NUTRIENT MANAGEMENT STUDIES IN MAIZE + SOYBEAN INTERCROPPING AND ITS RESIDUAL EFFECT ON THE SUCCEEDING FODDER OATS IN MAIZE + SOYBEAN – OATS CROPPING SYSTEM

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DECLARATION

I, hereby declared that the presented work in the thesis entitled "**NUTRIENT MANAGEMENT STUDIES IN MAIZE + SOYBEAN INTERCROPPING AND ITS RESIDUAL EFFECT ON THE SUCCEEDING FODDER OATS IN MAIZE + SOYBEAN -OATS CROPPING SYSTEM**" in fulfilment of degree of **DOCTOR OF PHILOSOPHY (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr. SANTOSH BASAVANT KORAV**, working as **Assistant Professor**, in **Department of Agronomy** 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 "**NUTRIENT MANAGEMENT STUDIES IN MAIZE + SOYBEAN INTERCROPPING AND ITS RESIDUAL EFFECT ON THE SUCCEEDING FODDER OATS IN MAIZE + SOYBEAN -OATS CROPPING SYSTEM**" submitted in fulfillment of the requirement for the award of degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the **Department of Agronomy**, is a research work carried out by **UMESH KUMAR SINGH**, **12215750**, 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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ABSTRACT

The field experiment, entitled "Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oats in maize + soybean – oats cropping system" was conducted during 2023-24 and 2024-25 at LPU, Punjab. The experiment was laid out in a split plot design with Five main factor including sole maize (M_1); sole soybean (M_2); maize + soybean (1M:1S) (M_3); maize + soybean (1M:2S) (M_4) and maize + soybean (2M:3S) (M_5). The five subplots were absolute control (S_1); 100% RDF (S_2); 70% RDF with two foliar applications of Nano NPK (S_3); 70% RDF with two foliar applications of Homemade NPK (S_4) and 70% RDF with two foliar applications of plant extract (S_5) with three replications. The experimental results indicate that 1: 1 row proportions of maize and soybean performed statistically similar to their sole planting system. Significantly higher DMA, CGR, RGR, number of leaves, leaf area, and yield were similar to their sole cropping but higher than the M_3, M_4 and M_5 planting system. Similarly, application of 70% RDF with foliar application of plant extract, Homemade NPK are at par with 100% RDF application. Interaction effect of M_3S_2 at par with M_1S_2 However, significantly higher proline content was recorded in the sole maize treated with absolute control treatment. The intercropping indices, such as land equivalent ratio (LER), and competition index (CI), as well as maize equivalent yield (MEY), were significantly higher under 1M:1S compared to 2M:1S and 2M:3S row proportions of maize and soybean intercropping. Similarly, residual effect of sole soybean with 100% RDF showed significantly higher growth and green fodder yield. The findings of this study suggest that maize and soybean intercropping in a 1M:1S row proportion can be a viable option for increasing crop yields and system productivity. Additionally, the application of 70% RDF with two foliar applications of plant extract or Homemade NPK can be an effective strategy for reducing fertilizer usage while maintaining crop yields.

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Place: Punjab **Umesh Kumar Singh**

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CHAPTER - 1

INTRODUCTION

The Indo-Gangetic Plain Region (IGPR) is one of the world's largest productive areas, accounting for almost half of the global total food grains and supporting the livelihoods of approximately 40% of the country's population (Pal *et al*, 2009). The introduction of green revolution technologies, including compact, short-*season*, and responsive to inputs varieties of rice and wheat, along with high input usage (chemical fertilizers) and intensive mechanization, has undoubtedly increased food production in the IGPR region (Pooniya *et al.,* 2017). However, the prolonged implementation of these practices has begun to show signs of exhaustion, characterized by a significant drop or stability in crop yields and farm revenue.

The primary factors contributing to the issues associated with IGPR are the excessive use of chemical fertilizers in intensive cereal-based farming systems, which has led to a significant decline in soil health (Singh *et al.*, 2011). Furthermore, the continuous cultivation of water-intensive cereal crops, including rice, sugarcane, and wheat, results in a substantial drop in the groundwater table (Mahajan *et al*., 2012). These issues are compounded by inefficient production practices combined with rapid urbanization and climate change (Pooniya *et al*., 2017). Considering these challenges and issues, the conventional approach of growing cereals sequentially must be replaced by location-specific, diversified farming systems that incorporate fodder, pulses, and other suitable grain crops.

Crop diversification can be a practical approach to overcome the limitations of the traditional cereal-cereal rotation system of IGPR and help growers achieve maximum profits. This method gives farmers more options when choosing crops and farming methods in a specific area, creating numerous opportunities to meet essential needs, stabilize farm income, provide balanced food and fodder supplies, conserve natural resources, and decrease the amount of agro - chemicals released into the environment. Considering the current market conditions, environmental issues, and declining farm income, diversifying cereal-based rotations of IGPR with maize + legume intercropping - forage crops, and suitable alternatives to rice and wheat offers promising opportunities.

The value of intercropping in farming practices has long been recognized. Crop mixing agriculture is an old method in India. It is a sort of informal insurance that covers the risk in situations when agricultural output is vulnerable to weather, pests, and diseases that affect each crop differently. The goal of intercropping is to maximize output per unit area and unit time. Intercropping utilizes the land surface more intensively than pure crop production. Intercropping can give a significant yield benefit over single cropping. Similarly, intercropping may provide improved yield stability over inputs by simply expanding the mixture.

Maize is widely regarded as a miracle crop and is the second most cultivated crop globally, after wheat and rice. Its exceptionally high yield potential makes it the 'queen of cereals', unmatched by any other cereal. This annual crop belongs to the Poaceae family and serves as a global source of carbohydrates. It is consumed by humans in developing regions and used as animal feed worldwide, including for poultry and pigs. Additionally, maize is used in the production of biofuel. In areas prone to drought, maize plays a vital role in ensuring food security. However, as agricultural land with suitable conditions becomes increasingly scarce, it is becoming more challenging to expand planting areas to boost cereal production Therefore, one of the most realistic efforts is to increase productivity. The increase in land productivity can be achieved through intercropping systems. The intercropping system is carried out to obtain an increase in total production and reduce the risk of crop failure or loss of one of the plants as well as reduce production costs and increase farm income. In an intercropping system, it is necessary to regulate plant density and select plant species to obtain an optimal population without neglecting the carrying capacity of the land, so that the reduction in yield of each plant due to competition for nutrients, water, and light will be compensated with the same population as the monoculture cropping system.

Food provision must keep pace with the steadily rising population. Serious challenges affecting food supplies include a scarcity of natural resources, as noted by Anastacio *et al.* (2017). This scarcity is compounded by a decline in the quality of these resources due to water and soil pollution, as well as an excessive reliance on chemical fertilizers (Chen *et al*., 2011). Furthermore, the impacts of climate change, biodiversity loss, and land degradation on food production areas (Mulyani *et al.,* 2016) also pose significant threats to food supplies.

Most concerns in agriculture focus on monoculture production, including technology, government policies, modern crop varieties, and research. However, drawbacks in modern systems have led some farmers to consider intercropping for fibre and food production. The rice-wheat system in Punjab is widespread but has hazardous soil conditions. In India, Punjab has the highest polluted water levels due to insecticides and chemicals. Studies show that maize and soybean are suitable for intercropping due to their growth patterns. They are cultivated and harvested together, making them suitable for mechanized farming. Maize and soybean also have ideal leaf shapes for light absorption on the same plot of land (Yang *et al*., 2015).

India is an agrarian country where an average of 70% of rural people are involved in agriculture, either directly or indirectly (IGFRI Vision, 2030). The major rice-wheat system has been adopted by farmers in the Punjab region. Farmers who continued to use this method of farming had to deal with difficulties including soil erosion, salinity, alkalinity, and loss of soil fertility on a daily basis.

Improving the microclimate in a field is crucial for boosting maize-soybean crop yields in intercropping systems. Intercropping systems with high temperatures, intense light, and low humidity enhance the rate of photosynthesis in leaves and contribute to improved biological properties of the maize plant. In maize and soybean intercropping systems, maize is the predominant crop that absorbs more sunlight than soybean.

The microclimate environment within soybean plant canopies is altered, including light intensity and spectral properties. Physiological and morphological changes can be seen, such as stem elongation, increased lodging, a decrease in the chlorophyll a/b ratio and leaf size, and enhancements in photosynthetic efficiency and specific leaf weight. The soybean recovery response to shade stress is notably enhanced under maize-soybean intercropping systems. This is particularly due to the effectiveness of wide-narrow row planting in alternating maize and soybean, with a 200 cm bandwidth arrangement of 2:2, maize-to-soybean rows. This arrangement facilitates high light interception for the soybean. Intercropping patterns of maize and soybean have a significant impact on the leaf area index and the amount of photosynthetically active radiation (PAR) that is intercepted.

Crop damage is often caused by weeds, pests, and diseases. These factors result in a reduction in the quality and yields of crop products. Intercropping serves a significant function in reducing weed, pest, and disease invasions. Ramert *et al.* (2002) also found that intercropping plays a significant role in reducing pest infestations. A study by Sekamatte *et al.* (2003) observed that maize- soybean intercropping resulted in significantly lower termite attacks compared to maize intercropped with common beans and groundnuts. Furthermore, Dolijanovic *et al.* (2009) reported that maize + soybean intercropping showed significant benefits in weed management.

Intercropping cereal crops with legumes is a sustainable land management approach that contributes to long-term nitrogen immobilization and reduces reliance on nitrogenous fertilizers. This practice, as noted by Regehr *et al.* (2015), also aids in preserving and enhancing soil fertility. Leguminous crops, such as soybean, cowpea, and groundnuts, are capable of accumulating significant amounts of nitrogen in the range of 80 to 350 kg per hectare. Intercropping with cereal crops enhances nitrogen absorption, reduces nitrogen waste, and increases biomass production.The land equivalent ratio (LER) is a widely used index for assessing land productivity in intercropping systems. A value of LER greater than 1 indicates effective land utilization in any intercropping system, resulting from the efficient use of resources by intercrops (Willey and Osiru, 1972). If a value of LER is more than 1.0, it indicates that yield for that particular crop combination of intercropping is more than growing a similar population of monoculture crops, and an LER value of less than 1.0 indicates that the beneficial yield of intercropping is lower than that monoculture crops Maize-soybean intercropping may also advantages in term of saving irrigation water, especially in the location of water scarcity.

In India, oats (*Avena sativa* L.) are cereal fodder crop during rabi *season*. The total area under oats production is around 1.0 million ha, with 35-50t ha^{-1} green fodder output (IGFRI Vision, 2050). Where irrigation is available, it is mostly farmed in Haryana, Punjab, Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, West Bengal, and Gujarat (Joshi *et al.*, 2023). From December to February, it yields luscious and extremely delicious green fodder. Oat fodder may also be made into hay or silage to feed the animals during the lean *season*. Oat grain is a well-balanced concentrate that may be used in the diets of poultry, cattle, sheep, and other animals.

The biggest issue of the day is the scarcity of green fodder, which threatens animal output and so draws the attention of both the general public and scientists. With the country's current feed and fodder supplies, only 46% of the overall demand is supplied, and that is by feeding poor quality forages. Given this, as well as the rising human population strain on limited land, it is critical to boost fodder output qualitatively as well as quantitatively by using various agronomic practices such as cutting management.

Nitrogen is an amino acid ingredient, and nitrogen deficit in cereal grain and straw, as well as fodder crops, can cause serious illnesses in animals and humans (Midha *et al.,* 2015). Among the many nutrients, oat reacts strongly to nitrogen application, producing greater tonnage per unit area per unit of time under favorable climatic circumstances. Cereal – legumes-based intercropping also plays significant role in fixing nutrients in the soil which are utilized by the succeeding crop. However, investigate the how nutrient management practices, combined with chemical fertilizers, organic substances, and forage legumes, impact system productivity, profitability, and soil properties in diverse food-fodder production systems are limited. Considering this, a research project was designed and carried out to focus on "**Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oats in maize + soybean - oats cropping system."** The main aim of study was to develop an economically and ecologically viable fodder-food production system and develop a sustainable nutrient management approach that enhances system productivity, farm profitability, and soil health while addressing environmental vulnerabilities. The objectives of study were as follows.

1. To study the effect of intercropping and nutrient management on the growth parameter, yield attributes, and yield of maize and soybean
2. To know the residual effect of maize + soybean intercropping and nutrient management on succeeding fodder oats crop
3. To evaluate the impact of intercropping and nutrient management on nutrient uptake and soil health in maize + soybean – oats cropping system
4. To work out the economics of maize + soybean – oats cropping system as influenced by intercropping and nutrient management

CHAPTER 2

REVIEW OF LITERATURE

This review synthesizes global and Indian studies on nutrient management in maize-soybean intercropping and its residual effects on fodder oats. This review focuses on various aspects, such as crop growth, nutrient management, productivity, and profitability. Furthermore, the study examines the influence of different crop arrangements and nutrient management practices on the performance of maize + soybean intercropping system. The review is presented under following sub headings.

2.1. Effect of intercropping on growth and development of maize

2.2. Effect of intercropping on growth development of soybean

2.3. Effect of nutrient management on growth and development of maize

2.4. Effect of nutrient management on growth and development of soybean

2.5. Effect of intercropping on yield attributes and yield of maize

2.6. Effect of intercropping on yield attributes and yield of soybean

2.7. Effect of nutrient management on yield attributes and yield of maize

2.8. Effect of nutrient management on yield attributes and yield of soybean

2.9. Interaction effect on intercropping and nutrient management on growth and development of maize

2.10. Interaction effect on intercropping and nutrient management on growth and development of soybean

2.11. Residual effect of maize + soybean intercropping on growth and biomass of fodder oat

2.12. Effect of maize + soybean intercropping and nutrient management on soil properties

2.13. Effects of intercropping and nutrient management on agronomic indices of maize + soybean intercropping system

2.14. Effect of maize + soybean – oat cropping system on economics

Studies conducted by Begam *et al.* (2024) and Nasar *et al.* (2024) have demonstrated that the integration of organic and inorganic nutrient sources can optimize these benefits, resulting in improved crop productivity. Additionally, adequate nitrogen fertilization in maize-soybean intercropping can boost plant nutrient content by modulating soil physio-chemical characteristics and enzymatic activities, ultimately leading to increased yield. The adoption of intercropping as an agricultural method may therefore offer superior yield gains and enhanced plant-soil nutrient enhancement compared to mono-cropping. Adeola *et al*. (2024) investigate the maize and soyabean Response to the Residual Influence of Early-*Season* Cropping System and Fertiliser. They observed that the residual effects of legume cropping significantly increased the succeeding crop growth and N uptake compared to the intercrop. They observed that residual effect of fertilisers NPK at 200 kg N ha^{-1}significantly increased succeeding crop height and yield compared to the other treatments due to proper utilization of land resources in food - fodder cropping system. Chai *et al.* (2021) observed that cereal + legume intercropping offers multiple benefits including enhancing crop productivity, improving soil nutrient availability, and maintaining soil multi-functionality and health. These advantages are largely attributed to the efficient acquisition and utilization of resources through spatial and temporal diversifications.

2.1. Effect of intercropping on growth and development of maize

Research on inter-cropping patterns and nutrient management effects on maize growth, yield, and quality has been conducted by Begam *et al*. (2024) indicated that intercropping significantly influences the plant height of maize compared to monoculture. This enhancement is likely attributed to improved nutritional synergies and more efficient light interception in intercropping. However, a different study by Kou *et al.* (2024) observed a 7.94% average reduction in plant height of intercropped maize compared to mono-cropped maize over a two-year period. It is worth noting that maize plant height increased with an increasing number of maize rows. Furthermore, plant height responded significantly to shade. Feng *et al*. (2024) reported that sole maize plant height was significantly higher than that of relay intercropping maize. Additionally, A1B1 (intercropping maize) plant height was significantly lower than A1B2 by 5.52%, due to reduced competition between plants compared to other treatments. Wei *et al.* (2022) found that intercropping maize was significantly increased the plant height of maize, due to competition for light, water, and nutrients was greater than their sole culture. With the advancement of the growth period, the degree of shading of maize increased, and the plants underwent a series of shading reactions to adapt to shading stress, resulting in the preferential supply of soybean photosynthates to stem elongation, thereby increasing plant height. Similarly, Wang *et al*. (2021) found that mono-cropped maize was recorded with the highest significant plant height compared to different intercropping row proportions due to solar interception directly affected the height of maize plants. Wide-row proportional cropping system had reduced plant height compared to narrow-row cropping pattern. Ali and Mohammad (2012), have also observed a positive effect of intercropping on the plant height of maize due to the positively competition between maize soybean intercropping system. Similarly, Abdel *et al.* (2012) found that the cropping system 2 maize; 2 soybeans (CS_2) resulted in significant increases in plant height in both *season*s, measuring

329 and 336.67 cm respectively. On the other hand, the cropping system 2 maize; 4 soybeans (CS_3) exhibited the highest significant values for leaf area.

Raza *et al.* (2022), observed different treatments significantly affected the total dry matter production of maize. Across different sampling stages and treatments, maize plants accumulated higher dry matter in their sole cropping compared to intercropping treatments. In addition, different maize planting density treatments in intercropping not only affected dry matter production of intercrops but also changed dry matter partitioning in various plant parts of maize. In research on the effect of row proportion of maize and soybean intercropping on growth and yield of component crops in sandy soil north Iombok, Indonesia, Astiko *et al*. (2021) found that, three rows of maize and three rows of soybean (P_3) intercropping treatment recorded the highest values of dry biomass weight, due to the plant density affected dry biomass weights of maize, and rest of treatment was obtained the maize biomass reduction from 3.5 to 4.5 times. Raza *et al.* (2021) found that dry matter accumulation in sole cropped maize was significantly greater than in maize-soybean intercropping systems, including single row relay-intercropping, double row relay-intercropping, and triple row relay-intercropping, at all sampling stages and in both years. Conversely, in the multi-stand system, the single row relay-intercropping system yielded the highest dry matter accumulation of maize at R_6, whereas the triple row relay-intercropping system exhibited the maximum dry matter accumulation in soybean at R_1. The dynamics of maximum dry matter accumulation at R_6 for maize and at R_1 for soybean under various treatments were consistent with those of the other measuring stages. This consistency was attributed to low competition between plant rows and higher light interception in sole crops compared to intercropped systems. In sole maize, dry matter accumulation was significantly higher than in intercropped treatments.

A study by Raza *et al.* (2019) investigated the effect of planting patterns on yield, nutrient accumulation, and distribution in maize and soybean under relay intercropping systems. The results showed that different planting patterns and locations had a substantial impact on plant dry matter accumulation of maize. Specifically, plants in sole maize (SM) consistently accumulated higher dry matter than those under single row relay-intercropping systems (SI) and double row relay-intercropping systems (SII) in the same measurement site. However, certain planting patterns, including SI and SII, and specific locations, such as Lezhi and Renshou, produced the highest dry matter accumulation of maize.

Deng *et al*. (2024) observed sole maize wear highest number of leaves compared to intercropping treatments because of higher light interception respectively. These leaves had lower SLA than corresponding leaves in sole maize. However, sun leaf adaptations were not found at other leaf positions and at other developmental stages in intercropping. Similarly, Kou *et al*. (2024) found Sole maize wear the highest significant leaves compared to intercropping treatments during two cropping *season*s. The number of leaves of maze increased with height of maize due to number of leaves responded significantly to height. Kussie *et al*. (2024) reported that the highest leaf number per plant of maize was obtained at the intercropping 1:1 row (15.49) followed by sole maize (15.01) than the intercropping ratio in the intercropping of 2:2 rows (14.75). The differences in number of leaves among the different intercropping patterns could be attributed to intercropping ratios that facilitated maize growth for light competition due to the fact that the taller plant, the higher the amount of light energy absorbed and the higher the rate of photosynthesis, and consequently the amount of assimilate produced by the leaves.

Dong *et al*. (2024) observed that sole maize was recorded highest leaf area compared to intercropping treatments because of higher light interception in their monoculture respectively. These leaves had lower SLA (specific leaf area) than corresponding leaves in sole maize. However, sun leaf adaptations were not found at other leaf positions and at other developmental stages in intercropping. According to Yang *et al*. (2022) reported the maximum leaf area was observed in their monoculture than intercropping system high maize plant density impairs maize performance, especially under monocropping. Integration with intercropping and high plant density changed leaf area size, leading to the modification of leaf anatomy. These changes in both leaf area size and leaf anatomy increased photosynthetic capacity. The positive effect was also shown by the increase in leaf area, which provided additional photosynthetic potential and assisted the recovery and growth of later crops. Stomata on the leaf surface that controlled gas exchange between the atmosphere and plants also influence potential leaf area and crop performance.

Raza *et al*. (2022) investigated the maize/soybean strip intercropping produces higher crop yields and saves water under semi-arid conditions. They found the LAI (Leaf area index) of maize under different planting were significantly lower under intercropping than sole maize. In intercropping treatments, at the final sampling time (125 DAS), the average highest maize (4.6) LAI was measured under D_2 (8 maize plants m^{-2}), whereas the average lowest maize (3.5) LAI was recorded in D_1(6 maize plants m^{-2}), respectively. It might be sole maize was likely associated with greater light use efficiency, water use efficiency, nutrient accumulation, and plasticity of edge-row plants. Raza *et al.* (2021) conducted a study that compared the leaf area index (LAI) of maize in different planting systems. The study found that sole planting of maize resulted in higher LAI values compared to intercropping systems. The results showed that the maximum maize LAI was observed in the one row strip intercropping (SI) treatment, with average values of 3.4, 4.0, and 2.4 at different stages of growth (TS, R3, and R6, respectively). In contrast, the minimum maize LAI was found in the triple row strip intercropping (SIII) treatment, with average values of 2.7, 3.2, and 2.0 at the same stages of growth.

The study also found that maize achieved higher LAI values when planted alone compared to the other intercropping treatments. Specifically, the highest LAI values were observed in the sole maize treatment, which were 2.1, 2.4, and 2.8 at different stages of growth. It is evident that maize achieved 79% higher LAI in sole maize compared to the other intercropping treatments. Overall, these results indicating that leaf area index of maize have a direct relationship with changing planting pattern, maize plants exhibited higher leaf area index when they planted under treatments P_1(sole), respectively, when planted in relay - intercropping system similar result was found by Raza *et al.* (2019). According to Wang X *et al*. (2020) observed that planting pattern did not affect the growth dynamics of leaf area index (LAI), but LAI was significantly lower in intercropping than that of monoculture after flowering. In 2015 and 2016, the LAI was decreased by more than 40% at 15–35 days after flowering in intercropping. In 2017, the LAI was decreased by more than 35% at 10–40 days after flowering in intercropping due to higher competition in intercropping for nutrients than sole culture respectively.

The study conducted by Begam *et al*. (2024) examined the effects of inter-cropping patterns and nutrient management on maize growth, yield, and quality. The study's findings indicated that the crop growth rate of maize increased positively until 70-90 days after sowing, after which it began to decline as the crop matured. Notably, treatment C_1, which involved growing maize as a sole crop, demonstrated significantly higher crop growth rates and relative growth rates throughout all periodic measurements. This was largely due to reduced competition for nutrients and increased light interception, resulting in higher dry matter accumulation in the sole crop compared to the mixed plot crops. The crop growth rate of maize is an important indicator of growth, and it is influenced not only by genetic factors but also by external variables such as nutrition and crop spacing. Pandey *et al.* (2017) reported the crop arrangement influenced the crop growth of maize in intercropping system. They found maximum crop growth rate CGR value was noticed between knee height stage to flowering phase (40-60 DAS). CGR under 2:4 replacement series (C_4) was almost two-fold higher than the sole maize which is showing the lowest CGR. C_4 was followed by 2:2 replacement series (C_3). However relative growth rate (RGR) and net assimilation ratio (NAR)was found their 2:4 row proportion maize planting system compared to rest of intercropping treatments, it was happened due to less competition of recourse, higher light interception and properly nutrient uptake by the sole plant. According to Addo *et al*. (2012) they showed that Maize crop and relative growth rates were not significantly ($p>0.05$) affected by spatial arrangements. The greater ability of the cereal component to absorb limited soil factors increased the interspecific competition in the intercrop.

Legba *et al*. (2025) found stem diameter significantly affected by the tested sowing patterns of sole maize, (1:1), (2:2) and (1:3). Highest significant stem girth was recorded under their monocropping due to higher light interception and less competition of light and proper spacing. Research on maize-soybean strip intercropping systems under drip fertigation in arid northwest China has demonstrated that stem diameter exhibits an inverse relationship with plant height. Specifically, Kou *et al.* (2024) found that plants with greater heights tend to have smaller stem diameters. Furthermore, the study revealed that stem diameter is significantly influenced by shade. According to Liu *et al*. (2023a) observed that stem diameter of intercropped maize was 6.31%, 8.78%, 10.9%, and 11.7% higher than that of monoculture maize, respectively. The two-year average shows that intercropping significantly increases maize stem diameter. Under the intercropping, stem diameter of maize increased by 6.28%, 13.9%, and 21.7%, respectively. It is most likely associated with higher water use efficiency, improved light use efficiency, and nutrient accumulation. Moreover, efficient uptake and utilization of nutrients and soil water enhance root system proliferation and lead to improved crop growth by promoting crop plant height, stem diameter, leaf area, and other growth indicators.

Cheng *et al*. (2022) observed that the maximum internode length, was record under the monocropping treatment compared to their internode treatment due to crops with the perfect canopy structure were propitious to intercept more light energy to promote stem morphogenesis. The stem of strip intercropped soybean was obviously weaker than that of monoculture in terms of external morphology. According to Chen *et al*. (2020) observed maximum internode length was under maize - soybean intercropping was higher than that of its sole cropping. 12-18 cm internode length affected the lodging resistance of plants, and intercropping significantly enhanced the lodging resistance of the above key internode positions. Morphological and physiological indexes of the intercropped maize were significantly higher than that of sole cropped maize and were positively correlated with stalk resistance index but negatively correlated with lodging rate.

Wei *et al*. (2022) found that the SPAD value of intercropping maize was significantly different from that of monocropping maize, and the SPAD value of intercropping maize was stronger than that of monocropping maize. Compared with monocropping, intercropping maize and soybean can maintain a higher level of SPAD, can effectively promote photosynthesis, and is conducive to increasing yield in the later period. According to Ren *et al*. (2021) found that different intercrop pattern has an impact on crop SPAD values on account of the above - and below-ground competition among intercropping systems. The SPAD of intercropped maize was increased 4% and 5% for M_2S_2 and M_2S_4 compared to monocrop. For above-ground interaction, the row planting patterns affect the light transmission rate of intercropping species, because close planting between different crops always causes mutual shading, especially for the shading of tall crops over short crops in intercropping systems, and then inevitably affect crop radiation interception, light interception, and photosynthetically active radiation transmittances.

Hussain *et al*. (2023) reported, intercropped crops can accumulate more solutes for their survival under moisture stress than monocrops. Similar was found in this work in which intercropping treatments significantly improved proline contents in maize crops. Furthermore, a strong positive correlation among proline, and antioxidant enzymes also showed help to sustain intercropping crops under moisture stress conditions. The synthesis and accumulation of proline also take place in plants to induce tolerance to water stress. It has been well established that proline also owns antioxidative belongings and protects the plant cells from dehydration when acting as chaperones to shield the macromolecule assembling. According to Rehman *et al*. (2025) reported, intercropping increases the proline content in kenaf and soybean under increasing levels of Cu in soil. Proline generation of plants in response to Cu toxicity, might be linked with the plant cells protection against oxidative damage and signal transduction. Excess of Cu might has broken osmoregulatory solutes and stimulated the synthesis of proline in plants. According to Silva *et al*. (2021) reported that neither the treatments nor their interactions had any significant effect on the accumulation of proline in corn plant leaves. This result is thought to be due to the fact that the plants did not undergo any conditions of stress regarding light, temperature, water, and nutrients proline accumulates only when plants are submitted to stress. They observed proline accumulation in corn plants submitted to water stress.

2.2. Effect of nutrient management on growth and development of maize

Begam *et al.* (2024) found that seaweed-based fertilizers, which contain bio-stimulants and micronutrients, significantly enhanced growth rates. Notably, the maximum plant height was observed in the seaweed-based fertilizer treatment, surpassing the other treatment options. This enhancement of growth rates through integrated nutrient management (INM) and organic bio-stimulants, such as seaweed, is particularly relevant in areas experiencing soil degradation and nutrient depletion. It contributes to the achievement of sustainable agriculture goals. A separate study conducted by Hussein *et al.* in 2021 also observed that the maximum plant height of maize was recorded in the seaweed extract treatment, compared to other nutrient management treatments. The seaweed extract was found to promote root and shoot growth, as well as improve plant stress tolerance, resulting in the observed maximum height. This may be attributed to the presence of distinctive types of polysaccharides, such as alginates, which are essential components of brown seaweed cell walls and play a crucial role in stimulating plant growth. Gorlach *et al*. (2021), reported, foliar application of nutrients resulted in a significant increase in nutrient concentration in all plant parts ten days after the last application, the maximum maize height was recorded under the basal + Foliar application of nutrient management treatment compared to conventional method of nutrient application due to higher penetration rate and high uptake efficiency than conventional application. This was mainly measurable in the plant regions directly affected by foliar fertilization. The lower uptake efficiency of nutrient might be attributable to the phenomenon of crystalline formation on the leaves. At low humidity, an increased accumulation of crystalline residues occurs that prevents the penetration of nitrogen into the leaf.

Sahoo *et al.* (2024) reported maximum dry matter accumulation was achieved with a nutrient application of 164:60:60 N: P_2O_5: K_2O, compared to the control treatment. This outcome is likely attributed to variations in nutrient doses and their split application. The results underscore the importance of nutrient requirements and the split application of nitrogen in maize. A separate study conducted by Ghosh *et al.* (2024) also highlighted the crucial role of nutrient management in maize growth. The study demonstrated that combining 75% recommended dietary allowance (RDF) with poultry manure yielded the most impressive results, including increased dry matter accumulation, which ultimately enhanced overall growth characteristics. This outcome can be attributed to the higher nitrogen efficiency uptake by plants when using poultry manure. According to Chandrawanshi *et al*. (2024) reported the combined approach to nutrient management improved maize growth, with specific treatments such as 50% RDN (Recommended dose of nitrogen) fertilization achieved using vermicompost and poultry manure enhancing dry matter accumulation, ultimately leading to increased crop yields, this was due to higher nutrient efficiency. According to Sairam *et al.* (2024) found that nutrient management has a considerable impact on maize growth, with sufficient nitrogen application at 200 kg/ha, combined with optimal levels of phosphorus and potassium, promoting dry matter accumulation. Split applications through a management approach based on sufficiency index further improve growth of maize. A study published by Begam *et al.* (2024) discovered that fertilizers made from seaweed led to higher maximum dry matter yields compared to a control treatment. This improvement in growth rates, achieved through the use of integrated nutrient management and organic bio-stimulants like seaweed, is especially notable in areas where soil degradation and nutrient depletion are occurring. It also contributes to the goal of adopting more sustainable agricultural practices.

Ghosh *et al.* (2024) found nutrient management plays a substantial role in maize growth, combining 75% RDF with poultry manure led to the most impressive results, including a leaf count of 12.16, ultimately enhancing overall growth characteristics. It was due to poultry manure proved higher nitrogen efficiency uptake by plants. Another study by Begam *et al*. (2024) observed role of seaweed-based fertilizers, enhancing growth rates through bio-stimulants and micronutrients was also evident. They were observed maximum number of leaves wear under seaweed-based fertiliser treatment than rest of treatment. The enhancement of growth rates through INM and organic bio-stimulants like seaweed is especially relevant in areas facing soil degradation and nutrient depletion, contributing to sustainable agriculture goals. According to Racz *et al*. (2021) reported maximum number of leaves of maize was recorded under the base and foliar nutrient application treatment, suggest that foliar fertilization is only a supplemental method that may correct nutrient deficiencies but cannot replace soil-applied fertilizers of major nutrients. They suggest the joint treatment of nutrient and foliar fertilization (which also contained N) may have resulted in the best N supply conditions for maize. Similarly, Aliyu *et al*. (2021) reported the number of leaves of maize significantly affected by the nutrient treatments, the maximum number of leaves was recorded of maize under the NPK and Zn treatment compared to control. This may be due to the improvement of fertilization uptake.

Ssemugenze *et al*. (2025) found LAI, canopy structural characteristic, has a quantifiable impact on the biochemical parameters of crops. The foliar application of fertilisers greatly influenced the growth and physiology of maize at different stages. The foliar nutrient application influenced leaf area index. Positive effect on growth parameters due to the application of biofertilizers extracted from seaweed. According to Kunjam *et al*. (2024) reported the maximum leaf area index was recorded RDF (90 N, 45 P_2O_5, 20 K_2O, and 10 $ZnSO_4$) kg ha^{-1} + seed inoculation with PSB + KSB treatment. The increase in periodic leaf is index with nutrient management practices may be attributed to increase in plant height, number of leaves, leaf area and leaf area index resulting thereby in better light interception by crop which accumulated more photosynthates and thus produced more dry matter. A sufficient supply of NPK is necessary for better crop growth and for improving the source-sink connection, which increases agricultural production. A co-factor of many enzymes, potassium primarily aids in the translocation mechanism and enhances the mobility and use of other elements. Nutrient management practices had a significant effect on both nutrient content leaf area and leaf area index and nutrient uptake Another study conducted by Racz *et al*. (2021) reported maximum leaf area index of maize was recorded under the base and foliar nutrient application treatment. The joint treatment of nutrient and foliar fertilization (which also contained N) may have resulted in the best N supply conditions for maize. They observed as correspondence with several studies which have shown that foliar application sufficiently decreased N loss in the waterlogged field where nitrate leaching is a substantial source of N loss.

Farouk *et al*. (2024) observed application of PBR (plant bio regulator) had a notable positive impact on all evaluated wheat characteristics, exhibiting a dose-dependent relationship, with a dosage of 0.08 g. The optimized rate resulted in a 138% increase in net assimilation rate, and an 181% increase in crop growth rate compared to the unsprayed control. The nutrient for a number of physiological processes in plants, such as regulating gas and water exchange, protein synthesis, enzyme activation, and photosynthesis. The organic extract has complex interactive effects on soil enzymes like phosphatase that regulate nutrient cycling. Both the organic matter additions and sufficient nutrient inputs are needed to sustain the enzyme activity and mineralization processes. According to Ssemugenze *et al*. (2024) reported that, different biofertilizer, was applied at a concentration of 0.25%, positively influencing maize growth and physiological indices, including crop growth rate (CGR), relative growth rate (RGR) and Net assimilation rate (NAR) of maize plant. Both biofertilisers (seaweed and Ortho Silicic Acid) indicated exceptions which need to be addressed while applying them. The biofertliser should be supplemented with NPK foliar fertilisers to boost nutrients concentrations to the required level while when using seaweed extract, create more effective in their growth.

Singh *et al*. (2024a) found the application of 100% RDF combined with EB yielded the highest SPAD values, followed by treatments with 100% RDF + VC and combinations involving 75% RDF with EB and μNM. This outcome can be attributed to the enhanced nutrient availability and uptake provided by the biofertilizers and organic amendments, which improve nitrogen assimilation and chlorophyll synthesis, thus maintaining higher leaf greenness. They observed that biofertilizers, particularly those containing plant growth-promoting rhizobacteria (PGPR), enhance nitrogen uptake efficiency, leading to increased chlorophyll content and improved SPAD readings in various crops. According to Ghosh *et al*. (2024), reported, integrated nutrient management greatly impacted the chlorophyll levels in maize. At harvest, the maximum chlorophyll content (40.84) was recorded in RDF (F_1) which was at par with 75 % RDF + PM at 2.5 t ha^{-1} (F_3) and minimum chlorophyll content (36.77) was found from the PM at 5 t ha^{-1} (F_2) due to the enhanced growth of crops at an optimal moisture and nutrient appears to stem from its ability to positively influence both the soil and plant environment, thus facilitating the development of key morphological and biochemical components crucial for plant growth. Nitrogen is vital for chlorophyll synthesis, a process of significant importance in plant physiology. Another study conducted by Singh *et al*. (2024) reported, higher leaf N content, improved photosynthetic rate when 122 kg N_2O_5 ha^{-1} was applied at LCC-5 over fixed time application of 125 kg N_2O_5 ha^{-1}. This could be attributed to better synchronization of N supply with crop N demand leading to higher N uptake due to real time application of 125 kg N_2O_5 ha^{-1} based upon need.

2.3. Effect of intercropping on yield attributes and yield of maize

Begam *et al.* (2024) reported that inter-cropping patterns and nutrient management on maize growth, yield, and quality found that monoculture maize produced the maximum number of cobs per plant. This phenomenon is potentially attributed to more efficient assimilation and translocation of photosynthates. As a result, there was an increase in key yield parameters, including the number of cobs per plant. This aligns with the yield advantages observed in sole maize cropping systems by Brooker *et al.* (2021). The sole system was found to have a higher potential to produce a greater number of cobs per plant compared to intercropping, likely due to reduced competition for water and nutrients. Similar results were obtained by Hertman *et al.* (2015), who reported that sole maize outperformed intercropping in terms of producing a higher number of cobs per plant. This is likely due to greater translocation of photosynthates compared to the intercropping treatment.

Salama *et al*. (2022). They found that maize crop in their sole cropping producing higher length of cobs per plant compared to their intercropping treatment respectively physiological and morphological differences between the two crops significantly affect their ability to utilize the environmental resources. According to Sali *et al.* (2022), revealed that the effect of inter row, intra row and their interaction effect had highly significant effect ($p>0.01$) on ear length. Statistical analysis result showed that the increase in ear length became progressively smaller as planting density increased. The highest cobs length (26.41 cm) was recorded at 85 cm while lowest cob length (20.95 cm) was recorded at 55 cm. These was due to interplant competition ear length was decreased at higher plant populations.

Mauriya *et al*. (2024) found that Cob girth (10.11 cm) was recorded under the sole crop of maize, which was statistically at par with all intercrops, i.e., maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio), except maize + cabbage (1:1 row ratio) due to less competition and higher light interception under the monoculture. According to Begam *et al*. (2024) found that, maximum cob girth under the monoculture treatments compared to intercropped maize, a phenomenon potentially linked to more effective assimilation and translocation of photosynthates. Another study conducted by Hartman *et al.* (2015) reported that sole maize was compete with intercropping treatment by producing maximum cob girth in intercropping system probably due to higher translocation of photosynthates comparted to intercropping treatment.

Begam *et al*. (2024) found that, maximum number of grain rows cob^{-1} under the monoculture treatments compared to intercropped maize, a phenomenon potentially linked to more effective assimilation and translocation of photosynthates. According to Suhi *et al.* (2022) observed that number of grains per cob differed significantly among the treatments (F ratio = 5.93, $p> 0.01$, Table 2). T_1 (sole maize) produced the highest number of grains row^{-1} cob^{-1} (598 ± 9) and was statistically similar to T_3 (553 ± 10). On the other hand, all the intercropping treatments T_3 to T_6, produced a relatively lower number of grains per cob. This suggests that intercropping treatment had less opportunity to accumulate sufficient assimilate to partition into grain. These results suggest that inter cropping maize yield was sacrificed due to competition between plants, which may be related to competition for soil nutrients and changes in climate conditions.

Maitra *et al*. (2024) found that maize sole (UR) produced the highest number of grain row^{-1}, which was statistically at par with sole maize (PR), maize (UR) + chickpea (1:1) and maize (PR) +

chickpea (2:2). The highest number of grains recorded with sole maize (UR) was probably due to absence of intra and inter-species competition. According to Li *et al*. (2024) they reported the number of grains per row^{-1} of maize was influenced by planting density Significant differences in yield were observed between years and treatments. Specifically, the average number of grains per cobs of maize in D_3(sole maize) treatment increased by 18.5% and 34.9% compared to the D_4 (intercropping) and D_5 (intercropping)treatments, respectively. This may be less interred and intra competition of crop in MS, Maize can achieve yields close to those of single-cultivation systems.

Mauriya *et al*. (2024) observed that number of grain cob^{-1} were recorded under the sole crop of maize, which was statistically at par with all intercrops, i.e., maize + potato (1:1 row ratio), maize + vegetable pea (1:2 row ratio), except maize + cabbage (1:1 row ratio) due to less competition and higher light interception under the monoculture. According to Suhi *et al.* (2022) reported that, number of grains cob^{-1} differed significantly among the treatments (F ratio = 5.93, p>0.01, Table 2). T_1 (sole maize) produced the highest number of grains cob^{-1} (598 ± 9) and was statistically similar to T_3 (553 ± 10). On the other hand, all the intercropping treatments, i.e., T_3 to T_6, produced a relatively lower number of grains per cob. They found inter cropping maize number of grain cob^{-1} was sacrificed due to competition between plants, which may be related to competition for soil nutrients and changes in climate conditions.

Adebayo *et al*. (2024) found that highest cob weight of maize was observed under intercropping treatment maize with cowpea. These yield components play a crucial role in increasing the overall grain yield compared to sole maize cultivation. When maize is intercropped with other crops, such as cowpea, the interaction between the crops can result in improved cob weight. Moreover, intercropping can enhance pollination efficiency and increase the cob weight. Begam *et al.* (2024), found that treatment C4 (MS2:1) yielded the highest single cob weight, with a value of 139.18 grams. This outcome is comparable to that of C_1 (sole maize) at 138.20 grams. The success of treatment C_4 can be attributed to the more efficient use of resources and land, facilitated by the legume effect. This effect enhances nitrogen nutrition and reduces weed competition in intercropping systems.

Kussie *et al.* (2024) showed that maize grain yields varied significantly among the different systems (P>0.05). However, the mean values of 100 seed weights of maize were not significantly different (P>0.05) between the various intercropping systems. In sole cropping, the highest value of 100 seed weight for maize was 36.68 g, which was close to the value of 36.34 g obtained in another sole cropping system. This may be attributed to spatial competition for light, as well as high plant density and reduced competition in sole maize cropping. Kou *et al.* (2024) reported that intercropping significantly reduced the 100-grain weight and increased the ear tip-barrenness length of maize (P> 0.05). However, intercropping had no significant effect on the row number per ear. On average, the

100-grain weight was reduced by 9% over two years compared to monocropping. Intercropping also significantly reduced maize grain yields due to side-row dominance compared to monocropping systems. Begam *et al*. (2024) found that the seed index of monoculture maize surpassed that of intercropped maize. This was potentially due to more effective assimilation and translocation of photosynthates, resulting in an increase in key yield 100 seed weight. This is consistent with the yield advantages observed in sole maize cropping systems.

Gidey *et al.* (2024) found grain yields of individual crops grown in monoculture were higher than those grown in intercropping systems. This difference may be attributed to the better use of essential growth resources, such as space, water, nutrients, and light, at a specific population density. Notably, the grain yield in treatment C_1 (monoculture) was significantly higher at 8.69 t ha^{-1}, comparable to treatments C_3 (MS1:1) and C_4 (MS 2:1), except for shelling percentage. The yield of monoculture maize exceeded that of intercropped maize, a phenomenon potentially linked to more efficient assimilation and translocation of photosynthates. Kou *et al.* (2024) observed that intercropping significantly reduced maize grain yields. However, all intercropping systems yielded higher population grain yields than mono-cropped maize, resulting in an intercropping advantage. The overall grain yield reduction of maize ranged from 7% to 25%, suggesting that wide and narrow rows in intercropped maize increase side row dominance, thereby reducing yield losses. Another study conducted by Manasa *et al.* (2020) reported the maximum maize grain yield (5669 $kgha^{-1}$) was noted with sole maize due to no competition, optimum nutrient management practices and better light interception and translocated sink to sources, but the highest system yield was recorded in intercropping system compared to their monoculture. Mandal *et al*. (2014) found that the intercropping system of maize and soybean yielded the highest recorded number of grains per cob in their sole cropping system. This outcome was statistically comparable to both sole maize and groundnut (1:2) and maize with groundnut (2:4) intercropping treatments.

TM *et al.* (2024) found sole sweet corn recorded significantly higher stover yield than grown in combination with vegetable legumes under different row proportions due to competition free environment for growth resources viz., light, soil moisture, air, nutrients and better agronomic practices which helped the crop to exhibit their full production potential. Begam *et al.* (2024) discovered that treatment C_4 (intercropping) produced the highest stover yield at 12.51 t ha^{-1}, which was comparable to treatments C_1 and C_3. It's worth noting that the stover yield of monoculture maize exceeded that of intercropped maize. This phenomenon may be attributed to more efficient assimilation and translocation of photosynthates. Another study conducted by the Yosung *et al.* (2024) reported sole crop significantly recorded superior crop yield (1382.41kg ha^{-1}) and stover yield (3219.42 kg ha^{-1}) and was substantially at par with row proportion (1:1). Higher yield in sole crop might be due to higher values of yield-attributing characters, such as lower competition for resources, *viz.* space, moisture, and nutrients in sole cropping, compared to intercropping.

