1.03 cm and 1.04 cm, respectively).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently showed the longest secondary roots at both 30 days after pre-cutting (1.04 cm) and 60 days after pre-cutting (1.05 cm), while A₁B₁ (0.25%) had the shortest secondary roots at 30 days (0.84 cm) and 60 days (0.84 cm). Among zinc basal treatments, A₂B₂ (75 g/tree) consistently demonstrated the longest secondary roots at 30 days (1.27 cm) and 60 days (1.30 cm) after pre-cutting, whereas A₂B₁ (50 g/tree) had the shortest at both time points (1.11 cm and 1.13 cm). The 5000 ppm IBA as post-cutting treatment consistently exhibited the longest secondary roots, with a mean of 2.70 cm at 30 days and 2.82 cm at 60 days after post-cutting treatment, significantly outperforming the control group, which had the shortest secondary roots (0.27 cm at 30 days and 0.28 cm at 60 days).

Pool data from both years at 30 days after pre-cutting treatment, A₁B₃ (0.75%) achieved the largest primary root diameter of 0.65 mm, while A₁B₁ (0.25%) had the smallest at 0.28 mm. Zinc basal pre-cutting treatment A₂B₂ reached 1.12 mm, the highest, and A₂B₁ the lowest at 0.83 mm. The 5000 ppm IBA post-cutting treatment resulted in a maximum root diameter of 1.50 mm, with the control at 0.14 mm. At 60 days after pre-cutting, A₁B₃ maintained the largest diameter at 0.67 mm, with A₁B₁ at 0.31 mm. A₂B₂ had 1.14 mm, the highest among zinc basal treatments, while A₂B₁

was 0.83 mm. The 5000 ppm IBA post-cutting treatment sustained the largest root diameter at 1.63 mm, with the control at 0.15 mm.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently had the largest secondary root diameter at 30 days after pre-cutting (0.32 mm) and 60 days after pre-cutting (0.33 mm), while A₁B₁ (0.25%) exhibited the smallest diameters at both time points 0.11 mm and 0.14 mm, respectively. Among zinc basal treatments, A₂B₂ (75 g/tree) had the largest secondary root diameter at both time points 0.67 mm at 30 days and 0.35 mm at 60 days after pre-cutting, whereas A₂B₁ (50 g/tree) had the smallest 0.42 mm and 0.28 mm, respectively. The 5000 ppm IBA treatment consistently achieved the largest secondary root diameter, with a mean of 0.92 mm at 30 days and 0.99 mm at 60 days after post-cutting treatment, significantly outperforming the control group, which had the smallest diameters (0.03 mm at both time points).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the highest fresh weight of roots at 30 days after pre-cutting 0.92 g and 60 days after pre-cutting 0.92 g. In contrast, A₁B₁ (0.25%) had the lowest fresh weight at both time points 0.77 g and 0.78 g, respectively. Among zinc basal treatments, A₂B₂ (75 g/tree) recorded the highest fresh weight at both intervals 1.18 g at 30 days and 1.22 g at 60 days after pre-cutting, while A₂B₁ (50 g/tree) had the lowest 1.00 g and 1.02 g, respectively. The 5000 ppm IBA treatment consistently showed the highest fresh weight of roots, with means of 2.31 g at 30 days and 2.39 g at 60 days after post-cutting treatment, significantly outperforming the control group, which had the lowest fresh weights of 0.26 g and 0.27 g.

Pooled data over two years showed that at 30 days after pre-cutting treatment, the A₁B₃ (0.75%) treatment consistently produced the highest fresh weight of secondary roots at 0.53 g, while A₁B₁ (0.25%) had the lowest at 0.30 g. Among zinc basal treatments, A₂B₂ (75 g/tree) achieved the maximum fresh weight at 0.90 g, while A₂B₁ (50 g/tree) had the lowest at 0.65 g. The 5000 ppm IBA treatment resulted in the highest fresh weight at 1.17 g, with the control group having the lowest at 0.11 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to show the highest fresh weight at 0.55 g, with A₁B₁ (0.25%) remaining the lowest at 0.31 g. A₂B₂ (75 g/tree) remained the best among zinc basal treatments at 0.91 g, while A₂B₁ (50 g/tree) had a

fresh weight of 0.70 g. The 5000 ppm IBA as post-cutting treatment maintained the highest fresh weight at 1.25 g, whereas the control group remained at the lowest with 0.11 g.

Pooled data from both years demonstrated that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently achieved the highest dry weight of primary roots at 0.28 g, while A₁B₁ (0.25%) had the lowest at 0.23 g. Among zinc basal treatments, A₂B₂ (75 g/tree) had the maximum dry weight at 0.35 g, and A₂B₁ (50 g/tree) had the minimum at 0.30 g. The 5000 ppm IBA treatment resulted in the highest dry weight at 0.69 g, with the control group showing the lowest at 0.08 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the highest dry weight at 0.28 g, with A₁B₁ (0.25%) again showing the lowest at 0.23 g. A₂B₂ (75 g/tree) led among zinc basal treatments at 0.37 g, while A₂B₁ (50 g/tree) had 0.31 g. The 5000 ppm IBA post-cutting treatment consistently had the highest dry weight at 0.72 g, and the control group remained the lowest at 0.08 g.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently had the highest dry weight of secondary roots at both 30 days (0.16 g) and 60 days (0.17 g) pre-cutting, while A₁B₁ (0.25%) recorded the lowest dry weight at 30 days (0.09 g) and 60 days (0.09 g) post-cutting. Among zinc basal treatments, A₂B₂ (75 g/tree) achieved the highest dry weight at both time points, with 0.27 g at 30 days and 0.27 g at 60 days pre-cutting, while A₂B₁ (50 g/tree) had the lowest dry weight, measuring 0.20 g at 30 days and 0.21 g at 60 days post-cutting. The 5000 ppm IBA treatment consistently resulted in the highest dry weight, with values of 0.47 g at 30 days and 0.54 g at 60 days post-cutting, compared to the control group, which had the lowest dry weight at 30 days (0.03 g) and 60 days (0.03 g) post-cutting.

Pooled data from both years showed that at 30 days post-treatment, A₁B₃ (0.75%) had the fewest days to sprout initiation at 27.17 days, while A₁B₁ (0.25%) had the most at 28.10 days. Among zinc basal treatments, A₂B₂ (75 g/tree) achieved the fewest days to sprout initiation at 24.04 days, with A₂B₁ (50 g/tree) having the most at 25.40 days. The 5000 ppm IBA treatment resulted in the shortest time to sprout initiation at 19.40 days, while the control group had the longest at 31.92 days.

Pooling data from both years, treatment A₁B₃ (0.75%) applied pre-cutting consistently achieved the highest sprouting percentage at both 30 days (36.86%) and 60 days (37.08%), while A₁B₁ (0.25%) applied pre-cutting had the lowest sprouting percentages at 30 days (38.18%) and 60 days (35.19%). Among zinc basal treatments, A₂B₂ (75 g/tree) applied pre-cutting showed the highest sprouting percentages at 30 days (39.05%) and 60 days (39.42%), whereas A₂B₁ (50 g/tree) applied pre-cutting had the lowest at 30 days (37.67%) and 60 days (38.09%). The 5000 ppm IBA post-cutting treatment consistently resulted in the highest sprouting percentages, with 67.89% at 30 days and 68.36% at 60 days, compared to the control group, which had the lowest sprouting percentages at 30 days (24.32%) and 60 days (24.32%).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently resulted in the highest number of sprouts at both 30 days after pre-cutting (0.89) and 60 days after pre-cutting (0.93), while A₁B₁ (0.25% /tree) had the lowest numbers at 30 days (0.55) and 60 days (0.56). Among zinc basal treatments, A₂B₂ (75 g/tree) demonstrated the maximum number of sprouts, with 1.32 at 30 days and 1.39 at 60 days after pre-cutting, whereas A₂B₁ (50 g/tree) had the minimum, with 1.03 at 30 days and 1.08 at 60 days. The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the highest number of sprouts at both 30 days (2.39) and 60 days (2.44), significantly outperforming the control group, which had the lowest numbers of sprouts at 30 days (0.14) and 60 days (0.16).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently resulted in the highest number of sprouts at both 30 days after pre-cutting (1.37) and 60 days after pre-cutting (1.41), while A₁B₁ (0.25% /tree) had the lowest numbers at 30 days (1.04) and 60 days (1.09). Among zinc basal treatments, A₂B₂ (75 g/tree) demonstrated the maximum number of sprouts, with 1.99 at 30 days and 2.02 at 60 days after pre-cutting, whereas A₂B₁ (50 g/tree) had the minimum, with 1.57 at 30 days and 1.57 at 60 days. The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the highest number of sprouts at both 30 days (3.19) and 60 days (3.35), significantly outperforming the control group, which had the lowest numbers of sprouts at 30 days (0.17) and 60 days (0.19).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently resulted in the highest number of sprouts at both 30 days after pre-cutting (2.05) and 60 days after pre-cutting (2.07), while A₁B₁ (0.25%) had the lowest numbers at 30 days (1.74) and 60 days (1.77). Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) demonstrated the maximum number of sprouts, with 2.58 at 30 days and 2.63 at 60 days after pre-cutting, whereas A₂B₁ (50 g/tree) had the minimum, with 2.23 at 30 days and 2.25 at 60 days. The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the highest number of sprouts at both 30 days (4.92) and 60 days (5.01), significantly outperforming the control group, which had the lowest numbers of sprouts at 30 days (0.32) and 60 days (0.34).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the maximum diameter of sprout at 30 days after pre-cutting (0.32 mm) and 60 days after pre-cutting (0.33 mm), while A₁B₁ (0.25%) recorded the minimum diameter of sprout at 30 days (0.11 mm) and 60 days (0.14 mm). Among zinc basal treatments applied pre-cutting, A₂B₂ (75 g/tree) demonstrated the maximum diameter of sprout at 30 days (0.67 mm) and 60 days (0.69 mm), whereas A₂B₁ (50 g/tree) had the minimum at 30 days (0.42 mm) and 60 days (0.43 mm). The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the maximum diameter of sprout at both 30 days (0.92 mm) and 60 days (0.99 mm), significantly outperforming the control group, which had the minimum diameter of sprout at 30 days (0.03 mm) and 60 days (0.04 mm).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the minimum length of sprout at 30 days after pre-cutting (7.68 cm) and 60 days after pre-cutting (7.58 cm), while A₁B₁ (0.25%) recorded the maximum length of sprout at 30 days (8.37 cm) and 60 days (8.14 cm). Among zinc basal treatments applied pre-cutting, A₂B₂ (75 g/tree) demonstrated the minimum length of sprout at 30 days (7.03 cm) and 60 days (6.97 cm), whereas A₂B₁ (50 g/tree) had the maximum at 30 days (7.50 cm) and 60 days (7.42 cm). The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the minimum length of sprout at both 30 days (5.53 cm) and 60 days (5.47 cm), significantly outperforming the control group, which had the minimum at 30 days (11.19 cm) and 60 days (11.14 cm).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the maximum diameter of a shoot at 30 days after pre-cutting (5.71 mm) and 60 days after pre-cutting (5.77 mm), while A₁B₁ (0.25%) recorded the minimum diameter of a shoot at 30 days (5.36 mm) and 60 days (5.41 mm). Among zinc basal treatments applied pre-cutting, A₂B₂ (75 g/tree) demonstrated the maximum diameter of a shoot at 30 days (6.26 mm) and 60 days (6.44 mm), whereas A₂B₁ (50 g/tree) had the minimum at 30 days (5.83 mm) and 60 days (5.91 mm). The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the maximum diameter of a shoot at both 30 days (7.50 mm) and 60 days (7.65 mm), significantly outperforming the control group, which had the minimum diameter of a shoot at 30 days (2.48 mm) and 60 days (2.61 mm).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the highest fresh weight of shoots at 30 days after pre-cutting (1.13 g) and 60 days after pre-cutting (1.19 g), while A₁B₁ (0.25%) recorded the lowest fresh weight of shoots at 30 days (0.76 g) and 60 days (0.78 g). Among zinc basal treatments, A₂B₂ (75 g/tree) demonstrated the maximum fresh weight of shoots, with 1.44 g at 30 days and 1.54 g at 60 days after pre-cutting, whereas A₂B₁ (50 g/tree) had the minimum, with 1.42 g at 30 days and 1.54 g at 60 days. The 5000 ppm IBA treatment, applied post-cutting, consistently resulted in the highest fresh weight of shoots at both 30 days (2.69 g) and 60 days (2.68 g), significantly outperforming the control group, which had the lowest fresh weight at 30 days (0.26 g) and 60 days (0.27 g).