Begam *et al.* (2024) reported shelling percentage of monoculture maize was significantly higher than that of intercropped maize. Specifically, treatment C_1 (sole maize) had a shelling percentage of 67.8%. This was comparable to treatments C_3 and C_4 (intercropping), which differed only in their shelling percentage. The observed difference was attributed to reduced competition for nutrients and light in the sole maize treatment. As a result, maize in treatment C_1 was able to undergo more effective assimilation and translocation of photosynthates. According to Santo *et al*. (2023) reported, row arrangement of intercrops and time of introducing groundnut into the intercropping system had no significant ($P>0.05$) effects on shelling percentage of maize, but their interaction effects were significant. This implies that there was little inter-specific competition between the two contributing crops for the available resources. According to Bugilla *et al*. (2023) the highest shelling percentage was noticed in 1 WAP × 2M2G in the major *season* of 2020 (82.5%) and in 0 WAP × G in the minor *season* of 2020 (85.2%), while the least shelling percentage was observed in 0 WAP × 1M2G in both *season*s of the trial (54.6% and 54.3%). This suggests that the row intercropping technique was a threat to the cooperation since it was competitive.

2.4. Effect of nutrient management on yield attributes and yield of maize

Krishna *et al.* (2024) reported site-specific nutrient management in maize (*Zea mays* L.) cultivation for enhancing growth and productivity under varying plant populations in Odisha's hot and moist sub-humid region revealed that the nutrient management treatment NE@10t ha^{-1} (153:58:79 kg ha^{-1} of N: P_2O_5:K_2O) yielded the highest number of cobs per plant (1.83) due to increased nutrient uptake by the crop. Furthermore, maize planted alone produced a significantly greater (1.0) number of cobs per plant in all nitrogen treatments compared to maize intercropped with soybean (0.95), as reported by Raza *et al.* (2021). Although the differences between these treatments were statistically non-significant, the application of nitrogen at higher levels (F_2: 90 kg ha^{-1} and F_3: 120 kg ha^{-1}) in different planting patterns resulted in a slightly greater number of cobs per plant compared to lower nitrogen levels. Additionally, a study conducted by Mahato *et al.* (2020) reported the maximum number of grains per cob (402.64) under the application of 75% RDF+ vermicompost @ 2 t ha^{-1}+ foliar application of $ZnSO_4$ @ 0.5%. This treatment remained statistically at par with 75% RDF+ vermicompost @ 2 t/ha + soil application of $ZnSO_4$ @ 25 kg/ha (388.22) and 75% RDF + yeast vinasse @ 2 t/ha+ foliar application of $ZnSO_4$@ 0.5% (382.13).

Krishna *et al*. (2024) reported, nutrient management, the treatment NE@10t ha-1 (153:58:79 kg ha^{-1} of N: P_2O5:K_2O) produced the highest length of the cob (24.17 cm), relation to fertilizer doses. Treatment NE@10t ha^{-1} (153:58:79 kg ha^{-1} of N: P_2O_5:K_2O) may offer a better supply of nutrients with optimal application of nitrogen. The NE@10t ha^{-1} treatment's quantitative improvement in yield attributes may help achieve a higher yield than 100% RDF. Paul *et al*. (2023) reported, the highest cob length was recorded in I3 × F3, while the lowest values of the mentioned parameters were observed in the one irrigation and poultry manure (5 t ha^{-1}) treatment. This might be due to the fact that optimum nutrient supply increased the turgidity of cells, stomatal opening, increased net assimilation and ultimately resulted in better cob development. According to Rajesh *et al*. (2021) reported, 75 per cent RDN, 100% P and K + foliar application of chemically synthesized nano N @ 4 ml/l and chemically synthesized nano Zn @ 2 ml/l at 25 and 50 DAS recorded higher cob length, this is mainly due to small size and large effective surface area of nano particles could easily penetrated into the plant lead to better uptake of nitrogen and zinc. Nitrogen is an essential element of all the amino acids in plant structures which are the building blocks of plant proteins, important in the growth and development of vital plant tissues and cells like the cell membranes and chlorophyll. Thus, plants with sufficient nitrogen will experience high rates of photosynthesis and typically exhibit vigorous plant growth and development.

Paul *et al*. (2023) found the interaction effect of $I_1 \times F_1$ was found to produce the highest cob diameter with husk (4.24 cm) and cob diameter without husk (3.62 cm) were recorded in $I_3 \times F_3$ whereas least performance was exhibited under $I_1 \times F_2$ treatment. This might be due to better availability of required nutrients in the crop root zone by combined application of inorganic fertilizers and manure with proper soil moisture by irrigation, which probably enhances nutrient availability and uptake by baby corn roots. Thus, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased productive plants, cob girth, with these integrated nutrient management treatments. According to Rajesh *et al*. (2021) observed that 75 per cent RDN, 100% P_2O_5 and K_2O + foliar application of chemically synthesized nano N @ 4 ml/l and chemically synthesized nano Zn @ 2 ml/l at 25 and 50 DAS recorded higher cob girth, this is mainly due to small size and large effective surface area of nano particles could easily penetrated into the plant lead to better uptake of nitrogen and zinc. Another research conducted by Kumari *et al*. (2025) reported, Among the seaweed sap treatment, foliar spray of S-Seaweed sap 10% recorded significantly higher yield attributes and yield. It progressively increased with increasing sap concentration up to 10%, thereafter it decreased which might be due to increased salt. The cob increases in seaweed treated plants is thought to be associated with the hormonal substances present in the extracts. Various seaweed concentrates and marine macro-algal extracts contain an array of phytohormones and plant growth regulators.

Begam *et al.* (2024) showed that cob^{-1} monoculture maize outperformed intercropped maize in terms of grain rows. This may be due to enhanced assimilation and translocation of photosynthates.

The combination of intercropping and integrated nutrient management (INM) led to improved grain numbers. This improvement can be attributed to the compensatory strategy between nutrient-exhaustive cereals and effective INM practices. INM also resulted in increased nutrient use efficiencies and the production of growth-promoting phytohormones through the addition of seaweed. According to Rajesh *et al.* (2021), a specific treatment consisting of 75% of the recommended dose of nitrogen, 100% phosphorus and potassium, and foliar application of chemically synthesized nano-nitrogen and nano-zinc at certain stages of growth resulted in higher grain rows per cob. This outcome is primarily due to the small size and large effective surface area of nano-particles, which facilitated better uptake of nitrogen and zinc by the plant.

Krishna *et al*. (2024) observed that nutrient management, the treatment NE@10t ha^{-1} (153:58:79 kg ha^{-1} of N: P_2O_5:K_2O) produced the highest number of grain row^{-1}, relation to fertilizer doses. Treatment NE@10t ha^{-1} (153:58:79 kg ha^{-1} of N: P_2O_5:K_2O) may offer a better supply of nutrients with optimal application of nitrogen. The NE@10t ha^{-1} treatment's quantitative improvement in yield attributes may help achieve a higher yield than 100% RDF. According to Paul *et al*. (2023) reported the highest Number of grains row^{-1} was recorded in I3 × F3, while the lowest values of the mentioned parameters were observed in the one irrigation and poultry manure (5 t ha^{-1}) treatment. This might be due to the fact that optimum nutrient supply increased the turgidity of cells, stomatal opening, increased net assimilation and ultimately resulted in better cob development. Another study conducted by Rajesh *et al*. (2021) observed that 75 per cent RDN (Recommended dose of Nitrogen)100% P_2O_5 and K_2O + foliar application of chemically synthesized nano N @ 4 ml/l and chemically synthesized nano Zn @ 2 ml/l at 25 and 50 DAS recorded higher Number of grain row^{-1}, this is mainly due to small size and large effective surface area of nano particles could easily penetrated into the plant lead to better uptake of nitrogen and zinc. Nitrogen is an essential element of all the amino acids in plant structures which are the building blocks of plant proteins, important in the growth and development of vital plant tissues and cells like the cell membranes and chlorophyll. The reason might be higher yield, nitrogen accumulation and uptake of NH_4^+.

Fayaz *et al.* (2025) observed that different nutrient management statistically significant impacts on different yield attributes. Maximum number of grains row^{-1} (28.1), the number of grains cob^{-1} (383.9) was recorded in T8 (T8: 25% N as basal LCC @30 (≤ 5) kg N_2O_5 ha^{-1}) as compared to other nitrogen treatments. The lowest values of different yield attributes were observed in the control treatment (T_1). Which probably was due to increase in the number of splits, losses of nitrogen through volatilization and denitrification decreased as nitrogen was correlated with the demand that ensued in higher grain yield. Krishna *et al.* (2023) found that the maximum number of grains per cob in treatment T_4, which used a nutrient management strategy based on non-equilibrium principles, may improve photosynthate assimilation and the subsequent transfer of these assimilates to the cob and grain. This treatment, which involved the site-specific application of primary nutrients through non-equilibrium principles for a target yield of 10 t ha^{-1} (153: 58: 79 kg ha-1 of N: P_2O_5: K_2O), may provide a more effective supply of nutrients, particularly when compared to the recommended dose of fertilizer. As a result, the optimal application of nitrogen in this treatment led to the highest recorded number of grains per cob.

Kumari *et al*. (2025) observed that foliar spray of S-Seaweed sap 10% recorded significantly maximum grain weight per cob(g). It progressively increased with increasing sap concentration up to 10%, thereafter it decreased which might be due to increased salt. The cob increases in seaweed treated plants is thought to be associated with the hormonal substances present in the extracts. Research by Begam *et al.* (2024) clearly indicates that in monoculture maize, the maximum grain weight per cob exceeded that of intercropped maize. This disparity can be attributed to more efficient photosynthate assimilation and translocation in monoculture maize. The synergistic relationship between intercropping and integrated nutrient management (INM) resulted in enhanced grain weight per cob, which can be linked to the compensatory strategy between nutrient-exhaustive cereals and effective INM practices. Afrida *et al*. (2024) reported nutrient omission techniques fertilization significantly affected maize grain weight per cob. Among all omission techniques fertilization, P_2O_5 (un-fertilizer of nitrogen) showed the highest inhibition of maize seed weight by 14.71%; 18.85%; 12.61; and 30.48%, respectively compared to completely fertilized.

Singh *et al.* (2024) observed that nitrogen application at 100% of the recommended dose significantly enhanced 100-grain weight under the sole maize at 60 × 20 cm spacing. Nitrogen management also played a crucial role in influencing maize test weight, which was directly influenced the grain yield. According to Behan *et al*. (2025) observed that F_4 which is made up of 75% CF and 25% FYM, had the highest seed index (272.52 g) for every 1000 seeds. This treatment showed that it could increase seed weight. F_3, comprising a balanced 50% CF and 50% FYM blend, also exhibited a relatively higher seed index (259.78 g), while F_1 (100% FYM) resulted in an average seed index of 255.17 g. However, F_2 (25% CF and 75% FYM) resulted in an average seed index of 253.98 g, and F_5 (100% CF) resulted in the lowest seed index (250 g). According to Magodia *et al*. (2024) observed that application of Sulphur along with the foliar application of multi micronutrients had significantly ($p<0.05$) affected among the various treatments. They observed that 100 grain weight in maize was higher in T_3 (NPK + S + Mn) (39.88g) at harvesting stage, it remaining at par with T_4 (41.22g). While the minimum 100 grain weight was found in control T_1 due to lack of sulphur can negatively impact crop yields, as it affects the availability and utilization of important nutrients such as nitrogen, phosphorus, and potassium by the crops. Micronutrient elements such as Cu, Zn, Mn, Fe, Bo and Mo are known to be essential for plant growth. According to Wang *et al*. (2022) reported, 100 grain weight were formed in the same process of accumulation and distribution of photosynthetic products, so there was an inseparable relationship between yield and quality. The 100 grains weight depends on the rate fertilization and the extent to which photosynthetic products are transferred to the grains after fertilization. The plants were under well irrigated conditions with a supply of well-balanced fertilizer resulted in the highest number grains per plant and plants that were under no irrigation and supplied only poultry manure resulted in the lowest number grains per cob.

Ma *et al.* (2025) observed that optimal nitrogen and phosphorus application rates significantly contribute to yield improvement. Under constant phosphorus application, increasing nitrogen inputs resulted in yield increases ranging from 1.67% to 45.78%. This effect is primarily attributed to nitrogen's role as a key component in proteins, nucleic acids, phospholipids, and other vital organic compounds, directly involved in regulating and facilitating the plant's metabolic processes. According to Yasari *et al*. (2024). They found that the fertilizer combination (N_2K_1) produced the highest average grain yield (9.84 t ha^{-1}) with an increase of 78.00% versus the control treatment (N_0K_0), which gave the lowest average grain yield (5.53 t ha^{-1}), followed by three other mineral fertilizer combinations, N_1K_1, N_1K_2, and N_2K_2, with grain yields of 9.59, 9.69, and 9.83 t ha^{-1}, respectively. It was due to higher nutrient utilization by the plant. According to Paul *et al*. (2023) reported, the highest grain yield was recorded in $I_3 \times F_3$, while the lowest values of the mentioned parameters were observed in the one irrigation and poultry manure (5 t ha^{-1}) treatment. This might be due to the fact that optimum nutrient supply increased the turgidity of cells, stomatal opening, increased net assimilation and ultimately resulted in better cob development. Another study conducted by Stewart *et al*. (2021) reported applying the right rate at the right time during periods of insufficient soil Mn supply was likely the primary driver for the significant 19% increase of 1.52 Mg ha^{-1} grain yield when compared to the control ($p = 0.006$) at the foliar Mn location. Inversely, when there is excess soil supply of the foliar-applied micronutrient, such as in the case of the foliar Zn only location (Winside), there may be yield reduction.

Naik *et al*. (2024) reported, application of recommended dose of fertilizers (180-60-50 kg NPK ha^{-1}) supplemented with 30 kg S ha^{-1} along with foliar application of $ZnSO_4$ + $FeSO_4$ @ 0.5% each at booting and silking resulted in higher stover yield of maize, which was significantly superior over the rest of the treatments tested. Supply of adequate nutrients lead to an increase in leaf area, photosynthesis etc., which inturn result in the formation of healthy cobs. Further, increase in cob length and girth with foliar spray might have been the result of increase in availability of nutrient caused by the direct absorption of the zinc by the foliar spray. proved beneficial and salubrious in enhancing all physiological and yield parameters of maize crop with good response interms of stover yield. According to Duvvada *et al.* (2024) observed nutrient management had a significant effect on stover yield. The higher stover yield was noticed with SSNM through Nutrient Expert (F_3), which was at par with 100% RDF (F_2), F_3 – P_2O_5 (F_5), and F_3 - K_2O (F_6), and the lower stover yield was noticed in control (F_0).The higher stover yield attributes and physiological indices recorded under SSNM(sole cropping + 100% RDF) lead to better crop health and a better source-sink relationship, which might resulted in enhanced maize yield over other nutrient management practices. Another study conducted by Paul *et al*. (2023) reported, the highest stover yield was recorded in $I_3 \times F_3$, while the lowest values of the mentioned parameters were observed in the one irrigation and poultry manure (5 t ha^{-1}) treatment. This might be due to the fact that optimum nutrient supply increased the turgidity of cells, stomatal opening, increased net assimilation and ultimately resulted in better cob development.

Bucao *et al*. (2024) reported, that combination of PD (MDR) and FR 200-100-100 kg N: P_2O_5: K_2O ha^{-1} obtained a higher percentage of shelling recovery of 93.23% than wider PD 75 cm×20 cm regardless of the level of FR applied ranging from 74.37% - 79.65%. N fertilizer rate was increased, both the grain and cob weight increased in equivalent proportions, which kept the shelling percentage constant. Thant *et al*. (2024) reported that mean values for shelling percent which were affected by different rates of nitrogen fertilizer application in both *season*s. There were highly significant differences in all treatments. The highest shelling percent (78% and 88%) was obtained at T_5 treatment in post monsoon and monsoon *season*s. The lowest shelling percent was resulted at T_1 treatment. it was due to enhanced nitrogen mobility inside the plant by nutrient application. Adhikari *et al*. (2023) reported, nitrogen levels were significantly (0.05) influenced by shelling percentage. A nitrogen level of 225 kg ha^{-1} (70.68%) resulted in a statistically (0.05) higher shelling percentage, followed by 200 kg ha^{-1} (70.37%) and 175 kg ha^{-1} (68.54%). The lower shelling percentage was observed with a nitrogen level of 150 kg ha^{-1} (68.27%). This was due to higher nutrient uptake of crop under 225 kg nitrogen ha^{-1} treatment.

2.5. Interaction effect on intercropping and nutrient management on growth and development of maize

Ngairangbam *et al*. (2024) observed that optimal plant density along with efficient applications of nitrogen, phosphorus, and potassium, notably boosts maize growth indicators like plant height, leaf number, and overall growth, underscoring the critical role of their interaction in increasing productivity. According to Begam *et al*. (2024) was found that Maize-Cowpea intercropping, particularly when the plants are arranged in a 1:1 row ratio, greatly improved maize growth. By combining 75 percent of the recommended nitrogen through chemical methods and 25 percent through organic sources (seaweed extract), optimal nutrient management led to enhanced maize performance. Raj *et al*. (2018) found that nutrient management practices have a more significant positive impact than cropping patterns in their interaction. The study found that implementing site-specific nutrient management in conjunction with specific cropping patterns resulted in substantial improvements to maize hybrid growth metrics, such as plant height, leaf area index, and dry matter accumulation, SPAD values compared to other methods. It was due to maximum aeration, higher light interception low competition with maximum nutrient uptake by the plant.

2.6. Effect of intercropping on growth development of soybean

Begam *et al*. (2024) investigated the effect of inter-cropping patterns and nutrient management effects on maize growth, yield and quality reported maximum height was under intercropping of maize + cowpea (2:2) due to less efficient light interception compared to monocropping. Kou *et al*. (2024), reported, the plant height of intercropped soybean was significantly increased by 16.02% compared to that of intercropped soybean in the two years. Soybean plant height increased with increasing number of maize rows and soybean rows; it was clear that plant height and stem diameter responded significantly to shade. Shen *et al*. (2021) reported, the intercropping soybean were significantly increased by 17.92% - 16.76% comparison with their monocropping respectively due to suffer shading from taller crops, thus increasing plant height and decreasing yield. According to Li *et al*. (2020) observed that soybean plants in sole cropping had a height of 85.7 - 90.4 cm, while those in intercropping reached 93.7 - 109 cm. This indicates that intercropped soybean was taller than sole soybean, likely due to competition with maize. According to Liu *et al.* (2017) investigated the changes in light environment, morphology, growth and yield of soybean in maize-soybean intercropping systems. They found that soybean plant height in the two intercropping treatments was 51% higher than that in the monoculture. The changes in the light environment led to increased plant height, these morphological changes enabled relatively more light interception and increased light use efficiency (LUE) of soybean due to the shading effect caused by maize.

Raza *et al*. (2022) reported, intercropping treatments significantly affected the total dry matter production of soybean. Across different sampling stages and treatments, soybean plants accumulated higher dry matter (52.4 g plant^{-1}) in their sole cropping. In addition, different maize planting density treatments in intercropping not only affected dry matter production of intercrops but also changed dry matter partitioning in various plant parts of soybean. According to Shen *et al*. (2021) observed, the intercropping of maize and soybeans is a weak competition system. Interspecific facilitation in maize-soybean intercrops may be due to increased efficiency of resource use. The maximum dry matter accumulation of soybean recorded under their monoculture, compared to intercropping due to less competition and light interception. Raza *et al*. (2021) observed that, sole soybean was found significantly higher than those in SI (one-row strip intercropping), SII (double-row strip intercropping), and SIII (triple-row strip intercropping) at all the sampling stages and in both years.

However, in MS (monocarp soybean), treatment SI produced the highest dry matter compared to their intercropping treatment respectively. This was due to less competition and optimum space utilization under the monoculture practices compared to intercropping treatment. Another study conducted by Liu *et al*. (2017). They found that SS (sole soybean) always caused higher dry matter level than the other treatments. The RI resulted in higher dry matter level than the other intercropping treatments before 50 DAS. After 70 DAS, the dry matter showed a trend of SS>SI_1>SI_2>SI_3>RI due to higher light interception under the sole cropping of soybean.

Dong *et al*. (2024) found sole soybean wear highest number of leaves compared to intercropping treatments because of optimum light interception. These leaves had lower SLA than corresponding leaves in sole maize. However, sun leaf adaptations were not found at other leaf positions and at other developmental stages in intercropping. Similarly, Kou *et al*. (2024) reported that sole soybean wear the highest significant leaves compared to intercropping treatments. The number of leaves of maze increased with height of soybean. It was clear that number of leaves responded significantly to height. According to Setiawan *et al*. (2023) observed that, the number of soybeans leaves at intercropping proportions of 3:1 and 5:1 is higher than monoculture soybeans. An intercropping population proportion of 2:1 results in a small number of leaves than monocultures. Light intensity is the dominant factor of plant biomass which is beneficial for triggering the activity of traits in plants (genetic) that affect the no. of leaves.

Dong *et al*. (2024) observed that sole soybean was recorded highest leaf area compared to intercropping treatments because of less competition and higher light interception of soybean in their monoculture respectively. According to Khonde *et al* (2022) indicated that the leaf of soybean decreased in maize-soybean intercropping, negatively impacting its growth. The highest leaf area was recorded in their sole crop due to higher light interception on soybean leaves. According to Raza *et al*. (2021) observed that the architectural responses of soybean, such as increased internode length, did not lead to improved yield, as the competition with taller maize plants resulted in reduced leaf area and overall performance for intercropped soybean compared to sole soybean.

Gu *et al.* (2024) found that the leaf area index of soybean was 14.81% lower in the four rows of maize and six rows of soybean in the narrow-wide row planting pattern (D-M_4S_6), 18.01% lower in the six rows of maize and six rows of soybean in the narrow-wide row planting pattern (D-M_6S_6), and 26.56% lower in the four rows of maize and four rows of soybean in the narrow-wide row planting pattern (D-M_4S_4) than in the soybean monoculture in the narrow-wide row planting pattern (D-S) due to improve the light transmittance ratio of soybean but also increased the photosynthetic area of crops under the monoculture. Another study was conducted by the Dudwal *et al.* (2021) indicated, the intercropping patterns significantly affected the LAI, higher LAI was recorded their sole crop respectively, due to low competition between the plant. Similarly, Issahaku *et al.* (2010), reported that the leaf area index LAI values of legume intercrops were lower compared to legume mono-crops, indicating dominance of corn in the grain legumes. The differences LAI can be attributed to the variations in canopy configuration, resulting in differences in leaf area. The sole soybean crop had a significantly higher LAI compared to all other treatments, indicated more effective in capturing light than the intercropped soybean.

Mohan *et al*. (2023) observed that, significantly highest crop growth rate, relative growth rate, and net assimilation rate at 30-60 DAS, were recorded at sole soybean. Sole soybean crop exhibited significantly higher CGR (10.46 g $m^{-2}day^{-1}$) than soybean as an intercrop. A higher relative growth rate of soybean (0.076 g g^{-1} day^{-1}) was observed in monoculture compared to intercropping systems might be due to no intercrop competition for light, nutrients, moisture, and space. The NAR of intercropped soybean (7.35 g m^{-2} day^{-1}) with cereal was less. This may be attributed to the less efficient conversion of light energy into dry matter in intercropped soybean. According to Ross *et al*. (2018) observed that crop growth rate (CGR), Relative growth rate (RGR) and Net assimilation rate (NAR) of soybeans in the intercropping system was negatively impacted, with yields 2 to 11% lower than monocultures. This reduction was associated with lower intercepted radiation (IPAR) and CGR, RGR, NAR in border rows during critical growth periods.

Legba *et al*. (2025) observed that, highest branches of moong been recorded under sole crop (3.4) compared to Maize + moong bean intercropping (1:2), (1:3) and (2:2), cropping pattern. The spacing and the spatial arrangement contributed to creating specific microclimatic conditions, including light interception, temperature, humidity, and wind patterns for each sowing pattern, which could explain the difference in moong bean growths. In addition, sole cropping provided good ground coverage, enhancing soil moisture conservation and microbial activities, which likely led to the observed performances. According to Wang *et al*. (2023) observed that maximum number of branches was recorded under the sole soybean treatment compared to maize -soybean due to intercropping reduced photosynthetic active radiation in the soybean canopy within the maize-soybean relay strip intercropping system influenced soybean morphogenesis, resulting in slender and weak stems that are prone to lodging and ultimately leading to a decline in soybean branches.

Shumet *et al*. (2022) observed that, rhizobium inoculation treatment on the sole plot resulted in the highest average number of nodules $plant^{-1}$ (51.9). When not inoculated with Rhizobium, both varieties resulted in the lowest number of nodule $plant^{-1}$.The increased number of nodules in sole cropping might be due to the reduced competition for resources from the maize crop. In research on Maize–legume intercropping promotes N uptake through changing the root spatial distribution, legume nodulation capacity, and soil N availability, Chuan *et al*., (2022) observed that the number of nodules of maize–soybean strip intercropping (IMS) was significantly greater than monoculture soybean (MS), by 34.4% at the full bloom stage, 63.9% at the full pod stage, and 170.9% at the full seed stage. This implied that intercropped with maize not only increases the number of soybean root nodules but also increases the size of root nodules. Thus, it was beneficial to improve the N fixation ability of intercropped soybean due to Probably symbiosis is a high energy-consuming activity, in which photosynthates are used as an energy source to drive processes.

Lin *et al*. (2024) investigated the Relay intercropped soybean promotes nodules development and nitrogen fixation by root exudates deposition. They found that planting pattern significantly influenced on nodule dry weight. Compared with monocrop, nodule dry weight in intercropped soybean was reduced by 19% and 26%. Meanwhile, in the maize-soybean relay strip intercropping system, soybean plants suffer from maize shading during their cogrowth period, and shaded leaves are thinner and smaller than those in normal sunlight, thus decreasing photosynthesis. Soybean nodule became the "reservoir" of preferential supply of photosynthetic products after the removal of shading and the nodule weight increased rapidly. Result also indicated that the lack of aboveground energy caused by the inhibition of the light environment was one of the factors that inhibited the formation of root nodules. In experiment on intercropping and rhizobium inoculation affected microclimate and performance of common bean (*Phaseolus vulgaris* L.) varieties, Shumet *et al*. (2022) observed that, the highest nodule dry weight (0.64 g plant^{-1}) was recorded on the Hawassa Dume variety planted on sole cropping with inoculated treatment. The lowest nodule dry weight was recorded by both varieties in the intercropping treatments regardless of the inoculation. The increment in nodule dry weight under sole cropping with inoculation may be due to the higher infection and compatibility between the variety and the inoculant, and better light use than uninoculated and sole cropping. Effective light use might be due to better soil nutrition for more nodule formation.

2.7. Effect of nutrient management on growth and development of soybean

Khanal *et al*. (2024) found rhizobium + 75% RDF treatment demonstrated the highest plant height compared to their sole culture soybean. This, in turn, results in enhanced hormone production by the microbes, which promotes the growth of soybean crop. According to Lestari *et al*. (2024) reported the increased availability of nitrogen elements is supporting plant vegetative growth, such as the plant height of soybean. Control plants exhibited the lowest average plant height. This can be attributed to the persistence of relatively acidic pH levels in the control plants, leading to a deficiency in essential macronutrients, such as nitrogen, phosphorus, and potassium, which are crucial for promoting plant vegetative growth. Varma *et al*. (2024) reported application of foliar nutrient, gradually impacted on growth parameters like plant height (cm) of soybean plant, improved the interception, absorption, and utilization of radiant energy. This in turn may have improved photosynthesis, which in turn increased plant height, ultimately leading to better growth. Similarly, Joshi *et al.* (2023) found that nutrient management notably impacted soybean growth, with 100% organic nutrient management yielding the greatest plant height (50.35 cm), dry weight (45.16 g), and effective root nodules (57), thereby highlighting the advantages of organic inputs over other treatments in promoting crop growth. Te *et al.* (2022) reported that soybean plant height is influenced by nitrogen application. This is because nitrogen is crucial for crop growth and development, as it promotes absorption and utilization, leading to increased crop height. Nitrogen competition among different crops is significant, but in cereal/legume intercropping systems, it is reduced due to legume nitrogen fixation. This process increases nitrogen availability for cereals, as reported by Shome *et al.* (2022). They found that a combination of 75% of the recommended NPK and striata extract resulted in the maximum plant height of the soybean crop. Interactions between plants and microorganisms have a substantial impact on soil biochemical processes related to nutrient availability and plant uptake, contributing to plant growth. However, excessive nitrogen can discourage nitrogen fixation, ultimately reducing soybean height. Notably, the maximum height of soybean was recorded under a 75% recommended NPK with striata extract compared to the 100% recommended dose treatment. Another study conducted by Lithourgidis *et al.* (2011), they attributed similar growth benefits to enhanced nitrogen availability and light utilization in legume intercropping systems. Soybean plant height is generally higher in intercropping systems compared to sole cropping. This phenomenon is primarily due to the competition for light, which induces shade avoidance responses in soybean plants, leading to increased internode elongation of soybean height.

Biswas *et al*. (2025) found maximum dry matter accumulation of soybean under the 75% RDF + 3t ha^{-1} farm yard manure compared to rest of treatment. It was also observed that nutrient management options impacted variably on pheno-phase durations as well as crop maturity. According to Dass *et al.* (2022) reported higher dry matter accumulation of soybean under the foliar application of B and Mo at 0.5% treatment compared to their control treatment respectively. Foliar application of macro- and micronutrients significantly influenced all of the studied parameters of soybean growth, Foliar application of B and Mo at 0.5% concentration also improved the DMA, compared to applications with NFN and MOP 0.5%. Most often, nutrients are supplied to soybean through soil applications only, which undergo several chemical reactions in the soil before the plants can absorb them, reducing their recovery efficiency and use efficiency due to fixation in the soil colloids and leaching, erosion, or volatilization losses. According to Shen *et al*. (2021) observed that the maximum dry matter accumulation of soybean recorded under their nutrient management compared to their control treatment.

Jarecki *et al*. (2024) found maximum number of leaves was recorded under the RDF treatment compared to control treatment, but were not statistically significant, On the other hand, at the second measurement date, the values obtained after the application of the foliar fertiliser were significantly higher compared to the applied control. According to Begam *et al*. (2024) observed that observed maximum number of leaves wear under seaweed-based fertiliser treatment than rest of treatment. The enhancement of growth rates through integrated nutrient management and organic bio-stimulants like seaweed is especially relevant in areas facing soil degradation and nutrient depletion, contributing to sustainable agriculture goals. According to Racz *et al*. (2021) reported maximum number of leaves of soybean was recorded under the base and foliar nutrient application treatment, suggest that foliar fertilization is only a supplemental method that may correct nutrient deficiencies but cannot replace soil-applied fertilizers of major nutrients. They observed joint treatment of nutrient and foliar fertilization (which also contained N) may have resulted in the best N supply conditions for maize resulting obtained maximum number of leaves of soybean.

Singh *et al*. (2024) found that optimal nutrient management can boost soybean growth like leaf area index by facilitating better nutrient uptake, expanding leaf area, and augmenting biomass accumulation. Proper fertilization and on-time nutrient application result in increased leaf area index of soybean, and increased resilience to biological and environmental stresses. According to Jarecki *et al*. (2024) observed the lowest plant biomass per 1 m^2 was observed in the control (without inoculation and nitrogen fertilization). After the second measurement, they demonstrated that the double dose of the HiStick Soy preparation exerted the most beneficial impact on LAI compared to control. Leaf area index (LAI) increased after inoculation or inoculation combined with nitrogen fertilization. However, this effect varied across the years of study LAI index and plant biomass significantly increased after the application of a high nitrogen dose (120 kg N_2O_5 ha^{-1}) compared to the control. Another study conducted by the Nasar *et al.* (2022) reported intercropping without fertilizer application showed lower trends in the growth indices of soybean crops such as leaf area (cm^2). However, with fertilizer application, intercropping showed significant ($p<0.05$) improvement in these indices of the soybean crop. However, with fertilizer application, intercropping showed significant ($p<0.05$) improvement in these indices of the soybean crop.

Ngui, *et al*. (2024) found that significant increase in relative leaf chlorophyll content in soybean plants cultivated in the amended with nutrient soils compared to those in the un amended soil group. Nitrogen is the most plant growth-limiting nutrient and plays a role in yield impact as well as the synthesis of protein in soybeans. According to Singh *et al*. (2024), reported, better nutrition, as indicated by higher leaf N content, improved photosynthetic rate when 122 kg N_2O_5 ha^{-1} was applied at LCC 5 over fixed time application of 125 kg N_2O_5 ha^{-1}. This could be attributed to better synchronization of N supply with crop N demand leading to higher N uptake due to real time application of 125 kg N_2O_5 ha^{-1} based upon need. Another study conducted by Jaybhay *et al*. (2021) observed the chlorophyll index (SPAD value) was significantly affected due to different foliar nutrition treatments. Chlorophyll index (SPAD value) was significantly high in treatment RDF + 2% Urea over control and RDF + water spray and was followed by RDF + 2% DAP and RDF + 0.5% MOP foliar spray at pod initiation stage.

Sireesha *et al*. (2025) found the significantly higher number of branches $plant^{-1}$ (10.23) of soybean were recorded with the application of 50% RDF as basal + 50% RDF at 25 DAS (T_5) which was at par with the application of 50% N with RDPK as basal + 50% N_2O_5 at 25 DAS (T_2), 50% NP with RDK as basal + 50% N_2O_5 P_2O_5 at 25 DAS (T_6), and 50% NK with RDP + 50% NK at 25 DAS (T_7) and found significantly superior over rest of the treatments. The split application of major nutrients, which increased the nutrient availability during grand growth period of the crop resulting increased the growth attributes of soybean. Similarly, Hussain *et al*. (2023) reported Fertilizer management practice significantly increased the branch number $plant^{-1}$ at different DAS. The highest number of branches $plant^{-1}$ were observed in treatment F_2 (4.17), followed by treatment F_3 (3.87) at 135 DAS. A significant interaction effect of variety and fertilizer management practices was on the branch number $plant^{-1}$ at 75 and 95 DAS. The maximum branches/plant (3.73) was found in V_1 in F_3 at 95 DAS. They were observed that integrated nutrients and biofertilizers increased branches per plant significantly in soybean compared to their control treatment due to higher nutrient uptake by plant under the integrated nutrients and biofertilizers treatment.

Jarecki *et al*. (2024) confirmed that the inoculation of soybean seeds significantly increased the number of nodules on the roots compared to nitrogen fertilization alone or the untreated control, where nodules were scarce. These results indicated that there were no symbiotic bacteria in the soil capable of establishing symbiosis with soybean plants. The double dose of inoculants positively affected the dry weight of nodules, but the differences obtained compared to the recommended dose were not statistically significant. It has confirmed that soybeans, when properly nodulated, do not require supplementary nitrogen fertilization for achievement of high seed yield. According to Zewide *et al.* (2023) reported, the improvement in nodule number for the inoculation treatment can be associated with enhanced N_2O_5 nutrition due to N_2 fixation. This is because an improved N supply improves light use efficiency and reduces abortion and the abscission of flowers and pods.

Jin *et al*. (2022) found that soybean nodulation is affected by both water and P availability. Low phosphorus (P) availability greatly inhibited nodule dry weight, restricting the ability of soybean to fix atmospheric nitrogen and acquire phosphorus (P). P_2O_5 addition significantly increased soybean nodule dry weight, increasing N_2O_5 and P_2O_5 accumulation. This may be because increasing nodule dry weight means more carbon investment and water use, similar to increasing root dry weight to enhance soybean N_2O_5 and P_2O_5 uptake. According to Li *et al.* (2022) reported the dry weight of nodules showed a gradually increasing trend with the advancement of the reproductive process. By comparing the dry weight of nodules, it was found that the dry weight of nodules increased under the phosphorus supply level of 1 mg/L–31 mg/L from the initial pod stage to the seed filling stage. The dry weight of nodules increased. Low phosphorus concentration can stimulate the growth of soybean nodules and inhibit nitrogen fixation by nodules. This may be due to the different levels of low-phosphorus stress or the change in the direction of phosphorus transport caused by low-phosphorus stress. This indicates that different phosphorus supply levels will significantly affect dry matter of nodules.

2.8. Effect of intercropping on yield attributes and yield of soybean

Wu *et al.* (2025) found sole soybean produce number of pods plant^{-1} compared to their intercropping due to taller crops affect the direct light interception and use efficiency of shorter crops in intercropping. Quantifying the light interception of shorter crops and optimizing it by manipulating the configurations could reduce lodging and produce a greater yield. According to Shen *et al*. (2021) reported that, intercropping reduces the number of pods plant^{-1} compared to their monoculture of soybeans, resulting in lower soybean yields. This study believes that the main reason for the reduction of soybean production by about 50-60% is that the shading of soybeans by maize will reduce the formation of soybean photosynthesis, and the lack of nutrients required for the growth of flowers and pods has led to the fall of soybean flowers and pods, which seriously affected soybean production.

Shumet *et al.* (2022) found highest number of seed per pods was recorded from inoculated under sole cropping, whereas the lowest number of pods per plant^{-1} was recorded in uninoculated and intercropped treatments of both varieties. This is because an improved N supply improves light use efficiency and reduces abortion and the abscission of flowers and pods. The lower number of seed pod^{-1} in both varieties which were inoculated and intercropped might be due to the microclimate effects of maize as the main crop which caused a reduction in photosynthetically active radiation (PAR).

Zewide *et al*. (2023) observed that highest (5) and lowest (2) number of seed per pod were recorded at 50 and 30 cm row spacing, respectively. Plants grown at wider spacing could have utilized their energy for more seed per pods due to the reduced competition for light and reduced overlapping from adjacent plants. Furthermore, increased plant density induced competition between the former and later emerged flowers, which could lead to flower abortion and, thus, lower pod set. According to Singh *et al*. (2023a) reported the highest number of pods plant^{-1} was recorded from sole soybean (238.75) and sole green gram (29.96). Reduction in number of pods per plant due to intercropping might be attributed to shorter plant height in intercropping and could utilize lower percentage of incoming solar radiation. Another study conducted by Shumet *et al*. (2022) reported, the cropping system coupled with inoculation affected the hundred seed weight. The highest hundred seed weight (35.56 g) was recorded on sole cropping with the inoculated plot. This might be due to higher light intensity and soil fertility as a result of Rhizobia inoculation. According to Li *et al*. (2022) reported 100-seed weight and yield of soybean differed significantly between years and among the interaction of years and fertilizer levels. The interaction of years and intercropping planting patterns significantly affected the 100 seed weight of soybean plant ($p<0.01$). The interaction of fertilizer level and intercropping planting pattern significantly affected the biomass per plant at R_5, as well as the 100-seed weight of soybean. Intercropping panting patterns also reduced biomass per plant compared with sole-crop soybean, due to intra-specific competition.

Singh *et al*. (2023) reported sole treatments provided the maximum seeds yield of 20.03 q ha^{-1} for soybean and 9.20 q ha^{-1} for green gram. However, among the two different row proportions, seed yield under intercropping of 1:2 row ratio was higher over yield at 1:1 row ratio due to higher planting density of intercrops in 1:2 proportions led to a greater number of pods and dry matter per unit area. In intercropping of maize due to plant height variation, the legumes could not able to receive the incoming solar radiation efficiently which affected the rate of photosynthesis. The results of Raza *et al.* (2021) demonstrate that varying treatments have a significant impact on the grain yield of soybean in both relay intercropping and sole cropping systems. The mean grain yield values for soybean over two years indicate that the highest yield (2378.5 kg ha^{-1}) was achieved under treatments SIII and SI, respectively. Notable advantages of planting in the edge row and radiation distribution, as well as the density advantage resulting from a higher soybean plant population in SS, were observed. These findings suggest that the higher total radiation use efficiency (RUE) of SS enables more efficient utilization of resources, leading to increased grain yield. Conversely, Feng *et al.* (2019) observed significant differences in soybean seed yield between sole cropping and 2M2S and 1M1S systems in field conditions over two years. These yield variations are likely attributed to differences in light interception and planting arrangements. Furthermore, mutual shading in intercropping systems altered light interception, which in turn affected the photosynthetic capacity (leaf area) of the crops. The narrow-wide row planting arrangement of maize and soybean intercropping condition substantially increased the soybean yield as compared to equal row planting arrangement which was might be due to the higher light transmission at soybean canopy, improved leaf area and enhanced photosynthetic rate of soybean canopy in wide rows especially during the co-growth period because initial growth and development of crops is very important to obtain higher seed yield.

TM *et al*. (2024) reported sole soybean recorded significantly higher stover yield compared to their intercropping treatment due to competition free environment for growth resources viz., light, soil moisture, air, nutrients and better agronomic practices which helped the crop to exhibit their full production potential. According to Singh *et al*. (2024) reported sole treatments provided the maximum stover yield of 20.03q ha^{-1} for soybean. However, among the two different row proportions, stover yield under intercropping of 1:2 row ratio was higher over yield at 1:1 row ratio due to less competition in monoculture, compared to Intercropping system. The highest photosynthate partition to the leaves will have the potential to give high stover yield because the leaves are the main recipients of light for the photosynthesis process. Another study conducted by Mohan *et al*. (2023) reported sole soybean provided the maximum stover yield of (3.61 t ha^{-1}) for soybean might be due to no intercrop competition for light, nutrients, moisture, and space. The highest photosynthate partition to the leaves will have the potential to give high stover yield because the leaves are the main recipients of light for the photosynthesis process.

2.9. Effect of nutrient management on yield attributes and yield of soybean

Zewide *et al*. (2023) reported, the rate of 150 kg NPS ha^{-1} resulted in the maximum number of pods per plant (22.89), while 0 kg NPS ha^{-1} produced the lowest number of pods (16.56). A sufficient supply of N, P, and S may have boosted number of pods per plant. Phosphorus fertilizer also encourages the formation of nodes and pods in legumes which is confirmed by the increase in the number of pods per plant as a result of P fertilizer application. According to Singh *et al*. (2023) reported number of pods per plant of soybean, were significantly influenced by various treatments. The highest number of pods was observed with the treatment of 100% RDF of soybean. The increase in a number of pods per plant might be due to the increased supply of almost all plant essential nutrients by translocation of the photosynthates accumulated under the influence of the sources of organic nutrients.

Zewide *et al*. (2023) reported treatment of mixed NPS fertilizer at the rate of 150 kg NPS ha^{-1} produced the maximum number of seeds per pod (7.05), while 0 kg NPS ha^{-1} produced the lowest numbers (5.0). The increase in seeds per pod observed with increasing NPS fertilizer application rates may result from an adequate supply of nutrients facilitating the formation of maximum seed per pod. According to Singh *et al*. (2023), conducted their experiment at Khalsa College, Amritsar Punjab, reported Yield attributes *i.e*., the number of seed per pod of soybean, were significantly influenced by various treatments. The highest yield attributes, were observed with the treatment of 100% RDF of soybean. The increase in a number of pods per plant might be due to the increased supply of almost all plant essential nutrients by translocation of the photosynthates accumulated under the influence of the sources of organic nutrients. According to Jaybhay *et al*. (2020), reported foliar application of nutrients to soybean crop resulted in significant increase in number of seed per pod. Result revealed that number of seed per pod were significantly higher in treatment RDF + 2% Urea (63.73) foliar application over control (54.70) and RDF + water spray (53.80) and was followed by DAP 2%, MOP 0.5%, molybdenum 0.1% and zinc chillated 0.5% along with RDF. This was due to higher nutrient uptake efficiency under the RDF + 2% Urea (63.73) foliar application treatment.

Singh *et al*. (2023) found that the highest 100 seed weight of soybean, were observed with the treatment of 100% RDF of soybean. The increase in a 100 seed weight, might be due to the increased supply of almost all plant essential nutrients by translocation of the photosynthates accumulated under the influence of the sources of organic nutrients. Begam *et al*. (2024) reported, INM practices, characterized by the synergistic use of inorganic and organic nutrients, significantly enhanced maize growth and yield, the 100 seed weight of soybean was higher due to effective assimilation and translocation of photosynthates the positive interaction between intercropping and INM, leading to improved yields, can be linked to the compensatory strategy between nutrient-exhaustive cereals and effective INM practices.

Jarecki *et al*. (2024) reported, nitrogen fertilization alone (without seed inoculation) resulted in increased yields only compared to the control. The availability of nitrogen from symbiosis and fertilization was therefore dependent on weather conditions, making it difficult to recommend the best variant for soybean cultivation. According to Zewide *et al*. (2023) reported treatment of mixed NPS fertilizer at the rate of 150 kg NPS ha^{-1} produced the highest seed yield, while 0 kg NPS ha^{-1} produced the lowest yield (5.0). The increase in seeds yield observed with increasing NPS fertilizer application rates may result from an adequate supply of nutrients facilitating the formation of maximum seed. According to Kubar *et al.* (2021) observed that remarkable significant ($p<0.05$) difference for seed yield in soybean under the different nitrogen rates (p£0.05). Treatments effects demonstrated that the N fertilization of 75, 150, 225, and 300 kg ha^{-1} increased seed yield of soybean by 4.71%, 3.44%, 10.18%, and 3.95%, respectively, in comparison the control (0 kg ha^{-1}). In comparison to control, the soybean had the maximum 100 seed index of 32.02 at 225 kg ha^{-1}. Another study conducted by Jaybhay *et al*. (2020) reported, increase in seed yield with application of 2% Urea along with 100% RDF was 14.57% over control and 15.34% on RDF + water spray. Foliar application of urea at R_2-R_3 growth stage increased soybean grain yield between 6 and 68% compared to control. It might be due to enhanced uptake of nutrients by soybean and by effective translocation of nutrients from sink to reproductive area of crop. The straw yield, seed index and harvest index were non-significantly affected due to foliar application of nutrients.

Singh *et al*. (2023) observed the increase in stover yield under the 100% recommended dose of fertilizer treatment might be due to the recommended dose of fertilizer produce higher dry matter production in plants. Higher production of dry matter in plants might have improved values of yield attributes under organic and inorganic nutrient combinations treatment which resulted in a higher straw yield of soybean. According to Chiluwal *et al*. (2021) reported late N fertilizer applications increased stover yield of soybean in two out of three locations due to an increase in photosynthetic efficiency depending on the location and year, and also an increase in seed weight. The N fertilizer applications delayed the date of R_7 and R_8 by<2 days compared with the unfertilized control, suggesting that the increase in stover yield was partially due to an increase in the nitrogenous fertilizer.

2.10. Interaction effect on intercropping and nutrient management on growth and development of soybean

Gavit *et al.* (2024) found that a positive interaction between nutrient management strategies was more pronounced than individual cropping patterns. The data demonstrates that the application of 100% RDF with sole soybean in conjunction with FYM and vermicompost, resulted in substantial improvements to soybean growth parameters, particularly plant height. According to Singh *et al*. (2023) observed that substantial interaction between crop arrangement and various nutrient management strategies. They found that application of 100% RDF with sole soybean notably enhanced growth metrics for soybeans, specifically plant height (118.21 cm), as compared to control treatments, which was likely due to more efficient nutrient utilisation compared to the control. Similarly, soybean growth was found to be significantly dependent on nutrient availability and interactions by Bagale *et al*. (2021) they observed that effective right nutrients, taking into account the specific crop patterns, improves growth characteristics and overall growth in soybean cultivation. Another study conducted by Rathore *et al.* (2009) reported, the use of seaweed extract with their sole pattern increased all the growth parameters measured for soybean with 15% treatment being significantly better. In general, a gradual increase in plant height was observed with increasing seaweed extract application. Plant height was significantly higher at 10% and higher concentrations of the seaweed extract. The increased growth of these crops may be due to the presence of some growth promoting substances present in the seaweed extract, in addition, the growth enhancing potential of the seaweed extract, might be attributed to the presence of macro and micronutrients.

2.11. Residual effect of maize + soybean intercropping on growth of fodder oat

Mukhametov *et al.* (2024) reported that sole maize as a preceding crop has a nonsignificant impact on the succeeding crop. They observed legume intercropping can enhance nutrient cycling and improve soil health, the direct residual effects on oats growth can vary significantly based on management practices and environmental conditions. According to Reddy *et al.* (2023) reported that growth attributes of fodder oats (*Avena sativa*) are influenced by cereal-legume intercropping on preceding crops. They observed height of succeeding crop under the residual effect of monoculture cereal. Different cropping pattern crops can alter soil properties and moisture availability, which are critical for the growth of subsequent crops. Jangir *et al.* (2022) reported the maximum plant height of succeeding crop was observed under the residual legume treatment compared to rest of treatment due to residual N is obtained from rhizodeposition and recoverable debris which become part of the active soil organic matter pool that derives the N pool in soil for the long term. The ability of legumes to fix atmospheric nitrogen as well as produce biomass and sequester carbon (C) is a crucial factor in reducing greenhouse gases emissions utilized by the succeeding crop.

Geng *et al*. (2023) observed legumes had played significant role in nutrient uptake by plant and enhancing the yield of subsequent wheat crops, regardless of whether grain harvesting occurs. Similar result was found when Yadav *et al.* (2017) conducted experiment and result show that cereal residue was recorded lower quality of succeeding fodder oats. It was probably due to maize is a high nitrogen demanding crop and might have used up almost all the applied N resulting minimum quality of fodder had been recorded by cereal residual treatment. The utilization of legume crops in various cropping systems can cause a significant and progressive yield increment on succeeding fodder oats crops as compared with non-legume crops. According to Louarn *et al*. (2015) reported that, higher dry matter of succeeding crop under the residues of legumes crop. Legume can be a source of more mineral nitrogen to succeeding crops than the residues of cereal due to their relatively high nitrogen contents and relative low C:N ratio in legume residue as compared with cereal residues. Nutrients derived from decomposed roots, nodules, root caps, root border cells, sloughed cells, and the epidermis (water-insoluble materials) significantly contribute to below ground nutrient transfer to succeeding crop and improved their growth and growth attributes. The residues of legumes can be a source of more mineral nitrogen to succeeding crops than the residues of cereal due to their relatively high nitrogen contents and relative low C:N ratio in legume residue as compared with cereal residues.

Thilakarathna *et al.* (2016) observed the part of the symbiotically fixed nitrogen in legumes is available to succeeding crops through the decomposition and mineralization of the legume residues resulting they provide nutrient to succeeding crop and improved their crop growth rate Number of tillers as well as overall growth and yield production. The presence of legumes in the intercropping system contributes to higher nitrogen levels in the soil. This nitrogen is essential for the growth of oats, as it is a key nutrient that supports leaf development and overall plant vigor of succeeding crop. According to Geijersstam *et al.* (2006) recorded positive effect of number of tillers and their growth attributes influenced by preceding legumes residue. It was due to field pea fixed the atmospheric nitrogen into the soil, these nitrogens retain in soil and provide nutrient for succeeding oats crop and improved their growth attributes. In the case of legume incorporation in the cropping system, these are positively impacted on the succeeding fodder oats.

Zhang *et al.* (2015) reported that soybean had significant advantage in yield, economy, land utilization ratio and reducing soil nitrate nitrogen (N) accumulation, as well as better residual effect on the subsequent wheat crop (*Triticum aestivum* L.) compared to the residue of maize treatment. In the Intercropping treatment higher, residual effect depend on the population of legumes crop in particular treatment, higher legumes provide higher nutrient on succeeding crop for their yield and yield attributes. It might be higher legumes fixed the higher nitrogen in the soil and provide higher nutrients to succeeding crop. Stoltz *et al*. (2014) investigated the effects of intercropping organically grown maize and faba bean under Swedish conditions on yield, forage quality, soil mineral nitrogen (N) content after harvest and weed incidence. They reported resulted in higher protein content and lower residual soil mineral N after harvest compared to monocrop maize. Intercropping can thus increase the sustainability of forage production by reducing the need for protein feed and the risk of N pollution. Intercropping may be an important strategy to reduce leaching of residual mineral N (NO^-_3 - N and NH_4^+- N) after harvest, which is a serious problem in maize production.

2.12. Effect of maize + soybean intercropping on soil properties

Nasar *et al*. (2024) reported intercropping treatments had enhanced soil available nutrient as well as organic matter, but reduced soil pH as compared with mono-cropping treatments. In contrast, when compared with mono-cropping treatments, intercropping treatments, had lower soil pH levels. Changes in soil-accessible phosphorus and potassium in intercropping are most likely due to root-releasing compounds (e.g., acid phosphatases and phytases), changes in the soil pH, and availability of soil bacteria such as P_2O_5 and K_2Osolubilizing bacteria. According to Wang *et al*. (2023) reported, maize/soybean intercropping can decrease soil pH and increase soil alkaline phosphatase. A decrease in soil pH and an increase in alkaline phosphatase were found in the intercropped soybean. Meanwhile, a significantly higher pH value was observed in the intercropping maize rhizosphere compared with in maize monocropping. PAC is the indicator of soil P activation ability, which reflects the difficulty of transforming TP into available P_2O_5. The PAC values in the rhizosphere soil from the maize/soybean intercropping were significantly higher than those in the corresponding monocultures, suggesting that maize/soybean intercropping has a positive effect on activating the soil phosphorus pool and enhancing rhizosphere soil phosphorus availability.

Zhang *et al*. (2024) observed that soil EC values of treatments under MM (monocrop maize) increased with greater levels of nitrogen application, significantly rising by 63.48% in N_3 over the N_0 (control) treatment ($P<0.05$). However, soil EC was affected differently under IM (Intercrop maize), being highest instead at the N_1 level, such that with more nitrogen applied, the soil EC values decreased, even falling below that of the N_0 treatment. For example, the soil EC value of N_3 was reduced by 9.17% in comparison with N_0. They observed that lower soil EC in the intercropping system than monoculture (MM). This could be explained by the strong adsorption capacity of soil TOC (total organic carbon), which contributes about 20% – 70% to soil EC and has a certain buffering effect, delaying the movement of surface salt ions into the deeper soil, thereby augmenting EC. According to Ariel *et al*. (2013) reported the EC values were significantly highest ($p<0.05$) in the sole corn and lowest in the sole soybean. The EC was initially low and similar among treatments and increased slightly over time until harvest corn, and intensely from this moment, except at sole soybean. It may be thought then that, when corn is grown, especially in sole culture, from the crop harvest the absence of nutrient uptake, as seen in the soil nitrates dynamics, led to more concentrated soil solutions, supported in this case also by a decrease in the amount of rainfall. However, the EC values did not exceed 2 dS m^{-1}, which is the usually considered threshold for salinity damage to most crops.

Li *et al*. (2024) found the intercropping system showed significantly reduced N_2O_5 emissions ($P<0.05$) with 38% less compared to maize monoculture. In the subsequent *season*, it exhibited 28% lower N_2O_5 emissions ($P<0.05$) than soybean monoculture and a 14% decrease (not statistically significant) compared to maize monoculture. This trend aligns with findings from earlier studies on intercropping, where N_2O emissions were notably lower in intercropping systems compared to their monoculture counterparts. Intercrop exhibited enhanced efficiency in nitrogen and moisture acquisition, resulting in lower residual mineral N (NH_4^+ and NO_3^-) and moisture content in the upper root zone. According to Lu *et al*. (2023) reported the concentrations of AN (Available nitrogen) in maize rhizosphere soil and the concentrations of SOM, AN and AP in soybean rhizosphere soil were significantly increased by intercropping compared with monocropping. The reason for increased AN concentration may be that the hyphal bridge formed between maize roots promoted the transfer of N fixed by soybean roots to the maize root zone, and the absorption of N in soybean soil by maize stimulated the growth of root nodules. In addition, maize and soybean can transform insoluble soil N by secreting extracellular enzymes.

Zhou *et al*. (2024) observed that intercropping boosted the available P fractions while reducing the insoluble P fractions (conc. HCl-Pi) and mainly organic P fractions (NaOH-Po and conc. HCl-Po). This may be due to maize/soybean system may facilitate P turnover the various P fractions, and interspecific interactions may facilitate maize and soybean crops to increase the effective P concentration by secreting organic acids or phosphatases to mobilize and hydrolyze insoluble forms of P. Furthermore, root exudate secretion and soil P mobilization may be the cause of an upsurge in available P in the rhizosphere soil of intercropping maize, which can counterbalance uptake-driven depletion and coexist with rhizosphere P depletion. According to Lu *et al*. (2023) reported, higher available phosphorus was recorded under the intercropping compared to their monocropping. Available Phosphorus (AP) in soybean rhizosphere soil were significantly increased by intercropping compared with monocropping. The reason for increased AP concentration in the rhizosphere soil of the two crops may be that intercropping increased the secretion of organic acids by roots, thus increasing the solubility of P compounds in the soil. In addition, insoluble P is released when root exudates chelate with metal elements.

Lu *et al*. (2023) found that reported, maize/soybean intercropping study has considerably changed the soil physio-chemical properties and available nutrients (i.e., available potash) as compared with mono-cropping. These include legumes symbiotic N_2 fixation, which enhances soil health by supplementing it with nutrients, root exudations (i.e., sugars, organic, and amino acids and secondary metabolites, such as flavonoids, phenolic, and terpenoids). Changes in soil-accessible available potassium in intercropping are most likely due to root-releasing compounds (e.g., acid phosphatases and phytases). Numerous other intercropping investigations have found considerable changes in soil physical and chemical properties and increased soil-accessible nutrients. According to Chen *et al*. (2023), reported, maximum available potassium was recorded under the maize soybean intercropping compared to their monocropping. Among the available nutrients, accounted potassium accounted for 7% increased under intensive intercropping. This suggests that intensive intercropping results in greater nutrient utilization efficiency in regions characterized by poor soil phosphorus and potassium fertility.

Zhang *et al*. (2024a) observed that, intercropping of cereal and legume crops is an important sustainable agricultural pattern that has been shown to improve the decomposition efficiency of organic matter in soil and promote SOC sequestration. The reason for this may be that the crop roots in the intercropping system can provide a more diverse carbon source for the soil microorganisms, which increases the abundance and diversity of microorganisms involved in C source utilization, thus promoting the utilization and fixation of straw residual MBC. According to Lu *et al*. (2023) observed that the maize rhizosphere soil and the concentrations of SOM in soybean rhizosphere soil were significantly increased by intercropping compared with monocropping. Increased SOM concentration in soybean soil may be related to the increase of root exudates and enzyme activities. This may be attributed to intercropping increasing the metabolic activity of maize and soybean roots and their penetration into soil, which improved the microbial habitat and increased soil permeability, thus increasing soil enzyme activity.

Wang *et al*. (2023) observed comprehending alterations in the soil microbial community composition in response to maize and soybean cultivation is vital for the sustainability of intercropping systems. The aforementioned groups might be more common colonizers in the rhizosphere soil of maize/soybean intercropping. However, while the abundance of soil microbial communities at the phylum and genus levels can provide insights, it may not always fully reveal the functional characteristics that vary under different agricultural systems. According to Liu *et al*. (2023)

reported the N fertilization had a strong effect on the microbial α-diversity of maize rhizosphere soil, but there were different effects on bacterial and fungal α-diversity. The bacterial Shannon and Simpson indices in both intercropping and monocropping treatments showed an increasing trend with N fertilization, but the fungal α-diversity of maize rhizosphere soil in both intercropping and monocropping treatments was significantly lower than that in the unfertilized treatments. Microbial α-diversity was higher in the maize-soybean intercropping treatments than in the monoculture treatments, although the difference between them was not significant. However, the bacterial community showed lower Shannon and Simpson indices in the rhizosphere soil of the maize-soybean intercropping system without fertilization than in that of the maize monoculture. They observed intercropping enhanced the activity of nitrogen-cycling microorganisms despite the absence of N fertilization.

Li *et al*. (2024) observed that soybean-corn intercropping could increase the activities of dehydrogenase and nitrate reductase in soil. The correlation analysis between yield and enzyme activity showed that there was a significant positive correlation between nitrogen metabolism-related enzyme activity in soil with corn yield indicating that corn yield could be increased with the increase in enzyme activity. Corn-soybean intercropping was favourable to increase dehydrogenase activity and increase the corn yield. It was found that the corn-soybean/peanut (not millet) intercropping with the planting patterns of 2 corn rows to 2, 3, and 4 NFC-crop rows could significantly increase the activities of enzymes related to nitrogen metabolism in the rhizosphere soil of corn under normal and reduced fertilizer. According to Zhao *et al*. (2022) reported, the interaction between crops significantly decreased protease and dehydrogenase activities in intercropped maize under intercropped peanut. Compared with sole maize (SM), the activity of dehydrogenase (DHO) decreased. DHO (Duncan test, $P<0.05$) decreased compared with those of peanut alone. Compared with cropping alone, the intercropping of maize and peanut significantly decreased the activities DHO. Furthermore, the activities of the four enzymes were not significant different among intercropped maize (IM), intercropped peanut (IP) and the shared soil of intercropped maize and peanut (II).

2.13. Effects of intercropping and nutrient management on agronomic indices of maize + soybean intercropping system

Deng *et al*. (2024) observed that the strip maize + soybean intercropping planting system exhibited LER > 1, indicating that maize–soybean intercropping planting is conducive to improving land use efficiency. During the two-year experiment, the 2.2 m and 1:1 bandwidth and row ratio system exhibited the best LER at 1.25, likely due to optimal light conditions for the accumulation of photosynthesis products, when the band width was consistent, planting one additional row of soybean decreased LER, which may be due to increased intraspecific competition for lights and nutrients but higher LER record in 1:1 row pattern with optimum nutrient management. Similarly, Raza *et al.* (2021) found that LER values of soybean and maize was significantly ($P<0.05$) changing the with their sole crop. Importantly in this experiment, the total LER values in all treatments SI (one row strip intercropping), SII (double row strip intercropping) and SIII (Triple row strip intercropping) were found higher than 1, indicating the advantage of the relay intercropping system over the sole cropping system (SS and SM). Another study conducted by Mao *et al.* (2012) reported the land equivalent ratios (LERs) in the intercropping systems with or without plastic film cover ranged from 1.18 to 1.47 in the 2 years, with all but one of the LER values between 1.34 and 1.47. Thus, there is a substantial land use advantage of intercropping in maize/pea intercrops, both with and without film cover. However, in the intercropping without a film cover in 2010, LER of the 1M:1P intercrop was significantly higher than in the 2M4P intercrops.

Talukdar *et al.* (2023) found the maize-soybean intercropping in a 1:1 ratio resulted in a higher maize equivalent yield, with a grain yield of 5541.67 kg ha^{-1}, showcasing the profitability of this intercropping system. This might be due to higher growth and yield attributes along with better utilization of the available resources. According to Nurgi *et al.* (2023) reported the maize equivalent yield (MEY) was significantly affected by varieties, spatial arrangement, and cropping system, Intercropping maize with faba bean variety Gachena variety produced significantly the highest MEY (6420.53 kg ha^{-1}). The additional faba bean yield from the intercropped treatments provided the highest maize equivalent yield for the intercrop treatments compared with sole crop maize. A higher maize equivalent yield was recorded in intercropped (5896 kg ha^{-1}) than the sole-cropped maize (5315 kg ha^{-1}). Similarly, higher maize equivalent yield produced in maize and faba bean combination illustrated that intercropping was more profitable over sole planting of maize. Erythrina *et al.* (2022) reported the MEY under maize–soybean intercropping was considerably higher than that for the sole maize crop. Intercropping gave greater combined yields than those obtained from either crop grown alone due to more efficient and complementary use of available growth resources. Another study conducted by Dudwal *et al.* (2021) observed the Maize-soybean (1:1) intercropping at 1:1 ratio had a significant impact on maize equivalent yield, with sole maize showing higher yields compared to intercropped maize due to higher compensation by soybean crop.

Khalid *et al.* (2023). They found that values of K_{maize} were greater than those of $K_{soybean}$. The values for A_{ms} and A_{sm} were positive and negative, respectively, in all the treatments showing that cereal is more competitive in comparison to the corresponding legume crop due to less competition between intercrop species occurs under appropriate planting patterns. Maize showed greater competitiveness than the soybean. According to Wei *et al.* (2022) reported the competition index of maize in the intercropping system was greater than 1, indicating that in the symbiotic period of maize and soybean, soybean was at a competitive disadvantage in the intercropping system, and maize was a competitive crop. There is strong interspecific competition among different crops in the intercropping system, and the resource competitiveness of Gramineae crops is higher than that of legumes. The intercropping of tall crops (maize) and dwarf crops (soybeans) is caused by the increase of above-ground light interception of maize and the improvement of underground nutrient and water use efficiency. The biological characteristics of soybean are different from those of maize, and it is in a disadvantageous position in the competition for soil water and nutrient absorption and the competition for light interception.

2.14. Effect of intercropping maize + soybean – oat on economics study

Ali *et al*. (2024) observed the maximum cost of cultivation obtained in intercropped compared to monocropping due to included fixed cost i.e. land preparation, fertilizer, irrigation, herbicide, labor, and land value and variable cost higher in intercropping compared to monocropping. According to Legba *et al*. (2025) found that maize-based intercropping generated a higher cost of cultivation than sole cropping due to higher labor involvement and fixed cost. Another study conducted by Yogesh *et al.* (2014) reported that cost of cultivation of sole maize and sole soybean was less than intercropped maize. This was due to the additional cost of soybean in intercropping. Among intercropping highest cost of cultivation was of maize: soybean, 1:1 (60×20 cm).

Kou *et al*. (2024) observed higher grass return recorded under intercropping than the monocropping in both years, while M_3S_4 and M_4S_6-MN showed higher economic efficiency than the monocropping only in 2022. They suggest that although land productivity increased in all intercropping systems, not all intercropping patterns are suitable for promotion from the point of view of economic efficiency. Row configurations are crucial parameters in the intercropping system, and the proper row configurations are conducive to reducing individual competitions and improving resource use efficiency. According to Raza *et al*. (2021) reported, economic analysis for soybean and maize production under maize/soybean relay intercropping systems and sole cropping systems. The highest total income (US \$2127 ha^{-1} in 2011 and US \$2230 ha^{-1} in 2012) was noticed in treatment SIII under MS, while the lowest total income (US \$927 ha^{-1} in 2011 and US \$971 ha^{-1} in 2012) was noted in SS treatment. Overall, average over the years, the total income was enhanced by 41% and 12% in SIII, compared to SII and SI, respectively.

Liang *et al*. (2024) observed combination with the highest N (Nitrogen) input (F_5) led to the highest grain yield but not the highest net return, primarily due to increased fertilizer costs, Furthermore, recorded under consistent N input for maize, soybean yield, and net return were significantly higher in F_2 compared to F_3. This phenomenon may stem from the saturation of N demand in soybeans under F_2, where continuous N fertilizer application can result in excessive N residue, thereby hindering biological N fixation and interspecific promotion in legume crops. Similarly, Fu *et al*. (2024) reported the Maize–soybean relay intercropping (IMS) achieved a net ecosystem economic benefit (NEEB) 133.5% higher than monoculture maize, primarily due to increased economic gains and reduced greenhouse gas costs, with optimal nitrogen application enhancing yield without raising environmental costs. According to Raza *et al.* (2022) recorded the maximum net profit in maize soybean intercropping over the sole maize and sole soybean under semi-arid conditions. Additionally, the higher net profit of intercropping over sole cropping suggested that farmers could plant soybean and maize together in intercropping with a minimal overall yield penalty. The improvement in greater economic returns mainly attributed to an extra yield of soybean with maintained maize yield, especially under D_2, which ultimately increased the total profit by 63% and 85% over sole maize and soybean because, in the local market, the price of soybean is three times expensive than maize price. Therefore, conclude that intercropping of soybean with maize, especially at eight maize plants m^{-2}, is the better planting practice to obtain high economic returns with limited resources.

Zhao *et al*. (2024) found that cropping system, supplemental irrigation, and nitrogen application rates significantly affected the economic benefits ($P<0.001$). Under the same irrigation scenario and N application rate, the intercropping system resulted in higher economic benefits by 14.31%-20.33% and 17.82%-22.06% than those under the monoculture in 2022 and 2023, respectively. Resource competition and complementarity in intercropping systems are the major factors controlling resource use efficiency and economics advantages. Jaswal *et al.* (2023) observed the intercropping maize + black gram (1:3) had the maximum (2.18) B:C ratio because of less cost of cultivation and maximum net return as compared to other cropping pattern, while lowest benefit cast ratio was observed in their sole maize due to higher cost of cultivation and low net return. This rise in economic returns can be attributed to the intercropping system's improved resource efficiency and lower input costs, as well as its higher yield, lower weed biomass, and higher nutrient uptake. On the opposite side, Paudel *et al.,* (2015) obtained highest gross return from two rows of soybean intercropped with two rows of maize contributed B: C ratio (2.53) over sole cropping. This was due to high compensation add by the soybean in maize - soybean intercropping.

CHAPTER 3

MATERIAL AND METHODS

The investigation entitled "**Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oats in maize + soybean – oats cropping system**" was conducted during the *Kharif-Rabi season*s of 2023-24 and 2024-25 at the "Agriculture farm, School of Agriculture, Lovely Professional University, Phagwara Punjab". This chapter dealt with description experimental materials and techniques used in the course of investigation.

3.1. Location of experimental site

The experimental site was located at a latitude of 31°22'31.81" N and a longitude of 75°23'03.02" E with an average elevation of 252 m from mean sea level. The location is under the central plain zone of agro-climatic zones of Punjab, India (Fig- 3.1.).

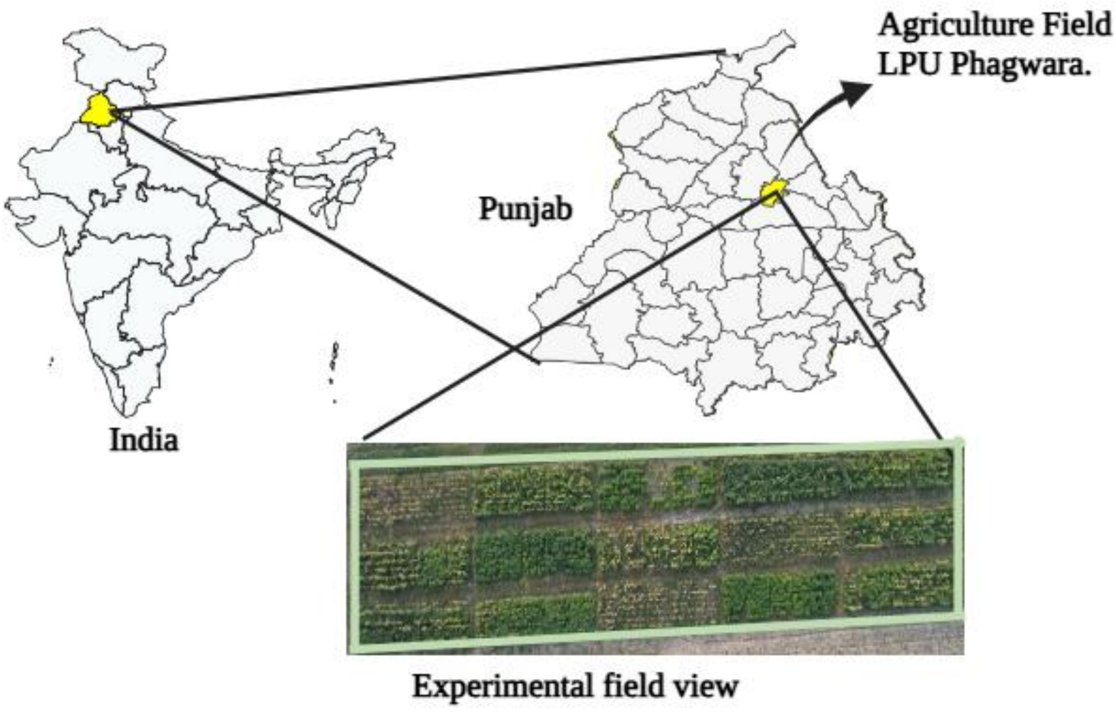


Fig-3.1. Location of the field and real time view.

3.2. Weather Observation at the experimental site

The climate in Phagwara is classified as sub-tropical with low rainfall and cold winters. In this region, the monsoon *season* typically begins in the first fortnight of July, continues through to September, and then subsides in the second week of October, with a decline in rainfall from September onwards and November to January temperature is very cool in this region.

The average weekly weather data on total rainfall (mm), average maximum, minimum temperature (C), average maximum and minimum relative humidity (%) and weekly total pan evaporation (mm week) for the period during cropping *season* was recorded at automated weather station of LPU (Phagwara) Jalandhar, Punjab is presented in Appendices -I, II and Fig-3.2-3.5).

In *Kharif*, the mean weekly maximum temperature during *Kharif season* was 34.03°C while minimum temperature was 23.93°C in 2023 (Fig-3.2) and maximum temperature was 35.56°C while minimum temperature was 24.82°C recorded during *Kharif season* 2024 respectively (Fig-3). In *Kharif* the mean weekly maximum relative humidity was 89.24% while the minimum humidity was 60.66% in 2023 and in *Kharif* 2024 the maximum relative humidity was 89.53% while minimum was 61.02% respectively. The average wind speed was 4.64 km h^{-1} in 2023 while minimum wind speed was 5.79 km h^{-1} recorded during *Kharif* 2024. In *Kharif* 2023, the 27th standard week maximum rainfall was 153.20 mm, followed by the 30th and 31st weeks. In *Kharif* 2024, the 33rd standard week maximum rainfall was 33 mm, followed by the 32nd and 34th weeks. In *Kharif* 2023, the total rainfall was 466.5mm and total evaporation was 479.53mm while in *Kharif* 2024, the total rain fall was 133.90mm and total evaporation was 846.30 mm. Accordingly standard metrological week, during *Kharif* 2023, the highest evaporation was done in 25th meteorological week and lowest was done in 32th meteorological week while during 2024 the maximum evaporation was 25 meteorological week followed by the 24 meteorological week and lowest was recorded in 33th meteorological week followed by the 43th meteorological week. The average sunshine hour was 6.38hr day^{-1} in 2023 and 6.81 in 2024. In *Rabi season* 2023-24, the maximum temperature was 20.57°C while the minimum temperature was 8.35°C, and during *Rabi season* 2024-25, the maximum humidity was 93.71% while minimum humidity was 62.64% (Fig-3.3). The average wind speed was 4.12 km h^{-1} and total rainfall (16 mm) and evaporation rate (119.20mm). In *Rabi season* 2024 the average maximum and minimum temperature was 23.78°C and 9.67°C. The maximum humidity was 93.38% while minimum humidity 55.68%, the average wind speed was 2 km h^{-1}, total rainfall 8.81mm and total evaporation (136.46mm) was recorded during cropping *season*.

3.3. Soil physico-chemical properties

The soil of LPU Phagwara, Punjab are formed from Indo-Gangetic alluvial, which is quite deep and sandy loam in texture. Soil chemical characteristics were determined by the collecting samples of each plot from 0 to 30cm depth after completion of experiment's layout. At the beginning of the experiment, initial soil sample from individual treatments were collected, and at the end of trial, final soil sample from individual treatments were collected, and evaluated for various chemical characteristics of the soil.

Soil sample from each plot were tested for pH, electrical conductivity (EC), organic carbon (OC), nitrogen, phosphorus, and potassium content. Table 3.1. shows the result s for the initial soil

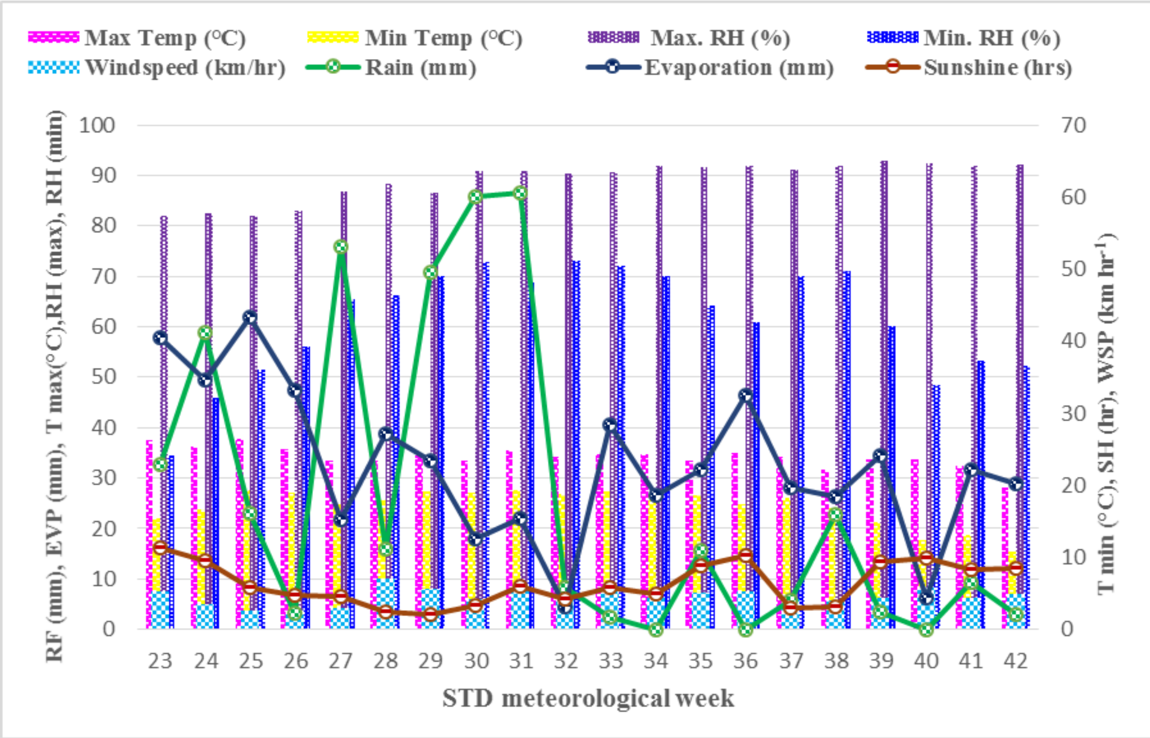


Fig-3.2. Weekly meteorological data during the *Kharif* crop 2023 (6 June to 15 November)

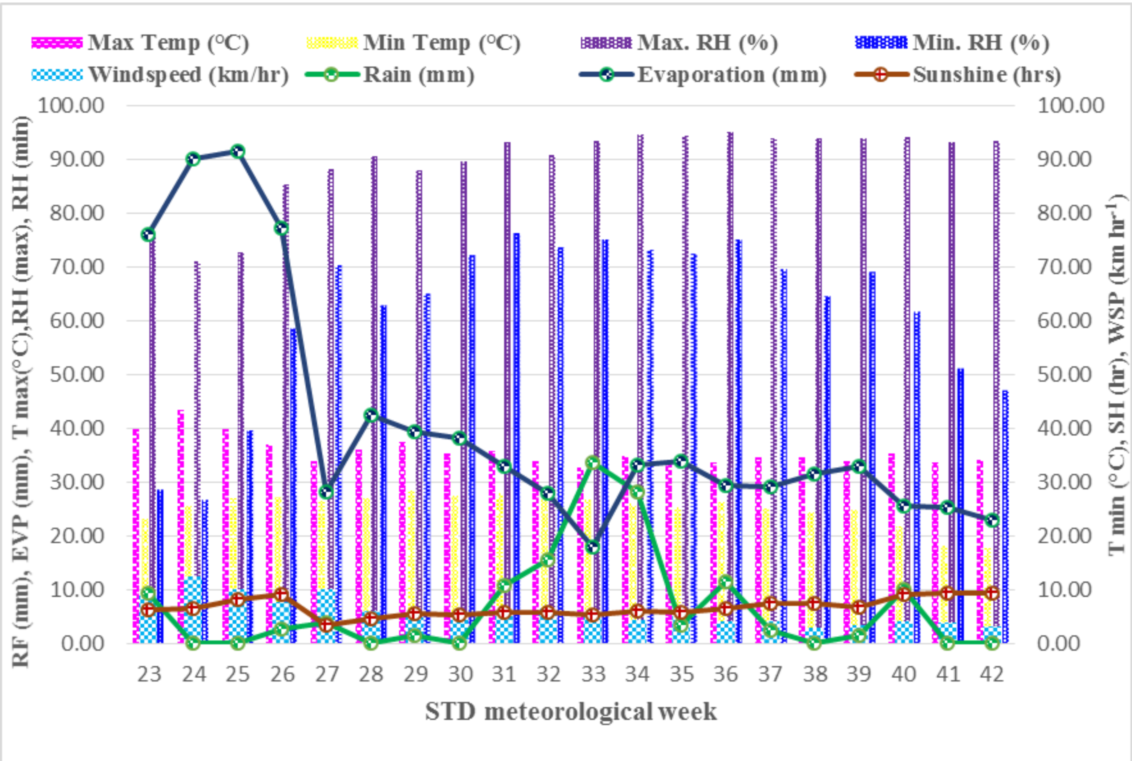


Fig-3.3. Weekly meteorological data during the *Kharif* crop 2024 (6 June, 2024 to 15 November)

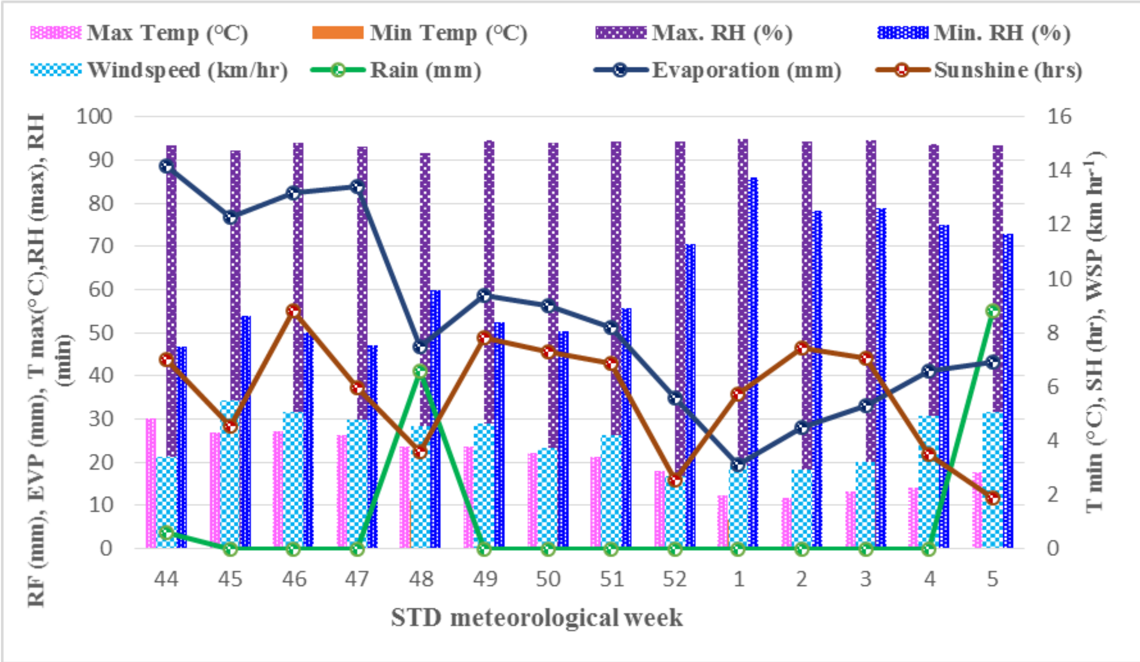


Fig-3.4. Weekly meteorological data during the *Rabi* crop 2023-24 (15 November to 6 February).

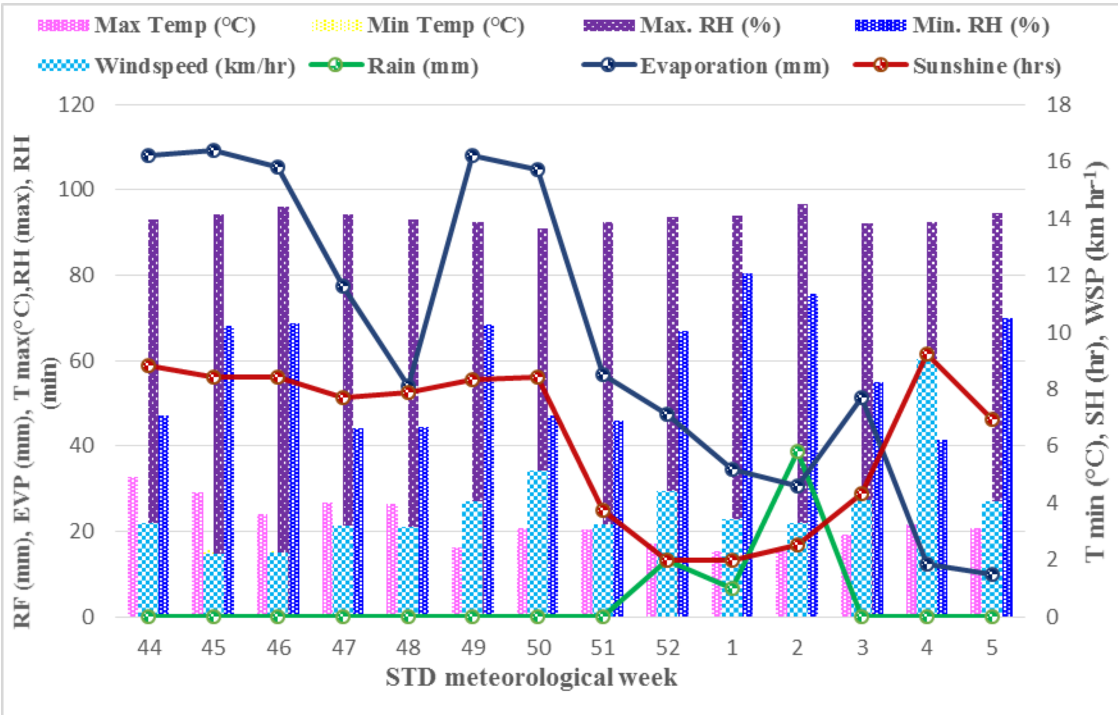


Fig-3.5. Weekly meteorological data during the *Rabi* crop 2024-25 (15 November to 6 February).

nutrient status and which shows that soil in the experimental field was somewhat alkaline in reaction and medium in organic carbon, nitrogen, phosphorus, and potassium.

3.4. Cropping history of the experimental field

The experimental field's cropping patterns over the past five years and the year of experimentation are detailed in Table 3.2.

3.5. Experimental details

The study was conducted using a Split plot design, with experiments carried out over two consecutive *Kharif-Rabi season*s in 2023-24 and 2024-25. Each experiment had three replications and consisted of five different crop arrangements and five fertility levels. The details are given in table 3.3 for visual representation and further information on the experiments.

3.5.1. Treatment Details

(A) *Kharif season*

Main factor: Intercropping (M)

M_1: Sole maize

M_2: Sole soybean

M_3: Maize + Soybean (1:1)

M_4: Maize + Soybean (1:2)

M_5: Maize + Soybean (2:3)

Subfactor: Nutrient management (N)

S_1: Absolute Control

S_2: 100% RDF through inorganic fertilizers

S_3: 70% RDF (inorganic fertilizers) + NPK nano fertilizer spray

S_4: 70% RDF (inorganic fertilizers) + Homemade NPK spray

S_5: 70% RDF (inorganic fertilizers) + Plant extract NPK spray

Design of experiment :	Split plot design
Number of replications:	3
Number of treatments :	25
Gross and Net plot size:	4.8 m × 5 m = 24.0 m^2, 2.4 × 4.6 = 11.04 m^2
Crop :	Maize (NK - 7328) + Soybean (SL - 958), Fodder Oats (OL - 15)
Spacing of crops :	Maize Sole – 60 × 20cm Soybean Sole – 45 × 5cm Maize + Soybean (1:1) – (Maize- 60 × 20cm) (Soybean- 30 × 10cm) Maize + Soybean (1:2) – (Maize- 90 × 20cm) (Soybean- 30 × 10cm) Maize + Soybean (2:3) – (Maize- 120 × 20cm) (Soybean- 30 ×10cm) Oats – 20×5cm

Table: 3.1. Soil physico-chemical properties of the experimental site (0-30cm depth)

Properties	Analysis value	Methods	
A. Mechanical composition			
Sand (%)	75.0	International pipette method (Black and Evans, 1965)	
Silt (%)	10.3		
Clay (%)	14.7		
Texture	Sandy loam		
B. Chemical analysis			
pH	7.52	Slightly alkaline	pH meter (Jackson, 1967)
EC (dS m^{-1})	0.32	Normal	Conductivity bridge (Jackson, 1967)
Organic carbon (%)	0.34	Low	Wet oxidation method (Walkley and Black,1934)
Available Nitrogen (kg ha^{-1})	180	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg ha^{-1})	22.5	Medium	Olsen's method Olsen *et al*. (1954)
Available Potash (kg ha^{-1})	185.2	Medium	Flame photometer method Richards (1954)

*Average data of all treatments

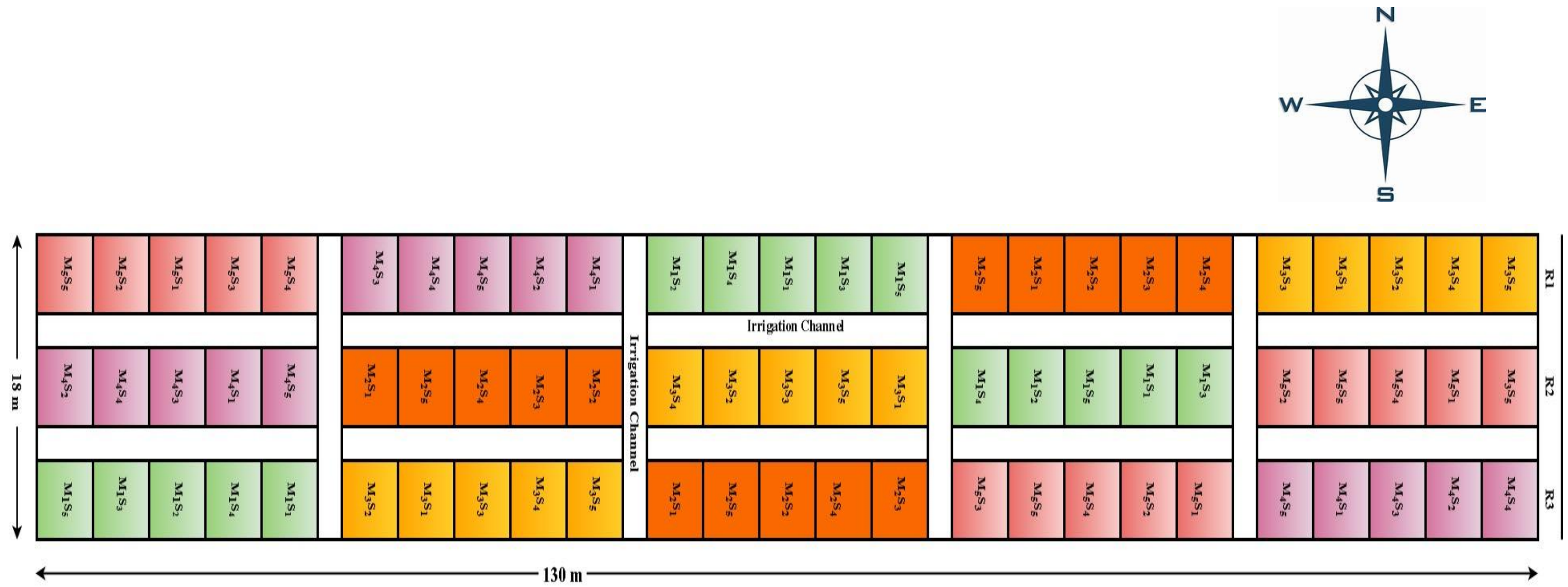
Table 3.2. Cropping history of the experimental field

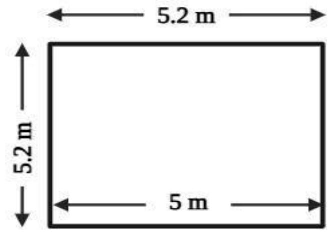
Year	***Kharif***	***Rabi***
2019	Maize	Wheat
2020	Maize	Wheat
2021	Black gram	Wheat
2022	Maize	Wheat

Table 3.3. Treatment combinations of the experiment

S.N.	Treatment combination	Treatment details
1	M_1S_1	Sole maize with control
2	M_1S_2	Sole maize with 100% RDF
3	M_1S_3	Sole maize with 70% RDF with two foliar application Nano NPK
4	M_1S_4	Sole maize with 70% RDF with two foliar applications Homemade NPK
5	M_1S_5	Sole maize with 70% RDF with two foliar application Plant Extract
6	M_2S_1	Sole Soybean with control
7	M_2S_2	Sole Soybean with 100% RDF
8	M_2S_3	Sole Soybean with 70% RDF with two foliar application Nano NPK
9	M_2S_4	Sole Soybean with 70% RDF with two foliar applications Homemade NPK
10	M_2S_5	Sole Soybean with 70% RDF with two foliar application Plant Extract
11	M_3S_1	Maze + soybean (1:1) with control
12	M_3S_2	Maze + soybean (1:1) with 100% RDF
13	M_3S_3	Maze + soybean (1:1) with 70% RDF with two foliar application Nano NPK
14	M_3S_4	Maze + soybean (1:1) with 70% RDF with two foliar applications Homemade NPK
15	M_3S_5	Maze + soybean (1:1) with 70% RDF with two foliar application Plant Extract
16	M_4S_1	Maze + soybean (1:2) with control
17	M_4S_2	Maze + soybean (1:2) with 100% RDF
18	M_4S_3	Maze + soybean (1:2) with 70% RDF with two foliar application Nano NPK
19	M_4S_4	Maze + soybean (1:2) with 70% RDF with two foliar applications Homemade NPK
20	M_4S_5	Maze + soybean (1:2) with 70% RDF with two foliar application Plant Extract
21	M_5S_1	Maze + soybean (2:3) with control
22	M_5S_2	Maze + soybean (2:3) with 100% RDF
23	M_5S_3	Maze + soybean (2:3) with 70% RDF with two foliar application Nano NPK
24	M_5S_4	Maze + soybean (2:3) with 70% RDF with two foliar applications Homemade NPK
25	M_5S_5	Maze + soybean (2:3) with 70% RDF with two foliar application Plant Extract

Layout of the field





Size of individual plot

Fig- 3.6. Layout details of the trial

3.6. Cultural operations

The schedule of various cultural operations carried out during the course of investigation is given below under different headings and their respective dates.