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the highest dry weight of shoots at 30 days after pre-cutting (0.62 g) and 60 days after pre-cutting (0.68 g), while A₁B₁ (0.25%) recorded the lowest dry weight of shoots at 30 days after pre-cutting (0.27 g) and 60 days after pre-cutting (0.30 g). Among zinc basal treatments applied pre-cutting, A₂B₃ (100 g/tree) demonstrated the maximum dry weight of shoots, with 1.19 g at 30 days and 1.25 g at 60 days, whereas A₂B₁ (50 g/tree) had the minimum, with 0.82 g at 30 days and 0.85 g at 60 days. The 5000 ppm IBA post-cutting treatment, applied post-cutting, consistently resulted in the highest dry weight of shoots at both 30 days (1.65 g) and 60 days (1.83 g), significantly

outperforming the control group, which had the lowest dry weight at 30 days (0.09 g) and 60 days (0.13 g).

Pooling data from both years reaffirmed the trends in leaf production. At 30 days after pre-cutting, treatment A₁B₃ (0.75%) consistently had the highest number of leaves at 2.35, while A₁B₁ (0.25%) recorded the lowest at 1.96. Among zinc basal treatments applied pre-cutting, A₂B₂ (75 g/tree) demonstrated the maximum number of leaves at 3.47, compared to A₂B₁ (50 g/tree), which had the minimum at 2.71. The 5000 ppm IBA treatment, applied post-cutting consistently yielded the highest average leaf count at 30 days (7.89), while the control group had the lowest (1.05). At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to lead with 2.41 leaves, while A₁B₁ (0.25%) had the lowest at 1.98. Zinc basal treatments showed A₂B₂ (75 g/tree) with the highest leaf count at 3.67 and A₂B₁ (50 g/tree) with the lowest at 2.75. The 5000 ppm IBA post-cutting treatment maintained the highest average leaf count at 60 days after pre-cutting (8.19), while the control group had the lowest (1.09).

Over two years, the data showed clear trends in leaf area. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently had the largest leaf area, measuring 1.92 cm², compared to 1.34 cm² for A₁B₁ (0.25%). Zinc basal pre-cutting treatments revealed A₂B₃ (100 g/tree) as having the largest leaf area at 2.62 cm², while A₂B₁ (50 g/tree) had the smallest at 2.17 cm². The 5000 ppm IBA post-cutting treatment also led to a leaf area of 6.93 cm², far exceeding the control group's 0.58 cm². By 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained its lead with a leaf area of 2.04 cm², whereas A₁B₁ (0.25%) had a smaller area of 1.44 cm². A₂B₃ (100 g/tree) continued outperforming other zinc treatments with a leaf area of 2.71 cm², while A₂B₁ (50 g/tree) had 2.17 cm². The IBA 5000 ppm post-cutting treatment still showed the largest leaf area at 7.30 cm², with the control group at 0.62 cm².

Pooling data from both years confirmed these results. At 30 days, A₁B₃ (0.75%) consistently had the highest chlorophyll content at 0.59 mg/g, while A₁B₁ (0.25%) had the lowest at 0.27 mg/g. Among zinc basal treatments, A₂B₂ (75 g/tree) showed the highest chlorophyll content at 1.08 mg/g, compared to 0.76 mg/g for A₂B₁ (50 g/tree). The 5000 ppm IBA post-cutting treatment led with the highest chlorophyll content at 1.55 mg/g, while the control group had the lowest at 0.08 mg/g. At 60 days after pre-

cutting treatment, A₁B₃ (0.75%) maintained the highest chlorophyll content at 0.61 mg/g, with A₁B₁ (0.25%) at 0.30 mg/g. For zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) had the highest chlorophyll content at 1.05 mg/g, whereas A₂B₁ (50 g/tree) had the lowest at 0.77 mg/g. The 5000 ppm IBA post-cutting treatment continued to show the highest chlorophyll content at 1.60 mg/g, with the control group at 0.09 mg/g.

Pooled data from both years confirmed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest fresh weight of leaves at 0.87 g, while A₁B₁ (0.25%) had the lowest at 0.44 g. Among zinc basal treatments, A₂B₂ (75 g/tree) achieved the highest fresh weight at 1.46 g, with A₂B₁ (50 g/tree) at the lowest at 1.07 g. The 5000 ppm IBA post-cutting treatment resulted in the greatest fresh weight of leaves at 2.79 g, while the control group had the least at 0.22 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the highest fresh weight at 0.90 g, and A₁B₁ (0.25%) was the lowest at 0.45 g. A₂B₂ (75 g/tree) continued to perform best among zinc basal treatments at 1.54 g, compared to A₂B₁ (50 g/tree) at 1.08 g. The 5000 ppm IBA treatment remained superior with the highest fresh weight at 2.83 g, while the control group stayed at the lowest at 0.22 g.

Across both years, data consistently showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) achieved the highest dry weight of leaves at 0.54 g, while A₁B₁ (0.25%) had the lowest at 0.23 g. Among the zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) led with a dry weight of 0.99 g, compared to A₂B₁ (50 g/tree) at 0.71 g. The 5000 ppm IBA post-cutting treatment produced the highest dry weight at 1.65 g, significantly higher than the control group, which had 0.08 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to show the highest dry weight at 0.55 g, while A₁B₁ (0.25%) remained the lowest at 0.23 g. A₂B₂ (75 g/tree) again topped the zinc basal treatments with 1.04 g, whereas A₂B₁ (50 g/tree) had 0.73 g. The 5000 ppm IBA post-cutting treatment maintained the highest dry weight at 1.75 g, with the control group at 0.08 g.

Pooled data from both years showed that at 30 days after pre-cutting treatment, A₁B₃ achieved the minimum root-to-shoot ratio of 0.82, while A₁B₁ had the maximum at 1.01. Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) led with a ratio of 0.75, and A₂B₁ (50 g/tree) had the highest at 0.78. The 5000 ppm IBA post-cutting

treatment had the highest ratio of 1.60, compared to 0.66 in the control group. At 60 days after pre-cutting treatment, A₁B₃ maintained the highest ratio at 1.05, while A₁B₁ had the lowest at 0.85. A₂B₂ again performed best at 1.30, and the 5000 ppm IBA treatment remained the highest at 1.80, with the control at 0.70.

Pooled data from both years revealed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest root index of 6.50, while A₁B₁ (0.25%) had the lowest at 4.33. Among zinc basal treatments, A₂B₂ (75 g/tree) led with a root index of 17.01, and A₂B₁ (50 g/tree) had the lowest at 10.34. The 5000 ppm IBA post-cutting treatment showed the highest Root Index of 49.70, compared to 2.12 in the control group. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to lead with a root index of 7.03, while A₁B₁ (0.25%) remained the lowest at 4.67. A₂B₂ (75 g/tree) achieved the highest index at 19.31, and the 5000 ppm IBA post-cutting treatment maintained the highest index of 50.89, with the control at 2.37.

Pooled data from both years showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) achieved the highest survival rate of 30.13%, while A₁B₁ (0.25%) had the lowest at 22.18%. Among zinc basal pre-cutting treatments, A₂B₃ (100 g/tree) had the highest rate at 38.11%, and A₂B₁ (50 g/tree) was the lowest at 34.48%. The 10000 ppm IBA post-cutting treatment led to a survival rate of 57.57%, whereas the control group had the lowest at 8.33%. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the highest survival rate at 30.89%, with A₁B₁ (0.25%) at 22.67%. A₂B₂ (75 g/tree) again showed the highest rate 38.56% among zinc treatments. The 10000 ppm IBA post-cutting treatment continued to lead with a survival rate of 58.94% and the control group at 9.33%.

Pooled data from both years demonstrated that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) exhibited the lowest mortality rate at 69.87%, while A₁B₁ (0.25%) had the highest at 77.82%. Among zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) had the lowest mortality rate at 62.64%, and A₂B₁ (50 g/tree) was the highest at 65.52%. The 10000 ppm IBA post-cutting treatment also showed the lowest mortality rate at 42.43%, with the control group having the highest at 91.67%. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) had the lowest mortality rate at 69.11%, whereas A₁B₁ (0.25%) had the highest at 77.33%. Among zinc pre-cutting treatments, A₂B₂

(75 g/tree) had the lowest rate at 62.38%, while A₂B₁ (50 g/tree) had the highest at 64.05%. The 5000 ppm IBA treatment maintained the lowest mortality rate at 40.53%, with the control group remaining the highest at 90.81%.

Experiment 2 (Shed net condition)

Pooling data from both years confirmed consistent trends in callus formation. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently showed the highest callus formation score at 7.82 mm, while A₁B₁ (0.25%) had the lowest at 6.97 mm. Among zinc basal treatments, A₂B₂ (75 g/tree) had the highest average callus formation score at 8.58 mm, while A₂B₁ (50 g/tree) had the lowest at 7.13 mm. The 5000 ppm IBA post-cutting treatment consistently yielded the highest callus formation score 14.78 mm, while the control group had the lowest at 5.76 mm. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) maintained the highest callus formation score at 8.27 mm, while A₁B₁ (0.25%) had the lowest at 7.31 mm. Among zinc basal treatments, A₂B₂ (75 g/tree) had the highest average callus formation score at 8.98 mm, while A₂B₁ (50 g/tree) had the lowest at 7.36 mm. The 5000 ppm IBA post cutting treatment continued to promote the highest callus formation score at 15.45 mm, while the control group had the lowest at 6.12 mm.