3.6.1. Field preparation

The field was prepared once the soil had reached a suitable working condition. The field was initially prepared using a tractor-drawn plough, followed by two passes with a cross harrow to achieve a well-pulverized seedbed. The weed and crop residues were eliminated to create a weed and stubble-free seed bed. The area was finally levelled using a tractor-driven leveller. The field was then laid out to accommodate 25 treatment combinations in each replication. The experimental plot was laid out in accordance with the specifications detailed in the layout plan. In *Rabi season* field preparation was done after the harvesting of preceding crop. There was done two ploughing in different treatment and planting them.

3.6.2. Characteristics of test crop variety

Maize (NK-7328)

The test crop variety used was maize hybrid 'Neelkanth-7328 (NK 7328). The NK-7328 variety has been developed by Syngenta India Limited for cultivation in the *Kharif season*. This medium-maturity variety features high, stable yields and displays attractive medium long ears with a golden orange semi-flint grain colour, also responding well to medium and high levels of fertilizer application. The hybrid matures in 110-115 days. The average yield of the hybrid ranges from 60 to 65 quintals per hectare.

Soybean (SL-958)

The grains of this variety have a light-yellow colour with a black hilum, and they consist of 41.7% protein and 20.2% oil. The plant exhibits a high level of resistance to yellow mosaic virus and soybean mosaic virus. It takes about 142 days to mature. The average seed yield per acre is approximately 22.6 quintals per hectare.

Oats (OL-15)

It is a single cut variety for irrigated areas of Punjab. Its plants are tall, having long and broad leaves with more leafiness and tillering ability. Its fodder quality is better than OL 12, OL-11, Kent and at par with OL-13. On an average, it yields about 319 quintals of green fodder per acre. Its seed yield is about 24.21 quintals per hectare.

Table 3.4. Cultural operation performed during Experimentation on field

S. No.	Cultural Operations	2023	2024
1	Ploughing and harrowing	06-06-2023	04-06-2024
2	Soil sampling	06-06-2023	04-06-2024
3	Planking, Layout Preparation,	07-06-2023	05-06-2024
4	Seed treatment, fertilizer application and sowing	08-06-2023	06-06-2024
5	Irrigation 1st Irrigation 2nd Irrigation 3rd Irrigation 4th Irrigation	 18-06-2023 08-07-2023 25-07-2023 07-08-2023	 16-06-2024 06-07-2024 23-07-2024 10-07-2024
6	Thinning and Gap filling	24-06-2023	22-06-2023
7	Earthing-up	29-06-2023	27-06-2023
8	Hand weeding	26-06-2023	23-06-2023
9	Spraying of Foliar spray at knee high stage at tasseling stage	 12-07-2023 28-07-2023	 10-07-2024 26-07-2024
10	Harvesting Maize Soybean	 10-10-2023 12-11-2023	 08-10-2024 10-11-2024
11	Land preparation	13-11-2023	03-11-2024
12	Sowing of Oats	16-11-2023	14-11-2024
13	Irrigation	17-11-2023 08-12-2023 28-12-2023	15-11-2024 06-12-2024 26-12-2024
14	Cutting fodder	18-01-2024	16-01-2025

3.6.3. Seed treatment

The seed of maize and soybean was treated with Bavistin at 4g kg^{-1} seed before sowing for protection against the various soil born disease and Soybean seed was treated with Rhizobium culture at 200g per 10 kg seed for optimum nitrogen fixation in the soil.

3.6.4. Sowing method and Spacing

After field preparation, sowing of seeds was done according to the respective cropping arrangements. Sowing was performed manually by planting seed at recommended by packages and practices of PAU. In sole maize(M1) seed were sown at spacing of 60 × 20cm (Fig-3.3.) and sole soybean(M2) was sown at spacing 45×5cm (Fig-3.4.). In maize + soybean (1:1), an additional series of intercropping was sown, in which maize spacing maintained 60×20cm and one additional soybean row add between two rows of maize (Fig-3.5.). In maize + soybean (1:2) were sown as replacement series, in which one maize row replaced by two rows of soybean. In this arrangement maize spacing 90 x 20cm and Soybean 30 ×10cm maintained (Fig- 3.6.). In maize + soybean (2:3) were planted two rows of maize 60 × 20cm and three rows of soybean 30 × 10cm row maintained (Fig-3.7.). In Succeeding fodder oats sowing was done line method and there was maintained 20cm spacing in row to row (Fig-3.8.).

3.6.5. Thinning and gap filling

On the field, the mortality of seedlings was visualized; subsequently, gap filling was conducted to ensure the necessary plant population per unit area. At 10 days of emergence, the crop was thinned by leaving one seedling per spot to achieve the desired plant density in accordance with the specified treatment. In June, the crop was sown. Maize and Soybean seed rates of approximately 18 kg per hectare for maize and 75 kg per hectare for soybean were utilised during both *season*s, calibrated in accordance with the specified crop geometry treatment.

3.6.6. Irrigation

The crop was grown in multiple row proportion and irrigation were supplied on critical stage of moisture.

3.6.7. Nutrient Management

For maize, the nitrogen was split into three equal portions; the first one-third was applied at sowing time, and the remaining two portions were divided in half and applied at the knee height and tasseling stages, entire amounts of P_2O_5 and K_2O fertilizers were applied as a basal dressing at planting time for both maize and soybean. while the whole amount of nitrogen dose for soybeans was applied

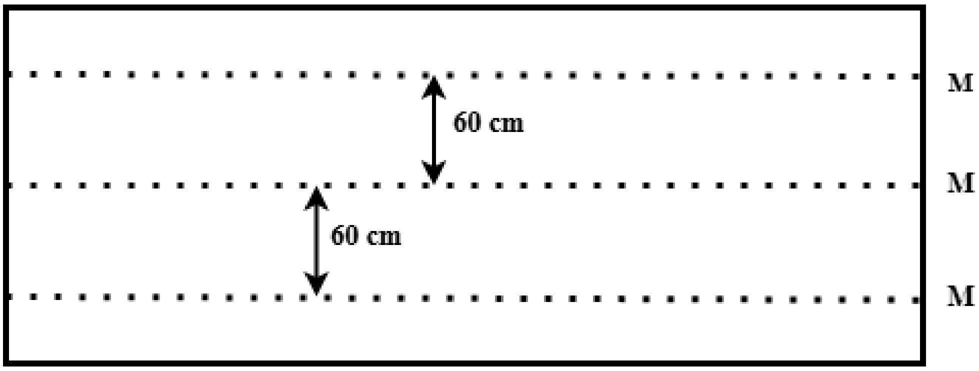


Fig-3.5. Systematic representation of sole maize pattern.

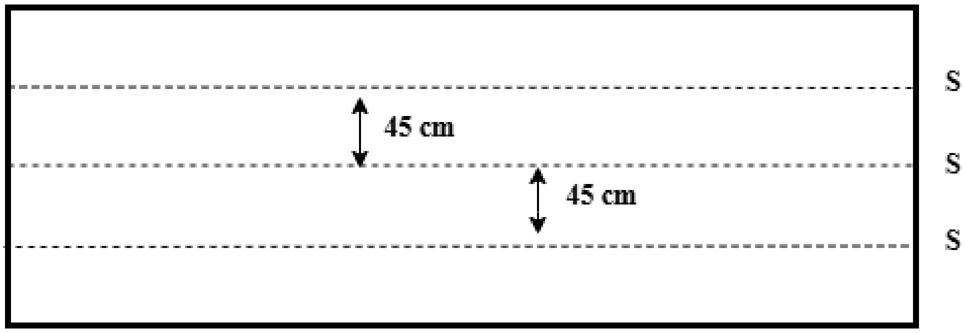


Fig-3.6. Systematic representation of sole soybean pattern.

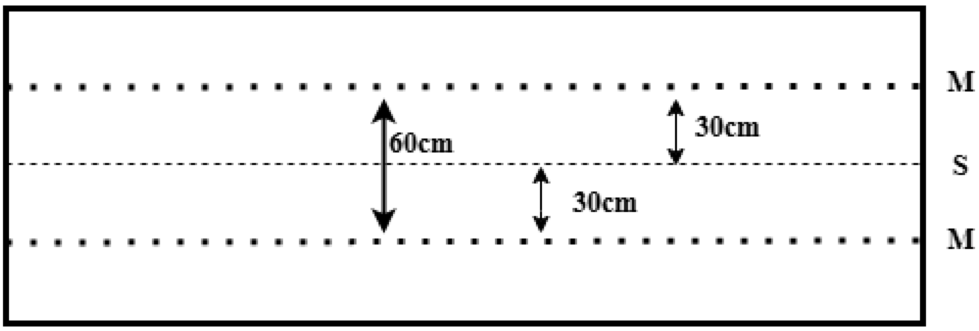


Fig-3.7. Systematic representation of Maize + Soybean intercropping (1:1) pattern in additive series, M- maize, S- soybean.

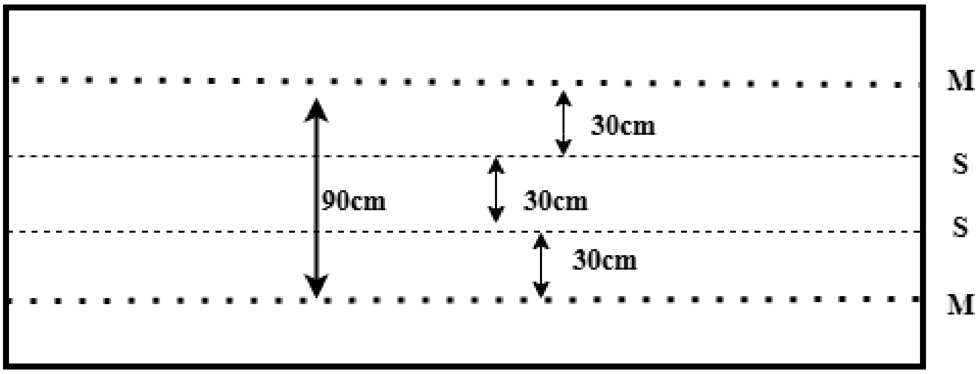


Fig-3.8. Systematic representation of Maize + Soybean intercropping (1:2) pattern in replacement series.

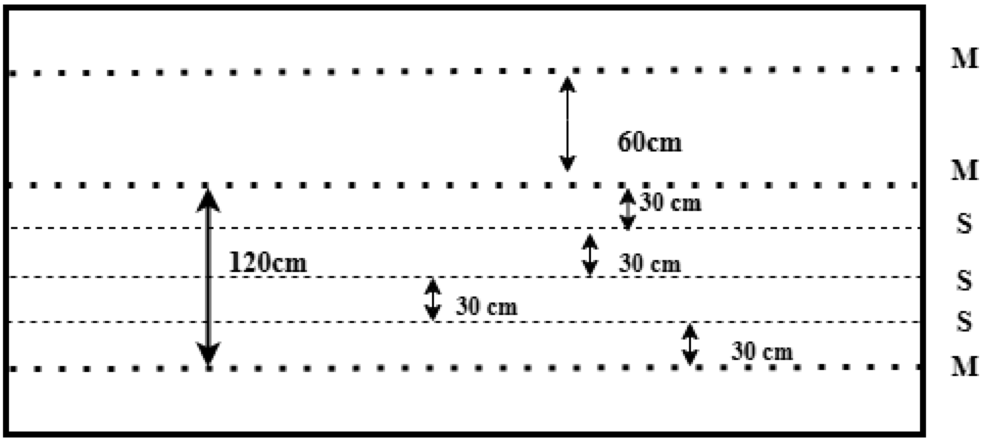


Fig-3.9., Systematic representation of maize + soybean intercropping (2:3) pattern in replacement series.

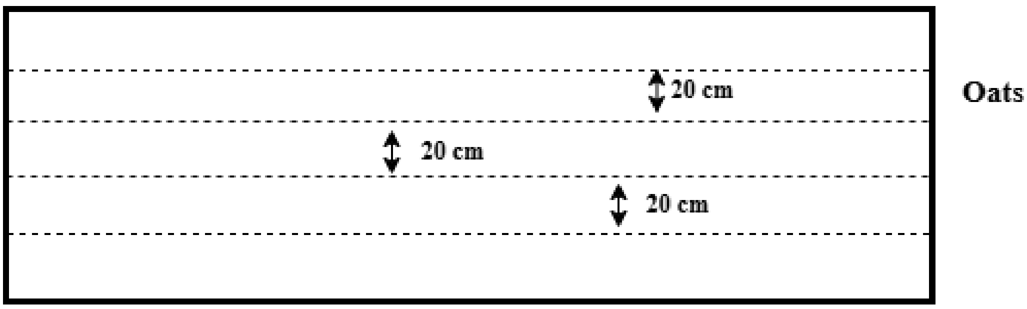


Fig-3.10. Systematic representation of fodder oats sowing pattern series.

as a basal application only. Fertilizers were applied at sowing in rows below the seeds. In case of 75% doses, all doses were applied at the sowing time for both maize and soybean crop and additional two foliar application of nano NPK (TAG NANO NPK by Sunantha Organic Farms, Karnataka, India), homemade NPK (Prepared the liquid compost using by kitchen waste), and plant extract (Prepared the liquid extract using the *Chenopodium album* and *Eichhornia crassipes* plant by Soxhlet method), was applied at knee high stage and tasseling stage of maize crop (Table 3.5).

The recommended dose of fertilizers for maize was 125:60:30 kg N: P_2O_5: K_2O per hectare, while for soybean, it was 20:60:40 kg N: P_2O_5: K_2O per hectare. The application rates of N, P_2O_5 and K_2O to crops vary according to different fertility levels. The quantity of fertilizer was dependent on the crop arrangement, the area occupied to the specific crop, and the respective fertilizer levels. In *Rabi season* there was no nutrient supplied from outside due to check the residual impact of preceding crop.

3.6.8. Interculture operations

The intercultural operations, including thinning, hoeing, weeding, top-dressing, and earthing up, were completed on time. Crop thinning was done 10 days after germination of seed to prevent overcrowding of the plants. Hand weeding was conducted at the 30 days after sowing (DAS). Earthing up in maize was done at the knee heigh growth stage. Top dressing was applied at the knee height and tasseling stages of maize crop.

Table 3.5. Amount of nutrient N, P_2O_5, K_2O

Nutrient level	Maize (N: P_2O_5: K_2O) kg ha^{-1}	Soybean (N: P_2O_5: K_2O) $kgha^{-1}$
Control	Absolute zero	Absolute zero
100%RDF	120:60:40	32.5:82.5:0
70 % RDF + two spray of Nano NPK	84.0 :42:28	22.75:57.7:0
70 % RDF + two spray of Homemade NPK	84.0 :42:28	22.75:57.7:0
70 % RDF + two spray of Plant extract	84.0 :42:28	22.75:57.7:0

Note- The quantities/sprays of nano NPK, homemade NPK and plant extract were decided to ensure 30 % requirement of NPK (both the crop).

We purchase the Nano NPK from Sunantha Organic Farms Karnataka and apply it as a foliar spray at the recommended dose of 4 ml per liter of water.

For homemade fertilizer preparation, mix 0.5 kg horse dung, 2 kg kitchen waste (comprising 0.5 kg each of potato peel, banana peel, watermelon peel, and eggshell), and 0.5 kg zeolite. Add 5 liters of water, stir well, cover the bucket, and keep it in the shade for 15 days to ferment. After fermentation, filter the mixture using Whatman paper-1, send the filtrate for laboratory analysis, and prepare it for foliar spraying at a rate of 10 ml per liter of water.

For plant extract preparation, take 1 kg each of Chenopodium (Goose foot) and water hyacinth weeds, sun-dry them for 2–3 days, then grind the dried material. Extract the compounds using the Soxhlet extraction process, conduct laboratory analysis on the extract, and prepare it for foliar spray at 10 ml per liter of water.

3.6.9. Plant protection

The maize and soybean crop were infested with a leaf-eating caterpillar specifically Pseudoplusia includens, and stem borer in the initial stage of the crop which was controlled by the chlorpyriphos @ 1.5 litres per hectare and carbofuran 3G granules @ 7.50 kg ha^{-1} was using at the six-week growth stage of plant.

3.6.10. Harvesting

Crops were harvested when crop reached maturity level. Two rows from each side of the plot and 40cm from other two ends were harvested separately. Samples from each plot of the plants were collected before the harvest of the crop for post-harvest studies. Maize was harvested at full maturity and soybeans was manually harvested from the net plot area when seeds became hard and their leaves had turned yellow. The harvesting was done by labours by using sickle.

The maize crop was harvested treatment-wise by removing the cobs from the plants. Similarly, stalks were cut slightly above the ground and left in the plot to sun-dry. The weight of the stover $plot^{-1}$ was recorded after it had completely dried in the sun. Soybean plants were harvested by cutting them just above the ground and collecting them from their net plots. Bundles of harvested plants were weighed with help of spring balance and transported to the threshing floor.

Fodder oats were harvested at 65 days after sowing (DAS), by cutting them just above the ground with sickle from their net plots. The bundles of green fodder were weight with weighing machine. One meter row of oats from each plot was collected for the qualities study, before the harvesting.

3.6.11. Threshing

The harvested produce was sun dried to achieve the optimal moisture level. Additionally, the moisture levels in the grains were measured using a moisture meter. The seeds were weighed and then adjusted to maintain consistent moisture levels of 14% for maize and 12% for soybean. The cobs were de-husked manually after harvesting and were allowed to dry for 3-4 days and thereafter the threshing was done using maize thresher. The maize grain yield was converted to t ha^{-1}. Soybean produce from each net plot was threshed separately using a wooden stick, then the seeds were manually cleaned with a hand fan (Supa) for each plot before weighing. The soybean grain yield was converted to t ha^{-1}.

3.7. Biometric observation

For Recording the growth and yield characteristics of the crop, five plants from each crop in the plot area were randomly selected and tagged for observation at various time intervals to recording the growth and yield parameters.

3.7.1. Pre-harvest observations of maize

7.1.1. Plant height (cm)

The plant height (cm) of maize was recorded at 30, 60,90 and at harvest. Five tagged plants were used for recording plant height, which was measured from the bottom of stem to top of the fully opened new leaf before the tasseling stage. After tasseling, plant height was measured from the base of the plant to base of the tassel and expressed incm. Mean height was then computed by dividing the summation with five.

7.1.2. Total dry matter (g plant^{-1})

The plants were dug out from the experimental field and dried in the sun. The samples were then oven dried temperature for 72 hr at 60℃ till weight become constant and the dry matter accumulation per plant was worked out at 30, 60 and 90 DAS and harvesting stage.

7.1.3. No. of leaves plant^{-1}

The number of fully opened leaves from five tagged plants was counted at 30,60 and 90 DAS. Averaged values were worked out and expressed number of leaves per plant.

7.1.4. Leaf area (cm^2)

The leaf area plant^{-1} was measured from the five tagged plants in each plot at intervals of 30, 60, and 90 days after sowing. The leaf area was measured incm^2 with the help of leaf area meter.

7.1.5. Leaf area Index (LAI)

The leaf area index (LAI) is calculated as the leaf area to ground area ratio, and the formula provided by Sestak *et al*. (1971) was used to determine this at each stage.

$$\mathrm{LAI} = \frac{\text{Total leaf area of plant (cm}^2\text{)}}{\text{Total ground area of plant (cm}^2\text{)}}$$

7.1.6. Crop growth rate (g plant^{-1}day^{-1})

Crop growth rate (CGR) is the rate of dry matter production per unit ground area per unit time and was computed between 0-30, 30-60, 60-90 DAS by formula given by Watson, (1952).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where W_1 and W_2 are the dry weight per unit area at the time t_1 and t_2, and P= area incm respectively.

7.1.7. Relative growth rate (g day^{-1})

Relative growth rate (g ^{1}day^{-1}) is the rate of increase in the dry weight per unit dry weight per unit of time and was calculated at 30-60, 60-90 DAS by formula given by Watson (1952).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 = Dry matter production per plant (g) at time t_2 and t_1 respectively. t_1 and t_2 = time intervals.

7.1.8. Net assimilation rate (g plant^{-1}day^{-1})

This refers to the rate of dry weight accumulation in plants per unit of leaf area over a given period. The NAR was determined using the specified formula (Radford *et al*., 1967).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{L_nA_2 - L_nA_1}{A_2 - A_1}$$

Where, W_2 and W_1 are plant dry weights at times t_1 and t_2, logeA_2 and logeA_1 are the natural logs of leaf areas A_1 and A_2 at times t_1 and t_2.

7.1.9. Stem girth (mm)

Stem girth measurements (mm) were taken on five tagged plants at 30, 60, and 90 days after sowing (DAS), as well as at harvest. At each time point, measurements were recorded with the help of Vernier callipers at the upper, middle, and lower sections of the stem, and the average stem girth was calculated.

7.1.10. Length of internodes (cm)

The length of the internode will be taken length between two nodes on stem, at harvesting stage.

7.1.11. Chlorophyll index (SPAD)

Chlorophyll content, measured by a chlorophyll meter (SPAD-502 plus), was recorded at 30, 60, and 90 days after sowing (DAS) for each of five maize plants per plot, and calculate mean of these values (Markwell *et al*., 1995).

7.1.12. Days to 50% tasseling

The number of days taken for 50 percent tasseling of the plants from each plot from the date of sowing will be recorded based on visual assessment and expressed in days.

7.1.13. Days to silking

The number of days taken for silking after tasseling of the plants from each plot from the date of sowing will be recorded based on visual assessment and expressed in days.

7.1.14. Days to physiological maturity

The number of days taken for physiological maturity will be recorded from each plot by visual assessment of drying of the silk, leaves and yellowing of husk on the cobs.

7.1.15. Growing degree day (day)

To calculate GDD, we will first find the mean temperature for the day. The mean temperature is found by adding together the high and low temperatures for the day and dividing by two (Mederski *et al*., 1973).

$$GDD = \frac{Max_{temp} + Min_{temp}}{2} - Base_{temp}$$

7.2. Post harvest observations of maize

Five cobs were randomly selected from each plot and all the post-harvest observations were recorded from these selected cobs.

7.2.1. Number of cobs plant^{-1}

The numbers of cobs plant^{-1} were counted on five tagged plants in each plot. The average number of cobs per plant was determined by calculating the mean of the cobs counted per plant.

7.2.2. Length of cobs plant^{-1}

The length of five cobs randomly selected from each plot was measured from the base of the lower most primary rachis to the tip of the cob and the average was recorded as cob length (cm).

7.2.3. Cob girth (cm) plant^{-1}

The circumference of cobs from five randomly selected cobs was measured at the centre of the cob and the average was recorded as cob girth/diameter in cm.

7.2.4. Number of grain rows cob^{-1}

After the maize harvest, the cobs will be separated from the sample plants, after which we will count the grain rows on each cob.

7.2.5. Number of grains row^{-1}

The average number of grains row^{-1} was calculated by counting the grains in five randomly selected cobs, and average number was noted as the number of grain row^{-1}.

7.2.6. Number of grains cob^{-1}

Grain number cob^{-1} was worked out by using the formula Number of grains cob^{-1} = Number of rows × Number of grains row^{-1}.

7.2.7. Grain weight per cob (g)

Grains were separated from sun-dried cobs of five randomly selected plants and then weighed. The average weight was recorded in g cob^{-1}.

7.2.8. 100 grain weight (g) (Seed index)

A representative sample of 100 grains was taken from the grain yield of each plot and was dried in the oven. The weight of oven dried samples by using sensitive measuring balance was recorded to represent 100 grain weight.

7.2.9. Grain yield (t ha^{-1})

At physiological maturity, the cobs were dehusked and collected from each experimental plot. The harvested cobs were dried in the air, shelled, cleaned, and weighted. Grain yield ha^{-1} was calculated from kg plot^{-1}, which was converted in t ha^{-1}.

7.2.10. Stover yield (t ha^{-1})

Plant samples from each plot were cut from ground level after separation of cobs from the plant and they are sundried until the reach constant weight, it was tied in to bundles. Then measured the bundle weight of the stover (kg plot^{-1}), which was converted into t ha^{-1}.

7.2.11. Biological weight (t ha^{-1})

Following the sun-drying process, the bundles from each plot were individually weighed using a calibrated hook balance. The component weights, specifically those of grain, straw, stover, and husk, were meticulously recorded for each treatment. From these data, the total biological yield per plot was calculated. Subsequently, this plot-level data was extrapolated to determine the biological yield per hectare, providing a quantitative assessment of total biomass production (t ha^{-1}).

7.2.12. Harvest index (%)

The harvest index refers to the proportion of the crop's economic yield in relation to its biological yield. The calculation was performed using the formula given by Donald (1962).

$$HI(\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

7.2.13. Shelling Percentage (%)

Ten cobs were randomly selected from each treatment, and the seeds were manually separated. Shelling percentage was subsequently calculated using formula (Horrocks *et al*., 1970).

$$\text{Shelling Percent} = \frac{\text{Seed weight}}{\text{Cob weight}} \times 100$$

7.2.14. Rain Water Use Efficiency

Rain water use efficiency (RWUE) was calculated and expressed in kilograms per hectare-millimetre (kg ha^{-1} mm) using the formula provided by Araya *et al.* (2010).

$$RWUE = \frac{\text{Seed kgha}^{-1}}{\text{Total rainfall(mm)}}$$

8.1. Pre-harvest observations of Soybean

8.1.1. Plant height (cm)

The plant height will be recorded from randomly selected five plants in each treatment from ground surface up to the base of the apical bud in soybean at 30, 60, 90 DAS and at harvest and expressed in centimetres (cm).

8.1.2. Number of leaves $plant^{-1}$

The number of leaves will be recorded from randomly selected five plants in each treatment at 30, 60, 90 DAS.

8.1.3. Total dry matter (g $plant^{-1}$)

Three representative randomly selected plants were harvested each time at 30, 60, 90 DAS and at harvest from each plot and plants were sun dried and oven dried at 65°C to a constant weight for recording dry matter accumulation (DMA) which was then expressed as g $plant^{-1}$, mean dry matter accumulation $plant^{-1}$ was calculated by dividing the summation with five and used for statistical analysis.

8.1.4. Leaf area (cm^2)

The leaf area plant^{-1} of soybean was measured from the five tagged plants in each plot at intervals of 30, 60, and 90 days after sowing. The leaf area was measured incm^2 with the help of leaf area meter, and mean leaf area plant^{-1} was calculated by dividing the summation with five and used for statistical analysis.

8.1.5. Leaf area Index (LAI)

The leaf area index (LAI), representing the leaf area to ground area ratio, was calculated at each developmental stage according to the formula presented by Sestak *et al*. (1971).

$$\mathrm{LAI} = \frac{\text{Total leaf area of plant } (\mathrm{cm}^2)}{\text{Total ground area of plant } (\mathrm{cm}^2)}$$

8.1.6. Crop growth rate (g plant^{-1} day^{-1})

Crop growth rate (CGR), defined as the rate of dry matter production per plant per day (g plant^{-1} day^{-1}), was calculated for the periods 30-60, and 60-90 days after sowing (DAS) using the method established by Watson (1952).

$$\mathrm{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where W_1 and W_2 are the dry weight per unit area at the time t_1 and t_2, and P= area incm respectively.

8.1.7. Relative growth rate (g day^{-1})

Relative growth rate (g ^{1}day^{-1}) is the rate of increase in the dry weight per unit dry weight per unit of time and was calculated at 30-60, 60-90 DAS by formula given by Watson (1952).

$$\mathrm{RGR} = \frac{\log_{10} W_2 - \log_{10} W_1}{t_2 - t_1}$$

W_1 and W_2 = Dry matter production per plant (g) at time t_2 and t_1 respectively. t_1 and t_2 = time intervals.

8.1.8. Net assimilation rate (g plant^{-1} day^{-1})

This refers to the rate of dry weight accumulation in plants per unit of leaf area over a given period. The NAR was determined using the specified formula (Radford *et al*., 1967).

$$\mathrm{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{L_nA_2 - L_nA_1}{A_2 - A_1}$$

Where, W_2 and W_1 are plant dry weights at times t_1 and t_2, $\log_e A_2$ and $\log_e A_1$ are the natural logs of leaf areas A_1 and A_2 at times t_1 and t_2.

8.1.9. Number of branches plant^{-1}

Number of branches were recorded from five tagged plants per plot at 30, 60, and 90 days after sowing. The mean number of branches for plant^{-1} was calculated by dividing the summation with five.

8.1.10. Number of nodules plant^{-1}

The number of nodules plant^{-1} will be counted from randomly selected five plants in each treatment from their respective root. The mean number of nodules plant^{-1} was calculated by dividing the summation with five and used for statistical analysis.

8.1.11. Nodule's dry weight (g)

Fresh and oven-dried nodules weight at 30, 60, and 90 Days After Sowing by electronic weight machine. The mean nodules weight(g) plant^{-1} was calculated by dividing the summation with five and used for statistical analysis.

8.1.12. Chlorophyll Index (SPAD)

Chlorophyll value was recorded from tagged plants with the help of the SPAD meter (Kariya *et al*., 1982) at 30, 60 and 90 DAS. The averages of top, middle and base value were expressed as SPAD (Soil plant Analysis Development) value. The mean Chlorophyll value plant^{-1} was calculated by dividing the summation with five and used for statistical analysis.

8.2. Post-harvest observations of soybean

Five soybean plant pods were randomly selected from each plot and all the post-harvest observations were recorded from these selected pods.

8.2.1. No. of pods plant^{-1}

To study the effect of varied treatments on soybean pod formation, the total number of pods was recorded from five randomly selected tagged plant and the mean was calculated by dividing the total number of pods by five for use in statistical analysis.

8.2.2. No. of seeds pod^{-1}

Average seed counts were determined by collecting and counting seeds from five mature pods of tagged plants from each plot.

8.2.3. 100 seed weight (g)

Samples were randomly selected from each net plot, with 100 healthy seeds from each plot being counted and then oven dried at 60˚C to achieve a constant weight. The weights of the seeds were measured in grams using an electronic digital balance.

8.2.4. Seed yield (t ha^{-1})

The grains collected from the net plot area were cleaned and weighed to compute the grain yield in t ha^{-1}.

8.2.5. Stover yield and Haulm yield (t ha^{-1})

The yield of the straw from the net plot area was recorded at the time of harvest. (Moisture content was determined by taking five plant samples). Finally fresh straw yield was converted into straw yield (on dry matter basis) and the pod straw yield was added and recorded in t ha^{-1}.

8.2.6. Harvest Index (%)

Harvest index, defined as the ratio of economic yield to biological yield, was calculated using the formula established by Donald (1962).

$$\mathrm{HI}(\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

8.2.7. Rain Water Use Efficiency (Kg ha-mm^{-1})

Finally, rain water use efficiency (RWUE) was calculated by using the following formula and expressed in kilogram per hectare millimetre (kg ha-mm^{-1}) (Araya *et al*., 2010).

$$\mathrm{RWUE} = \frac{\text{Seed kgha}^{-1}}{\text{Total rainfall(mm)}}$$

9. Observations on fodder Oats

9.1. Plant height (cm)

The plant height will be recorded from randomly selected five plants in each treatment from ground level to the base of top most fully opened leaf at 20, 40 DAS and at harvest stage and expressed in (cm).

9.2. Number of tillers (1 m row length)

Number of tillers recorded from randomly selected one meter row length of each treatment at the 20, 40 DAS and at harvesting stage.

9.3. Total dry weight (m^{-2})

Total dry weight was recorded at harvest stage. 1 m^2 area from each plot was uprooted at 20,40 and harvest stage was shade dried followed by oven dried at 60 ℃ until a constant weight will be obtained and expressed in grams per plant.

9.4. Fodder yield (t ha^{-1})

At the 60DAS, fodder oat was harvested from each net plot by cutting them at ground level. The harvested fodder oat from each plot were then tied into distinct bundles, maintaining plot-specific identification. Then measured the bundle weight of fodder (kg $plot^{-1}$), which was converted into t ha^{-1}.

10. Chemical analysis

10.1. Soil analysis

A composite sample was collected from 0 - 15cm soil depth from the experimental field at the initiation of the study to determine the soil fertility status. All the samples were oven dried, grounded and sieved. (Table 3.6).

Table 3.6. Methods used for nutrient content analysis in soil

S. N	Parameter	Method
1	Soil pH	pH meter (Jackson (1973)
2	Electric conductivity EC	EC meter (Jackson, 1973)
3	Available N (kg ha^{-1})	Alkaline permanganate method (Subbiah and Asija, 1956)
4	Available P_2O_5 (kg ha^{-1})	Olsen's method (Olsen *et al.*, 1954)
5	Available K_2O (kg ha^{-1})	Flame photometric method (Hanwy and Heiddle, 1952)

10.2. pH

A composite sample was collected from 0- 15cm soil depth from the experimental field at the initiation of the study to determine the soil fertility status. All the samples were oven dried, grounded and sieved, Jackson, (1973).

10.3. Electrical conductivity

Electrical conductivity of the soil samples will be measured in 1:2.5 soil: water extract using a conductivity bridge and the results will be expressed in terms of dS m^{-1} at 25 °C (Jackson, 1973).

10.4. Organic carbon

Organic carbon content in the soil will be determined by Walkley and Black wet oxidation method (Richards,1954) and expressed in percentage (%).

10.5. Microbial count

Soil microbial populations were quantified using a serial dilution plating technique. Ten grams of moist soil were dispersed in 95 ml of sterile water with glass beads, followed by tenfold dilutions (10^{-2} to 10^{-7}). One drop from each dilution was plated onto agar, incubated at 40°C for 24 hours, and resulting colonies were counted using a microbial colony counter (Clark *et al*., 1965).

10.6. Dehydrogenase activity

Soil dehydrogenase activity was determined through triphenyl tetrazolium chloride (TTC) reduction. Five grams of moist, sieved soil were weighed into four tubes. To three tubes, 4 ml of Tris 100 mmol/l pH 7, 6 and 1 mL of TTC substrate mmol/l (2 %) were added. The control tube received only 4 mL of Tris buffer. Tubes were briefly shaken, sealed, and incubated at 25 ± 1 °C for 6 hours. Triphenyl-formazan (TPF) was extracted by adding 25 mL of ethanol, followed by 1 hour of dark orbital agitation (250 rpm, 25 ± 1 °C). At the end of extraction, 1 mL of TTC substrate was added to the control. Supernatants were obtained by centrifuging at 2000R for 5 minutes and transferred to cuvettes. Absorbance was measured at 485 nm using a spectrophotometer, quantifying TPF and thus, dehydrogenase activity (Malachowska *et al*., 2019).

11. Studies on inter cropping system

Different parameters for intercropping systems were calculated to investigate the impact of various treatments.

11.1. Land equivalent ratio (LER)

Land equivalent ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of the fractions of the intercropped yields divided by the sole-crop yields (Willey *et al*., 1979).

$$\text{LER} = \frac{\text{Yms}}{\text{Ymm}} + \frac{\text{Ysm}}{\text{Yss}}$$

Where, Yms= Yield of maize in intercropping, Ysm= Yield of soybean in intercropping, Ymm= Yield of maize in pure stand, Yss= Yield of soybean in pure stand.

11.2. Maize-equivalent yield (MEY)

Maize-equivalent yield (MEY) was calculated by the formula as described by Verma and Modgal (1983).

$$\text{MEY} = \text{Grain yield of maize (t ha}^{-1}\text{)} + \frac{\text{seed yield of soybean} \times \text{Price of soybean}}{\text{Price of maize}}$$

11.3. Competition index (CI)

It is measure to find out the yield of various crops when grown together as well as separately. It shows that how much crop being affected by competition from mixed crop. CI was calculated followed by Bonser *et al.*, 2013. The negative values of CI show positive competition effect and negative values shows positive competition effect.

$$CI = \frac{(Yaa - Yab) \times (Ybb - Yba)}{Yaa \times Ybb}$$

Where, Yab- mixture yield of a crop grown with b. Yba- mixture yield of b crop grown with a. Yaa- yield in pure stand of crop a. Ybb-yield in pure stand of crop b.

11.4. Relative Crowding Coefficient (RCC):

It is used in replacement series of intercropping. It indicates whether a crop, when grown in mixed population, has produced more or less yield than expected (McGilchrist, 1965).

$$RCC = \frac{Yab}{Yaa \times Ybb} \times \frac{Zba}{Zab}$$

Where, Yab=Yield per unit area of crop a intercropped with crop b, Yaa= Yield per unit of sole crop a, Ybb= Yield per unit of sole crop b. Zab=Proportion of intercropped area initially allocated to crop, a. Zba=Proportion of intercropped area initially allocated to crop, b. RCC > 1 means yield advantage RCC = 1 no difference RCC < 1 yield disadvantage.

12. Economic Studies

Economic studies of production were conducted by keeping a record on the operations carried out, number of labors engaged, power and input utilized. The standard cultivation expense was determined based on rates fixed by the government. The gross returns, net return per hectare, and benefit to cost ratio were calculated using the following formula.

12.1. Cost of cultivation (₹ ha^{-1})

In computing the economics, different variable cost items will be considered treatment wise, includes the cost on land preparation, seeds, fertilizers, plant protection measures and irrigation cost. Labour required for sowing, irrigation, weeding, top dressing, spraying, harvesting and threshing etc., will be calculated based on prevailing market prices.

12.2. Gross return (₹ ha^{-1})

Gross return will be calculated by multiplying grain and stalk yield of maize and soybean (t ha^{-1}) with prevailing market price and expressed in rupees per hectare (₹ ha^{-1}).

12.3. Net return (₹ ha^{-1})

Net return will be calculated by deducting the cost of cultivation from gross return and expressed in rupees per hectare (₹ ha^{-1}).

12.4. Benefit-cost ratio

Benefit-cost ratio will be obtained by dividing gross return (₹ ha^{-1}) with cost of cultivation (Gittinger, 1982).

$$\text{Benefit – cost ratio} = \frac{\text{Gross return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

Statistical method- The data collected for various parameters were scrutinized employing the analysis of variance (ANOVA) methodology (Gomez and Gomez, 1984) within the framework of a split-plot design utilizing OP STAT software. The least significant difference test was employed to elucidate the influence of treatments at a 5% level of significance (P=0.05).

Field Preparation

Soil sample collection

Layout Preparation

Sowing

Seedling stage

Foliar application of nutrients

Harvesting of crops

Measuring the plant height of oats crop

Plate 1. Field operations carried out during experimentation

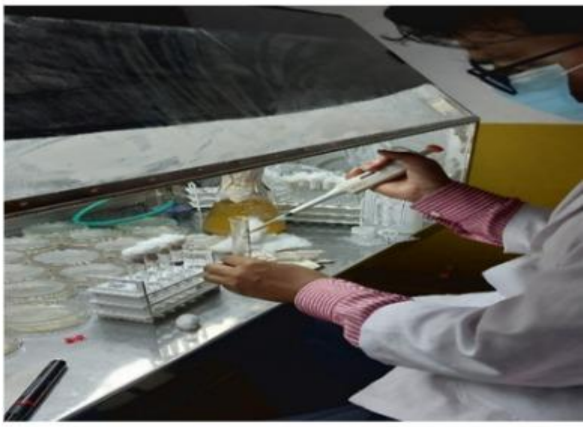
Reading data from titration method

Reading data from Spectrophotometer

Reading data from Flame Photometer

Reading data from pH meter

Reading data from EC meter



Taking data of Microbial counting

Reading data from centrifuge machine

Plant extract by Soxhlation method

Plate-2. Lab work carried out after experimentation

CHAPTER - 4

EXPERIMENTAL RESULTS

The results of the field experiment entitled **"Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oats in maize + soybean – oats cropping system"** carried out at the instructional Farm, Department of Agronomy, School of Agriculture, Lovely Professional University, Jalandhar during the *Kharif – Rabi season* of the year 2023 – 24 and 2024 – 25 are presented in this chapter along with statistical inference. The field observations and laboratory assessments data related to various treatments are tested for their significance using standard statistical methods. This chapter presents the results for main, sub, and interaction effects under the relevant headings, and graphical representations of the data have been included where necessary to facilitate a deeper understanding of key trends.

4.1. Growth parameters

The ecosystem's productivity is influenced by key abiotic components including temperature, rainfall, sunlight, and soil. Data from Fig. 3.2and 3.3, as well as Table I and II in Appendix A, indicate that *season*al conditions during crop growth periods were normal. The 2024-25 *season* was more favorable than usual, with optimal temperatures ranging from 32.1 to 43.9°C (maximum) and 16.28 to 28°C (minimum), along with suitable with well distribution of rainfall and solar radiation, which are ideal for maize and soybean growth, resulting in a higher grain yield. Both *season*s experienced minimal occurrences of severe pest and disease issues. The physical characteristics of soil were conducive to the growth of maize and soybeans. The soil had a slightly alkaline 7.52 pH, low available nitrogen and available phosphorus, and medium levels of potassium. In this experiment, both maize, soybean and fodder oat have shown positive responses to the cropping system and varying fertilizer levels in the maize + soybean - oat cropping system.

4.1. Growth of maize under maize + soybean - oat cropping system

4.1.1. Plant height (cm)

The data on plant height of maize is influenced by cropping system and nutrient management at 30, 60, 90 and at harvest during 2023 and 2024 (Table 4.1a).