Based on the pooled data over two years, treatment A₁B₃ (0.75%) consistently showed the shortest time to root initiation, with 24.10 days at 30 days and 24.01 days at 60 days. Conversely, A₁B₁ (0.25%) resulted in the longest root initiation times, at 24.59 days and 24.39 days, respectively. Among the pre-cutting zinc basal treatments, A₂B₂ (75 g/tree) also led in root initiation, with 22.40 days and 22.25 days at 30 and 60 days, while A₂B₁ (50 g/tree) had the longest initiation times. The post-cutting 5000 ppm IBA treatment significantly outperformed the control, showing the shortest days to root initiation with 19.19 days at 30 days and 19.13 days at 60 days.

Across both years, A₁B₃ (0.75%) consistently yielded the highest average rooting percentages, with 46.05% 30 days after the pre-cutting treatment and 48.04% 60 days after the pre-cutting treatment. Conversely, A₁B₁ (0.25%) showed the lowest rooting percentages, with 41.90% 30 days after the pre-cutting treatment and 44.21% 60 days after the pre-cutting treatment. Among the zinc basal treatments, A₂B₂ (75 g/tree)

recorded the highest rooting percentages, with 49.91% 30 days after the pre-cutting treatment and 52.13% 60 days after the pre-cutting treatment. In comparison, A₂B₁ (50 g/tree) had the lowest at 46.13% and 48.41%, respectively. The 5000 ppm IBA treatment, applied as a post-cutting treatment, achieved the highest rooting percentages overall, with 66.79% 30 days after treatment and 68.01% 60 days after treatment. In contrast, the control group had the lowest rooting percentages at 29.09% and 31.11% for both intervals.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently produced the highest number of primary roots, with 7.65 at 30 days after the pre-cutting treatment and 7.93 at 60 days after the pre-cutting treatment. In contrast, A₁B₃ (0.25%) had the lowest root numbers, with 6.35 at 30 days and 6.48 at 60 days. Among the zinc basal treatments, A₂B₂ (75 g/tree) consistently showed the highest primary root numbers, with 11.79 at 30 days and 12.77 at 60 days after the pre-cutting treatment, whereas A₂B₁ (50 g/tree) had the lowest, at 10.03 and 10.25, respectively. The 5000 ppm IBA treatment, applied as a post-cutting treatment, demonstrated the highest primary root numbers, averaging 16.72 at 30 days and 17.12 at 60 days, compared to the control group, which had the lowest root numbers, with 3.84 and 4.29, respectively.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently yielded the highest average number of secondary roots, with 21.60 at 30 days after the pre-cutting treatment and 21.93 at 60 days after the pre-cutting treatment. In contrast, A₁B₃ (0.25%) had the lowest number of secondary roots, with 20.32 at 30 days and 20.70 at 60 days. Among the zinc basal treatments, A₂B₂ (75 g/tree) consistently showed the highest average number of secondary roots, with 24.51 at 30 days and 24.86 at 60 days after the pre-cutting treatment, while A₂B₁ (50 g/tree) had the lowest, with 22.98 at 30 days and 22.30 at 60 days. The 5000 ppm IBA treatment, applied as a post-cutting treatment, resulted in the highest average number of secondary roots, with 29.83 at 30 days and 30.15 at 60 days, significantly outperforming the control group, which recorded the lowest secondary root numbers, with 10.85 at 30 days and 11.15 at 60 days.

Pooling data from 2022 and 2023, A₁B₃ (0.75%) consistently produced the longest root length at 30 days at 7.31 cm, while A₁B₁ (0.25%) had the shortest at 6.71 cm.

Among zinc basal treatments, A₂B₂ (75 g/tree) resulted in the longest roots at 8.38 cm, while A₂B₁ (50 g/tree) had the shortest at 7.54 cm. The 5000 ppm IBA treatment consistently produced the longest roots at 10.09 cm, while the control group had the shortest at 5.92 cm. At 60 days, A₁B₃ (0.75%) continued to show the longest roots at 7.36 cm, while A₁B₁ (0.25%) had the shortest at 6.77 cm. Among zinc basal treatments, A₂B₂ (75 g/tree) produced the longest roots at 8.65 cm, while A₂B₁ (50 g/tree) had the shortest at 7.66 cm. The 5000 ppm IBA treatment maintained the longest root length at 10.22 cm, while the control group had the shortest at 6 cm.

Pooling data from both years, at 30 days, A₁B₃ (0.75%) showed the longest secondary roots at 2.92 cm, while A₁B₁ (0.25%) had the shortest at 2.68 cm. Among zinc basal treatments, A₂B₂ (75 g/tree) produced the longest secondary roots at 3.25 cm, and A₂B₁ (50 g/tree) had the shortest at 3.01 cm. The 5000 ppm IBA post cutting treatment consistently resulted in the longest secondary roots at 4.13 cm, while the control group had the shortest at 2.16 cm. At 60 days, A₁B₃ (0.75%) continued to have the longest secondary roots at 2.94 cm, while A₁B₁ (0.25%) showed the shortest at 2.70 cm. Zinc basal treatments indicated that A₂B₂ (75 g/tree) performed the best, producing the longest secondary roots at 3.25 cm, while A₂B₁ (50 g/tree) had the shortest at 3.06 cm. The 5000 ppm IBA post cutting treatment maintained its lead, with secondary roots showing a pooled mean of 4.22 cm, while the control group had the shortest at 2.21 cm.

The pooled data revealed that at 30 days, A₁B₃ (0.75%) had the largest primary root diameter at 1.48 mm, while A₁B₁ (0.25%) had the smallest at 1.24 mm. Among zinc basal treatments, A₂B₂ (75 g/tree) recorded the largest diameter at 1.69 mm, and A₂B₁ (50 g/tree) had the smallest at 1.58 mm. The 5000 ppm IBA post-cutting treatment consistently showed the largest primary root diameter at 2.04 mm, with the control group being the smallest at 1.11 mm. At 60 days, A₁B₃ (0.75%) again had the largest primary root diameter at 1.48 mm, and A₁B₁ (0.25%) was the smallest at 1.26 mm. A₂B₂ maintained the largest diameter among zinc basal treatments at 1.75 mm, while A₂B₁ had the smallest at 1.54 mm. The 5000 ppm IBA treatment remained the best performer with a pooled root diameter of 2.06 mm, whereas the control group had the smallest at 1.17 mm.

The pooled data showed that A₁B₃ (0.75%) had the largest secondary root diameter among zinc basal treatments at 0.79 mm, while A₂B₁ had the smallest at 0.62 mm. For post-cutting treatments, the 5000 ppm IBA treatment consistently recorded the largest secondary root at 0.94 mm, while the control group had the smallest at 0.22 mm. At 60 days, A₁B₃ (0.75%) had the largest shoot diameter at 0.62 mm, with A₁B₃ (0.25%) being the smallest at 0.42 mm. Among zinc basal treatments, A₂B₂ (75 g/tree) maintained the highest pooled secondary root diameter at 0.79 mm, and A₂B₁ (50 g/tree) had the lowest at 0.70 mm. The 5000 ppm IBA treatment also had the largest pooled root diameter at 0.94 mm, while the control group had the smallest at 0.25 mm.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently achieved the highest fresh weight of primary roots at 30 days after pre-cutting 2.55 g and 60 days after pre-cutting 2.57 g. In contrast, A₁B₁ (0.25%) had the lowest fresh weight at both time points 2.34 g and 2.36 g, respectively. Among zinc basal treatments, A₂B₂ (75 g/tree) recorded the highest fresh weight at both intervals 2.79 g at 30 days and 2.88 g at 60 days after pre-cutting, while A₂B₁ (50 g/tree) had the lowest 2.68 g and 2.75 g, respectively. The 5000 ppm IBA treatment consistently showed the highest fresh weight of roots, with means of 3.53 g at 30 days and 3.69 g at 60 days after post-cutting treatment, significantly outperforming the control group, which had the lowest fresh weights of 2.07 g and 2.16 g.

Pooled data over two years showed that at 30 days after pre-cutting treatment, the A₁B₃ (0.75%) treatment consistently produced the highest fresh weight of secondary roots at 1.19 g, while A₁B₁ (0.25%) had the lowest at 0.94 g. Among zinc basal treatments, A₂B₂ (75 g/tree) achieved the maximum fresh weight at 1.49 g, while A₂B₁ (50 g/tree) had the lowest at 1.31 g. The 5000 ppm IBA treatment resulted in the highest fresh weight at 1.71 g, with the control group having the lowest at 0.76 g. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to show the highest fresh weight at 1.18 g, with A₁B₁ (0.25%) remaining the lowest at 0.95 g. A₂B₂ (75 g/tree) remained the best among zinc basal treatments at 1.52 g, while A₂B₁ (50 g/tree) had a fresh weight of 1.31 g. The 5000 ppm IBA as post-cutting treatment maintained the

highest fresh weight at 1.75 g, whereas the control group remained at the lowest with 0.77 g.

Pooled data showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest dry weight of primary root at 0.48 g, while A₁B₁ (0.25%) had the lowest at 0.18 g. Among zinc pre-cutting basal treatments, A₂B₂ (75 g/tree) had the highest dry weight at 0.83 g, and A₂B₁ (50 g/tree) had the lowest at 0.59 g. The 10000 ppm IBA post-cutting treatment had the highest dry weight at 0.95 g, with the control group the lowest at 0.11 g. At 60 days, A₁B₃ (0.75%) continued to have the highest dry weight at 0.50 g, while A₁B₁ had the lowest at 0.22 g. A₂B₂ had the highest dry weight among zinc treatments at 0.87 g, and A₂B₁ was the lowest at 0.64 g. The 10000 ppm IBA post cutting treatment maintained the highest dry weight at 0.98 g, with the control group the lowest at 0.57 g.

The pooled data indicated that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest dry weight of secondary root at 0.36 g, while A₁B₁ (0.25%) had the lowest at 0.11 g. Among zinc treatments, A₂B₂ had the highest dry weight of secondary root at 0.72 g, and A₂B₁ was the lowest at 0.46 g. The 5000 ppm IBA post-cutting treatment had the highest dry weight at 0.89 g, with the control group the lowest at 0.04 g. At 60 days, A₁B₃ (0.75%) continued to have the highest dry weight of secondary root at 0.38 g, while A₁B₁ (0.25%) had the lowest at 0.12 g. A₂B₂ had the highest dry weight among zinc treatments at 0.78 g, and A₂B₁ was the lowest at 0.50 g. The 5000 ppm IBA treatment maintained the highest dry weight of secondary root at 0.97 g, with the control group the lowest at 0.05 g.