The plant height of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole maize (M_1) increased plant height at 60 DAS (92.4 cm in 2023 and 95.36 cm in 2024), at 90 DAS (162.0 cm in 2023 and 163.5 cm in 2024) and at maturity (163.5 cm in 2023 and 165.6 cm in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (88.2 cm in 2023 and 93.6 cm in 2024), at 90 DAS (158.3 cm in

Table. 4.1a. Effect of planting system and nutrient management on plant height (cm) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Planting system								
M_1	17.4	17.59	92.38	95.36	162.03	163.56	163.55	165.59
M_3	17.22	17.35	88.24	93.57	158.3	160.61	161.1	162.63
M_4	16.87	17.11	83.84	89.66	156.42	158.87	158.76	160.92
M_5	16.84	16.87	84.01	85.67	155.03	156.77	158.4	158.53
SEm±	0.37	0.14	1.33	1.45	1.15	1.12	1.08	1.2
CD (P = 0.05)	NS	NS	4.69	5.12	4.07	3.93	3.82	4.22
Nutrient management								
S_1	16.45	16.88	81.87	88.04	149.64	151.59	151	151.58
S_2	17.66	17.35	90.77	93.48	162.34	164.57	165.69	167.7
S_3	17.11	17.34	85.38	89.08	156.81	157.81	158.59	159.14
S_4	17.07	17.27	88.18	92.06	160.42	162.35	163.17	164.89
S_5	17.12	17.32	89.4	92.65	160.51	163.44	163.8	166.27
SEm±	0.36	0.12	2.21	1.71	0.95	1	1.1	1.24
CD (P = 0.05)	NS	NS	NS	NS	2.76	2.89	3.18	3.59

4.1b. Interaction effect of planting system and nutrient management on plant height (cm) of maize at 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	155.35	151.92	149.03	142.28	**149.64**	156.06	152.52	155.41	142.38	**151.59**
S_2	167.30	163.11	160.44	158.49	**162.34**	169.39	164.16	161.28	163.45	**164.57**
S_3	161.03	156.95	156.04	153.21	**156.81**	160.68	161.13	155.57	153.84	**157.81**
S_4	161.99	157.60	161.86	160.25	**160.42**	165.27	161.23	161.03	161.87	**162.35**
S_5	164.48	161.89	154.72	160.93	**160.51**	166.37	164.03	161.03	162.34	**163.44**
Mean	**162.03**	**158.30**	**156.42**	**155.03**		**163.56**	**160.61**	**158.86**	**156.77**	
Subplot at same level of main plot										
SEm±	2.58					2.49				
CD (P = 0.05)	5.89					6.14				
Main plot at same or different level of subplot										
SEm±	2.06					2.11				
CD (P = 0.05)	6.37					6.47				

4.1c. Interaction effect of planting system and nutrient management on plant height (cm) of maize at maturity

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	155.85	153.03	151.1	144.03	**151**	155.09	154.4	156.54	140.31	**151.58**
S_2	169.29	167.2	163.44	162.86	**165.69**	173.24	166.61	163.98	166.98	**167.7**
S_3	160.94	159.4	157.86	156.17	**158.59**	162.21	162.78	156.75	154.81	**159.14**
S_4	164.26	160.21	165.22	162.98	**163.17**	168.02	162.9	163.66	164.97	**164.89**
S_5	167.41	165.65	156.19	165.96	**163.8**	169.41	166.44	163.67	165.57	**166.27**
Mean	**163.55**	**161.1**	**158.76**	**158.4**		**165.59**	**162.63**	**160.92**	**158.53**	
Subplot at same level of main plot										
SEm±	2.42					2.68				
CD (P = 0.05)	6.68					7.53				
Main plot at same or different level of subplot										
SEm±	2.24					2.52				
CD (P = 0.05)	6.82					7.65				

2023 and 160.6 cm in 2024) and at maturity (161.1 cm in 2023 and 162.6 cm in 2024). The lowest plant height was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (84.0 cm in 2023 and 85.7 cm in 2024), at 90 DAS (155.0 cm in 2023 and 156.8 cm in 2024) and at maturity (158.4 cm in 2023 and 158.5 cm in 2024).

Similarly, the nutrient application differed significantly on plant height at 90, and at maturity except 30 and 60 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the plant height at 90 DAS (162.3 cm in 2023 and 164.7 cm in 2024) and at maturity (165.7 cm in 2023 and 167.7 cm in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 90 DAS (161.3 cm in 2023 and 163.9 in 2024) and at maturity (163.8 cm in 2023 and 166.3 cm in 2024), and 70% RDF with two foliar application of Homemade NPK (S_4) at 90 DAS (162.3 cm in 2023 and 164.6 cm in 2024) and at maturity (163.2 cm in 2023 and 164.9 cm in 2024). The lowest plant height was observed in control treatment (S_1) at 90 DAS (149.6 cm in 2023 and 151.6 cm in 2024) and at maturity (151 cm in 2023 and 151.6 cm in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to plant height at maturity but there is no significant effect at 30 and 60 DAS (Table 4.1b–c) during both the years, M_1S_2 increased plant height at 90DAS (167.3 cm in 2023 and 169.4 cm in 2024), at maturity (169.3cm in 2023 and 173.2 cm in 2024) which was statistically similar with M_1S_5 at 90 DAS (164.5 cm in 2023 and 166.4 cm in 2024), at maturity(167.4 cm in 2023 and 169.4 cm in 2024), M_1S_4 at 90 DAS (162 cm in 2023 and 165.3 cm in 2024),at maturity (164.3cm in 2023 and 168.0 cm in 2024), M_3S_2 at 90 DAS (163.1 cm in 2023 and 164.2 cm in 2024), at maturity (167.2 cm in 2023 and 166.6 cm in 2024), M_3S_5 at 90 DAS (161.9 cm in 2023 and 164.0 cm in 2024), at maturity (165.6 cm in 2023 and 166.6 cm in 2024),M_4S_4 at 90 DAS (161.9 cm in 2023) at maturity (165.2 cm in 2023 and 163.7 cm in 2024). M_5S_2 at maturity (162.9 cm in 2023 and 167.0 cm in 2024). M_5S_4at at maturity (163.0 cm in 2023), M_5S_5 at maturity (166 cm in 2023).

4.1.2. Dry matter accumulation (g)

The data on dry matter accumulation of maize is influenced by cropping system and nutrient management at 30, 60, 90 and at harvest during 2023 and 2024 (Table 4.2a).

The dry matter accumulation of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole maize (M_1) cropping increased dry matter accumulation at 60 DAS (92.51 g in 2023 and 96.03 g in 2024), at 90 DAS (126.60 g in 2023 and 131.94 g in 2024) and at maturity (148.97 g in 2023 and 150.39 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (91.09 g in 2023 and 94.45 g in 2024), at 90 DAS (123.54 g in 2023 and 130.14 g in 2024) and at maturity (147.83 g in 2023 and 148 g in 2024). The lowest dry matter accumulation was observed in 2:3 row proportions of maize and

Table 4.2a. Effect of planting system and nutrient management on dry matter accumulation (g) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS		At maturity	
	2023	2024	2023	2024	2023	2024	2023	2024
Planting system								
M_1	30.33	32.84	92.51	96.03	126.60	131.94	148.97	150.39
M_3	29.45	32.10	91.09	94.45	123.54	130.14	147.83	148.11
M_4	29.39	31.90	85.53	87.85	115.63	120.24	140.24	141.59
M_5	29.11	31.59	81.25	83.77	108.26	112.69	136.29	138.65
SEm ±	0.35	0.33	0.76	0.75	1.12	0.91	1.40	1.22
CD (P = 0.05)	NS	NS	2.69	2.65	3.93	3.22	4.93	4.29
Nutrient management								
S_1	29.16	31.69	78.86	72.80	92.69	97.15	127.15	129.82
S_2	29.51	32.04	94.20	99.14	131.14	136.74	150.55	151.60
S_3	29.70	31.96	79.34	86.06	111.69	116.34	143.81	142.30
S_4	29.72	32.39	92.22	97.04	128.46	134.21	147.16	149.39
S_5	29.77	32.45	93.37	97.60	128.55	134.32	147.99	150.31
SEm±	0.17	0.34	0.81	0.74	0.98	0.89	1.67	1.19
CD (P = 0.05)	NS	NS	2.34	2.14	2.83	2.58	4.83	3.44

4.2b. Interaction effect of planting system and nutrient management dry matter accumulation (g) of maize at 60 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	76.87	72.88	66.62	64.10	**70.12**	79.85	76.13	68.39	66.82	**72.80**
S_2	99.64	97.20	96.04	90.82	**95.93**	103.10	100.95	98.62	94.09	**99.14**
S_3	91.24	88.52	77.18	75.52	**83.12**	94.52	92.09	79.17	78.48	**86.06**
S_4	97.55	97.47	93.13	87.31	**93.86**	100.96	101.22	95.45	90.52	**97.04**
S_5	98.31	98.11	95.47	85.76	**94.41**	101.74	101.88	97.84	88.93	**97.60**
Mean	**92.72**	**90.84**	**85.69**	**80.70**		**96.03**	**94.45**	**87.85**	**83.77**	
Subplot at same level of main plot										
SEm±	1.65					1.65				
CD (P = 0.05)	4.41					4.56				
Main plot at same or different level of subplot										
SEm±	1.49					1.53				
CD (P = 0.05)	4.54					4.65				

4.2c. Interaction effect of planting system and nutrient management dry matter accumulation (g) of maize at 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	99.41	96.79	90.08	84.46	**92.69**	104.69	102.05	94.27	87.60	**97.15**
S_2	139.22	133.92	128.99	122.45	**131.14**	144.89	142.54	133.56	125.95	**136.74**
S_3	124.16	121.05	103.99	97.57	**111.69**	129.68	126.54	108.32	100.83	**116.34**
S_4	134.62	132.87	127.57	118.78	**128.46**	140.24	139.88	132.20	124.54	**134.21**
S_5	135.58	133.08	127.50	118.04	**128.55**	140.21	139.70	132.85	124.51	**134.32**
Mean	**126.60**	**123.54**	**115.63**	**108.26**		**131.94**	**130.14**	**120.24**	**112.69**	
Subplot at same level of main plot										
SEm±	2.49					2.04				
CD (P = 0.05)	6.02					5.44				
Main plot at same or different level of subplot										
SEm±	2.07					1.84				
CD (P = 0.05)	6.38					5.61				

4.2d. Interaction effect of planting system and nutrient management dry matter accumulation (g) of maize at maturity

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	139.76	134.86	125.52	108.48	**127.15**	139.83	137.87	121.60	120.00	**129.82**
S_2	157.56	151.32	146.51	146.81	**150.55**	158.67	154.75	148.08	144.89	**151.60**
S_3	143.83	147.53	142.38	141.51	**143.81**	143.42	143.55	142.02	140.22	**142.30**
S_4	151.69	152.76	142.58	141.60	**147.16**	154.91	151.95	148.09	143.62	**149.39**
S_5	152.01	152.66	144.22	143.05	**147.99**	155.13	153.42	148.15	144.53	**150.31**
Mean	**148.97**	**147.82**	**140.24**	**136.29**		**150.39**	**148.11**	**141.59**	**138.65**	
Subplot at same level of main plot										
SEm±	3.12					2.72				
CD (P = 0.05)	10.04					7.24				
Main plot at same or different level of subplot										
SEm±	3.30					2.45				
CD (P = 0.05)	9.91					7.47				

soybean (M_5) at 60 DAS (81.25 g in 2023 and 83.77 g in 2024), at 90 DAS (108.26 g in 2023 and 112.69 g in 2024) and at maturity (136.29 g in 2023 and 138.65 g in 2024).

Similarly, the nutrient application differed significantly on dry matter accumulation at 60, 90 DAS and at maturity except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the dry matter accumulation at 60 DAS (94.20 g in 2023 and 99.14 g in 2024), at 90 DAS (131.14 g in 2023 and 136.74 g in 2024) and at maturity (150.55 g in 2023 and 151.60 g in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (93.37 g in 2023 and 97.60 g in 2024), at 90 DAS (128.55 g in 2023 and 134.32 g in 2024) and at maturity (147.99 g in 2023 and 150.31 g in 2024), and 70% RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (92.22 g in 2023 and 97.04 g in 2024), at 90 DAS (128.46 g in 2023 and 134.21 g in 2024) and at maturity (147.16 g in 2023 and 149.39 g in 2024). The lowest plant height was observed in control treatment (S_1) at 60 DAS (78.86 g in 2023 and 72.80 g in 2024), 90 DAS (92.63 g in 2023 and 97.15 g in 2024) and at maturity (127.15 g in 2023 and 129.82 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to dry matter accumulation at maturity but there is no significant effect at 30, 60, and 90 DAS (Table 4.2b-d), during both the years, M_1S_2 increased dry matter accumulation at 60 DAS (99.64 g in 2023 and 103.10 g in 2024), at 90 DAS (139.22 g in 2023 and 144.89 g in 2024), at maturity (157.56 g in 2023 and 158.67 g in 2024) which was statistically similar with M_1S_5 at 60 DAS (98.31 g in 2023 and 101.74 g in 2024), at 90 DAS (135.58 g in 2023 and 140.21 g in 2024), at maturity (1552.01 g in 2023 and 155.13 g in 2024), M_1S_4 at 60 DAS (97.55 g in 2023 and 100.96 g in 2024), at 90 DAS (134.62 g in 2023 and 140.24 g in 2024), at maturity (151.69 g in 2023 and 154.91 g in 2024), M_3S_2 at 60 DAS (97.28 g in 2023 and 100.95 g in 2024), at 90 DAS (133.92 g in 2023 and 142.54 g in 2024), at maturity (151.32 g in 2023 and 154.75 g in 2024), M_3S_5 60 DAS (98.11 g in 2023 and 101.88 g in 2024), at 90 DAS (133.08 g in 2023 and 139.70 g in 2024), at maturity (152.66 g in 2023 and 153.42 g in 2024), M_3S_4 60 DAS (97.47 g in 2023 and 100.95 g in 2024), at 90 DAS (132.87 g in 2023 and 139.88 g in 2024), at maturity (152.76 g in 2023 and 151.95 g in 2024), M_4S_2 at 60 DAS (96.04 g in 2023 and 98.62 g in 2024), at 90 DAS (128.99 g in 2023 and 133.56 g in 2024).The lowest dry matter accumulation was found in M_5S_1 at 60 DAS (64.10 g in 2023 and 66.82 g in 2024) at 90 DAS (64.10 g in 2023 and 66.82 g in 2024) and at maturity (84.46 g in 2023 and 87.60 g in 2024).

4.1.3. Number of leaves plant^{-1}

The data on number of leaves of maize is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.3a).

The number of leaves of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole maize (M_1) cropping increased number of leaves

Table 4.3a. Effect of planting system and nutrient management on number of leaves plant^{-1}of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60DAS		90DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	4.26	4.31	9.92	10.01	11.19	12.23
M_3	3.97	4.07	9.56	9.68	10.64	11.53
M_4	3.85	3.95	8.41	8.49	9.03	10.67
M_5	3.7	3.8	7.28	7.92	8.34	9.44
SEm±	0.2	0.12	0.37	0.38	0.28	0.26
CD (P = 0.05)	NS	NS	1.3	1.35	0.99	0.91
Nutrient management						
S_1	3.89	3.92	7.89	8.02	8	8.59
S_2	4.29	4.34	9.34	9.51	10.99	12.11
S_3	3.65	3.98	8.21	8.49	8.72	10.51
S_4	3.8	3.95	9.22	9.4	10.58	11.68
S_5	4.09	3.98	9.31	9.71	10.7	11.96
SEm±	0.17	0.15	0.45	0.5	0.2	0.21
CD (P = 0.05)	NS	NS	NS	NS	0.58	0.59

4.3b. Interaction effect of planting system and nutrient management on number of leaves Plant^{-1} of maize at 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	9.23	7.7	7.67	7.4	**8**	10.73	9.42	7.03	7.17	**8.59**
S_2	13.18	12.1	9.8	8.88	**10.99**	13.27	12.45	11.6	11.13	**12.11**
S_3	9.37	9.5	8.57	7.43	**8.72**	11.73	11.12	10.87	8.33	**10.51**
S_4	11.97	11.93	9.7	8.73	**10.58**	12.33	12.19	11.97	10.22	**11.68**
S_5	12.19	11.97	9.4	9.23	**10.7**	13.1	12.45	11.9	10.37	**11.96**
Mean	**11.19**	**10.64**	**9.03**	**8.34**		**12.23**	**11.53**	**10.67**	**9.44**	
Subplot at same level of main plot										
SEm±	0.63					0.58				
CD (P = 0.05)	1.25					1.27				
Main plot at same or different level of subplot										
SEm±	0.45					0.45				
CD (P = 0.05)	1.42					1.39				

at 60 DAS (9.92 in 2023 and 10.01 leaves per plant in 2024) and at 90 DAS (11.19 in 2023 and 12.23 leaves per plant in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (9.56 in 2023 and 9.68 in 2024), at 90 DAS (10.64 in 2023 and 11.53 leaves per plant in 2024). The lowest number of leaves were observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (7.28 in 2023 and 7.92 in 2024), at 90 DAS (8.27 in 2023 and 9.44 leaves per plant in 2024).

Similarly, the nutrient application differed significantly on number of leaves at 90 DAS and at maturity except 30 and 60 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of leaves at 90 DAS (10.99 in 2023 and 12.11 leaves per plant in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 90 DAS (10.70 in 2023 and 11.96 leaves per plant in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 90 DAS (10.58 in 2023 and 11.68 leaves per plant in 2024). The lowest number of leaves was observed in control treatment (S_1) at 90 DAS (8.0 in 2023 and 8.59 leaves per plant in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to dry matter accumulation at maturity but there is no significant effect at 30 and 60 DAS (Table 4.3b). during both the years, M_1S_2 increased number of leaves at 90 DAS (13.18 in 2023 and 13.27 leaves per plant in 2024) which was statistically similar with M_1S_5 (12.19 in 2023 and 13.10 leaves per plant in 2024), M_1S_4 (11.97 in 2023 and 12.33 leaves per plant in 2024), M_3S_2 (12.10 in 2023 and 12.45 leaves per plant in 2024), M_3S_4 (11.93 in 2023 and 12.19 leaves per plant in 2024) and M_3S_5 (11.97 in 2023 and 12.45 M_3S_4 (11.97 in 2023 and 12.45 leaves per plant in 2024). The lowest number of leaves was found in M_5S_1 at 90 DAS (7.40 in 2023 and 7.17 leaves per plant in 2024).

4.1.4. Leaf Area (cm^{-2} $plant^{-1}$)

The data on leaf area (cm^2) of maize is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.4a).

The leaf area (cm^2) of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole maize (M_1) cropping increased leaf area at 60 DAS (5653 cm^2 in 2023 and 5831 cm^2 in 2024) and at 90 DAS (4969 cm^2 in 2023 and 5149 cm^2 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (5613 cm^2 in 2023 and 5831 cm^2 in 2024), at 90 DAS (4969 cm^2 in 2023 and 5149 cm^2 in 2024). The leaf area was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (5126 cm^2 in 2023 and 5345 cm^2 in 2024), at 90 DAS (4640 cm^2 in 2023 and 4794 cm^2 in 2024).

Similarly, the nutrient application differed significantly on leaf area at 60 and 90 DAS except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the leaf

Table 4.4a. Effect of planting system and nutrient management on leaf area (cm^2) maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	1648	1812	5757	5989	5077	5265
M_3	1602	1768	5653	5831	4969	5149
M_4	1614	1815	5304	5509	4751	4915
M_5	1607	1821	5126	5345	4640	4794
SEm±	13	17	103	95	65	70
CD (P = 0.05)	NS	NS	365	336	228	231
Nutrient management						
S_1	1620	1802	4740	5005	4409	4546
S_2	1635	1822	6000	6166	5197	5394
S_3	1598	1790	4821	5080	4460	4601
S_4	1611	1798	5885	6060	5125	5317
S_5	1626	1808	5853	6031	5105	5296
SEm±	11	16	88	81	55	59
C.D(p=0.05)	NS	NS	255	235	159	172

4.4b. Interaction effect of planting system and nutrient management leaf area (cm^2) of maize at 60 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4920	5133	4512	4394	**4740**	5218	5351	4779	4670	**5005**
S_2	6530	6247	5550	5673	**6000**	6702	6378	5735	5849	**6166**
S_3	4993	4661	5182	4450	**4821**	5286	4916	5396	4721	**5080**
S_4	6083	6096	5556	5805	**5885**	6290	6239	5742	5971	**6060**
S_5	6257	6129	5721	5308	**5853**	6450	6269	5893	5512	**6031**
Mean	**5757**	**5653**	**5304**	**5126**		**5989**	**5831**	**5509**	**5345**	
Subplot at same level of main plot										
SEm±	231					213				
CD (P = 0.05)	544					501				
Main plot at same or different level of subplot										
SEm±	189					174				
CD (P = 0.05)	582					536				

4.4c. Interaction effect of planting system and nutrient management leaf area (cm^2) of maize at 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4554	4644	4256	4182	**4409**	4702	4800	4382	4302	**4546**
S_2	5560	5340	4904	4982	**5197**	5785	5549	5080	5163	**5394**
S_3	4600	4349	4674	4217	**4460**	4752	4482	4832	4340	**4601**
S_4	5280	5246	4909	5064	**5125**	5485	5447	5084	5251	**5317**
S_5	5389	5266	5011	4753	**5105**	5602	5469	5195	4917	**5296**
Mean	**5077**	**4969**	**4751**	**4640**		**5265**	**5149**	**4915**	**4794**	
Subplot at same level of main plot										
SEm±	144					156				
CD (P = 0.05)	340					366				
Main plot at same or different level of subplot										
SEm±	118					127				
CD (P = 0.05)	363					391				

area at 60 DAS (6000 cm^2 in 2023 and 6166 cm^2 in 2024), 90 DAS (5197 cm^2 in 2023 and 5394 cm^2 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (5853 cm^2 in 2023 and 6031 cm^2 in 2024), at 90 DAS (5105 cm^2 in 2023 and 5296 cm^2 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 60 DAS (5885 cm^2 in 2023 and 6060 cm^2 in 2024), at 90 DAS (5125 cm^2 in 2023 and 5317 cm^2 in 2024). The lowest leaf area was observed in control treatment (S_1) at 60 DAS (4740 cm^2 in 2023 and 5005 cm^2 in 2024), at 90 DAS (4409 cm^2 in 2023 and 4546 cm^2 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to leaf area at 90 DAS but there is no significant effect at 30 and 60 DAS (Table 4. 4b-c). During both the years, M_1S_2 increased leaf area at 60 DAS (6530 cm^2 in 2023 and 6702 cm^2 in 2024), at 90 DAS (5560 cm^2 in 2023 and 5785 cm^2 in 2024) which was statistically similar with M_1S_5 at 60 DAS (6257 cm^2 in 2023 and 6450 cm^2 in 2024), at 90 DAS (5389 cm^2 in 2023 and 5602 cm^2 in 2024), M_1S_4 at 60 DAS (6083 cm^2 in 2023 and 6290 cm^2 in 2024), at 90 DAS (5280 cm^2 in 2023 and 5485 cm^2 in 2024), M_3S_2 at 60 DAS (6247 cm^2 in 2023 and 6378 cm^2 in 2024), at 90 DAS (5340 cm^2 in 2023 and 5549 cm^2 in 2024), M_3S_4 at 60 DAS (6096 cm^2 in 2023 and 6239 cm^2 in 2024), at 90 DAS (5246 cm^2 in 2023 and 5447 cm^2 in 2024) and M_3S_5 at 60 DAS (6129 cm^2 2023 and 6269 cm^2 in 2024), at 90 DAS (5266 cm^2 2023 and 5469 cm^2 in 2024). The lowest leaf area was found in M_5S_1 at 60 DAS (4182 cm^2 in 2023 and 4302 cm^2 in 2024), at 90 DAS (4182 cm^2 in 2023 and 4302 cm^2 in 2024).

4.1.5. Leaf Area Index (LAI)

The data on leaf area index of maize is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.5a).

The leaf area index of maize differed significantly with cropping system at all the growth stages. During both the years, sole maize (M_1) cropping increased leaf area at 30 DAS (1.37 in 2023 and 1.51 in 2024), at 60 DAS (4.80 in 2023 and 4.99 in 2024) and at 90 DAS (4.23 in 2023 and 4.39 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 30 DAS (1.34 in 2023 and 1.47 in 2024), at 60 DAS (4.71 in 2023 and 4.86 in 2024), at 90 DAS (4.14 in 2023 and 4.29 in 2024). The leaf area was observed in 2:3 row proportions of maize and soybean (M_5) at 30 DAS (0.67 in 2023 and 0.76 in 2024), at 60 DAS (2.14 in 2023 and 2.23 in 2024), at 90 DAS (1.93 in 2023 and 2.00 in 2024).

Similarly, the nutrient application differed significantly on leaf area at 60 and 90 DAS except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the leaf area at 60 DAS (4.03 in 2023 and 4.13 in 2024), 90 DAS (3.47 in 2023 and 3.60 in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) at 60 DAS (3.93 in

Table 4.5a. Effect of planting system and nutrient management on leaf area index (LAI) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	1.37	1.51	4.80	4.99	4.23	4.39
M_3	1.34	1.47	4.71	4.86	4.14	4.29
M_4	0.90	1.01	2.95	3.06	2.64	2.73
M_5	0.67	0.76	2.14	2.23	1.93	2.00
SEm±	0.01	0.01	0.09	0.08	0.06	0.06
CD (P = 0.05)	0.04	0.05	0.31	0.29	0.19	0.21
Nutrient management						
S_1	1.07	1.19	3.18	3.35	2.94	3.04
S_2	1.08	1.20	4.03	4.13	3.47	3.60
S_3	1.06	1.18	3.20	3.37	2.95	3.05
S_4	1.06	1.18	3.92	4.03	3.40	3.53
S_5	1.08	1.19	3.93	4.04	3.41	3.54
SEm±	0.01	0.01	0.05	0.05	0.03	0.04
CD (P = 0.05)	NS	NS	0.15	0.14	0.10	0.10

4.5b. Interaction effect of planting system and nutrient management leaf area index of maize at 60 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4.10	4.28	2.51	1.83	**3.18**	4.35	4.46	2.66	1.95	**3.35**
S_2	5.44	5.21	3.08	2.37	**4.03**	5.59	5.32	3.19	2.44	**4.13**
S_3	4.16	3.89	2.88	1.85	**3.20**	4.41	4.10	3.00	1.97	**3.37**
S_4	5.07	5.08	3.09	2.42	**3.92**	5.24	5.20	3.19	2.49	**4.03**
S_5	5.22	5.11	3.18	2.21	**3.93**	5.37	5.23	3.27	2.30	**4.04**
Mean	**4.80**	**4.71**	**2.95**	**2.14**		**4.99**	**4.86**	**3.06**	**2.23**	
Subplot at same level of main plot										
SEm±	0.20					0.18				
CD (P = 0.05)	0.34					0.31				
Main plot at same or different level of subplot										
SEm±	0.13					0.12				
CD (P = 0.05)	0.42					0.38				

4.5c. Interaction effect of planting system and nutrient management leaf area (cm^2 $plant^{-1}$) of maize at 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	3.79	3.87	2.37	1.74	**2.94**	3.92	4.00	2.43	1.79	**3.04**
S_2	4.63	4.45	2.73	2.08	**3.47**	4.82	4.62	2.82	2.15	**3.60**
S_3	3.83	3.62	2.59	1.76	**2.95**	3.96	3.74	2.68	1.81	**3.05**
S_4	4.40	4.37	2.73	2.11	**3.40**	4.57	4.54	2.83	2.19	**3.53**
S_5	4.49	4.39	2.79	1.98	**3.41**	4.67	4.56	2.89	2.05	**3.54**
Mean	**4.23**	**4.14**	**2.64**	**1.93**		**4.39**	**4.29**	**2.73**	**2.00**	
Subplot at same level of main plot										
SEm±	0.12					0.13				
CD (P = 0.05)	0.21					0.23				
Main plot at same or different level of subplot										
SEm±	0.08					0.09				
CD (P = 0.05)	0.26					0.28				

2023 and 4.04 in 2024), at 90 DAS (3.41 in 2023 and 3.54 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 60 DAS (3.92 in 2023, 4.03 in 2024), at 90 DAS (3.40 in 2023 and 3.53 in 2024). The lowest leaf area index was observed in control treatment (S_1) at 60 DAS (3.18 in 2023 and 3.35 in 2024), at 90 DAS (2.94 in 2023 and 3.04 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to leaf area index at 60 and 90 DAS but there is no significant effect at 30 DAS (Table 4.5b-c). During both the years, M_1S_2 increased leaf area index at 60 DAS (5.44 in 2023 and 5.59 in 2024), at 90 DAS (4.63 in 2023 and 4.82 in 2024), which was statistically similar with M_1S_5 at 60 DAS (5.22 in 2023 and 5.37 in 2024), at 90 DAS (4.49 in 2023 and 4.67in 2024) and M_3S_2 at 60 DAS (5.21 in 2023 and 5.32 in 2024), at 90 DAS (4.45 in 2023 and 4.62). The lowest leaf area index was found in M_5S_1 at 60 DAS (1.83 in 2023 and 1.95 in 2024), at 90 DAS (1.74 in 2023 and 1.79 in 2024).

4.1.6. Crop growth rate (mg cm^{-2} day^{-1})

The data on CGR of maize is influenced by cropping system and nutrient management at 30 - 60 and 60 - 90 DAS 2023 and 2024 (Table 4.6a).

The crop growth rate (CGR) of maize differed significantly with cropping system at all the growth stages. During both the years, sole maize (M_1) cropping increased crop growth rate at 30 - 60 DAS (1.73 mg cm^{-2} day^{-1} in 2023 and 1.76 mg cm^{-2} day^{-1} in 2024) and at 60 - 90 DAS (0.94 mg cm^{-2} day^{-1} in 2023 and 1.0 mg cm^{-2} day^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 30 - 60 DAS (1.69 mg cm^{-2} day^{-1} in 2023 and 1.72 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.91 mg cm^{-2} day^{-1} in 2023 and 0.99 mg cm^{-2} day^{-1} in 2024). The lowest crop growth rate was observed in 2:3 row proportions of maize and soybean (M_5) at 30 - 60 DAS (1.43 mg cm^{-2} day^{-1} in 2023 and 1.47 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.77 mg cm^{-2} day^{-1} in 2023 and 0.79 mg cm^{-2} day^{-1} in 2024).

Similarly, the nutrient application differed significantly on crop growth rate at 30 - 60 DAS, and at 60 - 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the crop growth rate at 30 - 60 DAS (1.84 mg cm^{-2} day^{-1} in 2023 and 1.86 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.98 mg cm^{-2} day^{-1} in 2023 and 1.04 mg cm^{-2} day^{-1} in 2024). The lowest crop growth rate was observed in control treatment (S_1) at 30 - 60 DAS (1.14 mg cm^{-2} day^{-1} in 2023 and 1.14 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.63 mg cm^{-2} day^{-1} in 2023 and 0.68 mg cm^{-2} day^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to 30 - 60 DAS and 60 - 90 DAS (Table 4.6b-c). during both the years, M_1S_2 increased crop growth rate at 30 - 60 DAS M_1S_2 (1.93 mg cm^{-2} day^{-1} in 2023 and 1.97 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (1.10 mg cm^{-2} day^{-1} in 2023 and 1.16 mg cm^{-2} day^{-1} in 2024), which was statistically similar

Table 4.6a. Effect of planting system and nutrient management on crop growth rate (mg cm^{-2} day^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_1	1.73	1.76	0.94	1.00
M_3	1.69	1.72	0.91	0.99
M_4	1.56	1.56	0.83	0.90
M_5	1.43	1.47	0.77	0.79
SEm±	0.03	0.03	0.01	0.01
CD (P = 0.05)	0.09	0.10	0.05	0.04
Nutrient management				
S_1	1.14	1.14	0.63	0.68
S_2	1.84	1.86	0.98	1.04
S_3	1.48	1.50	0.79	0.84
S_4	1.78	1.82	0.96	1.01
S_5	1.79	1.81	0.95	1.02
SEm±	0.02	0.02	0.02	0.01
CD (P = 0.05)	0.06	0.07	0.05	0.04

4.6b. Interaction effect of planting system and nutrient management crop growth rate (mg cm^{-2} day^{-1}) of maize at 30 – 60 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.33	1.20	1.04	0.97	**1.14**	1.32	1.22	1.03	1.00	**1.14**
S_2	1.93	1.87	1.86	1.71	**1.84**	1.97	1.91	1.85	1.72	**1.86**
S_3	1.69	1.63	1.32	1.29	**1.48**	1.75	1.63	1.32	1.32	**1.50**
S_4	1.85	1.87	1.77	1.62	**1.78**	1.85	1.91	1.77	1.73	**1.82**
S_5	1.87	1.89	1.83	1.58	**1.79**	1.89	1.92	1.83	1.60	**1.81**
Mean	**1.73**	**1.69**	**1.56**	**1.43**		**1.76**	**1.72**	**1.56**	**1.47**	
Subplot at same level of main plot										
SEm±	0.06					0.06				
CD (P = 0.05)	0.13					0.15				
Main plot at same or different level of subplot										
SEm±	0.05					0.05				
CD (P = 0.05)	0.14					0.16				

4.6c. Interaction effect of planting system and nutrient management crop growth rate (mg day^{-1} cm^{-2}) of maize at 60 – 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	0.63	0.66	0.65	0.57	**0.63**	0.69	0.72	0.72	0.58	**0.68**
S_2	1.10	1.02	0.92	0.88	**0.98**	1.16	1.16	0.98	0.89	**1.04**
S_3	0.91	0.90	0.75	0.61	**0.79**	0.98	0.96	0.81	0.62	**0.84**
S_4	1.03	0.98	0.96	0.87	**0.96**	1.09	1.07	1.02	0.86	**1.01**
S_5	1.04	0.97	0.89	0.90	**0.95**	1.07	1.05	0.97	0.99	**1.02**
Mean	**0.94**	**0.91**	**0.83**	**0.77**		**1.00**	**0.99**	**0.90**	**0.79**	
Subplot at same level of main plot										
SEm±	0.03					0.03				
CD (P = 0.05)	0.11					0.08				
Main plot at same or different level of subplot										
SEm±	0.04					0.03				
CD (P = 0.05)	0.10					0.08				

with M_1S_5 at 30 - 60 DAS (1.87 mg cm^{-2} day^{-1} in 2023 and 1.89 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (1.04 mg cm^{-2} day^{-1} in 2023 and 1.07 mg cm^{-2} day^{-1} in 2024), M_1S_4 at 30 - 60 DAS (1.85 mg cm^{-2} day^{-1} in 2023 and 1.85 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (1.03 mg cm^{-2} day^{-1} in 2023 and 1.09 mg cm^{-2} day^{-1} in 2024), M_3S_2 at 30 -60 DAS (1.87 mg cm^{-2} day^{-1} in 2023 and 1.91 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS M_3S_2 (1.02 mg cm^{-2} day^{-1} in 2023 and 1.16 mg cm^{-2} day^{-1} in 2024), M_3S_5 at 30 - 60 DAS (1.89 mg cm^{-2} day^{-1} in 2023 and 1.92 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.97 mg cm^{-2} day^{-1} in 2023 and 1.05 mg cm^{-2} day^{-1} in 2024), M_3S_4 at 30 - 60 DAS (1.87 mg cm^{-2} day^{-1} in 2023 and 1.91 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS(0.98 mg cm^{-2} day^{-1} in 2023 and 1.07 mg cm^{-2} day^{-1} in 2024). The lowest crop growth rate was found in M_5S_1 at 30 - 60 DAS (0.97 mg cm^{-2} day^{-1} in 2023 and 1.0 mg cm^{-2} day^{-1} in 2024), and 60 - 90 DAS (0.57 mg cm^{-2} day^{-1} in 2023 and 0.58 mg cm^{-2} day^{-1} in 2024).

4.1.7. Relative growth rate (mg g^{-1} day^{-1})

The data on RGR of maize is influenced by cropping system and nutrient management at 30 - 60 and 60 - 90 DAS 2023 and 2024 (Table 4.7a).

The relative growth rate (RGR) of maize differed significantly with cropping system at 30 - 60 DAS and 60 - 90 DAS. During both the years, sole maize (M_1)cropping increased relative growth rate at 30 - 60 DAS (16.12 mg g^{-1} day^{-1} in 2023 and 15.48 mg g^{-1} day^{-1} in 2024) and at 60 – 90 DAS (4.47 mg g^{-1} day^{-1} – 4.57 mg g^{-1} day^{-1}) which was statically similar with 1:1 row proportional (M_3) at 30 – 60 DAS (15.97 mg g^{-1} day^{-1} in 2023 and 15.32 mg g^{-1} day^{-1} in 2024) at 60 – 90 DAS (4.43 mg g^{-1} day^{-1} 2023 and 4.62 mg g^{-1} day^{-1} in 2024) and lowest relative growth rate was observed in 2:3 row proportion of maize and soybean (M_5) at 30 – 60 DAS (14.64 mg g^{-1} day^{-1} in 2023 and 14.20 mg g^{-1} day^{-1} in 2024), at 60 – 90 DAS (4.22 mg g^{-1} day^{-1} in 2023 and 4.16 mg g^{-1} day^{-1} in 2024).

The nutrient application differed significantly on relative growth rate at 30 - 60 and 60 - 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the crop growth rate at 30 - 60 DAS (17.00 mg g^{-1} day^{-1} in 2023 and 16.34 mg g^{-1} day^{-1} in 2024), at 60 – 90 DAS (4.54 mg g^{-1} day^{-1} in 2023 and 4.64 mg g^{-1} day^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 30 - 60 DAS (16.63 mg g^{-1} day^{-1} in 2023 and 15.92 mg g^{-1} day^{-1} in 2024) at 60 - 90 DAS (4.47 mg g^{-1} day^{-1} in 2023 and 4.63 mg g^{-1} day^{-1} in 2024) and 70% RDF with two foliar applications of Homemade NPK (S_4) at 30 – 60 DAS (16.58 mg g^{-1} day^{-1} in 2023 and 15.98 mg g^{-1} day^{-1} in 2024) , at 60- 90 DAS (4.52 mg g^{-1} day^{-1}in 2023 and 4.58 mg g^{-1} day^{-1} in 2024). The lowest relative growth rate was observed in control treatment (S_1) at 30 - 60 DAS (12.60 mg g^{-1} day^{-1} in 2023 and 11.99 mg g^{-1} day^{-1} in 2024) and at 60 - 90 (4.05 mg g^{-1} day^{-1} in 2023 and 4.18 mg g^{-1} day^{-1} in 2024).

Table 4.7a. Effect of planting system and nutrient management on relative growth rate (mg g^{-1} day^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_1	16.12	15.48	4.47	4.57
M_3	15.97	15.32	4.43	4.62
M_4	15.34	14.61	4.34	4.55
M_5	14.64	14.20	4.22	4.16
SEm±	0.26	0.24	0.05	0.07
CD (P = 0.05)	0.92	0.83	0.17	0.24
Nutrient management				
S_1	12.60	11.99	4.05	4.18
S_2	17.00	16.34	4.54	4.64
S_3	14.79	14.28	4.25	4.34
S_4	16.58	15.98	4.52	4.58
S_5	16.63	15.92	4.47	4.63
SEm±	0.14	0.20	0.09	0.07
CD (P = 0.05)	0.43	0.56	0.25	0.19

4.7b. Interaction effect of planting system and nutrient management relative growth rate (mg g^{-1} day^{-1}) of maize at 30 - 60 DAS

M/S	2023					2024				
	M_1	M_3	M_4	M_5	Mean	M_1	M_3	M_4	M_5	Mean
S_1	14.13	12.99	11.88	11.39	**12.60**	13.15	12.39	11.28	11.14	**11.99**
S_2	17.26	17.10	17.18	16.47	**17.00**	16.83	16.63	16.39	15.52	**16.34**
S_3	15.87	15.68	13.88	13.72	**14.79**	15.88	14.64	13.22	13.40	**14.28**
S_4	16.58	17.03	16.72	15.97	**16.58**	15.62	16.49	15.94	15.86	**15.98**
S_5	16.77	17.05	17.03	15.66	**16.63**	15.94	16.46	16.21	15.06	**15.92**
Mean	**16.12**	**15.97**	**15.34**	**14.64**		**15.48**	**15.32**	**14.61**	**14.20**	
Subplot at same level of main plot										
SEm±	0.58					0.053				
CD (P = 0.05)	0.93					0.94				
Main plot at same or different level of subplot										
SEm±	0.37					0.42				
CD (P = 0.05)	1.18					1.30				

4.7c. Interaction effect of planting system and nutrient management relative growth rate (mg g^{-1} day^{-1}) of maize at 60 - 90 DAS

M/S	2023					2024				
	M_1	M_3	M_4	M_5	Mean	M_1	M_3	M_4	M_5	Mean
S_1	3.72	4.11	4.37	4.00	**4.05**	3.92	4.25	4.65	3.92	**4.18**
S_2	4.84	4.64	4.27	4.32	**4.52**	4.93	4.99	4.42	4.22	**4.64**
S_3	4.46	4.53	4.32	3.71	**4.25**	4.58	4.60	4.55	3.63	**4.34**
S_4	4.66	4.49	4.55	4.45	**4.54**	4.76	4.68	4.72	4.16	**4.58**
S_5	4.65	4.40	4.19	4.63	**4.47**	4.64	4.57	4.43	4.87	**4.63**
Mean	**4.47**	**4.43**	**4.34**	**4.22**		**4.56**	**4.62**	**4.55**	**4.16**	
Subplot at same level of main plot										
SEm±	0.11					0.023				
CD (P = 0.05)	0.50					0.069				
Main plot at same or different level of subplot										
SEm±	0.16					0.023				
CD (P = 0.05)	0.47					0.069				

The interaction effect of cropping system and nutrient management differed significantly with respect to 30 – 60 and 60 - 90 DAS (Table 4.7b-c). during both the years, M_1S_2 increased relative growth rate at30 – 60 DAS (17.26 mg g^{-1} day^{-1} in 2023 and 16.83 mg g^{-1} day^{-1} in 2024) and 60 - 90 DAS (4.84 mg g^{-1} day^{-1} in 2023 and 4.93 mg g^{-1} day^{-1} in 2024) which was statistically similar with M_1S_5 at 30 – 60 DAS (16.77 mg g^{-1} day^{-1} in 2023 and 15.94 mg g^{-1} day^{-1} in 2024)and at 60 – 90 DAS (4.65 mg g^{-1} day^{-1} in 2023), M_1S_4 at 30 – 60 DAS((16.58 mg g^{-1} day^{-1} in 2023), At 60 90 DAS (4.66 mg g^{-1} day^{-1} in 2023 in 2023), M_3S_2 at 30 - 60 DAS (17.1016.58 mg g^{-1} day^{-1} in 2023 in 2023 and 16.6316.58 mg g^{-1} day^{-1} in 2023 in 2024), at 60 – 90 DAS (4.64 mg g^{-1} day^{-1} in 2023and 4.99 16.58 mg g^{-1} day^{-1} in 2023 in 2024), M_4S_2 at 30-60 DAS (17.18 mg g^{-1} day^{-1} in 2023 and 16.3916.58 mg g^{-1} day^{-1} in 2023 in 2024).The lowest relative growth rate was found in M_1S_5 at 30 - 60 DAS(11.39 mg g^{-1} day^{-1} in 2023 and 11.14 mg g^{-1} day^{-1} in 2024) and M_1S_1 at 60 – 90 DAS (3.72 mg g^{-1} day^{-1} in 2023 and 3.63 mg g^{-1} day^{-1} in 2024).

4.1.8. Net assimilation rate NAR (mg cm^{-2} day^{-1})

The data on NAR of maize is influenced by cropping system and nutrient management at 30 - 60 and 60 - 90 DAS 2023 and 2024 (Table 4.8a).

The net assimilation rate (NAR) of maize differed significantly with cropping system at 30 - 60 DAS. During both the years, sole maize (M_1) increased net assimilation rate at 30 - 60 DAS (1.33 mg cm^{-2} day^{-1} in 2023 and 1.36 mg cm^{-2} day^{-1} in 2024) and at 60 - 90 DAS (0.83 mg cm^{-2} day^{-1} in 2023 and 0.85 mg cm^{-2} day^{-1} in 2024)which was statically similar with 1:1 row proportion (1:1) at 30 – 60 DAS (1.32 mg cm^{-2} day^{-1} in 2023 and 1.34 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.82 mg cm^{-2} day^{-1} in 2023 and 0.87 mg cm^{-2} day^{-1} in 2024) and 1:2 row proportion of maize and soybean (M_4) at 30 – 60 DAS (1.26 mg cm^{-2} day^{-1} in 2023 and 1.31 mg cm^{-2} day^{-1} in 2024. The lowest net assimilation rate was observed in 2:3 row proportions of maize and soybean (M_5) at 30 - 60 DAS (1.22 mg cm^{-2} day^{-1} in 2023 and 1.23 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.72 mg cm^{-2} day^{-1} in 2023 and 0.72 mg cm^{-2} day^{-1} in 2024).