The pooled data showed that at 30 days, A₁B₃ (0.75%) had the fewest days to sprout initiation at 22.06 days, while A₁B₁ (0.25%) took the most at 22.99 days. Among zinc treatments, A₂B₃ had the fewest days at 18.93, and A₂B₁ the most at 20.29. The 5000 ppm IBA post-cutting treatment consistently resulted in the fewest days to sprout initiation at 14.32, with the control group taking the most at 26.81 days. At 60 days, A₁B₃ (0.75%) continued to have the fewest days to sprout initiation at 22.33, and A₁B₁ (0.25%) the most at 22.83 days. A₂B₃ (100 g/tree) was the best among zinc treatments at 18.66 days, and A₂B₁ took the most at 20.02 days. The 5000 ppm IBA

treatment maintained the fewest days to sprout initiation at 14.02, with the control group taking the most at 27.06 days.

Sprouting percentages were highest in A₁B₃ (0.75%), with 73.67% at 30 days after pre-cutting treatment and 76.86% at 60 days after pre-cutting treatment. A₁B₁ (0.25%), had the lowest sprouting percentages 67.04 for 30 days and 70.74 for 60 days. Among zinc basal treatments, A₂B₂ (75 g/tree) showed the highest sprouting percentages 79.95% and 83.41%. The 5000 ppm IBA post-cutting treatment consistently achieved the highest sprouting percentages, with 95.08% at 30 days and 95.47% at 60 days.

The pooled data showed that at 30 days, A₁B₃ (0.75%/tree) had the highest number of sprouts at 3.71, while A₁B₁ (0.25%/tree) had the lowest at 3.12. Among zinc basal treatments, A₂B₂ (75 g/tree) had the most sprouts at 4.23, and A₂B₁ (50 g/tree) had the fewest at 3.89. The 5000 ppm IBA post cutting treatment had the longest secondary roots at 4.83, while the control had the shortest at 1.36. At 60 days, A₁B₃ (0.75%/tree) maintained the highest number of sprouts at 3.76, and A₁B₁ (0.25%/tree) had the lowest at 3.23. A₂B₂ (75 g/tree) led in the number of sprouts with 4.32, and A₂B₁ (50 g/tree) had the fewest at 3.94. The 5000 ppm IBA post cutting treatment continued to show the most sprouts at 4.94, with the control group having the shortest roots at 1.48.

The pooled data showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) had the highest number of sprouts at 5.71, while A₁B₁ (0.25%) had the lowest at 5.36. Among zinc basal treatments, A₂B₂ (75 g/tree) had the most sprouts at 6.26, with A₂B₁ (50 g/tree) the least at 5.83. The 5000-ppm IBA post-cutting treatment resulted in the highest number of sprouts at 7.50, and the control group had the lowest at 2.48. At 60 days, A₁B₃ (0.75%) had the highest dry weight at 5.77, while A₁B₁ (0.25%) had the lowest at 5.41. A₂B₂ (75 g/tree) led among zinc treatments with 6.44, and A₂B₁ (50 g/tree) had the lowest at 5.91. The 5000-ppm IBA post-cutting treatment maintained the highest number of sprouts at 7.65, with the control group at 2.61.

Pooled data from both years reinforced these trends. At 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently recorded the maximum diameter of sprouts at 0.96, with A₁B₁ (0.25%) the lowest at 0.33. A₂B₂ (75 g/tree) showed the maximum

diameter of sprouts at 2.01, and A₂B₁ (50 g/tree) had the lowest at 1.26. For post-cutting treatment with IBA, 5000-ppm concentration consistently had the maximum diameter of sprouts at 2.76, while the control group had the lowest at 0.09. At 60 days after pre-cutting, A₁B₃ (0.75%) had the highest number of sprouts at 0.99, while A₁B₁ (0.25%) had the lowest at 0.42. A₂B₂ (75 g/tree) was the best performer among zinc basal treatments with 2.07, and A₂B₂ (50 g/tree) had the lowest at 1.29. For post-cutting treatment with IBA, 5000-ppm concentration maintained the highest pooled maximum diameter of sprouts at 2.97 mm, and the control group remained the lowest at 0.09mm.

The pooled data showed that A₁B₃ (0.75%) consistently resulted in the longest sprouts at pre-cutting treatment both 30 days (5.91 cm) and 60 days (5.83 cm), while A₁B₁ (0.25%) had the shortest (6.44 cm and 6.26 cm, respectively). Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) produced the longest sprouts at 30 days (5.41 cm) and 60 days (5.36 cm), with A₂B₁ (50 g/tree) being the shortest (5.83 cm and 5.91 cm, respectively). The 5000 ppm IBA treatment consistently achieved the maximum sprout length at both 30 days (4.25 cm) and 60 days (4.21 cm), while the control group had the shortest (8.61 cm and 8.57 cm, respectively).

The pooled data showed A₁B₃ (0.75%) had the maximum change in shoot diameter at both 30 days (8.36 mm) and 60 days (8.46 mm), while A₁B₁ (0.25%) had the lowest (7.66 mm and 7.67 mm, respectively). Among zinc basal treatments, A₂B₂ (75 g/tree) showed the highest change in shoot diameter at 30 days (9.62 mm) and 60 days (9.85 mm), with A₂B₁ (50 g/tree) being the lowest (8.57 mm and 8.69 mm, respectively). The 5000 ppm IBA post-cutting treatment consistently achieved the maximum change in shoot diameter at both 30 days (16.27 mm) and 60 days (16.78 mm), while the control group had the lowest (5.39 mm and 5.51 mm, respectively).

The pooled data showed A₁B₃ (0.75%) had the highest fresh weight of shoots at both 30 days (2.68 g) and 60 days (2.69 g), while A₁B₁ (0.25%) had the lowest (2.26 g and 2.29 g, respectively). Among zinc basal treatments, A₂B₂ (75 g/tree) had the highest fresh weight at 3.42 g at 30 days and 3.43 g at 60 days, with A₂B₁ (50 g/tree) the lowest for both 2.97g. The 5000 ppm IBA post-cutting treatment consistently

achieved the highest fresh weight of shoots, 4.11 g at 30 days and 4.12 g at 60 days, while the control group had the lowest (2.02 g and 2.11 g, respectively).

The pooled data revealed that A₁B₃ (0.75%) had the highest dry weight of shoot at both 30 days after pre-cutting (1.09 g) and 60 days after pre-cutting (1.11 g), while A₁B₁ (0.25%) had the lowest (0.83 g and 0.87 g, respectively). Among pre-cutting zinc basal treatments, A₂B₂ (75 g/tree) had the highest dry weight at 1.55 g at 30 days and 1.63 g at 60 days, with A₂B₁ (50 g/tree) the lowest. The 5000 ppm IBA pot cutting treatment consistently achieved the highest dry weight, 1.92 g at 30 days and 1.95 g at 60 days, while the control group had the lowest at 0.69 g and 0.74 g, respectively.

Pooled data from both years showed consistent trends in leaf production. At 30 days pre-cutting treatment, the A₁B₃ treatment (0.75%) had the highest number of leaves at 9.36, while ZF1 (37.5 g/tree) had the lowest at 8.66. Among zinc basal treatments, ZB₂ had the highest leaf count at 10.62, and ZB₁ was the lowest at 9.57. The 5000 ppm IBA treatment resulted in the highest leaf count, averaging 17.27 leaves, while the control group had the lowest at 6.39 leaves.

Pooling data from both years, treatment A₁B₃ (0.75%) consistently had the largest leaf area 30 days after pre-cutting treatment (7.65 cm²) and 60 days after the dormant stage (8.04 cm²). In comparison, A₁B₁ (0.25%) exhibited the smallest leaf area (5.90 cm² and 6.31 cm², respectively). Among zinc basal treatments, A₂B₂ (75 g/tree) had the largest leaf area at both time points (8.49 cm² at 30 days and 8.40 cm² at 60 days), whereas A₂B₁ (50 g/tree) had the smallest (7.70 cm² and 7.65 cm², respectively). The 5000 ppm IBA post-cutting treatment consistently achieved the largest leaf area, with a mean of 15.17 cm² 30 days after pre-cutting and 15.83 cm² 60 days after the pre-cutting, compared to the control group, which had the smallest leaf area (3.53 cm² at 30 days and 3.88 cm² at 60 days).

The pooled data over two years showed consistent trends in chlorophyll content at 30 and 60 days after pre-cutting treatment. At 30 days, A₁B₃ (0.75%) had the highest chlorophyll content at 1.23 mg/g, while A₁B₁ (0.25%) had the lowest at 0.87 mg/g. Among zinc basal treatments, A₂B₂ (75 g/tree) had the highest chlorophyll content at 1.67 mg/g, and A₂B₁ (50 g/tree) was the lowest at 1.39 mg/g. The 5000 ppm IBA post-

cutting treatment resulted in the highest chlorophyll content at 2.29 mg/g, with the control group having the lowest at 0.65 mg/g. At 60 days, A₁B₃ (0.75%) again recorded the highest chlorophyll content at 1.23 mg/g, and A₁B₁ (0.25%) was the lowest at 0.90 mg/g. A₂B₂ (75 g/tree) maintained the highest content among zinc treatments at 1.72 mg/g, while A₂B₁ (50 g/tree) had the lowest at 1.41 mg/g. The 5000 ppm IBA post-cutting treatment showed the highest chlorophyll content at 2.27 mg/g, with the control group remaining the lowest at 0.67 mg/g.

The pooled data from both years showed consistent trends in fresh weight of leaves at 30- and 60-days post-treatment. At 30 days, A₁B₃ (0.75%) recorded the highest fresh weight at 2.59g, while A₁B₁ (0.25%) had the lowest at 2.02g. Among zinc basal treatments, A₂B₂ had the highest fresh weight at 3.48g, and A₂B₁ had the lowest at 2.83g. The 5000 ppm IBA treatment resulted in the highest fresh weight at 4.35g, with the control group having the lowest at 1.79g. At 60 days, A₁B₃ (0.75%) again showed the highest fresh weight at 2.65g, and A₁B₁ (0.25%) was the lowest at 2.06g. A₂B₂ (75 g/tree) continued to perform best among zinc treatments with 3.51g, while A₂B₁ (50 g/tree) had the lowest at 2.87g. The 5000 ppm IBA post-cutting treatment maintained the highest fresh weight at 4.35g, and the control group had the lowest at 1.8g.

The pooled data over two years highlighted consistent trends in the dry weight of leaves at 30 and 60 days after pre-cutting treatment. At 30 days, A₁B₃ (0.75%) had the highest dry weight at 1.12g, while A₁B₁ (0.25%) had the lowest at 0.79g. Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) recorded the highest dry weight at 1.75g, and A₂B₁ (50 g/tree) was the lowest at 1.26g. The 5000 ppm IBA post-cutting treatment resulted in the highest dry weight of 2.53g, with the control group having the lowest at 0.62g. At 60 days, A₁B₃ again had the highest dry weight at 1.17g, and A₁B₁ was the lowest at 0.81g. A₂B₂ (75 g/tree) continued to perform best among zinc treatments with a dry weight of 1.85g, while A₂B₁ (50 g/tree) had the lowest at 1.33g. The 5000 ppm IBA post-cutting treatment maintained the highest dry weight at 2.54g, with the control group remaining the lowest at 0.63g.

Pooled data from both years showed that at 30 days after pre-cutting treatment, A₁B₃ (0.75%) consistently had the lowest root-to-shoot ratio at 0.95, while A₁B₁ (0.25%) had the highest at 1.04. Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree)

achieved the lowest ratio at 0.86, and A₂B₁ (50 g/tree) was the highest at 0.90. The 5000-ppm IBA post-cutting treatment resulted in the lowest ratio with an average of 0.83, compared to the control group's highest ratio of 1.03. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) continued to show the lowest ratio at 0.95, while A₁B₁ (0.25%) had the highest at 1.03. A₂B₂ (75 g/tree) remained the best among zinc basal treatments at 0.91, and the 5000-ppm IBA treatment maintained the lowest ratio at 0.90, with the control group at the highest of 1.03.

The pooled data from both years showed consistent trends in root index at 30 and 60 days after pre-cutting treatment. At 30 days, A₁B₃ (0.75%) had the highest root index at 55.94, while A₁B₁ (0.25%) had the lowest at 42.85. Among zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) had the highest root index at 98.84, with A₂B₁ (50 g/tree) the lowest at 75.66. The 5000 ppm IBA post-cutting treatment resulted in the highest root index at 171.16, compared to the control group's 23.06. At 60 days, A₁B₃ (0.75%) again showed the highest root index at 58.37, with A₁B₁ (0.25%) the lowest at 43.82. A₂B₂ (75 g/tree) had the highest root index among zinc treatments at 110.62, while A₂B₁ (50 g/tree) had the lowest at 78.55. The 5000 ppm IBA post-cutting treatment maintained the highest root index at 177.05, with the control group remaining the lowest at 25.82.

Pooled data from both years showed that at 30 days after pre-cutting treatment, the A₁B₃ treatment (0.75%) consistently achieved the highest survival rate at 56.86%, while A₁B₁ (0.25% /tree) had the lowest at 51.89%. Among zinc basal pre-cutting treatment, A₂B₂ (75 g/tree) had the highest survival rate at 67.91%, with A₂B₁ (50 g/tree) at the lowest at 64.24%. The 10,000 ppm IBA post-cutting treatment resulted in the highest survival rate at 76.35%, while the control group had the lowest at 73.85%. At 60 days, A₁B₃ (0.75%) maintained the highest survival rate at 57.45%, and A₁B₁ (0.25%) was the lowest at 52.47%. A₂B₂ (75 g/tree) continued to have the highest survival rate among zinc basal treatments, while A₂B₁ (50 g/tree) had the lowest. The 10,000 ppm IBA post-cutting treatment sustained the highest survival rate at 76.74%, with the control group falling to the lowest at 31.81%.

The pooled data from both years showed consistent trends in mortality rates. At 30 days after pre-cutting, A₁B₃ (0.75%) had the lowest mortality rate (43.14%), while

A₁B₁ (0.25%) had the highest (48.11%). For zinc basal pre-cutting treatments, A₂B₂ (75 g/tree) had the lowest rate (32.09%), and A₂B₁ (50 g/tree) was the highest (35.76%). The 10000 ppm IBA post-cutting treatment significantly reduced mortality to 23.65%, compared to the control group's 68.87%. At 60 days after pre-cutting treatment, A₁B₃ (0.75%) again had the lowest rate (42.35%), with A₁B₁ (0.50%) at 47.53%. A₂B₂ (75 g/tree) had the lowest rate among zinc basal treatments (31.61%), and A₂B₁ (50 g/tree) had the highest (36.20%). The 10000 ppm IBA post-cutting treatment maintained the lowest mortality rate at 23.26%, while the control group remained the highest at 68.19%.

Conclusion

The study highlights the effectiveness of zinc, particularly basal application at 75g per tree, in enhancing root induction in guava cuttings, showing results comparable to traditional IBA hormone treatments. Zinc's sustained soil availability, root uptake efficiency, and role in auxin stimulation make it a strong alternative to synthetic hormones. Its use supports sustainable agriculture practices and aligns with SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production).

Industry uses and Future applications

Future research should refine zinc application methods and investigate its physiological and biochemical effects on root initiation and development in guava. Exploring zinc's interaction with other micronutrients, conducting long-term field trials, and assessing environmental and seasonal factors can optimize propagation techniques. Additionally, evaluating different cutting types and zinc dose variations may enhance rooting success. These efforts can lead to more efficient, sustainable, and climate-resilient horticultural propagation strategies.

Industry application of these findings can help nurseries and commercial guava growers enhance propagation success by using standardized zinc and IBA treatments. Extension services and training programs can promote the adoption of foliar and basal application methods. Additionally, the development of ready-to-use propagation kits with pre-measured nutrients can simplify field-level implementation and improve efficiency in guava cultivation.

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APPENDICES

Analysis of variance for different parameters

Experiment 1 – Open field condition

1. ANOVA table for callus formation (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.024			
Factor A	2	63.893	31.946	4,39,333.37	< 0.001
Factor B	2	59.482	29.741	4,09,000.93	< 0.001
Int A X B	4	160.545	40.136	5,51,961.75	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	1.322	1.322	41,039.19	< 0.001
Int A X C	2	0.105	0.052	1,629.48	< 0.001
Int B X C	2	0.063	0.031	975.903	
Int A X B X C	4	0.384	0.096	2,980.21	
Error	18	0.001	0.000		
Total	53	285.819			

2. ANOVA table for root initiation

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.017			
Factor A	2	319.752	159.876	1,31,379.13	< 0.001
Factor B	2	297.111	148.556	1,22,076.59	< 0.001
Int A X B	4	675.109	168.777	1,38,693.75	
Error(a)	16	0.019	0.001		
Factor C	1	6.556	6.556	51,038.22	
Int A X C	2	2.436	1.218	9,481.11	< 0.001
Int B X C	2	0.416	0.208	1,618.84	
Int A X B X C	4	0.454	0.113	883.38	< 0.001
Error	18	0.002	0.000		

3. ANOVA table for rooting percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.057			
Factor A	2	1,323.30	661.649	6,14,442.96	
Factor B	2	1,032.28	516.14	4,79,314.77	< 0.001
Int A X B	4	2,256.58	564.146	5,23,896.11	
Error(a)	16	0.017	0.001		
Factor C	1	0.43	0.43	226.484	< 0.001
Int A X C	2	0.016	0.008	4.106	0.03396
Int B X C	2	0.014	0.007	3.761	0.04317
Int A X B X C	4	0.106	0.026	13.91	0.00002
Error	18	0.034	0.002		
Total	53	4,612.84			

4. ANOVA table for primary number of root

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.028			
Factor A	2	187.734	93.867	10,45,834.99	< 0.001
Factor B	2	96.129	48.065	5,35,519.30	
Int A X B	4	206.078	51.519	5,74,012.45	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	1.236	1.236	13,566.95	< 0.001
Int A X C	2	0.125	0.063	687.765	< 0.001
Int B X C	2	0.058	0.029	318.173	< 0.001
Int A X B X C	4	0.057	0.014	157.33	< 0.001
Error	18	0.002	0.000		
Total	53	491.45			

5. ANOVA table for secondary number of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.034			
Factor A	2	181.651	90.826	9,17,350.33	< 0.001
Factor B	2	165.556	82.778	8,36,069.93	0
Int A X B	4	381.591	95.398	9,63,530.23	0
Error(a)	16	0.002	0.000		
Factor C	1	0.313	0.313	1,445.84	0
Int A X C	2	0.021	0.011	49.315	< 0.001
Int B X C	2	0.008	0.004	18.16	< 0.001
Int A X B X C	4	0.029	0.007	33.22	< 0.001
Error	18	0.004	0.000		
Total	53	729.209			

6. ANOVA table for the length of the primary root (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor A	2	24.331	12.165	64,716.67	
Factor B	2	13.799	6.899	36,703.77	
Int A X B	4	34.261	8.565	45,565.69	< 0.001
Error(a)	16	0.003	0.000		
Factor C	1	0.021	0.021	196.581	< 0.001
Int A X C	2	0.004	0.002	17.341	0.00006
Int B X C	2	0.008	0.004	35.955	< 0.001
Int A X B X C	4	0.003	0.001	7.287	0.00113
Error	18	0.002	0.000		
Total	53	72.461			

7. ANOVA table for the length of the secondary root (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	7.278	3.639	49,901.19	
Factor B	2	6.208	3.104	42,560.07	< 0.001
Int A X B	4	15.722	3.931	53,897.99	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.013	0.013	248.058	< 0.001
Int A X C	2	0.007	0.004	67.191	< 0.001
Int B X C	2	0.003	0.001	25.729	< 0.001
Int A X B X C	4	0.007	0.002	30.935	< 0.001
Error	18	0.001	0.000		
Total	53	29.263			

8. ANOVA table for the diameter of primary root (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.028			
Factor A	2	1.211	0.606	4,346.54	< 0.001
Factor B	2	0.474	0.237	1,700.64	< 0.001
Int A X B	4	3.035	0.759	5,444.25	
Error(a)	16	0.002	0.000		
Factor C	1	0.148	0.148	931.336	< 0.001
Int A X C	2	0.248	0.124	779.563	< 0.001
Int B X C	2	0.294	0.147	921.895	< 0.001
Int A X B X C	4	0.554	0.138	869.003	< 0.001
Error	18	0.003	0.000		
Total	53	5.997			

9. ANOVA table for the diameter of the secondary root (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	1.567	0.783	7,780.93	
Factor B	2	0.721	0.361	3,581.52	< 0.001
Int A X B	4	2.618	0.655	6,501.46	
Error(a)	16	0.002	0.000		
Factor C	1	0.008	0.008	140.508	< 0.001
Int A X C	2	0.001	0.000	7.673	0.00389
Int B X C	2	0.001	0.001	12.335	0.00042
Int A X B X C	4	0.002	0.001	10.488	0.00014
Error	18	0.001	0.000		
Total	53	4.949			