The nutrient application differed significantly on net assimilation rate at 30 - 60 DAS and 60 - 90 DAS during 2023 and 2024. During year 2024, 100% RDF (S_2) application increased the net assimilation rate at 30 - 60 DAS (1.38 mg cm^{-2} day^{-1} in 2023 and 1.40 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.85 mg cm^{-2} day^{-1} in 2023 and 0.88 mg cm^{-2} day^{-1} in 2024), which was statically similar 70 % RDF with two foliar application of plant extract at 30 – 60 DAS (1.36 mg cm^{-2} day^{-1} in 2023 and 1.38 mg cm^{-2} day^{-1} in 2024), at 60-90 DAS (0.84 mg cm^{-2} day^{-1} in 2023 and 0.87 mg cm^{-2} day^{-1} in 2024) and 70 % RDF with two foliar application of Homemade NPK application at 30 – 60 DAS (1.36 mg cm^{-2} day^{-1} in 2023 and 1.38 mg cm^{-2} day^{-1} in 2024), 60 – 90 DAS (0.84 mg cm^{-2} day^{-1} in 2023 and 0.86 mg cm^{-2} day^{-1} in 2024) and the lowest net assimilation rate was observed in control treatment

Table 4.8a. Effect of planting system and nutrient management on net assimilation rate (mg cm^{-2} day^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_1	1.33	1.36	0.83	0.85
M_3	1.32	1.34	0.82	0.87
M_4	1.26	1.31	0.77	0.82
M_5	1.22	1.23	0.72	0.72
SEm±	0.02	0.03	0.01	0.01
C.D(p=0.05)	0.08	0.09	0.04	0.03
Nutrient management				
S_1	1.00	1.05	0.62	0.65
S_2	1.38	1.40	0.85	0.88
S_3	1.31	1.35	0.78	0.81
S_4	1.36	1.37	0.84	0.86
S_5	1.36	1.38	0.84	0.87
SEm±	0.02	0.03	0.02	0.01
C.D(p=0.05)	0.07	0.07	0.05	0.04

4.8b. Interaction effect of planting system and nutrient management on net assimilation rate (mg cm^{-2} day^{-1}) of maize at 30 – 60 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.14	1.00	0.94	0.94	**1.00**	1.21	1.03	0.99	0.97	**1.05**
S_2	1.48	1.47	1.37	1.32	**1.38**	1.53	1.53	1.50	1.36	**1.40**
S_3	1.36	1.46	1.08	1.22	**1.31**	1.36	1.36	1.13	1.26	**1.35**
S_4	1.34	1.39	1.39	1.31	**1.36**	1.38	1.39	1.43	1.26	**1.36**
S_5	1.34	1.39	1.40	1.30	**1.36**	1.36	1.40	1.45	1.32	**1.38**
Mean	**1.33**	**1.32**	**1.26**	**1.22**		**1.36**	**1.34**	**1.31**	**1.23**	
Subplot at same level of main plot										
SEm±	0.05					0.06				
CD (P = 0.05)	0.15					0.15				
Main plot at same or different level of subplot										
SEm±	0.05					0.05				
CD (P = 0.05)	0.15					0.16				

4.8c. Interaction effect of planting system and nutrient management net assimilation rate (mg cm^{-2} day^{-1}) of maize at 60 – 90 DAS

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	0.60	0.63	0.66	0.58	**0.62**	0.64	0.66	0.72	0.58	**0.65**
S_2	0.91	0.91	0.84	0.79	**0.85**	0.95	0.94	0.87	0.77	**0.88**
S_3	0.88	0.87	0.70	0.62	**0.78**	0.91	0.92	0.74	0.62	**0.80**
S_4	0.88	0.85	0.87	0.77	**0.84**	0.91	0.90	0.91	0.74	**0.86**
S_5	0.87	0.83	0.80	0.84	**0.84**	0.88	0.87	0.84	0.90	**0.87**
Mean	**0.83**	**0.82**	**0.77**	**0.72**		**0.85**	**0.87**	**0.82**	**0.72**	
Subplot at same level of main plot										
SEm±	0.02					0.02				
CD (P = 0.05)	0.11					0.08				
Main plot at same or different level of subplot										
SEm±	0.03					0.03				
CD (P = 0.05)	0.10					0.08				

(S_1) at 30 - 60 DAS (1.0 mg cm^{-2} day^{-1} in 2023 and 1.05 mg cm^{-2} day^{-1} in 2024), at the 60 - 90 DAS (0.62 mg cm^{-2} day^{-1} in 2023 and 0.65 mg cm^{-2} day^{-1} in 2024)

The interaction effect of cropping system and nutrient management differed significantly with respect to 30 - 60 and 60 - 90 DAS (Table 4.8b-c). during both the years, M_1S_2 increased net assimilation rate at 30 - 60 DAS (1.48 mg cm^{-2} day^{-1} in 2023 and 1.53 mg cm^{-2} day^{-1} in 2024) at 60 – 90 DAS (0.91 mg cm^{-2} day^{-1} in 2023 1.95 mg cm^{-2} day^{-1} in 2024) and which was statistically similar with M_1S_5 at 30 – 60 DAS (1.34 mg cm^{-2} day^{-1} in 2023 and 1.36 mg cm^{-2} day^{-1} in 2024),at 60 – 90 DAS (0.87 mg cm^{-2} day^{-1} in 2023 and 0.88 mg cm^{-2} day^{-1} in 2024) and M_1S_4 at 30 – 60 DAS (1.34 mg cm^{-2} day^{-1} in 2023 and 1.38 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.88 mg cm^{-2} day^{-1} in 2023 and 0.91 mg cm^{-2} day^{-1} in 2024), M_3S_2 at 30 – 60 DAS (1.47 mg cm^{-2} day^{-1} in 2023 and 1.53 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.91 mg cm^{-2} day^{-1} in 2023 and 0.94 mg cm^{-2} day^{-1} in 2024), M_3S_3 (1.46 mg cm^{-2} day^{-1} in 2023 and 1.36 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.87 mg cm^{-2} day^{-1} in 2023 and 0.92 mg cm^{-2} day^{-1} in 2024) M_3S_4 at 30 – 60 DAS (1.39 mg cm^{-2} day^{-1} in 2023 and 1.39 mg cm^{-2} day^{-1} in 2024), At 60 – 90 DAS (0.85 mg cm^{-2} day^{-1} in 2023 and 0.90 mg cm^{-2} day^{-1} in 2024) M_3S_5 at 30 - DAS (1.39 mg cm^{-2} day^{-1} in 2023 and 1.40 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.83 0.85 mg cm^{-2} day^{-1} in 2023 and 0.90 mg cm^{-2} day^{-1} in 2024 in 2023 and 0.87 0.85 mg cm^{-2} day^{-1} in 2023 and 0.90 mg cm^{-2} day^{-1} in 2024in 2024) . The lowest net assimilation rate was found with M_5S_1 (0.94 mg cm^{-2} day^{-1} in 2023 and 0.97 mg cm^{-2} day^{-1}) at 60 – 90 DAS (0.58 mg cm^{-2} day^{-1} in 2023 and 0.58 mg cm^{-2} day^{-1} in 2024).

4.1.9. Stem diameter (mm)

The data on stem diameter (mm) of maize is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.9).

The stem diameter (mm) of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole maize (M_1) cropping increased stem diameter at 60 DAS (17.90 mm in 2023 and 19.21 mm in 2024) and at 90 DAS (21.11 mm in 2023 and 21.19 mm in 2024), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (17.68 mm in 2023 and 18.65 mm in 2024), at 90 DAS (19.90 mm in 2023 and 20.61 mm in 2024). The stem girth was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (15.21 mm in 2023 and 16.71 mm in 2024), at 90 DAS (16.36 mm in 2023 and 16.79 mm in 2024).

Similarly, the nutrient application differed significantly on stem diameter at 90 DAS except 30 and 60 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the stem diameter at 90 DAS (19.59 mm in 2023 and 20.00 mm in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) at 90 DAS (19.52 mm in 2023 and 19.83 mm in 2024) and 70% RDF with two foliar applications of Homemade NPK (S_4) 90 DAS (19.53 mm

Table 4.9. Effect of planting system and nutrient management on stem diameter (mm) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	8.71	9.57	17.9	19.21	21.11	21.19
M_3	7.8	9.59	17.68	18.65	19.9	20.61
M_4	7.81	9.26	16.94	17.26	18.26	18.65
M_5	7.49	8.91	16.71	16.71	16.36	16.79
SEm±	0.38	0.29	0.25	0.35	0.54	0.4
CD (P = 0.05)	NS	NS	0.88	1.23	1.92	1.41
Nutrient management						
S_1	7.71	9.07	16.91	17.46	17.81	18.44
S_2	8.15	9.54	17.51	18.36	19.59	20
S_3	8.19	9.28	17.24	17.89	18.09	18.53
S_4	7.81	9.32	17.44	18.04	19.53	19.77
S_5	7.92	9.46	17.44	18.03	19.52	19.83
SEm±	0.36	0.3	0.28	0.36	0.48	0.38
CD (P = 0.05)	NS	NS	NS	NS	1.38	1.11

in 2023 and 19.77 mm in 2024). The lowest stem diameter was observed in control treatment (S_1) at 90 DAS (17.81 mm in 2023 and 18.44 mm in 2024).

The interaction effect of cropping system and nutrient management is not significantly with respect to stem girth at 30, 60 and 90 DAS.

4.1.10. Internode length (mm)

The data on internode length (mm) of maize is influenced by cropping system and nutrient management at maturity during 2023 and 2024 (Table 4.10).

The internode length of maize differed significantly with cropping system at maturity stage. During both the years, sole maize (M_1) cropping increased internode length at maturity (12.30 cm in 2023 and 12.79cm in 2024), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at maturity (10.98 cm in 2023 and 11.27 cm in 2024). The internode length was observed in 2:3 row proportions of maize and soybean (M_5) at maturity (9.12 cm in 2023 and 2.24 cm in 2024).

Similarly, the nutrient application differed significantly on internode length at maturity during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the internode length at maturity (12.50 cm in 2023 and 13.00 cm in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at maturity (11.42 cm in 2023 and 11.87 cm in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at maturity (11.05 cm in 2023 and 11.49 cm in 2024). The lowest internode length was observed in control treatment (S_1) at maturity (7.93 cm in 2023 and 8.25 cm in 2024).

The interaction effect of cropping system and nutrient management is not significantly with respect to internode length at maturity stage.

4.1.11. Chlorophyll index (SPAD value)

The data on chlorophyll index of maize is influenced by cropping system and nutrient management at 30, 60 and 90 DAS 2023 and 2024 (Table 4.11a).

The chlorophyll index (SPAD value) of maize differed significantly with cropping system at 60 and 90 DAS growth stages. During both the years, sole maize (M_1) cropping increased chlorophyll index at 60 DAS (40.35 in 2023 and 40.42 in 2024) and at 90 DAS (42.88 in 2023 and 45.78 in 2024), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (39.25 in 2023 and 39.39 in 2024), at 90 DAS (42.01 in 2023 and 44.11 in 2024). The lowest of chlorophyll index was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (33.61 in 2023 and 33.30 in 2024), at 90 DAS (37.07 in 2023 and 38.77 in 2024).

Table 4.10. Effect of planting system and nutrient management on internode length (cm) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	At maturity	
	2023	2024
Planting system		
M_1	12.30	12.79
M_3	10.98	11.27
M_4	9.60	9.91
M_5	9.12	9.48
SEm±	0.60	0.64
CD (P = 0.05)	2.12	2.24
Nutrient management		
S_1	7.93	8.25
S_2	12.50	13.00
S_3	9.59	9.71
S_4	11.05	11.49
S_5	11.42	11.87
SEm±	1.03	1.09
CD (P = 0.05)	2.98	3.15

Table 4.11a. Effect of planting system and nutrient management chlorophyll index of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	26.68	29.54	40.35	40.42	42.88	45.78
M_3	25.79	29.27	39.25	39.39	42.01	44.11
M_4	25.77	29.40	36.11	36.33	39.16	40.86
M_5	25.89	28.84	33.61	33.30	37.07	38.77
SEm±	0.25	0.44	0.35	0.40	0.59	0.55
CD (P = 0.05)	NS	NS	1.25	1.40	2.09	1.94
Nutrient management						
S_1	25.73	28.34	27.53	28.99	35.36	37.36
S_2	26.40	29.37	40.59	40.13	42.57	44.70
S_3	25.84	29.43	39.30	38.26	40.92	43.04
S_4	26.10	29.50	39.61	39.62	41.28	43.41
S_5	26.09	29.67	39.62	39.80	41.28	43.40
SEm±	0.16	0.37	0.41	0.43	0.54	0.54
CD (P = 0.05)	NS	NS	1.18	1.24	1.55	1.57

4.11b. Interaction effect of planting system and nutrient management chlorophyll index (SPAD) of maize at 60 DAS

M/S	2023					2024				
	M_1	M_3	M_4	M_5	**Mean**	M_1	M_3	M_4	M_5	**Mean**
S_1	28.32	28.26	27.40	26.15	**27.53**	30.12	29.15	28.68	28.02	**28.99**
S_2	44.50	42.35	38.80	36.69	**40.59**	44.03	42.34	38.45	35.70	**40.13**
S_3	42.52	41.46	37.82	35.40	**39.30**	41.79	41.03	36.96	33.26	**38.26**
S_4	43.28	41.94	38.15	35.05	**39.61**	43.02	42.16	38.76	34.52	**39.62**
S_5	43.14	42.22	38.36	34.74	**39.62**	43.14	42.26	38.79	35.01	**39.80**
Mean	**40.35**	**39.25**	**36.11**	**33.61**		**40.42**	**39.39**	**36.33**	**33.30**	
Subplot at same level of main plot										
SEm±	0.79					0.89				
CD (P = 0.05)	2.59					2.46				
Main plot at same or different level of subplot										
SEm±	0.81					0.86				
CD (P = 0.05)	2.45					2.61				

4.11c. Interaction effect of planting system and nutrient management chlorophyll index (SPAD) of maize at 90 DAS

M/S	2023					2024				
	M_1	M_3	M_4	M_5	**Mean**	M_1	M_3	M_4	M_5	**Mean**
S_1	35.48	35.99	35.79	34.19	**35.36**	38.38	36.69	37.49	36.89	**37.36**
S_2	46.67	44.89	40.36	38.36	**42.57**	49.57	47.09	42.06	40.06	**44.7**
S_3	43.83	43.06	39.46	37.32	**40.92**	46.73	45.26	41.16	39.02	**43.04**
S_4	44.21	43.57	40.1	37.24	**41.28**	47.11	45.77	41.8	38.94	**43.41**
S_5	44.2	43.55	40.11	37.24	**41.28**	47.1	45.75	41.81	38.94	**43.4**
Mean	**42.88**	**42.01**	**39.16**	**37.07**		**45.78**	**44.11**	**40.86**	**38.77**	
Subplot at same level of main plot										
SEm±	1.32					1.23				
CD (P = 0.05)	3.29					3.31				
Main plot at same or different level of subplot										
SEm±	1.13					1.12				
CD (P = 0.05)	3.46					3.4				

Similarly, the nutrient application differed significantly on chlorophyll index at 60 DAS, and 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased chlorophyll index (SPAD value) at 60 DAS (40.59 in 2023 and 40.13 in 2024), at 90 DAS (42.57 in 2023 and 44.70 in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (39.62 in 2023 and 39.80 in 2024), at 90 DAS (41.28 in 2023 and 43.40 in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (39.61 in 2023 and 39.62 nodules plant^{-1} in 2024), at 90 DAS (41.28 in 2023 and 43.41 in 2024). The lowest chlorophyll index (SPAD value) was observed in control treatment (S_1) at 60 DAS (27.53 in 2023 and 28.99 in 2024), at 90 DAS (35.36 in 2023 and 37.36 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to chlorophyll index at 60, and 90 DAS (Table 4.11 b-d), during both the years, M_2S_2 increased chlorophyll index (SPAD value) at 60 DAS (44.03 in 2023 and 44.50 in 2024), at 90 DAS (49.95 in 2023 and 52.79 in 2024), which was statistically similar with M_2S_5 at 60 DAS(43.14 in 2023 and 43.14 in 2024), at 90 DAS(44.20 in 2023 and 47.10 in 2024), M_2S_4 at 60 DAS (43.02 in 2023 and 43.28 in 2024), at 90 DAS (44.21 in 2023 and 47.11 in 2024), M_2S_3 at 60 DAS (41.79 in 2023 and 42.52 in 2024), at 90 DAS (43.83 in 2023 and 46.73 in 2024), M_3S_2 at 60 DAS (42.34 in 2023 and 42.35 in 2024), at 90 DAS (44.89 in 2023 and 47.09 in 2024), M_3S_5 at 60 DAS (42.26 in 2023 and 42.22 in 2024), at 90 DAS(43.55 in 2023), M_3S_4 at 60 DAS (42.16 in 2023). The lowest chlorophyll index (SPAD) was found in M_5S_1 at 60 DAS (28.02 in 2023 and 26.15 in 2024) and at 90 DAS (34.19 in 2023 and 36.89 in 2024).

4.1.12. Days to 50% tasseling, 50 % silking and maturity

The data on days to 50 % tasselling, 50 % silking and maturity of maize is influenced by cropping system and nutrient management 2023 and 2024 (Table 4.12).

The days to 50 % tasseling, 50 % silking and maturity of maize differed significantly with cropping system. During both the years, 2:3 row proportion of maize and soybean (M_5) was observed significant early 50 % tasselling (48 days in 2023 and 47 days in 2024), 50% silking (54 days in 2023 and 54 days in 2024) and maturity (109 days in 2023 and 109 days in 2024), which was statistically similar with 1:2 row proportion of maize and soybean (M_4) 50 % tasselling (48 days in 2023 and 47 days in 2024). 50% silking (54days in 2023 and 54 days in 2024) and maturity (107 days in 2023 and 108 days in 2024). The lowest of value was observed in sole maize (M_1) 50% tasselling (43 days in 2023 and 46 days in 2024), 50% silking (49 days in 2023 and 52 days in 2024) and maturity (104 days in 2023 and 105 days in 2024).

Similarly, the nutrient application differed significantly on 50 % tasselling, 50 % silking and maturity of maize during 2023 and 2024. During both the years, 100% RDF (S_2) application increased

Table 4.12. Effect of planting system and nutrient management on days to 50% tasselling, 50% silking, and maturity of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	50% tasselling		50% silking		Maturity	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	43	46	49	52	104	105
M_3	46	46	52	53	106	107
M_4	47	46	54	53	107	108
M_5	48	47	54	54	109	109
SEm±	1	0	1	0	0	1
CD (P = 0.05)	3	0	3	1	1	3
Nutrient management						
S_1	42	42	47	47	101	105
S_2	48	48	55	55	109	108
S_3	46	47	52	53	107	107
S_4	47	47	53	54	108	107
S_5	47	48	53	54	109	108
SEm±	.6	0.6	1	0.2	0.2	0.2
C.D(p=0.05)	2	2	3	1	1	1

50 % tasselling (48 days in 2023 and 48 days in 2024), 50 % silking (55 days in 2023 and 55 days in 2024) and maturity of maize (109 days in 2023 and 108 days in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) 50% tasselling (47 days in 2023 and 48 days in 2024), 50% silking (53 days in 2023 and 54 days in 2024), and maturity (109 days in 2023 and 108 days in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) 50% tasselling (47 days in 2023 and 47 days in 2024), 50% silking (53 days in 2023 and 54 days in 2024) and maturity (108 days in 2023 and 107 days in 2024).The lowest 50 % tasselling, 50 % silking and maturity of maize was observed in control treatment (S_1) 50 % tasselling (42 days in 2023 and 42 days in 2024), 50 % silking (47 days in 2023 and 47 days in 2024) and maturity (101 days in 2023 and 105 days in 2024). The interaction effect of cropping system and nutrient management, there was no significant interaction was recorded respect to 50% tasselling, 50% silking and maturity.

4.2. Yield and yield parameters

4.2.1. Number of cobs plant^{-1}

The data on number of cobs plant^{-1} of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.13a).

The number of cobs plant^{-1} of maize crop was non- significant with the cropping system, during both the year, here was non-significant difference was noticed with the cropping pattern of maize crop.

The nutrient application differed significantly on number of cobs plant^{-1}**,** during 2023 and 2024. During both the years, 100% RDF (S_2) application increased number of cobs plant^{-1} (1.70 in 2023 and 1.71 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (1.52 in 2023 and 1.56 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (2.10 in 2023 and 2.19 in 2024). The lowest number of cobs plant^{-1} was observed in control treatment (S_1) (0.52 in 2023 and 0.59 g in 2024).

The interaction effect of cropping system and nutrient management, there was no interaction effect respect to number of cobs plant^{-1}.

4.2.2. No. of grain row cob^{-1}

The data on number of grain row cob^{-1} of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.13).

The grain row cob^{-1} of maize differed significantly with cropping system. During both the years, sole maize increased number of grain row cob^{-1} (15.02 in 2023 and 15.02 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (13.68 in 2023 and 14.48 in

Table 4.13a. Effect of planting system and nutrient management on number of cobs plant^{-1}, number of grain row^{-1} cob^{-1} and number of grain row cob^{-1} of maize under maize + soybean - oat cropping system (2023-24)

Treatment	Number of cobs plant^{-1}		No. of grain row cob^{-1}		No. of grain row^{-1} cob^{-1}	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	1.39	1.41	15.02	15.02	21.19	21.53
M_3	1.33	1.37	13.68	14.48	20.32	21.04
M_4	1.29	1.32	12.58	13.89	19.21	19.77
M_5	1.23	1.25	12.03	12.99	18.03	18.28
SEm±	0.09	0.06	0.42	0.06	0.35	0.16
CD (P = 0.05)	NS	NS	1.47	0.23	1.24	0.56
Nutrient management						
S_1	0.52	0.59	11.06	10.99	16.64	17.34
S_2	1.70	1.71	14.2	15.1	20.96	21.28
S_3	1.31	1.32	13.55	14.66	19.7	20.02
S_4	1.49	1.51	13.89	14.76	20.52	21.06
S_5	1.52	1.56	13.93	14.97	20.62	21.08
SEm±	0.09	0.06	0.17	0.08	0.21	0.14
CD (P = 0.05)	0.27	0.18	0.48	0.23	0.62	0.4

4.13b. Interaction effect of planting system and nutrient management on grain row cob^{-1} of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	11.85	11.15	10.69	10.55	**11.06**	11.69	11.17	10.86	10.24	**10.99**
S_2	15.85	14.34	13.83	12.79	**14.20**	16.00	15.45	14.80	14.16	**15.10**
S_3	15.78	14.23	12.68	11.49	**13.55**	15.76	15.22	14.50	13.16	**14.66**
S_4	15.80	14.37	12.75	12.64	**13.89**	15.81	15.28	14.64	13.33	**14.76**
S_5	15.81	14.28	12.93	12.70	**13.93**	15.84	15.30	14.66	14.06	**14.97**
Mean	**15.02**	**13.67**	**12.58**	**12.03**		**15.02**	**14.48**	**13.89**	**12.99**	
Subplot at same level of main plot										
SEm±	0.93					0.14				
CD (P = 0.05)	1.10					0.49				
Main plot at same or different level of subplot										
SEm±	0.51					0.16				
CD (P = 0.05)	1.70					0.48				

4.13c. Interaction effect of planting system and nutrient management on grain row^{-1} cob^{-1} of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	17.19	17.15	16.35	15.85	**16.64**	18.63	17.97	17.69	15.04	**17.33**
S_2	22.08	22.05	21.01	18.71	**20.96**	22.49	22.23	20.78	19.64	**21.28**
S_3	21.57	20.20	18.43	18.57	**19.69**	22.11	20.85	19.20	17.89	**20.01**
S_4	22.55	21.09	20.11	18.33	**20.52**	22.33	22.00	20.55	19.37	**21.06**
S_5	22.57	21.09	20.15	18.68	**20.62**	22.11	22.12	20.64	19.45	**21.08**
Mean	**21.19**	**20.32**	**19.21**	**18.03**		**21.53**	**21.03**	**19.77**	**18.28**	
Subplot at same level of main plot										
SEm±	0.79					0.35				
CD (P = 0.05)	1.37					0.85				
Main plot at same or different level of subplot										
SEm±	0.52					0.29				
CD (P = 0.05)	1.66					0.91				

2024). The lowest number of grain row cob^{-1} was observed in 2:3 row proportion of maize and soybean (M_5) (18.03 in 2023 and 18.28 in 2024).

Similarly, the nutrient application differed significantly on number of grain row cob^{-1} during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of grain row cob^{-1} (14.20 in 2023 and 15.10 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (13.93 in 2023 and 14.97 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (13.89 in 2023 and 14.76 in 2024). The lowest number of grain row cob^{-1} was observed in control treatment (S_1) (11.06 in 2023 and 10.99 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to number of grain row^{-1} cob^{-1} (Table 4.13b), during both the years, M_1S_2 increased number of grain row cob^{-1} (22.08 in 2023 and 22.49 in 2024) which was statistically similar with M_1S_5 (22.57 in 2023 and 22.11 in 2024), M_1S_4 (22.55 in 2023 and 22.33 in 2024), M_1S_3 (21.57 in 2023 and 22.11 in 2024), M_3S_2 (22.05 in 2023 and 22.23 in 2024), M_3S_5 (21.09 in 2023 and 22.12 in 2024), M_3S_4 (21.09 in 2023 and 22.0 in 2024), M_3S_5 (21.01 in 2023). The lowest number of grain row cob^{-1} was found in M_5S_1 (15.85 in 2023 and 15.04 in 2024).

4.2.3. Number of grain row cob^{-1}

The data on number of grain row cob^{-1} of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.13).

The number of grain row^{-1} cob^{-1} of maize differed significantly with cropping system. During both the years, sole maize increased number of grain row^{-1} cob^{-1} (21.19 in 2023 and 21.53 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (20.32 in 2023 and 21.04 in 2024). The lowest number of grain row^{-1} cob^{-1} was observed in 2:3 row proportion of maize and soybean (M_5) (18.03 in 2023 and 18.28 in 2024).

Similarly, the nutrient application differed significantly on number of grain row^{-1} cob^{-1} during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of grain row^{-1} cob^{-1} (20.96 in 2023 and 21.28 in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) (20.62 in 2023 and 21.08 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (20.52 in 2023 and 21.06 in 2024). The lowest number of grain row^{-1} cob^{-1} was observed in control treatment (S_1) (16.64 in 2023 and 17.34 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to number of grain row^{-1} cob^{-1} (Table 4.13c), during both the years, M_1S_2 increased number of grain row^{-1} cob^{-1} (22.08 in 2023 and 22.49 in 2024) which was statistically similar with M_1S_5 (22.57 in 2023 and 22.11 in 2024), M_1S_4 (22.55 in 2023 and 22.33 in 2024), M_1S_3 (21.57 in 2023 and 22.11 in

2024), M_3S_2 (22.05 in 2023 and 22.23 in 2024), M_3S_5 (21.09 in 2023 and 22.12 in 2024), M_3S_4 (21.09 in 2023 and 22.0 in 2024), M_3S_5 (21.01 in 2023) . The lowest number of grain row^{-1} cob^{-1} was found in M_5S_1 (15.85 in 2023 and 15.04 in 2024).

4.2.4. Cob girth (cm)

The data on cob girth (cm) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.14a).

The cob girth (cm) of maize differed significantly with cropping system. During both the years, sole maize increased cob girth (4.37 cm in 2023 and 4.61 cm in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (4.09 cm in 2023 and 4.52 cm in 2024). The lowest cob girth (cm) was observed in 2:3 row proportion of maize and soybean (M_5) (18.03 cm in 2023 and 18.28 cm in 2024).

Similarly, the nutrient application differed significantly on cob girth (cm) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the cob girth (4.25 cm in 2023 and 4.79 cm in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (4.20 cm in 2023 and 4.78 cm in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (4.19 cm in 2023 and 4.74 cm in 2024). The lowest cob girth (cm) was observed in control treatment (S_1) (2.95 cm in 2023 and 3.46 cm in 2024).

The interaction effect of cropping system and nutrient management, there was no interaction effect respect to cob girth (cm).

4.2.5. Cob length (cm)

The data on cob length (cm) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.14a).

The cob length (cm) of maize differed significantly with cropping system. During both the years, sole maize increased cob length (15.33 cm in 2023 and 16.23 cm in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (15.05 cm in 2023 and 16.14 cm in 2024). The lowest cob length (cm) was observed in 2:3 row proportion of maize and soybean (M_5) (14.55 cm in 2023 and 15.62 cm in 2024).

Similarly, the nutrient application differed significantly on cob length (cm) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the cob length (15.21 cm in 2023 and 16.46 cm in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (15.16 cm in 2023 and 16.39 cm in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (15.15 cm in 2023 and 16.24 cm in 2024). The lowest cob length (cm) was observed in control treatment (S_1) (13.91 cm in 2023 and 16.23 cm in 2024).

Table 4.14a. Effect of planting system and nutrient management on yield attributes of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	Cob girth (cm)		Cob length (cm)		100 seed weight (g)	
	2023	2024	2023	2024	2023	2024
Planting system						
M_1	4.37	4.61	15.33	16.23	34.1	36.62
M_3	4.09	4.52	15.05	16.14	32.24	33.60
M_4	3.72	4.49	14.68	16.09	30.26	30.78
M_5	3.59	4.37	14.55	15.62	26.97	28.06
SEm±	0.03	0.02	0.03	0.05	0.36	0.36
C.D (0.05)	0.12	0.08	0.11	0.18	1.26	1.26
Nutrient management						
S_1	2.95	3.46	13.91	14.84	29.91	30.67
S_2	4.25	4.79	15.21	16.46	31.91	33.91
S_3	4.13	4.71	15.09	16.18	30.57	31.74
S_4	4.19	4.74	15.15	16.24	30.78	32.09
S_5	4.2	4.78	15.16	16.39	31.31	32.94
SEm±	0.03	0.03	0.03	0.08	0.38	0.38
C.D (0.05)	0.09	0.09	0.09	0.23	1.09	1.09

4.14b. Interaction effect of planting system and nutrient management on 100 seed weight (g) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	30.89	30.62	29.76	28.36	**29.91**	31.41	30.97	29.98	30.31	**30.67**
S_2	35.91	33.57	30.9	27.24	**31.91**	39.54	35.76	31.83	28.5	**33.91**
S_3	34.07	32.37	29.84	25.97	**30.57**	36.57	33.82	30.12	26.45	**31.74**
S_4	34.57	31.57	30.37	26.6	**30.78**	37.38	32.52	30.98	27.47	**32.09**
S_5	35.07	33.07	30.4	26.67	**31.31**	38.19	34.95	31.02	27.58	**32.94**
Mean	**34.1**	**32.24**	**30.26**	**26.97**		**36.62**	**33.6**	**30.78**	**28.06**	
Subplot at same level of main plot										
SEm±	0.8					1.29				
CD (P = 0.05)	2.28					3.7				
Main plot at same or different level of subplot										
SEm±	0.76					1.23				
CD (P = 0.05)	2.31					3.74				

The interaction effect of cropping system and nutrient management, there was no interaction effect respect to cob length (cm).

4.2.6. 100 seed weight (g)

The data on 100 seed weight of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.14a).

The 100 seed weight (g) of maize differed significantly with cropping system. During both the years, sole maize increased seed weight (34.10 g in 2023 and 36.62 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (32.24 g in 2023 and 33.60 g in 2024). The lowest seed weight was observed in 2:3 row proportion of maize and soybean (M_5) (26.97 g in 2023 and 28.06 g in 2024).

Similarly, the nutrient application differed significantly on seed weight (g), during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the seed weight (31.91 g in 2023 and 3.91 g in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) (31.31 g in 2023 and 32.94 g in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (30.78 g in 2023 and 32.09 in 2024). The lowest seed weight was observed in control treatment (S_1) (29.91 g in 2023 and 30.67 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to seed weight (g) (Table 4.14b), during both the years, M_1S_2 increased seed index(35.91g in 2023 and 39.54 in 2024) which was statistically similar with M_1S_5 (35.07 g in 2023 and 38.19 g in 2024), M_1S_4 (34.57 g in 2023 and 37.38 g in 2024), M_1S_3 (34.07 g in 2023 and 36.57 g in 2024). The lowest seed index(g) was found in M_5S_3 (25.97 g in 2023 and 26.45 g in 2024).

4.2.7. Cob weight plant^{-1} (g)

The data on cob weight plant^{-1} (g) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.15a).

The cob weight plant^{-1} (g) of maize differed significantly with cropping system. During both the years, sole maize (M_1) increased cob weight plant^{-1} (280.29 g in 2023 and 281.59 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (278.28 g in 2023 and 281.19 g in 2024). The lowest cob weight plant^{-1} (g) was observed in 2:3 row proportion of maize and soybean (M_5) (274.16 g in 2023 and 275.77 g in 2024).

Similarly, the nutrient application differed significantly on cob weight plant^{-1} (g) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the cob weight plant^{-1} (282.90 g in 2023 and 283.61 g in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) (282.72 g in 2023 and 283.11 g in 2024), and 70% RDF with two

Table 4.15a. Effect of planting system and nutrient management on yield attributes of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	Grain weight (g cob^{-1})		Cob weight (g $plant^{-1}$)		Shelling (%)	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**
Planting system						
M_1	154.99	157.52	280.29	281.59	55.3	55.92
M_3	151.82	155.13	278.28	281.19	54.52	55.15
M_4	149.97	153.81	276.84	279.89	54.14	54.93
M_5	147.36	150.64	274.16	275.77	53.7	54.6
SEm±	0.43	0.14	0.46	0.31	0.15	0.07
C.D (0.05)	1.51	0.5	1.63	1.09	0.54	0.25
Nutrient management						
S_1	136.39	141.1	258.74	267.72	52.69	52.7
S_2	155.24	158.17	282.9	283.61	54.87	55.79
S_3	154.21	156.79	281.05	281.01	54.87	55.77
S_4	154.48	157.49	281.55	282.59	54.87	55.73
S_5	154.85	157.83	282.72	283.11	54.77	55.75
SEm±	0.25	0.2	0.49	0.31	0.12	0.11
C.D (0.05)	0.73	0.58	1.42	0.89	0.36	0.32

4.15b. Interaction effect of planting system and nutrient management on cobs weight (g) $plant^{-1}$ of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	265.55	260.15	255.69	253.55	**258.74**	269.17	268.62	267.12	265.95	**267.72**
S_2	284.43	283.31	283.32	280.89	**282.9**	285.24	284.84	284.79	279.58	**283.61**
S_3	283.45	281.9	280.68	278.15	**281.05**	284.19	283.73	279.57	276.57	**281.01**
S_4	283.94	282.37	281.26	278.64	**281.55**	284.47	284.23	283.76	277.91	**282.59**
S_5	284.09	283.65	283.25	279.55	**282.72**	284.86	284.54	284.21	278.83	**283.11**
Mean	**280.29**	**278.28**	**276.84**	**274.16**		**281.59**	**281.19**	**279.89**	**275.77**	
Subplot at same level of main plot										
SEm±	1.04					0.69				
CD (P = 0.05)	2.98					1.87				
Main plot at same or different level of subplot										
SEm±	1					0.63				
CD (P = 0.05)	3.01					1.92				

4.15c. Interaction effect of planting system and nutrient management on grain weight (g) cob^{-1} of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M$_1$	**M$_3$**	**M$_4$**	**M$_5$**	**Mean**	**M$_1$**	**M$_3$**	**M$_4$**	**M$_5$**	**Mean**
S$_1$	146.85	136.15	133.69	128.88	**136.39**	145.32	142.29	140.89	135.9	**141.1**
S$_2$	157.36	156.3	154.83	152.46	**155.24**	161.06	158.77	157.65	155.18	**158.17**
S$_3$	156.78	155.23	153.35	151.49	**154.21**	159.83	157.75	156.2	153.38	**156.79**
S$_4$	156.9	155.51	153.73	151.79	**154.48**	160.46	158.29	157.04	154.19	**157.49**
S$_5$	157.08	155.88	154.26	152.16	**154.85**	160.93	158.58	157.28	154.53	**157.83**
Mean	**154.99**	**151.81**	**149.97**	**147.36**		**157.52**	**155.13**	**153.81**	**150.64**	
Subplot at same level of main plot										
SEm±	1.08					0.32				
CD (P = 0.05)	0.94					1.19				
Main plot at same or different level of subplot										
SEm±	0.55					0.38				
CD (P = 0.05)	1.85					1.14				

4.15d. Interaction effect of planting system and nutrient management on shelling (%) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M$_1$	**M$_3$**	**M$_4$**	**M$_5$**	**Mean**	**M$_1$**	**M$_3$**	**M$_4$**	**M$_5$**	**Mean**
S$_1$	55.3	52.34	52.29	50.83	**52.69**	53.99	52.97	52.75	51.1	**52.7**
S$_2$	55.39	55.18	54.65	54.28	**54.87**	56.47	55.74	55.36	55.51	**55.77**
S$_3$	55.31	55.07	54.63	54.46	**54.87**	56.24	55.6	55.88	55.46	**55.79**
S$_4$	55.26	55.07	54.66	54.47	**54.87**	56.41	55.69	55.34	55.48	**55.73**
S$_5$	55.22	54.95	54.46	54.43	**54.77**	56.5	55.73	55.34	55.42	**55.75**
Mean	**55.3**	**54.52**	**54.14**	**53.69**		**55.92**	**55.15**	**54.93**	**54.59**	
Subplot at same level of main plot										
SEm±	0.34					0.16				
CD(p=0.05)	0.77					0.65				
Main plot at same or different level of subplot										
SEm±	0.27					0.21				
CD(p=0.05)	0.83					0.62				

foliar applications of Homemade NPK (S_4) (281.55 g in 2023 and 282.59 g in 2024). The lowest cob weight plant^{-1} (g) was observed in control treatment (S_1) (258.74 g in 2023 and 267.72 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to cob weight plant^{-1} (g) (Table 4.15b), during both the years, M_1S_2 increased cob weight plant^{-1} (284.43 g in 2023 and 285.24 g in 2024) which was statistically similar with M_1S_5 (284.09 g in 2023 and 284.86 g in 2024), M_1S_4 (283.94 g in 2023 and 284.47 g in 2024), M_1S_3 (283.45 g in 2023 and 284.19 g in 2024), M_3S_2 (283.31 g in 2023 and 284.84 g in 2024), M_3S_5 (283.65 g in 2023 and 284.54 g in 2024), M_3S_4 (282.37 g in 2023 and 284.23 g in 2024), M_3S_3 (281.90 g in 2023 and 283.73 g in 2024), M_4S_2(283.32 g in 2023 and 284.79 g in 2024), M_4S_5 (283.25 g in 2023 and 284.21 g in 2024), M_5S_4 (283.76 g in 2024). The lowest grain weight cob^{-1} was found in M_5S_1 (253.55 g in 2023 and 265.95 g in 2024).

4.2.8. Grain weight (g) cob^{-1}

The data on grain weight cob^{-1} (g) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.15a).

The grain weight cob^{-1} (g) of maize differed significantly with cropping system. During both the years, sole maize (M_1) increased grain weight cob^{-1} (154.99 g in 2023 and 157.52 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (151.82 g in 2023 and 155.13 g in 2024). The lowest grain weight cob^{-1} was observed in 2:3 row proportion of maize and soybean (M_5) (147.36 g in 2023 and 150.64 g in 2024).

Similarly, the nutrient application differed significantly on grain weight cob^{-1} (g) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the grain weight cob^{-1} (155.49 g in 2023 and 158.17 g in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (154.85 g in 2023 and 157.83 g in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (154.48 g in 2023 and 157.49 g in 2024). The lowest grain weight cob^{-1} was observed in control treatment (S_1) (136.39 g in 2023 and 141.10 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to grain weight cob^{-1} (Table 4.15c), during both the years, M_1S_2 increased grain weight cob^{-1} (157.36 g in 2023 and 161.06 g in 2024) which was statistically similar with M_1S_5 (157.08 g in 2023 and 160.93 g in 2024), M_1S_4 (156.90 g in 2023 and 160.46 g in 2024), M_1S_3 (156.78 g in 2023 and 159.83 g in 2024). The lowest grain weight cob^{-1} was found in M_5S_1 (128.88 g in 2023 and 135.90 g in 2024).

4.2.9. Shelling %

The data on shelling (%) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.15a).

The shelling (%) of maize differed significantly with cropping system. During both the years, sole maize (M_1) increased shelling (%) (55.30 % in 2023 and 55.92 % in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (54.52% in 2023 and 55.15 % in 2024). The lowest shelling (%) was observed in 2:3 row proportion of maize and soybean (M_5) (53.70 % in 2023 and 54.60 % in 2024).

Similarly, the nutrient application differed significantly on shelling (%) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the shelling (%) (54.87 % in 2023 and 55.79 % in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (54.77 % in 2023 and 55.75 % in 2024), 70% RDF with two foliar applications of Homemade NPK (S_4) (54.87 % in 2023 and 55.73 % in 2024) and 70% RDF with two foliar applications of nano NPK (S_3) (54.87 % in 2023 and 55.77 % in 2024). The selling % was observed in control treatment (S_1) (52.69 % in 2023 and 52.70 % in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to shelling (%) (Table 4.15d), during both the years, M_1S_2 increased cob weight plant^{-1} (55.39 % in 2023 and 56.47 % in 2024) which was statistically similar with M_1S_5 (54.62 % in 2023 and 56.50 % in 2024), M_1S_4 (55.26 % in 2023 and 56.41 % in 2024), M_1S_3 (55.31 % in 2023 and 56.24% in 2024), M_3S_2 (55.18 % in 2023), M_3S_5 (54.95 % in 2023) , M_3S_4 (55.07 % in 2023), M_3S_3 (55.07 % in 2023), M_4S_2(54.65 % in 2023), M_4S_4 (54.66 % in 2023), M_5S_3 (54.63 % in 2024),The lowest shelling (%) was found in M_5S_1 (50.83 % in 2023 and 51.10% in 2024).

4.2.10. Grain yield of maize (t ha^{-1})

The data on grain yield (t ha^{-1}) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.16a).

The grain yield (t ha^{-1}) of maize differed significantly with cropping system at harvesting. During both the years, sole maize (M_1) cropping increased grain yield (t ha^{-1}) (5.47 t ha^{-1} in 2023 and 5.68 t ha^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (5.26 t ha^{-1} in 2023 and 5.52 t ha^{-1} in 2024). The lowest grain yield (t ha^{-1}) was observed in 2:3 row proportions of maize and soybean (M_5) (3.83 t ha^{-1} in 2023 and 3.97 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on grain yield (t ha^{-1}) at harvesting during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the grain yield (4.87 t ha^{-1} in 2023 and 5.11 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (4.83 t ha^{-1} in 2023 and 5.09 t ha^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (4.82 t ha^{-1} in 2023 and 5.01 t ha^{-1} in 2024). The lowest grain yield was observed in control treatment (S_1) (3.88 t ha^{-1} in 2023 and 4.17 t ha^{-1} in 2024).

Table 4.16a. Effect of planting system and nutrient management on grain yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	Grain yield (t ha^{-1})		Stover yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index (%)	
	2023	2024	2023	2024	2023	2024	2023	2024
Planting system								
M_1	5.47	5.68	7.14	7.26	12.62	12.94	43.34	43.89
M_3	5.26	5.52	7.11	7.12	12.37	12.64	42.52	43.62
M_4	3.94	4.09	5.77	5.77	9.71	9.85	40.57	41.42
M_5	3.83	3.97	5.72	5.84	9.55	9.82	40.10	40.44
SEm±	0.02	0.01	0.04	0.03	0.05	0.04	0.15	0.10
C.D (0.05)	0.06	0.05	0.13	0.09	0.16	0.13	0.92	0.34
Nutrient management								
S_1	3.88	4.17	5.52	6.04	9.40	10.21	41.07	40.57
S_2	4.87	5.11	6.58	6.69	11.45	11.78	42.34	43.07
S_3	4.73	4.69	6.67	6.31	11.39	11.01	41.36	42.50
S_4	4.82	5.01	6.70	6.70	11.52	11.71	41.71	42.60
S_5	4.83	5.09	6.72	6.75	11.55	11.86	41.70	42.90
SEm±	0.03	0.04	0.04	0.03	0.05	0.06	0.24	0.18
C.D (0.05)	5.47	5.68	7.14	7.26	12.62	12.94	0.69	0.51

4.16b. Interaction effect of planting system and nutrient management on grain yield (t ha^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	M_3	M_4	M_5	Mean	M_1	M_3	M_4	M_5	Mean
S_1	4.74	4.04	3.42	3.32	**3.88**	4.97	4.64	3.58	3.48	**4.16**
S_2	5.71	5.65	4.11	4.00	**4.87**	6.03	5.85	4.32	4.20	**5.11**
S_3	5.57	5.44	4.01	3.90	**4.73**	5.51	5.44	3.97	3.86	**4.69**
S_4	5.66	5.59	4.07	3.96	**4.82**	5.88	5.82	4.23	4.11	**5.01**
S_5	5.68	5.59	4.09	3.97	**4.83**	5.99	5.84	4.34	4.22	**5.09**
Mean	**5.47**	**5.26**	**3.94**	**3.83**		**5.68**	**5.52**	**4.09**	**3.97**	
Subplot at same level of main plot										
SEm±	0.04					0.03				
CD (P = 0.05)	0.20					0.21				
Main plot at same or different level of subplot										
SEm±	0.06					0.07				
CD (P = 0.05)	0.18					0.19				

4.16c. Interaction effect of planting system and nutrient management on stover yield (t ha^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	M_3	M_4	M_5	Mean	M_1	M_3	M_4	M_5	Mean
S_1	5.58	5.68	5.50	5.32	**5.52**	6.58	6.25	5.75	5.59	**6.04**
S_2	7.63	7.33	5.86	5.71	**6.58**	7.59	7.45	5.88	5.83	**6.69**
S_3	7.44	7.45	5.92	5.77	**6.67**	7.11	7.05	5.54	5.54	**6.31**
S_4	7.55	7.51	5.94	5.79	**6.70**	7.48	7.42	5.80	6.10	**6.70**
S_5	7.52	7.57	5.84	5.84	**6.72**	7.56	7.44	5.86	6.15	**6.75**
Mean	**7.14**	**7.11**	**5.77**	**5.72**		**7.26**	**7.12**	**5.77**	**5.84**	
Subplot at same level of main plot										
SEm±	0.08					0.06				
CD (P = 0.05)	0.25					0.19				
Main plot at same or different level of subplot										
SEm±	0.08					0.06				
CD (P = 0.05)	0.25					0.20				

4.16d. Interaction effect of planting system and nutrient management on biological yield (t ha^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	10.32	9.71	8.73	8.83	**9.40**	11.54	10.89	9.33	9.06	**10.21**
S_2	13.30	12.97	9.97	9.70	**11.45**	13.59	13.30	10.20	10.02	**11.78**
S_3	13.09	12.89	9.93	9.66	**11.39**	12.63	12.49	9.51	9.40	**11.00**
S_4	13.15	13.10	10.01	9.75	**11.52**	13.35	13.24	10.03	10.22	**11.71**
S_5	13.21	13.17	9.92	9.81	**11.55**	13.58	13.28	10.20	10.37	**11.86**
Mean	**12.61**	**12.37**	**9.71**	**9.55**		**12.94**	**12.64**	**9.85**	**9.81**	
Subplot at same level of main plot										
SEm±	0.10					0.08				
CD (P = 0.05)	0.33					0.34				
Main plot at same or different level of subplot										
SEm±	0.11					0.11				
CD (P = 0.05)	0.32					0.32				

4.16e. Interaction effect of planting system and nutrient management on harvest index (%) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	42.97	42.55	40.12	40.33	**41.07**	43.02	42.59	38.35	38.33	**40.57**
S_2	45.43	43.51	41.24	41.18	**42.34**	44.12	43.99	42.32	41.87	**43.07**
S_3	42.53	42.19	40.39	40.39	**41.36**	43.64	43.57	41.73	41.03	**42.49**
S_4	42.84	42.69	40.69	40.64	**41.71**	44.01	43.96	42.18	40.26	**42.60**
S_5	43.67	42.47	41.19	40.49	**41.70**	44.36	43.98	42.55	40.70	**42.90**
Mean	**43.34**	**42.52**	**40.53**	**40.06**		**43.83**	**43.62**	**41.42**	**40.44**	
Subplot at same level of main plot										
SEm±	0.33					0.21				
CD (P = 0.05)	1.42					1.04				
Main plot at same or different level of subplot										
SEm±	0.45					0.33				
CD (P = 0.05)	1.35					0.97				

The interaction effect of cropping system and nutrient management differed significantly with respect to grain yield (t ha^{-1}) (Table 4.16b), during both the years, M_1S_2 increased grain yield (5.71 t ha^{-1} in 2023 and 6.03 t ha^{-1} in 2024) which was statistically similar with M_1S_5 (5.68 t ha^{-1} in 2023 and 5.99 t ha^{-1} in 2024), M_1S_4 (5.66 t ha^{-1} in 2023 and 5.88 t ha^{-1} in 2024), M_1S_3 5.57 t ha^{-1} in 2023), M_3S_2 (5.65 t ha^{-1} in 2023 and 5.85 t ha^{-1} in 2024), M_3S_5 (5.59 t ha^{-1} in 2023 and 5.84 t ha^{-1} in 2024), M_3S_4 (5.59 t ha^{-1} in 2023 and 5.82 t ha^{-1} in 2024). The lowest grain yield (t ha^{-1}) was found in M_5S_1 (3.32 t ha^{-1} in 2023 and 3.48 t ha^{-1} in 2024).

4.2.11. Stover yield (t ha^{-1})

The data on Stover yield (t ha^{-1}) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.16a).

The stover yield (t ha^{-1}) of maize differed significantly with cropping system at harvesting. During both the years, sole maize (M_1) cropping increased stover yield (t ha^{-1}) (7.14 t ha^{-1} in 2023 and 7.26 t ha^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (7.11 t ha^{-1} in 2023 and 7.12 t ha^{-1} in 2024). The lowest stover yield (t ha^{-1}) was observed in 2:3 row proportions of maize and soybean (M_5) (5.72 t ha^{-1} in 2023 and 5.84 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on stover yield (t ha^{-1}) at harvesting during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the stover yield (6.58 t ha^{-1} in 2023 and 6.69 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (6.72 t ha^{-1} in 2023 and 6.75 t ha^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (6.70 t ha^{-1} in 2023 and 6.70 t ha^{-1} in 2024). The lowest stover yield was observed in control treatment (S_1) (5.52 t ha^{-1} in 2023 and 6.04 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to stover yield (t ha^{-1}) (Table 4.16c), during both the years, M_1S_2 increased stover yield (7.63 t ha^{-1} in 2023 and 7.59 t ha^{-1} in 2024) which was statistically similar with M_1S_5 (7.52 t ha^{-1} in 2023 and 7.56 t ha^{-1} in 2024), M_1S_4 (7.55 t ha^{-1} in 2023 and 7.48 t ha^{-1} in 2024), M_1S_3 7.44 t ha^{-1} in 2023), M_3S_2 (7.33 t ha^{-1} in 2023 and 7.45 t ha^{-1} in 2024), M_3S_5 (7.57 t ha^{-1} in 2023 and 7.44 t ha^{-1} in 2024), M_3S_4 (7.51 t ha^{-1} in 2023 and 7.42 t ha^{-1} in 2024), M_3S_3 (7.45 t ha^{-1} in 2023).The lowest stover yield (t ha^{-1}) was found in M_5S_1 (5.32 t ha^{-1} in 2023 and 5.59 t ha^{-1} in 2024).

4.2.12. Biological yield (t ha^{-1})

The data on biological yield (t ha^{-1}) of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.16a).

The biological yield (t ha^{-1}) of maize differed significantly with cropping system at harvesting. During both the years, sole maize (M_1) cropping increased biological yield (t ha^{-1}) (12.62 t ha^{-1} in 2023 and 12.94 t ha^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (12.37 t ha^{-1} in 2023 and 12.64 t ha^{-1} in 2024). The lowest biological yield (t ha^{-1}) was observed in 2:3 row proportions of maize and soybean (M_5) (9.55 t ha^{-1} in 2023 and 9.82 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on biological yield (t ha^{-1}) at harvesting during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the biological yield (11.45 t ha^{-1} in 2023 and 11.78 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (11.55 t ha^{-1} in 2023 and 11.86 t ha^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (11.52 t ha^{-1} in 2023 and 11.71 t ha^{-1} in 2024). The lowest biological yield was observed in control treatment (S_1) (9.40 t ha^{-1} in 2023 and 10.21 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to biological yield (t ha^{-1}) (Table 4.16d), during both the years, M_1S_2 increased biological yield (13.30 t ha^{-1} in 2023 and 13.59 t ha^{-1} in 2024) which was statistically similar with M_1S_5 (13.21 t ha^{-1} in 2023 and 13.58 t ha^{-1} in 2024), M_1S_4 (13.15 t ha^{-1} in 2023 and 13.35 t ha^{-1} in 2024), M_1S_3 13.09 t ha^{-1} in 2023), M_3S_2 (13.30 t ha^{-1} in 2024), M_3S_5 (13.17 t ha^{-1} in 2023 and 13.28 t ha^{-1} in 2024), M_3S_4 (13.10 t ha^{-1} in 2023 and 13.24 t ha^{-1} in 2024).The lowest biological yield (t ha^{-1}) was found in M_5S_1 (8.83 t ha^{-1} in 2023 and 9.06 t ha^{-1} in 2024).

4.2.13. Harvest index

The data on harvest index of maize is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.16a).

The harvest index of maize differed significantly with cropping system at harvesting. During both the years, sole maize (M_1) increased harvest index (43.34 in 2023 and 43.89 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (42.52 in 2023 and 43.62 in 2024). The lowest harvest index was observed in 2:3 row proportion of maize and soybean (M_3) (40.10 in 2023 and 40.44 in 2024).

Similarly, the nutrient application differed significantly on harvest index at harvesting during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the harvest index (42.34 in 2023 and 43.07 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (41.70 in 2023 and 42.90 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (41.71 in 2023 and 42.60 in 2024). The lowest harvest index was observed in control treatment (S_1) (41.07 in 2023 and 40.57 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to harvest index (Table 16e), M_1S_1 increased harvest index (45.43 in 2023 and 44.12 in 2024) which was statistically similar with M_1S_5 (44.36 in 2024), M_1S_4 (44.01 in 2024), M_1S_3 (43.64in 2024),

M_3S_2 (43.99 in 2024), M_3S_5 (43.98 in 2024), M_3S_4 (43.96 in 2024), M_5S_1 (43.57 in 2024). The lowest harvest index was found in M_3S_1 (40.33 in 2023 and 38.33 in 2024).

4.3.1. Growth parameter of soybean crop under maize + soybean - oat cropping system (2023 and 2024)

4.3.1. Plant height (cm)

The data on plant height of soybean is influenced by cropping system and nutrient management at 30, 60, 90 and at harvest during 2023 and 2024 (Table 4.17a).

The plant height of soybean differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, 2:3 row proportions of maize and soybean (M_5) cropping increased plant height at 60 DAS (44.91 cm in 2023 and 46.09 cm in 2024), at 90 DAS (88.58 cm in 2023 and 90.16 cm in 2024) and at maturity (95.65 cm in 2023 and 97.71 cm in 2024) which was statistically similar with 1:2 row proportion of maize and soybean (M_4) at 60 DAS (42.57 cm in 2023 and 44.12 cm in 2024), at 90 DAS (87.06 cm in 2023 and 88.60 cm in 2024) and at maturity (93.66 cm in 2023 and 95.67 cm in 2024). The lowest plant height was observed in sole soybean (M_5) at 60 DAS (37.28 cm in 2023 and 38.70 cm in 2024), at 90 DAS (82.00 cm in 2023 and 84.67cm in 2024) and at maturity (88.19 cm in 2023 and 90.54 cm in 2024).

Similarly, the nutrient application differed significantly on plant height at 90, and at maturity except 30 and 60 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the plant height at 90 DAS (89.61 cm in 2023 and 91.68 cm in 2024) and at maturity (98.07 cm in 2023 and 99.70 cm in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 90 DAS (89.39 cm in 2023 and 90.11 in 2024) and at maturity (96.70 cm in 2023 and 98.38 cm in 2024), and 70% RDF with two foliar application of Homemade NPK (S_4) at 90 DAS (88.75 cm in 2023 and 90.11 cm in 2024) and at maturity (95.87 cm in 2023 and 97.64 cm in 2024). The lowest plant height was observed in control treatment (S_1) at 90 DAS (76.92 cm in 2023 and 78.55 cm in 2024) and at maturity (81.30 cm in 2023 and 82.56 cm in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to plant height at maturity but there is no significant effect at 30 and 60 DAS (Table 4.17b-c), during both the years, M_5S_2 increased plant height at 90 DAS (92.75 cm in 2023 and 96.05 cm in 2024), at maturity (101.09 cm in 2023 and 105.40 cm in 2024) which was statistically similar with M_5S_5 at 90 DAS(92.48 cm in 2023 and 95.93 cm in 2024), at maturity(165.96 cm in 2023 and 165.57 cm in 2024), M_5S_4 at 90 DAS (91.77 cm in 2023 and 94.87 cm in 2024), at maturity (99.82 cm in 2023 and 103.86 cm in 2024),M_4S_2 at 90 DAS(91.36 cm in 2023 and 94.96 cm in 2024) at maturity(99.28 cm in 2023 and 103.98 cm in 2024), M_4S_5 at 90 DAS(91.77 cm in 2023 and 93.39 cm in 2024), at maturity (165.96 cm in 2023 and 165.57 cm in 2024),M_4S_4 at 90 DAS(91.37 cm in 2023 and 91.64 cm

Table 4.17a. Effect of planting system and nutrient management on plant height (cm) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60DAS		90DAS		At maturity	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
Planting system								
M_2	11.64	14.8	37.28	38.7	82	84.67	88.07	90.54
M_3	11.74	15.12	39.27	40.4	84.75	86.15	91.08	92.47
M_4	12.15	15.48	42.57	44.12	87.06	88.6	93.66	95.67
M_5	12.46	15.63	44.91	46.09	88.58	90.16	95.65	97.71
SEm±	0.18	0.18	1.27	1.49	1.19	1.12	1.27	1.46
CD (P = 0.05)	NS	NS	4.47	5.26	4.19	3.94	4.47	5.14
Nutrient management								
S_1	11.41	14.54	39.8	40.41	76.92	78.55	81.3	82.56
S_2	12.38	15.94	41.7	43.34	89.61	91.68	98.07	99.7
S_3	11.97	14.96	40.76	42.36	83.32	85.95	88.78	92.21
S_4	12.13	15.2	41.12	42.76	88.75	90.11	95.87	97.64
S_5	12.09	15.66	41.65	42.76	89.39	90.67	96.7	98.38
SEm±	0.26	0.36	0.91	1.1	0.93	0.99	1.24	1.29
CD (P = 0.05)	NS	NS	NS	NS	2.69	2.86	3.59	3.73

4.17b. Interaction effect of planting system and nutrient management on plant height (cm) of soybean at 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	74.56	81.98	74.40	76.75	**76.92**	78.00	82.29	75.04	78.88	**78.55**
S_2	86.93	87.38	91.36	92.75	**89.61**	87.41	88.30	94.96	96.05	**91.68**
S_3	76.92	80.47	86.72	89.17	**83.32**	84.47	86.33	87.94	85.06	**85.95**
S_4	85.72	86.13	91.37	91.77	**88.75**	86.63	87.29	91.64	94.87	**90.11**
S_5	85.89	87.77	91.42	92.48	**89.39**	86.84	86.53	93.39	95.93	**90.67**
Mean	**82.00**	**84.75**	**87.05**	**88.58**		**84.67**	**86.15**	**88.60**	**90.16**	
Subplot at same level of main plot										
SEm±	2.66					2.50				
CD (P = 0.05)	5.78					6.07				
Main plot at same or different level of subplot										
SEm±	2.04					2.09				
CD (P = 0.05)	6.35					6.42				

4.17c. Interaction effect of planting system and nutrient management on plant height (cm) of soybean at maturity

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	80.23	87.04	77.13	80.8	**81.3**	81.84	87.44	77.97	82.99	**82.56**
S_2	95.67	96.25	99.28	101.09	**98.07**	94.11	95.28	103.98	105.4	**99.69**
S_3	80.42	85.05	93.22	96.42	**88.78**	90.27	92.71	94.81	91.04	**92.21**
S_4	91.91	92.45	99.29	99.82	**95.87**	93.11	93.96	99.64	103.86	**97.64**
S_5	92.13	94.59	99.35	100.73	**96.7**	93.37	92.97	101.93	105.24	**98.38**
Mean	**88.07**	**91.08**	**93.65**	**95.65**		**90.54**	**92.47**	**95.67**	**97.71**	
Subplot at same level of main plot										
SEm±	2.83					3.259				
CD (P = 0.05)	7.56					7.924				
Main plot at same or different level of subplot										
SEm±	2.55					2.73				
CD (P = 0.05)	7.79					8.39				

in 2024) at maturity(99.29 cm in 2023 and 99.64 cm in 2024), M_3S_2 at 90 DAS(87.38 cm in 2023) at maturity(96.25 cm in 2023),M_3S_5 at 90 DAS(87.77 cm in 2023) at maturity(94.59 cm in 2023), M_2S_2 at maturity (95.67 cm in 2023). The lowest plant height was found in M_2S_1 at maturity at 90 DAS (74.56 cm in 2023) at maturity (80.23 cm in 2023), and M_4S_2 at 90DAS (75.04 cm in 2024), at maturity (77.97 cm in 2024 and 103.98 cm in 2024).

4.3.2. Dry matter accumulation (g)

The data on dry matter accumulation of maize is influenced by cropping system and nutrient management at 30, 60, 90 and at harvest during 2023 and 2024 (Table 4.18a).

The dry matter accumulation of maize differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole soybean (M_2) cropping increased dry matter accumulation at 60 DAS (15.67 g in 2023 and 19.03 g in 2024), at 90 DAS (37.48 g in 2023 and 38.31 g in 2024) and at maturity (48.42 g in 2023 and 48.86 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (15.06 g in 2023 and 18.27 g in 2024), at 90 DAS (35.60 g in 2023 and 36.18 g in 2024) and at maturity (43.45 g in 2023 and 44.45 g in 2024). The lowest dry matter accumulation was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (11.50 g in 2023 and 14.59 g in 2024), at 90 DAS (24.43 g in 2023 and 25.28 g in 2024) and at maturity (33.54 g in 2023 and 35.66 g in 2024).

Similarly, the nutrient application differed significantly on dry matter accumulation at 60, 90 DAS and at maturity except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the dry matter accumulation at 60 DAS (15.89 g in 2023 and 19.11 g in 2024), at 90 DAS (38.17 g in 2023 and 38.51 g in 2024) and at maturity (48.21 g in 2023 and 49.52 g in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (15.22 g in 2023 and 18.30 g in 2024), at 90 DAS (36.08 g in 2023 and 36.33 g in 2024) and at maturity (45.60 g in 2023 and 47.22 g in 2024), and 70% RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (14.82 g in 2023 and 18.37 g in 2024), at 90 DAS (34.81 g in 2023 and 36.11 g in 2024) and at maturity (44.02 g in 2023 and 45.99 g in 2024). The lowest plant height was observed in control treatment (S_1) at 60 DAS (11.75 g in 2023 and 14.54 g in 2024), 90 DAS (25.24 g in 2023 and 25.73 g in 2024) and at maturity (32.05 g in 2023 and 31.98 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to dry matter accumulation at 60, and 90 DAS and maturity (Table 4.18b-d) during both the years, M_2S_2 increased dry matter accumulation at 60 DAS (17.16 g in 2023 and 21.55 g in 2024), at 90 DAS (42.14 g in 2023 and 45.55 g in 2024), at maturity (53.68 g in 2023 and 58.05 in 2024 g) which was statistically similar with M_2S_5 at 60 DAS(16.68 g in 2023 and 20.21 g in 2024), at 90 DAS (40.64 g in 2023 and 42.72 g in 2024), at maturity (51.80 g in 2023 and 55.01 g in 2024), M_2S_4 at 60

Table 4.18a. Effect of planting system and nutrient management on number of dry matter accumulation (g) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2023	2024	2023	2024	2023	2024	2023	2024
Planting system								
M_2	4.41	4.96	15.67	19.03	37.48	38.31	48.42	48.86
M_3	4.40	4.94	15.06	18.27	35.60	36.18	43.45	44.45
M_4	4.39	4.92	13.38	16.73	30.13	31.07	36.62	39.52
M_5	4.30	4.75	11.50	14.59	24.43	25.28	33.54	35.66
SEm±	0.02	0.05	0.35	0.51	1.17	1.01	1.45	1.14
CD (P = 0.05)	NS	NS	1.24	1.81	4.13	3.56	5.11	4.04
Nutrient management								
S_1	4.32	4.78	11.75	14.54	25.24	24.89	32.05	31.98
S_2	4.40	4.95	15.89	19.11	38.17	38.51	48.21	49.52
S_3	4.38	4.90	11.81	15.46	25.27	27.69	32.67	35.90
S_4	4.39	4.92	14.82	18.37	34.81	36.11	44.02	45.99
S_5	4.39	4.92	15.22	18.30	36.08	36.33	45.60	47.22
SEm±	0.02	0.05	0.40	0.29	1.23	1.04	1.54	1.24
C.D(p=0.05)	NS	NS	1.15	0.84	3.56	3.00	4.46	3.59

4.18b. Interaction effect of planting system and nutrient management on dry matter accumulation (g) of soybean at 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	13.34	12.50	11.28	9.89	**11.75**	16.41	15.52	16.20	10.01	**14.54**
S_2	17.16	17.40	16.21	12.80	**15.89**	21.55	19.96	17.74	17.20	**19.11**
S_3	14.02	12.03	9.53	11.66	**11.81**	17.27	15.96	15.07	13.52	**15.46**
S_4	17.13	16.62	15.26	10.28	**14.82**	19.72	19.88	17.84	16.02	**18.37**
S_5	16.68	16.76	14.60	12.86	**15.22**	20.21	20.01	16.78	16.21	**18.30**
Mean	**15.67**	**15.06**	**13.38**	**11.50**		**19.03**	**18.27**	**16.73**	**14.59**	
Subplot at same level of main plot										
SEm±	0.83					1.15				
CD (P = 0.05)	2.39					1.86				
Main plot at same or different level of subplot										
SEm±	0.80					0.73				
CD (P = 0.05)	2.42					2.34				

4.18c. Interaction effect of planting system and nutrient management on dry matter accumulation (g) of soybean at 90 DAS

M/S	2023					2024				
	M_2	M_3	M_4	M_5	**Mean**	M_2	M_3	M_4	M_5	**Mean**
S_1	30.20	27.57	23.77	19.40	**25.24**	28.07	28.15	29.89	13.46	**24.89**
S_2	42.14	42.86	39.16	28.50	**38.17**	45.55	42.36	33.33	32.80	**38.51**
S_3	32.42	26.26	17.44	24.95	**25.27**	32.53	29.53	27.43	21.29	**27.69**
S_4	42.02	40.42	36.18	20.62	**34.81**	42.67	38.65	34.01	29.12	**36.11**
S_5	40.64	40.86	34.12	28.68	**36.08**	42.72	42.19	30.68	29.72	**36.33**
Mean	**37.48**	**35.59**	**30.13**	**24.43**		**38.31**	**36.18**	**31.07**	**25.28**	
Subplot at same level of main plot										
SEm±	2.60					2.26				
CD (P = 0.05)	7.47					6.29				
Main plot at same or different level of subplot										
SEm±	2.49					2.11				
CD (P = 0.05)	7.56					6.41				

4.18d. Interaction effect of planting system and nutrient management on dry matter accumulation (g) of soybean at maturity

M/S	2023					2024				
	M_2	M_3	M_4	M_5	**Mean**	M_2	M_3	M_4	M_5	**Mean**
S_1	38.75	33.47	28.71	27.25	**32.05**	35.36	34.5	37.18	20.88	**31.98**
S_2	53.68	52.58	47.95	38.63	**48.21**	58.05	51.85	43.15	45.06	**49.52**
S_3	44.32	31.62	20.55	34.19	**32.67**	41.35	36.23	35.35	30.68	**35.9**
S_4	53.53	49.53	44.23	28.78	**44.02**	54.53	48.12	40.83	40.47	**45.99**
S_5	51.8	50.08	41.65	38.85	**45.6**	55.01	51.55	41.08	41.21	**47.21**
Mean	**48.42**	**43.45**	**36.62**	**33.54**		**48.86**	**44.45**	**39.52**	**35.66**	
Subplot at same level of main plot										
SEm±	3.25					2.56				
CD (P = 0.05)	9.34					7.52				
Main plot at same or different level of subplot										
SEm±	3.12					2.5				
CD (P = 0.05)	9.45					7.56				

DAS (17.13 g in 2023 and 19.72 in 2024), at 90 DAS (42.02 g in 2023 and 42.67 g in 2024) and at maturity (53.53 g in 2023 and 54.53 g in 2024), M_3S_2 at 60 DAS (17.40 g in 2023 and 19.36 g in 2024), at 90 DAS (42.86 g in 2023 and 42.36 g in 2024), at maturity (52.58 g in 2023 and 51.85 g in 2024), M_3S_5 at 60 DAS (16.76 g in 2023 and 20.01 g in 2024), at 90 DAS (40.86 g in 2023 and 42.19 g in 2024), at maturity (50.08 g in 2023 and 51.55g in 2024), M_3S_4 at 60 DAS (16.62 g in 2023 and 19.88 g in 2024), at 90 DAS (40.42 g in 2023), at maturity (49.53 g in 2023) and M_4S_2 (47.95 g in 2023). The lowest dry matter accumulation was found in M_5S_1 at maturity (9.89 g in 2023 and 10.01 g in 2024), at 90 DAS (19.40 g in 2023 and 13.46 g in 2024), at maturity (27.25 g in 2023 and 20.88 g in 2024).

4.3.3. Number of leaves plant^{-1}

The data on number of leaves of soybean is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.19a).

The number of leaves of soybean differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole soybean (M_1) cropping increased number of leaves at 60 DAS (12.41 in 2023 and 13.66 leaves per plant in 2024) and at 90 DAS (14.91 in 2023 and 16.12 leaves per plant in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (11.24 in 2023 and 12.18 in 2024), at 90 DAS (14.73 in 2023 and 15.81 leaves per plant in 2024). The lowest number of leaves were observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (9.95 in 2023 and 10.20 in 2024), at 90 DAS (12.64 in 2023 and 12.83 leaves per plant in 2024).

Similarly, the nutrient application differed significantly on number of leaves at 90 DAS and at maturity except 30 and 60 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of leaves at 90 DAS (14.67 in 2023 and 15.49 leaves per plant in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 90 DAS (14.23 in 2023 and 15.24 leaves per plant in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 90 DAS (14.11 in 2023 and 15.07 leaves per plant in 2024). The lowest number of leaves was observed in control treatment (S_1) at 90 DAS (12.70 in 2023 and 12.93 leaves per plant in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to dry matter accumulation at maturity but there is no significant effect at 30 and 60 DAS (Table 4.19b). during both the years, M_2S_2 increased number of leaves at 90 DAS (17.12 in 2023 and 17.50 leaves per plant in 2024) which was statistically similar with M_2S_5 (17.49 leaves per plant in 2024), M_2S_4 (16.98 leaves per plant in 2024), M_2S_3 (16.94 leaves per plant in 2024), M_3S_2 (15.58 in 2023 and 16.79 leaves per plant in 2024), M_3S_4 (16.07 leaves per plant in 2024) and M_3S_5 (16.44)

Table 4.19a. Effect of planting system and nutrient management on number of leaves plant^{-1} of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60DAS		90DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	3.71	4.39	12.41	13.66	14.91	16.12
M_3	3.39	3.97	11.24	12.18	14.73	15.81
M_4	3.27	4.39	10.74	10.72	13.35	13.99
M_5	3.29	4.81	9.95	10.2	12.64	12.83
SEm±	0.09	0.17	0.44	0.65	0.36	0.32
CD (P = 0.05)	NS	NS	1.55	2.29	1.26	1.11
Nutrient management						
S_1	3.27	3.96	10.68	11.26	12.7	12.93
S_2	3.59	4.66	11.12	11.85	14.67	15.49
S_3	3.27	4.32	11.09	11.85	13.85	14.73
S_4	3.5	4.44	11.25	11.77	14.11	15.07
S_5	3.44	4.57	11.29	11.71	14.23	15.24
SEm±	0.1	0.18	0.26	0.33	0.25	0.24
CD (P = 0.05)	NS	NS	NS	NS	0.72	0.71

4.19b. Interaction effect of planting system and nutrient management on number of leaves of soybean at 90 DAS

M/S	Number of leaves at 90 DAS									
	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	13.28	13.09	12.06	12.36	**12.70**	11.71	13.91	12.48	13.61	**12.93**
S_2	17.12	15.58	13.58	12.41	**14.67**	17.50	16.79	15.12	12.56	**15.49**
S_3	14.52	15.22	13.34	12.33	**13.85**	16.94	15.86	13.71	12.42	**14.73**
S_4	14.66	15.41	13.54	12.82	**14.11**	16.98	16.07	14.02	13.19	**15.07**
S_5	14.97	14.37	14.26	13.31	**14.22**	17.49	16.44	14.62	12.39	**15.24**
Mean	**14.91**	**14.73**	**13.35**	**12.64**		**16.12**	**15.81**	**13.99**	**12.83**	
Subplot at same level of main plot										
SEm±	0.80					0.71				
CD (P = 0.05)	1.56					1.52				
Main plot at same or different level of subplot										
SEm±	0.57					0.54				
CD (P = 0.05)	1.79					1.68				

M_3S_4 (11.97 in 2023 and 12.45 leaves per plant in 2024). The lowest number of leaves was found in M_2S_1 at 90 DAS (13.28 in 2023 and 11.71 leaves per plant in 2024).

4.3.4. Leaf area (cm^2)

The data on leaf area (cm^2) of soybean is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.20a).

The leaf area (cm^2) of soybean differed significantly with cropping system at all the growth stages except at 30 DAS. During both the years, sole soybean (M_2) cropping increased leaf area at 60 DAS (984.58 cm^2 in 2023 and 990.12 cm^2 in 2024) and at 90 DAS (1286.54 cm^2 in 2023 and 1440.0 cm^2), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (940.52 cm^2 in 2023 and 969.47 cm^2 in 2024), at 90 DAS (1223.60 cm^2 in 2023 and 1403.59 cm^2 in 2024). The leaf area was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (755.05 cm^2 in 2023 and 829.21 cm^2 in 2024), at 90 DAS (958.64 cm^2 in 2023 and 1117.73 cm^2 in 2024).

Similarly, the nutrient application differed significantly on leaf area at 60 and 90 DAS except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the leaf area at 60 DAS (968.76 cm^2 in 2023 and 977.89 cm^2 in 2024), 90 DAS (1263.95 cm^2 in 2023 and 1452.12 cm^2 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (945.08 cm^2 in 2023 and 956.57 cm^2 in 2024), at 90 DAS (1230.12 cm^2 in 2023 and 1371.71 cm^2 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 60 DAS (935.96 cm^2 in 2023 and 948.37 cm^2 in 2024), at 90 DAS (1217.08 cm^2 in 2023 and 1357.65 cm^2 in 2024). The lowest leaf area was observed in control treatment (S_1) at 60 DAS (733.83 cm^2 in 2023 and 836.03 cm^2 in 2024), at 90 DAS (928.33 cm^2 in 2023 and 1073.19 cm^2 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to leaf area at 60 and 90 DAS except 30 DAS (Table 4.20b-c). During both the years, M_2S_2 increased leaf area at 60 DAS (1145.26 cm^2 in 2023 and 1085 cm^2 in 2024), at 90 DAS (1516.08 cm^2 in 2023 and 1669 cm^2 in 2024), which was statistically similar with M_2S_5 at 60 DAS (1065.03 cm^2 in 2023 and 1013 cm^2 in 2024), at 90 DAS (1401.47 cm^2 in 2023 and 1013.5 cm^2 in 2024), M_2S_4 at 60 DAS (1047.317 cm^2 in 2023 and 997.6 cm^2 in 2024), at 90 DAS (1376.17 cm^2 in 2023 and 1547.2 cm^2 in 2024), M_3S_2 at 60 DAS (1058.05 cm^2 in 2023 and 1075.2 cm^2 in 2024), at 90 DAS (1391.50 cm^2 in 2023 and 1599.7 cm^2 in 2024), M_3S_4 at 60 DAS (1044.63 cm^2 in 2023 and 1063.2 cm^2 in 2024), at 90 DAS (1372.17 cm^2 in 2023 and 1547.3 cm^2 in 2024) and M_3S_5 at 60 DAS (1047.317 cm^2 2023 and 1065.6 cm^2 in 2024), at 90 DAS (1376.17 cm^2 2023 and 1553.9 cm^2 in 2024). The lowest leaf area was found in M_5S_1 at 60 DAS (679.7cm^2 in 2023 and 836.0 cm^2 in 2024), at 90 DAS (851.00 cm^2 in 2023 and 1026.7 cm^2 in 2024).

Table 4.20a. Effect of planting system and nutrient management on leaf area (cm^2) of soybean under maize + soybean - oat cropping system (2023 and 2024)

M/S	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	537.05	619.34	984.58	990.12	1286.54	1440.00
M_3	536.61	618.95	940.52	969.47	1223.60	1403.59
M_4	511.69	579.67	815.31	856.78	1044.73	1156.00
M_5	513.09	573.78	755.05	829.21	958.64	1117.73
SEm±	19.54	16.14	22.43	20.76	32.04	33.18
CD (P = 0.05)	NS	NS	79.13	73.23	113.04	117.07
Nutrient management						
S_1	487.43	574.68	733.83	836.03	928.33	1073.19
S_2	555.44	635.89	968.76	977.89	1263.95	1452.12
S_3	501.62	587.46	785.69	838.12	1002.42	1141.99
S_4	514.71	591.74	935.96	948.37	1217.08	1357.65
S_5	563.85	599.89	945.08	956.57	1230.12	1371.71
SEm±	21.48	17.80	18.38	17.83	26.25	26.40
CD (P = 0.05)	NS	NS	53.17	51.58	75.96	76.39

4.20b. Interaction effect of planting system and nutrient management on leaf area (cm^2) of soybean at 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	827.3	703.9	724.5	679.7	**733.8**	1044.6	756.5	775.1	768.1	**836**
S_2	1145.3	1058.1	872.9	798.8	**968.8**	1085.7	1075.2	908.6	842	**977.9**
S_3	838	848.8	773.6	682.4	**785.7**	809.2	886.9	819.3	837.1	**838.1**
S_4	1047.3	1044.6	864.9	787	**936**	997.6	1063.2	901.4	831.3	**948.4**
S_5	1065	1047.3	840.7	827.3	**945.1**	1013.5	1065.6	879.6	867.6	**956.6**
Mean	**984.6**	**940.5**	**815.3**	**755**		**990.1**	**969.5**	**856.8**	**829.2**	
Subplot at same level of main plot										
SEm±	50.2					46.4				
CD (P = 0.05)	113.7					109.9				
Main plot at same or different level of subplot										
SEm±	39.8					38				
CD (P = 0.05)	123.2					117.3				

4.20c. Interaction effect of planting system and nutrient management on leaf area (cm^2) of soybean at 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1061.8	885.5	915.0	851.0	**928.3**	1208.1	1050.7	1007.2	1026.7	**1073.2**
S_2	1516.1	1391.5	1127.0	1021.2	**1264.0**	1693.6	1599.7	1289.5	1225.6	**1452.1**
S_3	1077.2	1092.5	985.2	854.8	**1002.4**	1224.2	1266.2	1084.1	993.5	**1142.0**
S_4	1376.2	1372.3	1115.5	1004.3	**1217.1**	1524.2	1547.3	1215.8	1143.2	**1357.7**
S_5	1401.5	1376.2	1081.0	1061.8	**1230.1**	1549.9	1553.9	1183.4	1199.7	**1371.7**
Mean	**1286.5**	**1223.6**	**1044.7**	**958.6**		**1440.0**	**1403.6**	**1156.0**	**1117.7**	
Subplot at same level of main plot										
SEm±	71.6					74.2				
CD (P = 0.05)	162.5					163.8				
Main plot at same or different level of subplot										
SEm±	56.8					57.7				
CD (P = 0.05)	175.9					179.1				

4.3.5. Leaf Area Index (LAI)

The data on leaf area index of soybean is influenced by cropping system and nutrient management at 30, 60, 90 DAS during 2023 and 2024 (Table 4.21a).

The leaf area index of soybean differed significantly with cropping system at all the growth stages. During both the years, sole soybean (M_2) cropping increased leaf area index at 30 DAS (2.39 in 2023 and 2.75 in 2024), at 60 DAS (4.38 in 2023 and 4040 in 2024) and at 90 DAS (5.72 in 2023 and 6.40 in 2024). The lowest leaf area was observed in 2:3 row proportions of maize and soybean (M_5) at 30 DAS (1.71 in 2023 and 2.25 in 2024), at 60 DAS (2.52 in 2023 and 3.04 in 2024), at 90 DAS (3.20 in 2023 and 3.73 in 2024).

Similarly, the nutrient application differed significantly on leaf area at 60 and 90 DAS except 30 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the leaf area index at 60 DAS (3.55 in 2023 and 3.56 in 2024), 90 DAS (4.63 in 2023 and 5.31 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (3.45 in 2023 and 3.47 in 2024), at 90 DAS (4.49 in 2023 and 5.00 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 60 DAS (3.41 in 2023 and 3.44 in 2024), at 90 DAS (4.44 in 2023 and 4.95 in 2024). The lowest leaf area index was observed in control treatment (S_1) at 60 DAS (2.67 in 2023 and 3.08 in 2024), at 90 DAS (3.39 in 2023 and 3.91 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to leaf area index at 60 and 90 DAS but there is no significant effect at 30 DAS (Table 4.21b–c). During both the years, M_2S_2 increased leaf area index at 60 DAS (5.09 in 2023 and 4.83 in 2024), at 90 DAS (6.74 in 2023 and 7.53 in 2024), which was statistically similar with M_2S_5 at 60 DAS (4.73 in 2023 and 4.50 in 2024), at 90 DAS (6.23 in 2023 and 6.89 in 2024) and M_2S_4 at 60 DAS (4.66 in 2023 and 4.43 in 2024). The lowest leaf area index was found in M_5S_1 at 60 DAS (2.26 in 2023 and 2.56 in 2024), at 90 DAS (M_5S_1 2.84 in 2023 and M_4S_1 3.36 in 2024).

4.3.6. Crop growth rate (mg cm^{-2} day^{-1})

The data on CGR of soybean is influenced by cropping system and nutrient management at 30 – 60 and 60 – 90 DAS 2023 and 2024 (Table 4.22a).

The crop growth rate (CGR) of soybean differed significantly with cropping system at all the growth stages. During both the years, sole soybean (M_2) cropping increased crop growth rate at 30 - 60 DAS (1.668 mg cm^{-2} day^{-1} in 2023 and 2.085 mg cm^{-2} day^{-1} in 2024) and at 60 - 90 DAS (3.232 mg cm^{-2} day^{-1} in 2023 and 2.856 mg cm^{-2} day^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 30 - 60 DAS (1.561 in 2023). The lowest crop growth rate was observed in 2:3 row proportions of maize and soybean (M_5) at 30 - 60 DAS (1.066 mg cm^{-2} day^{-1}

Table 4.21a. Effect of planting system and nutrient management on LAI of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	2.39	2.75	4.38	4.4	5.72	6.4
M_3	1.79	2.06	3.14	3.23	4.08	4.68
M_4	1.71	1.93	2.72	2.86	3.48	3.85
M_5	1.71	1.91	2.52	2.76	3.2	3.73
SEm±	0.07	0.06	0.09	0.08	0.13	0.14
C.D(p=0.05)	0.24	0.2	0.33	0.29	0.47	0.5
Nutrient management						
S_1	1.77	2.08	2.67	3.08	3.39	3.91
S_2	2.01	2.3	3.55	3.56	4.63	5.31
S_3	1.82	2.13	2.85	3.02	3.64	4.15
S_4	1.87	2.15	3.41	3.44	4.44	4.95
S_5	2.02	2.17	3.45	3.47	4.49	5
SEm±	0.08	0.07	0.07	0.07	0.1	0.1
CD (P = 0.05)	NS	NS	0.2	0.19	0.29	0.29

4.21b. Interaction effect of planting system and nutrient management on LAI of soybean at 60 DAS

M/S	Leaf area Index (LAI) at 60 DAS									
	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	3.68	2.34	2.41	2.26	**2.67**	4.64	2.52	2.58	2.56	**3.08**
S_2	5.09	3.53	2.91	2.66	**3.55**	4.83	3.58	3.03	2.80	**3.56**
S_3	3.72	2.83	2.58	2.28	**2.85**	3.60	2.96	2.73	2.79	**3.02**
S_4	4.66	3.48	2.88	2.62	**3.41**	4.43	3.54	3.00	2.77	**3.44**
S_5	4.73	3.49	2.80	2.76	**3.45**	4.50	3.55	2.93	2.89	**3.47**
Mean	**4.37**	**3.13**	**2.72**	**2.52**		**4.40**	**3.23**	**2.86**	**2.76**	
Subplot at same level of main plot										
SEm±	0.21					0.19				
CD (P = 0.05)	0.43					0.41				
Main plot at same or different level of subplot										
SEm±	0.16					0.14				
CD (P = 0.05)	0.48					0.45				

4.21c. Interaction effect of planting system and nutrient management on LAI of soybean at 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4.72	2.95	3.05	2.84	**3.39**	5.37	3.50	3.36	3.42	**3.91**
S_2	6.74	4.64	3.76	3.40	**4.63**	7.53	5.33	4.30	4.08	**5.31**
S_3	4.79	3.64	3.28	2.85	**3.64**	5.44	4.22	3.61	3.31	**4.15**
S_4	6.12	4.57	3.72	3.35	**4.44**	6.77	5.16	4.05	3.81	**4.95**
S_5	6.23	4.59	3.60	3.54	**4.49**	6.89	5.18	3.94	4.00	**5.00**
Mean	**5.72**	**4.08**	**3.48**	**3.20**		**6.40**	**4.68**	**3.85**	**3.72**	
Subplot at same level of main plot										
SEm±	0.30					0.31				
CD (P = 0.05)	0.62					0.64				
Main plot at same or different level of subplot										
SEm±	0.22					0.25				
CD (P = 0.05)	0.69					0.71				

Table 4.22a. Effect of planting system and nutrient management on crop growth rate (CGR) (mg cm^{-2} day^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_2	1.668	2.085	3.232	2.856
M_3	1.561	1.481	2.283	1.99
M_4	1.331	1.311	1.862	1.594
M_5	1.066	1.094	1.439	1.187
SEm±	0.044	0.068	0.095	0.081
CD (P = 0.05)	0.155	0.239	0.336	0.285
Nutrient management				
S_1	1.078	1.191	1.655	1.259
S_2	1.702	1.728	2.707	2.378
S_3	1.101	1.286	1.667	1.501
S_4	1.547	1.632	2.453	2.185
S_5	1.606	1.628	2.539	2.211
SEm±	0.062	0.035	0.1	0.104
CD (P = 0.05)	0.18	0.102	0.289	0.301

4.22b. Interaction effect of planting system and nutrient management on CGR (mg cm^{-2} day^{-1}) of soybean at 30 – 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.330	1.123	1.037	0.823	**1.078**	1.710	1.193	1.277	0.583	**1.191**
S_2	1.890	1.920	1.737	1.260	**1.702**	2.457	1.667	1.407	1.380	**1.728**
S_3	1.427	1.130	0.757	1.090	**1.101**	1.823	1.223	1.117	0.980	**1.286**
S_4	1.883	1.807	1.610	0.887	**1.547**	2.187	1.657	1.433	1.250	**1.632**
S_5	1.810	1.827	1.517	1.270	**1.606**	2.247	1.667	1.323	1.277	**1.629**
Mean	**1.668**	**1.561**	**1.332**	**1.066**		**2.085**	**1.481**	**1.311**	**1.094**	
Subplot at same level of main plot										
SEm±	0.105					0.151				
CD (P = 0.05)	0.369					0.229				
Main plot at same or different level of subplot										
SEm±	0.120					0.093				
CD (P = 0.05)	0.359					0.300				

4.22c. Interaction effect of planting system and nutrient management on CGR (mg cm^{-2} day^{-1}) of soybean at 60 – 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	2.497	1.677	1.387	1.060	**1.655**	1.728	1.404	1.521	0.383	**1.259**
S_2	3.700	2.830	2.550	1.747	**2.707**	3.556	2.489	1.733	1.733	**2.378**
S_3	2.727	1.583	0.880	1.477	**1.667**	2.260	1.507	1.373	0.864	**1.501**
S_4	3.687	2.647	2.327	1.150	**2.453**	3.401	2.085	1.796	1.456	**2.185**
S_5	3.550	2.680	2.167	1.760	**2.539**	3.334	2.464	1.545	1.500	**2.211**
Mean	**3.232**	**2.283**	**1.862**	**1.439**		**2.856**	**1.990**	**1.594**	**1.187**	
Subplot at same level of main plot										
SEm±	0.205					0.181				
CD (P = 0.05)	0.606					0.624				
Main plot at same or different level of subplot										
SEm±	0.201					0.203				
CD (P = 0.05)	0.608					0.609				

in 2023 and 1.094 g cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (1.439 mg cm^{-2} day^{-1} in 2023 and 1.187 mg cm^{-2} day^{-1} in 2024).

Similarly, the nutrient application differed significantly on crop growth rate at 30 - 60 DAS, and at 60 – 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the crop growth rate at 30 - 60 DAS (1.702 mg cm^{-2} day^{-1} in 2023 and 1.728 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (2.707 mg cm^{-2} day^{-1} in 2023 and 2.378 mg cm^{-2} day^{-1} in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 30 – 60 DAS (1.606 mg cm^{-2} day^{-1} in 2023 and 1.628 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (2.539 mg cm^{-2} day^{-1} in 2023 and 2.211 mg cm^{-2} day^{-1} in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) at 30 – 60 DAS (1.547 mg cm^{-2} day^{-1} in 2023 and 1.632 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (2.453 mg cm^{-2} day^{-1} in 2023 and 2.185 mg cm^{-2} day^{-1} in 2024). The lowest crop growth rate was observed in control treatment (S_1) at 30 - 60 DAS (1.078 mg cm^{-2} day^{-1} in 2023 and 1.191 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (1.655 mg cm^{-2} day^{-1} in 2023 and 1.259 mg cm^{-2} day^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to 30 – 60 DAS and 60 – 90 DAS (Table 4.22b-c). during both the years, increased crop growth rate M_3S_2 at 30 – 60 DAS (1.920 mg cm^{-2} day^{-1} in 2023) and (M_2S_2) (2.457 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS M_2S_2 (3.700 mg cm^{-2} day^{-1} in 2023 and 3.556 mg cm^{-2} day^{-1} in 2024), which was statistically similar with M_2S_5 at 30 - 60 DAS (1.810 mg cm^{-2} day^{-1} in 2023 and 2.247 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (3.550 mg cm^{-2} day^{-1} in 2023 and 3.334 in 2024), M_2S_4 at 30 – 60 (1.883 mg cm^{-2} day^{-1} in 2023 and 2.187 mg cm^{-2} day^{-1} in 2024), at 60 – 90 (3.687 mg cm^{-2} day^{-1} in 2023 and 3.401 mg cm^{-2} day^{-1} in 2024), M_2S_2 at 30 – 60 DAS (1.890 mg cm^{-2} day^{-1} in 2023), M_3S_5 at 30 – 60 DAS (1.827 mg cm^{-2} day^{-1} in 2023), M_3S_4 at 30 – 60 DAS (1.807 mg cm^{-2} day^{-1} in 2023), M_4S_2 at 30 - 60 DAS (1.737 mg cm^{-2} day^{-1} in 2023), M_4S_4 at 30 – 60 DAS (1.610 mg cm^{-2} day^{-1} in 2023). The lowest crop growth rate was found in M_5S_1 at 30 – 60 DAS (0.823 mg cm^{-2} day^{-1} in 2023 and 0.583 mg cm^{-2} day^{-1} in 2024), and at 60 – 90 DAS M_4S_3 (0.880 mg cm^{-2} day^{-1} in 2023) and (M_5S_1 0.383 mg cm^{-2} day^{-1} in 2024).