10. ANOVA table for the fresh weight of the primary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	5.156	2.578	11,593.52	< 0.001
Factor B	2	4.707	2.354	10,583.97	< 0.001
Int A X B	4	11.431	2.858	12,851.30	< 0.001
Error(a)	16	0.004	0.000		
Factor C	1	0.008	0.008	436.813	< 0.001
Int A X C	2	0.003	0.002	94.449	< 0.001
Int B X C	2	0.001	0.001	33.635	< 0.001
Int A X B X C	4	0.003	0.001	36.411	< 0.001
Error	18	0.000	0.000		
Total	53	21.341			

11. ANOVA table for the fresh weight of the secondary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.022			
Factor A	2	1.591	0.796	14,832.627	< 0.001
Factor B	2	1.011	0.506	9,423.247	< 0.001
Int A X B	4	3.595	0.899	16,754.866	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.018	0.018	376.627	< 0.001
Int A X C	2	0.003	0.002	33.373	< 0.001
Int B X C	2	0.001	0.000	9.385	0.002
Int A X B X C	4	0.005	0.001	27.081	< 0.001
Error	18	0.001	0.000		
Total	53	6.248			

12. ANOVA table for the dry weight of the primary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor A	2	0.496	0.248	1,070.89	< 0.001
Factor B	2	0.458	0.229	987.885	< 0.001
Int A X B	4	1.107	0.277	1,194.02	< 0.001
Error(a)	16	0.004	0.000		
Factor C	1	0.002	0.002	10.177	0.005
Int A X C	2	0.001	0.001	3.28	0.061
Int B X C	2	0.002	0.001	4.793	0.021
Int A X B X C	4	0.002	0.001	2.608	0.07
Error	18	0.004	0.000		
Total	53	2.104			

13. ANOVA table for the dry weight of the secondary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.028			
Factor A	2	0.256	0.128	555.759	< 0.001
Factor B	2	0.155	0.078	336.571	< 0.001
Int A X B	4	0.558	0.139	604.494	< 0.001
Error(a)	16	0.004	0.000		
Factor C	1	0.004	0.004	49.077	< 0.001
Int A X C	2	0.002	0.001	12.827	< 0.001
Int B X C	2	0.001	0.001	6.495	0.008
Int A X B X C	4	0.002	0.001	7.019	0.001
Error	18	0.002	0.000		
Total	53	1.012			

14. ANOVA table for days to sprout initiation

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.009			
Factor A	2	130.748	65.374	42,997.728	< 0.001
Factor B	2	142.539	71.270	46,875.312	
Int A X B	4	391.228	97.807	64,329.288	< 0.001
Error(a)	16	0.024	0.002		
Factor C	1	1.128	1.128	11,093.424	< 0.001
Int A X C	2	0.111	0.056	546.192	
Int B X C	2	0.105	0.053	516.663	< 0.001
Int A X B X C	4	0.224	0.056	549.53	< 0.001
Error	18	0.002	0.000		
Total	53	666.119			

15. ANOVA table for the sprouting percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	-0.007			
Factor A	2	2,977.31	1,488.66	458,806.829	< 0.001
Factor B	2	2,323.48	1,161.74	358,049.878	< 0.001
Int A X B	4	5,077.19	1,269.30	391,199.701	
Error(a)	16	0.052	0.003		
Factor C	1	0.882	0.882	3,662.84	
Int A X C	2	0.109	0.054	226.122	< 0.001
Int B X C	2	0.109	0.055	226.665	< 0.001
Int A X B X C	4	0.169	0.042	175.096	< 0.001
Error	18	0.004	0.000		
Total	53	10,379.296			

16. ANOVA table for number of sprouts at 30 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.022			
Factor A	2	6.637	3.318	28,687.10	
Factor B	2	4.94	2.47	21,353.93	
Int A X B	4	14.424	3.606	31,174.22	
Error(a)	16	0.002	0.000		
Factor C	1	0.021	0.021	422.927	< 0.001
Int A X C	2	0.006	0.003	62.315	< 0.001
Int B X C	2	0.000	0.000	0.117	0.89068
Int A X B X C	4	0.004	0.001	18.122	< 0.001
Error	18	0.001	0.000		
Total	53	26.057			

17. ANOVA table for number of sprouts at 60 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.025			
Factor A	2	7.767	3.883	42,678.28	< 0.001
Factor B	2	9.796	4.898	53,829.32	< 0.001
Int A X B	4	26.123	6.531	71,771.53	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.034	0.034	598.217	< 0.001
Int A X C	2	0.01	0.005	85.511	< 0.001
Int B X C	2	0.004	0.002	37.678	< 0.001
Int A X B X C	4	0.012	0.003	53.562	< 0.001
Error	18	0.001	0.000		
Total	53	43.775			

18. ANOVA table for number of sprouts at 90 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.028			
Factor A	2	16.974	8.487	96,726.58	< 0.001
Factor B	2	23.664	11.832	1,34,854.93	< 0.001
Int A X B	4	54.882	13.721	1,56,377.84	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.04	0.04	348.87	< 0.001
Int A X C	2	0.011	0.005	47.489	< 0.001
Int B X C	2	0.005	0.003	23.449	< 0.001
Int A X B X C	4	0.011	0.003	23.198	< 0.001
Error	18	0.002	0.000		
Total	53	95.619			

19. ANOVA table for the diameter of sprouts (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.021			
Factor A	2	1.563	0.782	1,842.06	< 0.001
Factor B	2	0.704	0.352	829.891	< 0.001
Int A X B	4	2.637	0.659	1,554.03	
Error(a)	16	0.007	0.000		
Factor C	1	0.009	0.009	115.588	< 0.001
Int A X C	2	0.002	0.001	12.023	< 0.001
Int B X C	2	0.002	0.001	10.977	0.001
Int A X B X C	4	0.003	0.001	9.434	< 0.001
Error	18	0.001	0.000		
Total	53	4.949			

20. ANOVA table for the length of sprouts (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.035			
Factor A	2	3.902	1.951	7,166.98	< 0.001
Factor B	2	35.297	17.649	64,836.59	< 0.001
Int A X B	4	88.342	22.085	81,135.84	
Error(a)	16	0.004	0.000		
Factor C	1	0.017	0.017	123.305	< 0.001
Int A X C	2	0.21	0.105	780.487	
Int B X C	2	0.022	0.011	82.78	< 0.001
Int A X B X C	4	0.043	0.011	79.798	< 0.001
Error	18	0.002	0.000		
Total	53	127.875			

21. ANOVA table for the diameter of shoot (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.039			
Factor A	2	2.351	1.175	2,790.876	< 0.001
Factor B	2	28.778	14.389	34,166,790	
Int A X B	4	64.426	16.107	38,244,788	
Error(a)	16	0.007	0.00		
Factor C	1	0.204	0.204	561.252	< 0.001
Int A X C	2	0.045	0.022	61.347	< 0.001
Int B X C	2	0.013	0.007	18.094	< 0.001
Int A X B X C	4	0.014	0.004	9.716	< 0.001
Error	18	0.007	0.00		
Total	53	95.883			

22. ANOVA table for the fresh weight of the shoot (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor A	2	6.189	3.095	23,302.15	< 0.001
Factor B	2	5.38	2.69	20,254.15	< 0.001
Int A X B	4	16.564	4.141	31,181.36	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	0.039	0.039	339.341	< 0.001
Int A X C	2	0.026	0.013	112.311	< 0.001
Int B X C	2	0.002	0.001	9.861	0.00128
Int A X B X C	4	0.002	0.000	3.608	0.025
Error	18	0.002	0.000		
Total	53	28.235			

23. ANOVA table for the dry weight of the shoot (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor A	2	4.384	2.192	35,498.48	
Factor B	2	2.189	1.095	17,724.38	
Int A X B	4	8.016	2.004	32,449.11	
Error(a)	16	0.001	0.000		
Factor C	1	0.046	0.046	337.157	< 0.001
Int A X C	2	0.007	0.004	27.175	< 0.001
Int B X C	2	0.004	0.002	15.224	< 0.001
Int A X B X C	4	0.02	0.005	36.601	< 0.001
Error	18	0.002	0.000		
Total	53	14.699			

24. ANOVA table for the Number of leaves

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	102.537	51.268	3,93,279.87	
Factor B	2	51.96	25.98	1,99,293.84	< 0.001
Int A X B	4	125.906	31.477	2,41,456.62	
Error(a)	16	0.002	0.000		
Factor C	1	0.126	0.126	1,071.74	< 0.001
Int A X C	2	0.03	0.015	125.865	< 0.001
Int B X C	2	0.01	0.005	40.861	< 0.001
Int A X B X C	4	0.068	0.017	143.621	< 0.001
Error	18	0.002	0.000		
Total	53	280.667			

25. ANOVA table for the leaf area (cm²)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.031			
Factor A	2	93.592	46.796	3,11,333.24	
Factor B	2	45.68	22.84	1,51,953.27	< 0.001
Int A X B	4	112.778	28.194	1,87,576.40	
Error(a)	16	0.002	0.000		
Factor C	1	0.263	0.263	1,818.87	< 0.001
Int A X C	2	0.098	0.049	339.439	< 0.001
Int B X C	2	0.036	0.018	123.985	< 0.001
Int A X B X C	4	0.071	0.018	122.696	< 0.001
Error	18	0.003	0.000		
Total	53	252.555			

26. ANOVA table for chlorophyll

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	3.335	1.667	13,314.04	
Factor B	2	1.828	0.914	7,297.07	
Int A X B	4	6.554	1.639	13,084.46	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	0.003	0.003	44.857	< 0.001
Int A X C	2	0.006	0.003	43.967	< 0.001
Int B X C	2	0.001	0.001	11.445	0.00062
Int A X B X C	4	0.001	0.000	4.173	0.01452
Error	18	0.001	0.000		
Total	53	11.758			

27. ANOVA table for the fresh weight of leaves (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	11.969	5.984	77,028.80	
Factor B	2	0.881	0.441	5,672.25	
Int A X B	4	3.695	0.924	11,890.82	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.411	0.411	3,963.46	< 0.001
Int A X C	2	0.941	0.47	4,538.42	< 0.001
Int B X C	2	0.998	0.499	4,812.52	< 0.001
Int A X B X C	4	2.025	0.506	4,884.01	< 0.001
Error	18	0.002	0.000		
Total	53	20.946			

28. ANOVA table for the dry weight of leaves (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Factor A	2	4.52	2.26	17,077.15	
Factor B	2	2.161	1.081	8,165.12	
Int A X B	4	7.494	1.873	14,156.71	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	0.01	0.01	244.86	< 0.001
Int A X C	2	0.003	0.002	40.327	< 0.001
Int B X C	2	0.001	0.001	16.203	< 0.001
Int A X B X C	4	0.007	0.002	38.535	< 0.001
Error	18	0.001	0.000		
Total	53	14.226			

29. ANOVA table for Root index

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.866			
Factor A	2	6,892.32	3,446.16	84,845.24	< 0.001
Factor B	2	2,731.25	1,365.62	33,621.98	< 0.001
Int A X B	4	5,834.30	1,458.58	35,910.47	
Error(a)	16	0.65	0.041		
Factor C	1	14.458	14.458	12,868.78	< 0.001
Int A X C	2	2.225	1.113	990.322	< 0.001
Int B X C	2	2.422	1.211	1,077.99	< 0.001
Int A X B X C	4	1.713	0.428	381.219	< 0.001
Error	18	0.02	0.001		
Total	53	15,481.22			

30. ANOVA table for Root to shoot ratio

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0			
Factor A	2	0.345	0.173	272.541	< 0.001
Factor B	2	0.02	0.010	15.484	< 0.001
Int A X B	4	0.197	0.049	77.807	< 0.001
Error(a)	16	0.01	0.001		
Factor C	1	0.004	0.004	13.248	0.00187
Int A X C	2	0.007	0.004	12.255	< 0.001
Int B X C	2	0.001	0.000	1.009	0.3842
Int A X B X C	4	0.001	0.000	0.913	0.4778
Error	18	0.005	0.000		
Total	53	0.59			

31. ANOVA table for the survival percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
	2	0.028			
Factor A	2	2,135.32	1,067.66	51,11,547.60	< 0.001
Factor B	2	2,282.46	1,141.23	54,63,776.71	
Int A X B	4	7,550.17	1,887.54	90,36,854.95	
Error(a)	16	0.003	0.000		
Factor C	1	19.392	19.392	18,48,927.18	< 0.001
Int A X C	2	7.009	3.505	3,34,145.69	< 0.001
Int B X C	2	5.849	2.925	2,78,853.07	< 0.001
Int A X B X C	4	6.644	1.661	1,58,356.46	< 0.001
Error	18	0.000	0.000		
Total	53	12,006.87			

32. ANOVA table for the mortality percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	-0.003			
Factor A	2	2,135.75	1,067.88	8,18,204.88	< 0.001
Factor B	2	2,436.63	1,218.31	9,33,468.63	< 0.001
Int A X B	4	7,396.99	1,849.25	14,16,889.18	< 0.001
Error(a)	16	0.021	0.001		
Factor C	1	19.336	19.336	23,547.13	< 0.001
Int A X C	2	7.021	3.511	4,275.04	< 0.001
Int B X C	2	5.957	2.978	3,626.83	< 0.001
Int A X B X C	4	6.508	1.627	1,981.32	
Error	18	0.015	0.001		
Total	53	12,008.22			

Experiment 2 Shed net condition

1. ANOVA table for the callus formation (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.022			
Factor A	2	188.683	94.342	4,92,265.63	< 0.001
Factor B	2	68.465	34.233	1,78,622.40	
Int A X B	4	240.842	60.21	3,14,172.27	< 0.001
Error(a)	16	0.003	0.000		
Factor C	1	2.201	2.201	16,737.34	< 0.001
Int A X C	2	0.092	0.046	348.926	< 0.001
Int B X C	2	0.003	0.001	10.145	< 0.001
Int A X B X C	4	0.534	0.133	1,015.01	< 0.001
Error	18	0.002	0.000		
Total	53	500.848			

2. ANOVA table for the root initiation

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Factor A	2	18.434	9.217	3,00,847.33	
Factor B	2	165.647	82.823	27,03,359.57	< 0.001
Int A X B	4	337.841	84.46	27,56,784.54	
Error(a)	16	0	0		
Factor C	1	2.726	2.726	29,144.65	< 0.001
Int A X C	2	1.365	0.682	7,296.70	< 0.001
Int B X C	2	1.493	0.746	7,978.94	< 0.001
Int A X B X C	4	4.075	1.019	10,893.06	
Error	18	0.002	0		
Total	53	531.609			

3. ANOVA table for the rooting percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	-0.051			
Factor A	2	798.466	399.233	87,888.81	
Factor B	2	1,461.37	730.683	1,60,855.44	
Int A X B	4	3,763.35	940.838	2,07,119.87	
Error(a)	16	0.073	0.005		
Factor C	1	58.28	58.28		
Int A X C	2	0.327	0.164	11,333.71	< 0.001
Int B X C	2	0.28	0.140	9,688.60	
Int A X B X C	4	5.287	1.322	91,491.33	< 0.001
Error	18	0.000	0.000		
Total	53	6,087.38			

4. ANOVA table for the primary number of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	291.814	145.907	5,70,260.02	< 0.001
Factor B	2	169.451	84.726	3,31,139.67	
Int A X B	4	486.098	121.525	4,74,963.89	
Error(a)	16	0.004	0.000		
Factor C	1	2.707	2.707	14,981.83	< 0.001
Int A X C	2	0.768	0.384	2,124.20	< 0.001
Int B X C	2	0.293	0.146	809.599	< 0.001
Int A X B X C	4	0.399	0.100	552.524	< 0.001
Error	18	0.003	0.000		
Total	53	951.561			

5. ANOVA table for the secondary number of roots

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.024			
Factor A	2	75.191	37.595	1,85,046.31	
Factor B	2	431.637	215.818	10,62,265.66	< 0.001
Int A X B	4	971.071	242.768	11,94,911.57	
Error(a)	16	0.003	0.000		
Factor C	1	1.374	1.374	6,835.15	< 0.001
Int A X C	2	0.004	0.002	8.83	0.00213
Int B X C	2	0.007	0.003	17.3	< 0.001
Int A X B X C	4	0.007	0.002	8.627	< 0.001
Error	18	0.004	0.000		
Total	53	1,479.32			

6. ANOVA table for the length of the primary root (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	24.702	12.351	81,574.91	< 0.001
Factor B	2	16.441	8.22	54,292.53	< 0.001
Int A X B	4	50.706	12.676	83,723.82	
Error(a)	16	0.002	0.000		
Factor C	1	0.183	0.183	1,198.46	
Int A X C	2	0.024	0.012	79.707	< 0.001
Int B X C	2	0.027	0.014	88.75	< 0.001
Int A X B X C	4	0.012	0.003	19.173	< 0.001
Error	18	0.003	0.000		
Total	53	92.127			

7. ANOVA table for the length of the secondary root (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Factor A	2	24.316	12.158	95,713.71	< 0.001
Factor B	2	16.397	8.198	64,542.13	< 0.001
Int A X B	4	48.948	12.237	96,337.82	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	0.152	0.152	1,285.79	
Int A X C	2	0.028	0.014	118.205	< 0.001
Int B X C	2	0.031	0.016	133.227	< 0.001
Int A X B X C	4	0.021	0.005	43.647	< 0.001
Error	18	0.002	0.000		
Total	53	89.923			

8. ANOVA table for diameter of the primary root (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.024			
Factor A	2	1.155	0.577	1,017.05	
Factor B	2	0.703	0.351	619.105	< 0.001
Int A X B	4	2.476	0.619	1,090.30	< 0.001
Error(a)	16	0.009	0.001		
Factor C	1	0.006	0.006	26.579	0.00007
Int A X C	2	0.002	0.001	4.097	0.03417
Int B X C	2	0.003	0.001	5.424	0.01433
Int A X B X C	4	0.007	0.002	7.864	0.00075
Error	18	0.004	0.000		
Total	53	4.389			

9. ANOVA table for diameter of the secondary root (mm)

Source of Variation	D F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	0.676	0.338	2,129.38	< 0.001
Factor B	2	0.353	0.176	1,111.19	< 0.001
Int A X B	4	1.581	0.395	2,490.10	< 0.001
Error(a)	16	0.003	0.000		
Factor C	1	0.03	0.03	435.685	< 0.001
Int A X C	2	0.02	0.01	147.503	< 0.001
Int B X C	2	0.004	0.002	28.391	< 0.001
Int A X B X C	4	0.003	0.001	11.051	< 0.001
Error	18	0.001	0.000		
Total	53	2.693			

10. ANOVA table for the fresh weight of the primary root (g)

Source of Variation	D F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	2.938	1.469	13,815.66	< 0.001
Factor B	2	2.086	1.043	9,808.24	
Int A X B	4	5.901	1.475	13,872.42	
Error(a)	16	0.002	0.000		
Factor C	1	0.113	0.113	575.048	< 0.001
Int A X C	2	0.035	0.017	87.667	< 0.001
Int B X C	2	0.007	0.003	17.079	0.00007
Int A X B X C	4	0.009	0.002	11.332	0.00009
Error	18	0.004	0.000		
Total	53	11.121			

11. ANOVA table for the fresh weight of the secondary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.025			
Factor A	2	1.223	0.612	3,244.01	< 0.001
Factor B	2	0.769	0.385	2,039.86	< 0.001
Int A X B	4	2.798	0.699	3,709.65	< 0.001
Error(a)	16	0.003	0.000		
Factor C	1	0.002	0.002	19.585	0.00033
Int A X C	2	0.003	0.002	14.025	0.00021
Int B X C	2	0.003	0.001	10.103	0.00114
Int A X B X C	4	0.002	0.000	3.129	0.04055
Error	18	0.002	0.000		
Total	53	4.83			

12. ANOVA table for the dry weight of the primary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.033			
Factor A	2	1.614	0.807	2,603.45	
Factor B	2	0.986	0.493	1,590.16	
Int A X B	4	3.32	0.83	2,676.92	< 0.001
Error(a)	16	0.005	0.000		
Factor C	1	0.016	0.016	67.748	< 0.001
Int A X C	2	0.003	0.001	5.499	0.014
Int B X C	2	0.003	0.002	6.747	0.007
Int A X B X C	4	0.006	0.002	6.577	0.002
Error	18	0.004	0.000		
Total	53	5.99			

13. ANOVA table for the dry weight of the secondary root (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.024			
Factor A	2	0.536	0.268	2,708.27	
Factor B	2	0.235	0.118	1,188.53	
Int A X B	4	0.977	0.244	2,467.61	
Error(a)	16	0.002	0.000		
Factor C	1	0.005	0.005	45.84	< 0.001
Int A X C	2	0.001	0.001	6.723	0.007
Int B X C	2	0.000	0.000	1.13	0.345
Int A X B X C	4	0.003	0.001	5.74	0.004
Error	18	0.002	0.000		
Total	53	1.786			

14. ANOVA table for the days to sprout initiation

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.019			
Factor A	2	513.906	256.953	1,46,09,706.65	< 0.001
Factor B	2	2,474.56	1,237.28	7,03,48,770.10	
Int A X B	4	6,485.74	1,621.44	9,21,90,814.45	< 0.001
Error(a)	16	0	0		
Factor C	1	95.722	95.722	2,63,339.99	< 0.001
Int A X C	2	9.893	4.946	13,607.60	
Int B X C	2	0.209	0.105	287.58	< 0.001
Int A X B X C	4	9.993	2.498	6,872.76	
Error	18	0.007	0		
Total	53	9,590.06			

15. ANOVA table for the sprouting percentage

Source of Variation	D F	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.019			
Factor A	2	513.906	256.953	1,46,09,706.65	< 0.001
Factor B	2	2,474.56	1,237.28	7,03,48,770.10	
Int A X B	4	6,485.74	1,621.44	9,21,90,814.45	< 0.001
Error(a)	16	0.000	0.000		
Factor C	1	95.722	95.722	2,63,339.99	< 0.001
Int A X C	2	9.893	4.946	13,607.60	
Int B X C	2	0.209	0.105	287.58	< 0.001
Int A X B X C	4	9.993	2.498	6,872.76	
Error	18	0.007	0.000		
Total	53	9,590.06			

16. ANOVA table for the number of sprouts at 30 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.027			
Factor A	2	6.159	3.08	14,204.68	< 0.001
Factor B	2	5.827	2.914	13,438.44	< 0.001
Int A X B	4	19.058	4.765	21,976.19	
Error(a)	16	0.003	0.000		
Factor C	1	0.073	0.073	328.383	< 0.001
Int A X C	2	0.023	0.012	52.052	< 0.001
Int B X C	2	0.003	0.001	6.241	0.00873
Int A X B X C	4	0.003	0.001	3.489	0.02814
Error	18	0.004	0.000		
Total	53	31.181			

17. ANOVA table for the number of sprouts at 60 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.031			
Factor A	2	3.565	1.783	14,815.79	< 0.001
Factor B	2	11.924	5.962	49,548.32	0
Int A X B	4	34.162	8.54	70,977.00	0
Error(a)	16	0.002	0.000		
Factor C	1	0.075	0.075	424.224	< 0.001
Int A X C	2	0.005	0.003	14.869	< 0.001
Int B X C	2	0.002	0.001	4.585	0.02459
Int A X B X C	4	0.007	0.002	10.237	< 0.001
Error	18	0.003	0.000		
Total	53	49.776			

18. ANOVA table for the number of sprouts at 90 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.021			
Factor A	2	2.365	1.182	5,053.72	< 0.001
Factor B	2	28.808	14.404	61,571.98	< 0.001
Int A X B	4	64.33	16.082	68,746.28	
Error(a)	16	0.004	0		
Factor C	1	0.209	0.209	859.124	< 0.001
Int A X C	2	0.046	0.023	93.897	< 0.001
Int B X C	2	0.013	0.006	26.127	< 0.001
Int A X B X C	4	0.014	0.004	14.457	< 0.001
Error	18	0.004	0		
Total	53	95.814			

19. ANOVA table for the diameter of sprouts (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.031			
Factor A	2	14.156	7.078	20,807.36	
Factor B	2	6.589	3.295	9,685.16	
Int A X B	4	23.662	5.916	17,389.87	< 0.001
Error(a)	16	0.005	0.000		
Factor C	1	0.076	0.076	867.877	< 0.001
Int A X C	2	0.008	0.004	44.502	< 0.001
Int B X C	2	0.015	0.007	84.872	< 0.001
Int A X B X C	4	0.023	0.006	64.724	< 0.001
Error	18	0.002	0.000		
Total	53	44.567			

20. ANOVA table for the length of sprouts (cm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	2.318	1.159	32,508.31	< 0.001
Factor B	2	20.946	10.473	2,93,798.76	
Int A X B	4	52.269	13.067	3,66,572.54	< 0.001
Error(a)	16	0.001	0.000		
Factor C	1	0.011	0.011	101.239	< 0.001
Int A X C	2	0.122	0.061	554.492	< 0.001
Int B X C	2	0.012	0.006	56.54	< 0.001
Int A X B X C	4	0.026	0.006	58.027	< 0.001
Error	18	0.002	0.000		
Total	53	75.729			

21. ANOVA table for the diameter of shoots (mm)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.024			
Factor A	2	127.994	63.997	5,48,323.97	
Factor B	2	85.627	42.813	3,66,825.16	< 0.001
Int A X B	4	273.991	68.498	5,86,888.37	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	1.957	1.957	15,000.53	
Int A X C	2	1.91	0.955	7,320.72	
Int B X C	2	0.382	0.191	1,463.01	< 0.001
Int A X B X C	4	1.16	0.29	2,223.67	
Error	18	0.002	0.000		
Total	53	493.049			

22. ANOVA table for the Fresh weight of shoots (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.029			
Factor A	2	7.598	3.799	20,746.25	< 0.001
Factor B	2	3.768	1.884	10,288.43	
Int A X B	4	12.355	3.089	16,866.83	
Error(a)	16	0.003	0.000		
Factor C	1	0.009	0.009	77.565	< 0.001
Int A X C	2	0.006	0.003	25.938	< 0.001
Int B X C	2	0.001	0.001	6.415	0.00788
Int A X B X C	4	0.005	0.001	11.828	< 0.001
Error	18	0.002	0.000		
Total	53	23.777			

23. ANOVA table for the dry weight of shoots (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Factor A	2	2.471	1.236	9,903.90	< 0.001
Factor B	2	1.338	0.669	5,362.14	< 0.001
Int A X B	4	4.369	1.092	8,755.16	< 0.001
Error(a)	16	0.002	0.000		
Factor C	1	0.044	0.044	328.552	< 0.001
Int A X C	2	0.006	0.003	21.528	0.00002
Int B X C	2	0.003	0.001	10.883	0.0008
Int A X B X C	4	0.007	0.002	12.661	0.00004
Error	18	0.002	0.000		
Total	53	8.269			

24. ANOVA table for the number of leaves

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.025			
Factor A	2	183.064	91.532	6,01,773.08	
Factor B	2	131.15	65.575	4,31,120.70	< 0.001
Int A X B	4	312.841	78.21	5,14,190.61	
Error(a)	16	0.002	0.000		
Factor C	1	0.333	0.333	2,401.06	< 0.001
Int A X C	2	0.092	0.046	333	< 0.001
Int B X C	2	0.023	0.011	82.494	< 0.001
Int A X B X C	4	0.158	0.039	284.467	< 0.001
Error	18	0.002	0.000		
Total	53	627.692			

25. ANOVA table for the leaf area (cm²)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.018			
Factor A	2	183.179	91.589	3,59,442.36	
Factor B	2	139.744	69.872	2,74,211.81	
Int A X B	4	392.12	98.03	3,84,719.12	
Error(a)	16	0.004	0.00		
Factor C	1	1.882	1.882	15,039.34	< 0.001
Int A X C	2	0.478	0.239	1,909.43	
Int B X C	2	0.089	0.044	353.971	< 0.001
Int A X B X C	4	0.098	0.024	195.576	< 0.001
Error	18	0.002	0.00		
Total	53	717.613			

26 ANOVA table for the chlorophyll content

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.034			
Factor A	2	3.665	1.833	7,275.45	
Factor B	2	2.042	1.021	4,054.20	
Int A X B	4	7.697	1.924	7,639.55	
Error(a)	16	0.004	0		
Factor C	1	0.009	0.009	121.206	< 0.001
Int A X C	2	0.001	0.001	8.294	0.0028
Int B X C	2	0.003	0.001	17.938	0.00005
Int A X B X C	4	0.002	0.001	7.191	0.00121
Error	18	0.001	0		
Total	53	13.458			

27. ANOVA table for the fresh weight of leaves (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.026			
Factor A	2	12.014	6.007	50,099.87	
Factor B	2	6.065	3.032	25,290.81	< 0.001
Int A X B	4	20.285	5.071	42,297.61	
Error(a)	16	0.002	0.00		
Factor C	1	0.012	0.012	129.948	< 0.001
Int A X C	2	0.001	0.001	7.714	0.00381
Int B X C	2	0.001	0.001	6.267	0.0086
Int A X B X C	4	0.002	0.00	3.998	0.01714
Error	18	0.002	0.00		
Total	53	38.41			

28. ANOVA table for the dry weight of leaves (g)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.021			
Factor A	2	6.619	3.31	15,096.49	< 0.001
Factor B	2	3.436	1.718	7,835.30	< 0.001
Int A X B	4	10.707	2.677	12,209.64	
Error(a)	16	0.004	0		
Factor C	1	0.024	0.024	220.15	< 0.001
Int A X C	2	0.008	0.004	35.42	< 0.001
Int B X C	2	0.001	0.001	6.16	0.00916
Int A X B X C	4	0.001	0	3.201	0.03766
Error	18	0.002	0		
Total	53	20.823			

29. ANOVA table for the root index

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.123			
Factor A	2	44,326.39	22,163.19	53,03,341.10	
Factor B	2	22,533.03	11,266.51	26,95,918.66	
Int A X B	4	61,949.97	15,487.49	37,05,939.56	
Error(a)	16	0.067	0.004		
Factor C	1	313.054	313.054	54,798.63	< 0.001
Int A X C	2	98.184	49.092	8,593.34	< 0.001
Int B X C	2	19.85	9.925	1,737.32	< 0.001
Int A X B X C	4	56.189	14.047	2,458.90	
Error	18	0.103	0.006		
Total	53	129296.95			

30. ANOVA table for the root to shoot ratio

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.00			
Factor A	2	0.086	0.043	1,469.88	0
Factor B	2	0.02	0.01	347.298	< 0.001
Int A X B	4	0.106	0.027	911.282	< 0.001
Error(a)	16	0.00	0.000		
Factor C	1	0.004	0.004	175.781	< 0.001
Int A X C	2	0.004	0.002	90.172	< 0.001
Int B X C	2	0.00	0.000	7.027	0.00555
Int A X B X C	4	0.001	0.000	14.286	0.00002
Error	18	0.00	0.000		
Total	53	0.222			

31. ANOVA table for the survival percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Factor A	2	877.834	438.917	4,93,043.72	
Factor B	2	2,177.19	1,088.60	12,22,841.22	
Int A X B	4	5,625.37	1,406.34	15,79,770.24	
Factor C	1	10.691	10.691	12,009.29	< 0.001
Int A X C	2	2.494	1.247	1,400.86	
Int B X C	2	0.754	0.377	423.25	< 0.001
Int A X B X C	4	1.937	0.484	544.052	< 0.001
Error	36	0.032	0.001		
Total	53	8,696.30			
Factor A	2	877.834	438.917	4,93,043.72	
Factor B	2	2,177.19	1,088.60	12,22,841.22	

32. ANOVA table for the mortality percentage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.023			
Factor A	2	1,119.63	559.817	2,512,825.718	
Factor B	2	2,316.31	1,158.155	5,198,559,541	< 0.001
Int A X B	4	5,524.76	1,381.191	6,199,690.958	< 0.001
Error(a)	16	0.004	0.000		
Factor C	1	4.023	4.023	18,533.71	< 0.001
Int A X C	2	0.145	0.073	334.882	< 0.001
Int B X C	2	1.237	0.619	2,849.45	< 0.001
Int A X B X C	4	1.172	0.293	1,349.82	
Error	18	0.004	0.000		
Total	53	8,967.314			