4.3.7. Relative growth rate RGR (mg g^{-1} day^{-1})

The data on relative growth rate of soybean is influenced by cropping system and nutrient management at 30 – 60 and 60 – 90 DAS 2023 and 2024 (Table 4.23a).

The relative growth rate (RGR) of soybean differed significantly with cropping system at 30 – 60 DAS and 60 – 90 DAS. During both the years, sole soybean (M_2) cropping increased relative growth rate at 30 - 60 DAS (18.224 mg g^{-1} day^{-1} in 2023 and 19.298 mg g^{-1} day^{-1} in 2024), at 60 – 90 DAS (12.530 mg g^{-1} day^{-1} in 2023 and 9.881 mg g^{-1} day^{-1} in 2024) which was statically similar with 1:1 row proportion of maize and soybean at 30 - 60 DAS (17.623 mg g^{-1} day^{-1} in 2023 and 18.787 mg

Table 4.23a. Effect of planting system and nutrient management on relative growth rate (mg g^{-1} day^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_2	18.224	19.298	12.530	9.881
M_3	17.623	18.787	12.295	9.666
M_4	15.753	17.503	11.305	8.696
M_5	14.073	15.916	10.731	7.396
SEm±	0.361	0.344	0.218	0.306
CD (P = 0.05)	1.274	1.213	0.771	1.078
Nutrient management				
S_1	14.329	15.719	10.873	7.305
S_2	18.358	19.360	12.510	9.791
S_3	14.169	16.498	10.692	8.291
S_4	17.325	18.897	12.098	9.498
S_5	17.910	18.907	12.403	9.665
SEm±	0.449	0.257	0.214	0.322
CD (P = 0.05)	1.300	0.743	0.621	0.933

4.23b. Interaction effect of planting system and nutrient management on RGR (mg g^{-1} day^{-1}) of soybean at 30 – 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	15.990	15.363	14.003	11.960	**14.329**	17.540	16.907	17.740	10.690	**15.719**
S_2	19.677	19.853	18.260	15.643	**18.358**	21.127	20.067	17.787	18.460	**19.360**
S_3	16.727	14.487	11.063	14.400	**14.169**	18.023	16.947	15.760	15.260	**16.498**
S_4	19.597	19.183	17.963	12.557	**17.325**	19.760	20.013	18.453	17.360	**18.897**
S_5	19.130	19.227	17.477	15.807	**17.910**	20.040	20.000	17.777	17.810	**18.907**
Mean	**18.224**	**17.623**	**15.753**	**14.073**		**19.298**	**18.787**	**17.503**	**15.916**	
Subplot at same level of main plot										
SEm±	0.867					0.769				
CD (P = 0.05)	2.716					1.603				
Main plot at same or different level of subplot										
SEm±	0.895					0.574				
CD (P = 0.05)	2.696					1.791				

4.23c. Interaction effect of planting system and nutrient management on RGR (mg g^{-1} day^{-1}) of soybean at 60 – 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	11.640	11.433	10.767	9.650	**10.873**	7.723	8.316	8.876	4.302	**7.304**
S_2	12.997	13.053	12.487	11.503	**12.510**	10.657	10.838	8.474	9.194	**9.791**
S_3	12.140	11.217	8.520	10.890	**10.692**	9.140	8.891	8.622	6.509	**8.291**
S_4	12.990	12.870	12.463	10.070	**12.098**	11.155	9.525	9.053	8.258	**9.498**
S_5	12.883	12.900	12.287	11.543	**12.403**	10.728	10.757	8.454	8.719	**9.665**
Mean	**12.530**	**12.295**	**11.305**	**10.731**		**9.881**	**9.665**	**8.696**	**7.396**	
Subplot at same level of main plot										
SEm±	0.390					0.684				
CD (P = 0.05)	1.136					1.956				
Main plot at same or different level of subplot										
SEm±	0.378					0.653				
CD (P = 0.05)	1.145					1.980				

g^{-1} day^{-1} in 2024), at 60 - 90 DAS (12.295 mg g^{-1} day^{-1} in 2023 and 9.666 mg g^{-1} day^{-1} in 2024). The lowest relative growth rate was found with 2:3 row proportion of maize and soybean (M_5) at 30 - 60 DAS (14.073 mg g^{-1} day^{-1} in 2023 and 15.916 mg g^{-1} day^{-1} in 2024) and at 60 - 90 DAS (10.731 mg g^{-1} day^{-1} in 2023 and 7.396 mg g^{-1} day^{-1} in 2024).

The nutrient application differed significantly on relative growth rate at 30 - 60 and 60 - 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the crop growth rate at 30 - 60 DAS (18.358 mg g^{-1} day^{-1} in 2023 and 19.360 mg g^{-1} day^{-1}in 2024), at 60 - 90 (12.510 mg g^{-1} day^{-1} in 2023 and 9.791 mg g^{-1} day^{-1} in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 30 - 60 DAS (17.910 mg g^{-1} day^{-1} in 2023 and 18.907 mg g^{-1} day^{-1}), at 60 - 90 DAS (12.403 mg g^{-1} day^{-1} in 2023 and 9.665 mg g^{-1} day^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 30 - 60 DAS (17.325 mg g^{-1} day^{-1} in 2023 and 18.897 mg g^{-1} day^{-1} in 2024), at 60 - 90 DAS (12.098 mg g^{-1} day^{-1} in 2023 and 9.498 mg g^{-1} day^{-1} in 2024). The lowest relative growth rate was observed in 70 % RDF with two foliar applications of nano NPK (S_3) at 30 – 60 DAS (14.169 mg g^{-1} day^{-1} in 2023), at 60 - 90 DAS (10.692 mg g^{-1} day^{-1} in 2023) and control (S_1) at 30 - 60 DAS (15.719 mg g^{-1} day^{-1} in 2024), at 60 – 90 DAS (7.305 mg g^{-1} day^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to 30 - 60 DAS and 60 - 90 DAS (Table 4.23b-c). during both year, increased relative growth rate at 30 - 60 DAS, M_3S_2 (19.853 mg g^{-1} day^{-1} in 2023), and M_2S_2 (21.127 mg g^{-1} day^{-1} in 2024), at 60 - 90 DAS, M_3S_2 (13.053 mg g^{-1} day^{-1} in 2023) and M_2S_4 (11.155 mg g^{-1} day^{-1} in 2024) which was statically similar at 30 - 60 DAS M_2S_2 (19.67 mg g^{-1} day^{-1} in 2023), M_2S_4 (19.597 mg g^{-1} day^{-1} in 2023 and 19.760 mg g^{-1} day^{-1} in 2024), M_2S_5 (19.130 mg g^{-1} day^{-1} in 2023 and 20.040 mg g^{-1} day^{-1} in 2024), M_3S_4 (19.183 mg g^{-1} day^{-1}in 2023 and 20.013 mg g^{-1} day^{-1} in 2024),M_3S_5 (19.227 mg g^{-1} day^{-1} in 2023 and 20.013 mg g^{-1} day^{-1} in 2024), M_4S_2 (18.260 mg g^{-1} day^{-1} in 2023), M_4S_4 (17.963 mg g^{-1} day^{-1} in 2023) and M_4S_5 (17.477 mg g^{-1} day^{-1} in 2023), at 60 – 90 DAS M_2S_2 (12.997 mg g^{-1} day^{-1} in 2023 and 10.657 mg g^{-1} day^{-1} in 2024), M_2S_3(12.140 mg g^{-1} day^{-1} in 2023 and 1.914 mg g^{-1} day^{-1} in 2024), M_2S_4(12.990 mg g^{-1} day^{-1} in 2023), M_2S_5 (12.883 mg g^{-1} day^{-1} in 2023 and 10.728 mg g^{-1} day^{-1} in 2024), M_3S_4 (12.870 mg g^{-1} day^{-1} in 2023 and 9.525 mg g^{-1} day^{-1} in 2024), M_3S_5 (12.900 mg g^{-1} day^{-1} in 2023 and 10.757 mg g^{-1} day^{-1} in 2024), M_4S_2 (12.487 mg g^{-1} day^{-1} in 2023),M_4S_4 (12.463 mg g^{-1} day^{-1} in 2023), M_4S_5 (12.287 mg g^{-1} day^{-1} in 2023). The lowest crop growth rate was found in M_4S_3 at 30 - 60 DAS (11.063 mg cm^{-2} day^{-1} in 2023) and M_5S_1 (10.690 mg cm^{-2} day^{-1} in 2024), and 60 - 90 DAS M_4S_3(8.520 mg cm^{-2} day^{-1} in 2023) and M_5S_1 (4.302 mg cm^{-2} day^{-1} in 2024).

4.3.8. Net assimilation rate (NAR) (mg cm^{-2} day^{-1})

The data on net assimilation rate of soybean is influenced by cropping system and nutrient management at 30 - 60 and 60 - 90 DAS 2023 and 2024 (Table 4.24a).

Table 4.24a. Effect of planting system and nutrient management on net assimilation rate (NAR) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 - 60 DAS		60 - 90 DAS	
	2023	2024	2023	2024
Planting system				
M_2	0.101	1.353	0.067	1.343
M_3	0.092	1.293	0.065	1.279
M_4	0.080	1.260	0.058	1.201
M_5	0.055	1.078	0.048	0.876
SEm±	0.008	0.051	0.003	0.065
C.D(p=0.05)	0.028	0.179	0.010	0.229
Nutrient management				
S_1	0.062	1.047	0.050	0.900
S_2	0.099	1.367	0.069	1.343
S_3	0.063	1.171	0.049	1.019
S_4	0.099	1.334	0.063	1.309
S_5	0.086	1.312	0.066	1.303
SEm±	0.009	0.038	0.003	0.067
C.D(p=0.05)	0.025	0.109	0.009	0.195

4.24b. Interaction effect of planting system and nutrient management on NAR (mg cm^{-2} day^{-1}) of soybean at 30 - 60 DAS

M/S	2023					2024				
	M_2	M_3	M_4	M_5	**Mean**	M_2	M_3	M_4	M_5	**Mean**
S_1	0.077	0.030	0.096	0.047	**0.063**	1.037	1.273	1.333	0.543	**1.047**
S_2	0.122	0.108	0.112	0.054	**0.099**	1.480	1.343	1.287	1.357	**1.367**
S_3	0.076	0.075	0.034	0.066	**0.063**	1.393	1.140	1.107	1.043	**1.171**
S_4	0.111	0.131	0.100	0.054	**0.099**	1.420	1.353	1.333	1.230	**1.334**
S_5	0.120	0.114	0.057	0.053	**0.086**	1.433	1.357	1.240	1.217	**1.312**
Mean	**0.101**	**0.092**	**0.080**	**0.055**		**1.353**	**1.293**	**1.260**	**1.078**	
Subplot at same level of main plot										
SEm±	0.018					0.114				
CD (P = 0.05)	0.052					0.236				
Main plot at same or different level of subplot										
SEm±	0.017					0.084				
CD (P = 0.05)	0.052					0.264				

4.24c. Interaction effect of planting system and nutrient management on NAR (mg cm^{-2} day^{-1}) of soybean at 60 – 90 DAS

M/S	2023					2024				
	M_2	M_3	M_4	M_5	**Mean**	M_2	M_3	M_4	M_5	**Mean**
S_1	0.058	0.058	0.047	0.038	**0.050**	0.760	0.897	1.137	0.050	**0.711**
S_2	0.070	0.075	0.077	0.056	**0.070**	1.420	1.293	1.163	1.127	**1.251**
S_3	0.064	0.049	0.029	0.052	**0.049**	1.103	0.857	0.973	0.490	**0.856**
S_4	0.073	0.070	0.071	0.037	**0.063**	1.467	1.083	1.207	0.907	**1.166**
S_5	0.070	0.071	0.068	0.055	**0.066**	1.330	1.327	1.013	0.917	**1.147**
Mean	**0.067**	**0.065**	**0.058**	**0.048**		**1.216**	**1.091**	**1.099**	**0.698**	
Subplot at same level of main plot										
SEm±	0.006					0.128				
CD (P = 0.05)	0.019					0.401				
Main plot at same or different level of subplot										
SEm±	0.006					0.132				
CD (P = 0.05)	0.019					0.398				

The net assimilation rate (NAR) of soybean differed significantly with cropping system at 30 – 60 DAS. During both the years, sole soybean (M_2) cropping increased net assimilation rate at 30 - 60 DAS (0.101 mg cm^{-2} day^{-1} in 2023 and 1.353 mg cm^{-2} day^{-1} in 2024) at 60- 90 DAS (0.067 mg cm^{-2} day^{-1} in 2023 and 1.343 mg cm^{-2} day^{-1} in 2024), which was statically similar with 1:1 row proportion of maize and soybean (M_3) at 30 - 60 DAS (0.092 mg cm^{-2} day^{-1} in 2023 and 1.293 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.065 mg cm^{-2} day^{-1} in 2023 and 1.279 mg cm^{-2} day^{-1} in 2024). The lowest net assimilation rate was observed in 2:3 row proportions of maize and soybean (M_4) at 30 - 60 DAS (0.055 mg cm^{-2} day^{-1} in 2023 and 1.078 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.048 mg cm^{-2} day^{-1} in 2023 and 0.876 mg cm^{-2} day^{-1} in 2024).

The nutrient application differed significantly on net assimilation rate (NAR) at 30 - 60 DAS and 60 - 90 DAS during 2023 and 2024. During year both year , 100% RDF (S_2) application increased the net assimilation rate at 30 - 60 DAS (0.099 mg cm^{-2} day^{-1} in 2023 and 1.367 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.069 mg cm^{-2} day^{-1} in 2023 and 1.343 mg cm^{-2} day^{-1} in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 30 - 60 DAS (0.086 mg cm^{-2} day^{-1} in 2023 and 1.312 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.066 mg cm^{-2} day^{-1} in 2023 and 1.303 mg cm^{-2} day^{-1} in 2024) and 70 % RDF with two foliar application of Homemade NPK (S_4) application at 30 – 60 DAS (0.099 mg cm^{-2} day^{-1} in 2023 and 1.334 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.063 mg cm^{-2} day^{-1} in 2023 and 1.309 mg cm^{-2} day^{-1} in 2024. The lowest net assimilation rate was observed in control treatment (S_1) at 30 – 60 DAS (0.062 mg cm^{-2} day^{-1} in 2023 and 1.047 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.050 mg cm^{-2} day^{-1} in 2023 and 0.900 mg cm^{-2} day^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to 60 - 90 DAS (Table 4.24b-c). during both the years, M_2S_2 increased net assimilation rate at 30 - 60 DAS (0.122 mg cm^{-2} day^{-1} in 2023 and 1.480 mg cm^{-2} day^{-1} in 2024) and at 60 - 90 DAS, M_4S_2 (0.077 mg cm^{-2} day^{-1} in 2023) and M_2S_4 (1.96 mg cm^{-2} day^{-1} in 2024) increased the highest net assimilation rate, which was statistically similar with M_2S_5 at 30 - 60 DAS (0.120 mg cm^{-2} day^{-1} in 2023 and 1.433 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.070 mg cm^{-2} day^{-1} in 2023 and 1.330 mg cm^{-2} day^{-1} in 2024), M_2S_4 at 30 – 60 DAS (0.111 mg cm^{-2} day^{-1} in 2023 and 1.420 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.073 mg cm^{-2} day^{-1} in 2023 and 1.467 mg cm^{-2} day^{-1} in 2024), M_2S_3 at 30 - 60 DAS (0.076 mg cm^{-2} day^{-1} in 2023 and 1.397 in 2024), at 60 – 90 DAS (0.064 mg cm^{-2} day^{-1} in 2023 and 1.103 in 2024), M_3S_2 at 30 – 60 DAS (0.108 mg cm^{-2} day^{-1} in 2023 and 1.343 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.075 mg cm^{-2} day^{-1} in 2023 and 1.293 mg cm^{-2} day^{-1} in 2024), M_3S_4 at 30 - 60 DAS (0.131 mg cm^{-2} day^{-1} in 2023 and 1.353 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.070 mg cm^{-2} day^{-1} in 2023 and 1.083 mg cm^{-2} day^{-1} in 2024), M_3S_5 at 30 – 60 DAS (0.114 mg cm^{-2} day^{-1} in 2023 and 1.357 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.071 mg cm^{-2} day^{-1} in 2023 and 1.327 mg cm^{-2} day^{-1} in 2024) and M_4S_1 at 30 - 60 DAS (0.096 mg cm^{-2} day^{-1} in 2023 and 1.333 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (1.137 mg cm^{-2} day^{-1} in 2024). M_4S_2 at 30 - 60 DAS (0.112 mg cm^{-2} day^{-1} in 2023 and 1.287 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (0.177 mg cm^{-2} day^{-1} in 2023 and 1.137 mg cm^{-2} day^{-1} in 2024) M_4S_4 at 30 - 60 DAS (0.100 mg cm^{-2} day^{-1} in 2023 and 0.98 mg cm^{-2} day^{-1} in 2024), at 60 – 90 DAS (0.071 mg cm^{-2} day^{-1} in 2023 and 1.333 mg cm^{-2} day^{-1} in 2024).The lowest net assimilation rate was found at 30 - 60 DAS (M_5S_1 0.047 mg cm^{-2} day^{-1} in 2023and with M_5S_1 0.543 mg cm^{-2} day^{-1} in 2024), at 60 - 90 DAS (M_5S_3 0.029 mg cm^{-2} day^{-1} in 2023 and with M_5S_1 0.050 mg cm^{-2} day^{-1} in 2024).

4.3.9. Number of branches $plant^{-1}$

The data on number of branches $plant^{-1}$ of soybean is influenced by cropping system and nutrient management at 60 and 90 DAS during 2023 and 2024 (Table 4.25).

The number of branches $plant^{-1}$ of soybean differed significantly with cropping system at all the growth stages. During both the years, sole soybean (M_2) cropping number of branches $plant^{-1}$ at 60 DAS (4.02 branch $plant^{-1}$ 2023 and 4.39 branch $plant^{-1}$ in 2024), at 90 DAS (7.079 branch $plant^{-1}$ in 2023 and 7.80 branch $plant^{-1}$ in 2024) which was statically similar with 1:1 row proportion of maize soybean (M_3) at 60 DAS (4.00 branch $plant^{-1}$ in 2023 and 4.30 branch $plant^{-1}$ in 2024), and at 90 DAS (7.021 branch $plant^{-1}$ in 2023 and 7.53 branch $plant^{-1}$ in 2024).The lowest number of branch was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (3.96 branch $plant^{-1}$ in 2023 and 4.17 branch $plant^{-1}$ in 2024), at 60 DAS (6.485 branch $plant^{-1}$ in 2023 and 6.07 in 2024), at 90 DAS (3.20 in 2023 and 4.23 in 2024).

Similarly, the nutrient application differed significantly on number of branches at 60 and 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of branch at 60 DAS (4.41 branch $plant^{-1}$ in 2023 and 4.70 branch $plant^{-1}$ in 2024), 90 DAS (7.33 branch $plant^{-1}$ in 2023 and 7.69 branch $plant^{-1}$ in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (4.33 branch $plant^{-1}$ in 2023 and 4.62 branch $plant^{-1}$ in 2024), at 90 DAS (7.56 branch $plant^{-1}$ in 2023 and 7.34 branch $plant^{-1}$ in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) at 60 DAS (4.31 branch $plant^{-1}$ in 2023 4.61 branch $plant^{-1}$ in 2024), at 90 DAS (7.32 branch $plant^{-1}$ in 2023 and 7.30 branch $plant^{-1}$ in 2024). The lowest number of branches was observed in control treatment (S_1) at 60 DAS (2.64 branch $plant^{-1}$ in 2023 and 2.95 branch $plant^{-1}$ in 2024), at 90 DAS (5.16 branch $plant^{-1}$ in 2023 and 5.70 branch $plant^{-1}$ in 2024).

The interaction effect of cropping system and nutrient management, there is no significant effect at 60 and 90 DAS respect to number of branches.

Table 4.25. Effect of planting system and nutrient management on number of branches plant^{-1} of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	60 DAS		90 DAS	
	2023	2024	2023	2024
Planting system				
M_2	4.02	4.39	7.08	7.8
M_3	4	4.3	7.02	7.53
M_4	3.98	4.23	6.75	6.44
M_5	3.96	4.17	6.49	6.07
SEm±	0.01	0.04	0.12	0.12
C.D (0.05)	0.03	0.14	0.41	0.41
Nutrient management				
S_1	2.64	2.95	5.16	5.7
S_2	4.41	4.7	7.33	7.69
S_3	4.27	4.48	6.8	6.77
S_4	4.31	4.61	7.32	7.3
S_5	4.33	4.62	7.56	7.34
SEm±	0.08	0.1	0.15	0.21
C.D (0.05)	0.23	0.29	0.44	0.62

4.3.10. Nodules dry weight (g plant^{-1})

The data on dry weight of nodules (g) plant^{-1} of soybean is influenced by cropping system and nutrient management at 30, 60 and 90 DAS 2023 and 2024 (Table 4.26a).

The dry weight of nodules (g) plant^{-1} of soybean differed significantly with cropping system at 60 and 90 DAS growth stages. During both the years, sole soybean (M_2) cropping increased dry weight of nodules (g) plant^{-1} at 60 DAS (0.757 g in 2023 and 0.838 in 2024) and at 90 DAS (0.964 in 2023 and 0.996 in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (0.730 g in 2023 and 0.827 g in 2024), at 90 DAS (0.954 g in 2023 and 0.986 g in 2024). The lowest dry weight of nodules (g) plant^{-1} was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (0.656 g in 2023 and 0.795 in 2024), at 90 DAS (0.925 in 2023 and 0.956 g in 2024).

Similarly, the nutrient application differed significantly on dry weight of nodules (g) plant^{-1} at 60 DAS, and 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the dry weight of nodules (g) plant^{-1} at 60 DAS (0.742 g in 2023 and 0.855 in 2024), at 90 DAS (0.977 g in 2023 and 0.998 g in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (0.732 g in 2023 and 0.850 g in 2024), at 90 DAS (0.975 g in 2023 and 0.998 g in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (0.717 g in 2023 and 0.850 g in 2024), at 90 DAS (0.975 g in 2023 and 0.992 g in 2024). The lowest dry weight of nodules (g) plant^{-1} was observed in control treatment (S_1) at 60 DAS (0.626 g in 2023 and 0.697 g in 2024), at 60 – 90 DAS (0.835 g in 2023 and 0.922 g in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to dry weight of nodules (g) plant^{-1} at 60, and 90 DAS (Table 4.26b-c), during both the years, M_2S_2 increased dry weight of nodules (g) plant^{-1} at 60 DAS (0.857 g in 2023 and 0.874 g in 2024), at 90 DAS(1.00 g in 2023 and 1.018 g in 2024), which was statistically similar with M_2S_5 at 60 DAS(0.862 in 2024) , at 90 DAS(1.014 in 2025 g), M_2S_4 at 60 DAS (0.870 g in 2023), at 90 DAS (1.014 g in 2024), M_2S_3 at 60 DAS (0.867 g in 2023) at 90 DAS (1.013 g in 2024) and M_3S_2 at 90 DAS (1.013 g in 2024). The lowest dry matter accumulation was found in M_5S_1 at 60 DAS (0.615 g in 2023 and 0.685g in 2024), at 90 DAS (0.830 g in 2023 and 0.918 g in 2024).

4.3.11. Nodules count plant^{-1}

The data on nodules count plant^{-1} of soybean is influenced by cropping system and nutrient management at 30, 60 and 90 DAS 2023 and 2024 (Table 4.27a).

The nodules count plant^{-1} of soybean differed significantly with cropping system at 60 and 90 DAS growth stages. During both the years, sole soybean (M_2) cropping increased nodules count plant^{-1}

Table 4.26a. Effect of planting system and nutrient management on dry weight of nodules (g plant^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	0.339	0.375	0.757	0.838	0.964	0.996
M_3	0.325	0.354	0.73	0.827	0.954	0.986
M_4	0.314	0.36	0.68	0.819	0.945	0.976
M_5	0.315	0.353	0.656	0.795	0.925	0.956
SEm±	0.009	0.013	0.01	0.002	0.003	0.002
CD (P = 0.05)	NS	NS	0.034	0.016	0.011	0.012
Nutrient management						
S_1	0.293	0.352	0.626	0.697	0.835	0.922
S_2	0.339	0.385	0.742	0.855	0.977	0.998
S_3	0.317	0.35	0.712	0.848	0.973	0.99
S_4	0.334	0.354	0.717	0.85	0.975	0.992
S_5	0.333	0.36	0.732	0.85	0.975	0.992
SEm±	0.012	0.009	0.009	0.001	0.001	0.003
CD (P = 0.05)	NS	NS	0.027	0.006	0.003	0.008

4.26b. Interaction effect of planting system and nutrient management on dry weight (g) of nodules of soybean at 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	0.634	0.632	0.624	0.615	**0.626**	0.705	0.702	0.694	0.685	**0.697**
S_2	0.857	0.765	0.696	0.649	**0.742**	0.874	0.860	0.858	0.827	**0.855**
S_3	0.759	0.743	0.691	0.656	**0.712**	0.867	0.856	0.847	0.820	**0.848**
S_4	0.763	0.753	0.695	0.656	**0.717**	0.870	0.858	0.849	0.821	**0.850**
S_5	0.770	0.754	0.696	0.706	**0.732**	0.872	0.858	0.848	0.820	**0.850**
Mean	**0.757**	**0.729**	**0.680**	**0.656**		**0.838**	**0.827**	**0.819**	**0.795**	
Subplot at same level of main plot										
SEm±	0.021					0.004				
CD (P = 0.05)	0.057					0.012				
Main plot at same or different level of subplot										
SEm±	0.019					0.004				
CD (P = 0.05)	0.059					0.009				

4.26c. Interaction effect of planting system and nutrient management on dry weight of nodules of soybean at 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	0.84	0.84	0.83	0.83	**0.835**	0.924	0.925	0.92	0.918	**0.922**
S_2	1	0.983	0.973	0.95	**0.977**	1.018	1.013	0.993	0.969	**0.998**
S_3	0.993	0.98	0.973	0.947	**0.973**	1.013	0.993	0.989	0.964	**0.99**
S_4	0.993	0.983	0.973	0.95	**0.975**	1.014	1	0.989	0.965	**0.992**
S_5	0.993	0.983	0.973	0.95	**0.975**	1.014	0.999	0.99	0.965	**0.992**
Mean	**0.964**	**0.954**	**0.944**	**0.925**		**0.997**	**0.986**	**0.976**	**0.956**	
Subplot at same level of main plot										
SEm±	0.006					0.005				
CD (P = 0.05)	0.007					0.017				
Main plot at same or different level of subplot										
SEm±	0.003					0.006				
CD (P = 0.05)	0.01					0.017				

at 60 DAS (49.88 nodules plant^{-1} in 2023 and 59.50 nodules plant^{-1} in 2024) and at 90 DAS (81.67 nodules plant^{-1} in 2023 and 90.46 nodules plant^{-1} in 2024), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (48.30 nodules plant^{-1} in 2023 and 57.94 nodules plant^{-1} in 2024), at 90 DAS (80.48 nodules plant^{-1} in 2023 and 89.58 in 2024). The lowest of nodules plant^{-1} was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (43.13 nodules plant^{-1} in 2023 and 51.09 nodules plant^{-1} in 2024), at 90 DAS (77.14 nodules plant^{-1} 2023 and 86.82 nodules plant^{-1} in 2024).

Similarly, the nutrient application differed significantly on nodules count plant^{-1} at 60 DAS, and 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the nodules plant^{-1} at 60 DAS (48.86 nodules plant^{-1} in 2023 and 59.52 nodules plant^{-1} in 2024), at 90 DAS (81.88 nodules plant^{-1} in 2023 and 91.80 nodules plant^{-1} in 2024**)**, which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (48.34 nodules plant^{-1} in 2023 and 58.76 nodules plant^{-1} in 2024), at 90 DAS (81.20 nodules plant^{-1} in 2023 and 91.62 in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (47.27 nodules plant^{-1} in 2023 and 58.75 nodules plant^{-1} in 2024), at 90 DAS (81.14 nodules plant^{-1} in 2023 and 91.62 nodules plant^{-1} in 2024). The lowest nodules plant^{-1} was observed in control treatment (S_1) at 60 DAS (40.95 nodules plant^{-1} in 2023 and 42.78 nodules plant^{-1} in 2024), at 90 DAS (73.26 nodules plant^{-1} in 2023 and 77.97 nodules plant^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to nodules count plant^{-1} at 60, and 90 DAS (Table 4.27b-c), during both the years, M_2S_2 increased nodules count at 60 DAS (54.57 nodules plant^{-1} in 2023 and 64.03 nodules plant^{-1} in 2024), at 90 DAS (84.12 nodules plant^{-1} in 2023 and 93.94 in 2024), which was statistically similar with M_2S_5 at 60 DAS(61.87 nodules plant^{-1} in 2024), at 90 DAS(83.64 nodules plant^{-1} in 2024), M_2S_4 at 60 DAS (61.83 nodules plant^{-1} in 2024), at 90 DAS (83.59 g in 2024), M_2S_3 at 60 DAS (0.867 g in 2023) at 90 DAS (83.54 nodules plant^{-1} in 2023) and M_3S_2 at 90 DAS (83.51 and 92.52 nodules plant^{-1} in 2024in 2023 and 92.52 nodules plant^{-1} in 2024). The lowest dry matter accumulation was found in M_5S_1 at 60 DAS (41.01 and 92.52 nodules plant^{-1} in 2024 in 2023 and 34.41 and 92.52 nodules plant^{-1} in 2024 in 2024), at 90 DAS (72.82 and 92.52 nodules plant^{-1} in 2024 in 2023 and 77.44 and 92.52 nodules plant^{-1} in 2024 in 2024).

4.3.12. Chlorophyll index (SPAD value)

The data on chlorophyll index of soybean is influenced by cropping system and nutrient management at 30, 60 and 90 DAS 2023 and 2024 (Table 4.28a).

The chlorophyll index (SPAD value) of soybean differed significantly with cropping system at 60 and 90 DAS growth stages. During both the years, sole soybean (M_2) cropping increased

Table 4.27a. Effect of planting system and nutrient management on nodules count plant^{-1} of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	11.36	14.51	49.86	59.30	81.67	90.46
M_3	11.22	14.17	48.30	57.94	80.48	89.58
M_4	11.12	13.65	44.48	53.68	79.40	88.71
M_5	10.71	13.42	43.13	51.09	77.14	86.82
SEm±	0.13	0.23	0.52	0.60	0.26	0.20
CD (P = 0.05)	NS	NS	1.84	2.10	0.92	0.70
Nutrient management						
S_1	10.63	13.56	40.95	42.78	73.26	77.97
S_2	11.48	14.38	48.86	59.52	81.88	91.80
S_3	11.03	13.73	46.79	57.71	80.90	91.46
S_4	11.09	13.88	47.27	58.75	81.14	91.62
S_5	11.28	14.12	48.34	58.76	81.20	91.62
SEm±	0.20	0.23	0.61	0.45	0.27	0.07
C.D(p=0.05)	NS	NS	1.76	1.31	0.79	0.21

4.27b Interaction effect of planting system and nutrient management on nodules count plant^{-1} of soybean at 60 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	41.18	41.68	39.95	41.01	**40.95**	48.65	47.36	40.7	34.41	**42.78**
S_2	54.57	50.22	46.1	46.53	**48.86**	64.03	60.92	57.39	55.73	**59.52**
S_3	50.75	49.41	44.91	42.11	**46.79**	60.14	59.78	55.86	55.08	**57.71**
S_4	50.56	50.1	45.72	42.7	**47.27**	61.83	60.83	57.23	55.12	**58.75**
S_5	52.24	50.11	45.74	43.3	**48.34**	61.87	60.83	57.23	55.1	**58.76**
Mean	**49.86**	**48.3**	**44.48**	**43.13**		**59.3**	**57.94**	**53.68**	**51.09**	
Subplot at same level of main plot										
SEm±	1.17					1.33				
CD (P = 0.05)	3.66					2.82				
Main plot at same or different level of subplot										
SEm±	0.55					1				
CD (P = 0.05)	1.67					3.13				

4.27c. Interaction effect of planting system and nutrient management on nodules count plant^{-1} of soybean at 90 DAS

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	73.48	73.62	73.12	72.82	**73.26**	78.44	78.24	77.74	77.44	**77.97**
S_2	84.12	83.51	81.21	78.67	**81.88**	93.94	92.52	91.49	89.25	**91.8**
S_3	83.54	81.29	80.84	77.94	**80.9**	93.23	92.22	91.43	88.96	**91.46**
S_4	83.59	81.98	80.87	78.1	**81.14**	93.28	92.44	91.49	89.27	**91.62**
S_5	83.64	82	80.97	78.17	**81.2**	93.43	92.46	91.43	89.16	**91.62**
Mean	**81.67**	**80.48**	**79.4**	**77.14**		**90.46**	**89.57**	**88.71**	**86.82**	
Subplot at same level of main plot										
SEm±	0.58					0.44				
CD (P = 0.05)	1.65					0.49				
Main plot at same or different level of subplot										
SEm±	0.55					0.24				
CD (P = 0.05)	1.67					0.79				

Table 4.28a. Effect of planting system and nutrient management on chlorophyll index (SPAD) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	30 DAS		60 DAS		90 DAS	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	22.05	23.51	40.42	40.35	42.88	43.78
M_3	22.03	23.21	39.39	39.25	42.01	42.11
M_4	21.98	23.47	36.33	36.11	39.16	38.86
M_5	21.59	23.27	33.30	33.61	37.07	36.77
SEm±	0.23	0.19	0.40	0.35	0.59	0.55
CD (P = 0.05)	NS	NS	1.40	1.25	2.09	1.94
Nutrient management						
S_1	21.59	22.86	28.99	27.53	35.36	35.36
S_2	22.21	23.75	40.13	40.59	42.57	42.70
S_3	21.67	23.20	38.26	39.30	40.92	41.04
S_4	21.94	23.48	39.62	39.61	41.28	41.41
S_5	22.15	23.54	39.80	39.62	41.28	41.40
SEm±	0.17	0.23	0.43	0.41	0.54	0.54
CD (P = 0.05)	NS	NS	1.24	1.18	1.55	1.57

4.28b. Interaction effect of planting system and nutrient management on chlorophyll index (SPAD) of soybean at 60 DAS

M/S	2023					2024				
	M_2	M_3	M_4	M_5	Mean	M_2	M_3	M_4	M_5	Mean
S_1	30.12	29.15	28.68	28.02	**28.99**	28.32	28.26	27.40	26.15	**27.53**
S_2	44.03	42.34	38.45	35.70	**40.13**	44.50	42.35	38.80	36.69	**40.59**
S_3	41.79	41.03	36.96	33.26	**38.26**	42.52	41.46	37.82	35.40	**39.30**
S_4	43.02	42.16	38.76	34.52	**39.62**	43.28	41.94	38.15	35.05	**39.61**
S_5	43.14	42.26	38.79	35.01	**39.80**	43.14	42.22	38.36	34.74	**39.62**
Mean	**40.42**	**39.39**	**36.33**	**33.30**		**40.35**	**39.25**	**36.11**	**33.61**	
Subplot at same level of main plot										
SEm±	0.89					0.79				
CD (P = 0.05)	2.59					2.46				
Main plot at same or different level of subplot										
SEm±	0.86					0.81				
CD (P = 0.05)	2.61					2.45				

4.28c. Interaction effect of planting system and nutrient management on Chlorophyll index of soybean at 90 DAS

M/S	2023					2024				
	M_2	M_3	M_4	M_5	Mean	M_2	M_3	M_4	M_5	Mean
S_1	35.48	34.99	35.79	35.19	**35.36**	36.38	34.69	35.49	34.89	**35.36**
S_2	46.67	44.89	40.36	38.36	**42.57**	47.57	45.09	40.06	38.06	**42.70**
S_3	43.83	43.06	39.46	37.32	**40.92**	44.73	43.26	39.16	37.02	**41.04**
S_4	44.21	43.57	40.10	37.24	**41.28**	45.11	43.77	39.80	36.94	**41.41**
S_5	44.20	43.55	40.11	37.24	**41.28**	45.10	43.75	39.81	36.94	**41.40**
Mean	**42.88**	**42.01**	**39.16**	**37.07**		**43.78**	**42.11**	**38.86**	**36.77**	
Subplot at same level of main plot										
SEm±	1.32					1.23				
CD (P = 0.05)	3.29					3.31				
Main plot at same or different level of subplot										
SEm±	1.13					1.12				
CD (P = 0.05)	3.46					3.40				

chlorophyll index at 60 DAS (40.42 in 2023 and 40.35 in 2024) and at 90 DAS (42.88 in 2023 and 43.78 nodules plant^{-1} in 2024), which was statistically similar with 1:1 row proportion of maize and soybean (M_3) at 60 DAS (39.39 in 2023 and 39.25 in 2024), at 90 DAS (42.01 in 2023 and 42.11 in 2024). The lowest of chlorophyll index was observed in 2:3 row proportions of maize and soybean (M_5) at 60 DAS (40.86 in 2023 and 42.30 in 2024), at 90 DAS (44.04 in 2023 and 44.96 in 2024).

Similarly, the nutrient application differed significantly on chlorophyll index (SPAD value) at 60 DAS, and 90 DAS during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the chlorophyll index at 60 DAS (40.13 in 2023 and 40.59 in 2024), at 90 DAS (42.57 in 2023 and 42.70 in 2024), which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at 60 DAS (39.80 in 2023 and 39.62 in 2024), at 90 DAS (41.28 in 2023 and 41.40 in 2024), and 70 % RDF with two foliar application of Homemade NPK (S_4) at 60 DAS (39.62 in 2023 and 39.61 in 2024), at 90 DAS (41.28 in 2023 and 41.41 in 2024). The lowest chlorophyll index (SPAD value) was observed in control treatment (S_1) at 60 DAS (28.99 in 2023 and 27.53 in 2024), at 90 DAS (35.36 in 2023 and 35.36 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to chlorophyll index (SPAD value) at 60, and 90 DAS (Table 4.28 b-c), during both the years, M_2S_2 increased nodules count at 60 DAS (44.03 in 2023 and 44.50 in 2024), at 90 DAS (46.67 in 2023 and 47.57 in 2024), which was statistically similar with M_2S_5 at 60 DAS(43.14 in 2023 and 43.14 in 2024), at 90 DAS(44.20 in 2023 and 45.10 in 2024), M_2S_4 at 60 DAS (43.02 in 2023 and 43.28 in 2024), at 90 DAS (44.21 in 2023 and 45.11 in 2024), M_2S_3 at 60 DAS (41.79 in 2023 and 42.52 in 2024), M_3S_2 at 60 DAS (42.34 in 2023 and 42.35 in 2024), at 90 DAS (44.89 in 2023 and 45.09 in 2024), M_3S_5 at 60 DAS (42.26 in 2023 and 42.22 in 2024),at 90 DAS(43.55 in 2023 and 43.75 in 2024), M_3S_4 at 60 DAS(42.16 in 2023), at 90 DAS(41.94 in 2024). The lowest chlorophyll index (SPAD) was found in M_5S_1 at 60 DAS (28.02 in 2023 and 26.15 in 2024) and M_3S_1 at 90 DAS (34.99 in 2023 and 34.69 in 2024).

4.4. Yield parameters of soybean crop under maize + soybean - oat cropping system (2023 and 2024)

4.4.1. Number of pods plant^{-1}

The data on number of pods plant^{-1} of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.29a).

The number of pods plant^{-1} of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased number of pods plant^{-1} (44.68 pods in 2023 and 46.5 pods in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (42.85

Table 4.29a. Effect of planting system and nutrient management on number of pods plant^{-1}, Seed index (g) and haulm yield (t) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	Number of pods plant^{-1}		Seed index (g)		Haulm yield (t)	
	2023	2024	2023	2024	2023	2024
Planting system						
M_2	44.68	46.5	21.24	21.38	1.67	1.80
M_3	42.85	45.82	20.96	21.33	1.57	1.72
M_4	41.23	44.85	20.56	21.3	1.48	1.63
M_5	39.79	42.14	19.97	21.12	1.19	1.44
SEm±	0.2	0.13	0.07	0.01	0.01	0.01
C.D (0.05)	0.71	0.46	0.25	0.04	0.04	0.03
Nutrient management						
S_1	34.35	37.65	20.5	20.83	1.28	1.58
S_2	44.66	47.28	20.85	21.5	1.55	1.69
S_3	43.6	46.12	20.62	21.29	1.51	1.64
S_4	44.04	46.54	20.7	21.38	1.52	1.66
S_5	44.05	46.55	20.75	21.43	1.52	1.66
SEm±	0.3	0.29	0.05	0.02	0.01	0.01
C.D (0.05)	0.85	0.84	0.15	0.06	0.03	0.03

4.29b. Interaction effect of planting system and nutrient management on seed index (g) of maize under maize + soybean - oat cropping system (2023-24)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	20.67	20.63	20.47	20.02	**20.50**	20.98	20.82	20.81	20.69	**20.83**
S_2	21.52	21.16	20.68	20.22	**20.85**	21.54	21.52	21.49	21.44	**21.50**
S_3	21.25	20.94	20.49	19.79	**20.62**	21.41	21.39	21.37	20.98	**21.29**
S_4	21.34	20.98	20.58	19.90	**20.70**	21.46	21.44	21.40	21.21	**21.38**
S_5	21.43	21.07	20.59	19.92	**20.75**	21.52	21.48	21.45	21.28	**21.43**
Mean	**21.24**	**20.96**	**20.56**	**19.97**		**21.38**	**21.33**	**21.30**	**21.12**	
Subplot at same level of main plot										
SEm±	0.16					0.03				
CD (P = 0.05)	0.33					0.12				
Main plot at same or different level of subplot										
SEm±	0.12					0.04				
CD (P = 0.05)	0.37					0.11				

4.29c. Interaction effect of planting system and nutrient management on haulm yield (t ha^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024).

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.41	1.39	1.34	0.98	**1.28**	1.63	1.61	1.56	1.40	**1.58**
S_2	1.75	1.65	1.55	1.24	**1.55**	1.89	1.79	1.69	1.53	**1.69**
S_3	1.72	1.58	1.49	1.26	**1.51**	1.81	1.72	1.61	1.41	**1.64**
S_4	1.73	1.62	1.50	1.25	**1.52**	1.83	1.74	1.64	1.42	**1.66**
S_5	1.73	1.62	1.50	1.24	**1.52**	1.84	1.74	1.64	1.42	**1.66**
Mean	**1.67**	**1.57**	**1.48**	**1.19**		**1.80**	**1.72**	**1.63**	**1.44**	
Subplot at same level of main plot										
SEm±	0.024					0.017				
CD (P = 0.05)	0.063					0.062				
Main plot at same or different level of subplot										
SEm±	0.021					0.020				
CD (P = 0.05)	0.065					0.060				

pods in 2023 and 45.82 pods in 2024). The lowest number of pods plant^{-1} was observed in 2:3 row proportion of maize and soybean (M_5) (39.79 pods in 2023 and 42.14 pods in 2024).

Similarly, the nutrient application differed significantly on number of pods plant^{-1} during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the number of pods plant^{-1} (44.66 pods in 2023 and 47.28 pods in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (44.05 pods in 2023 and 46.55 pods in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (44.04 pods in 2023 and 46.54 pods in 2024). The lowest number of pods plant^{-1} was observed in control treatment (S_1) (34.35 pods in 2023 and 37.65 pods in 2024).

The interaction effect of cropping system and nutrient management, there was no interaction effect respect to number of pods plant^{-1}**.**

4.4.2. Seed index (g)

The data on seed index (g) of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.29).

The test weight (g) of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased seed index (g) (21.24 g in 2023 and 21.38 g in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (20.96 g in 2023 and 21.33 g in 2024). The lowest seed index (g) was observed in 2:3 row proportion of maize and soybean (M_5) (19.97 g in 2023 and 21.12 g in 2024).

Similarly, the nutrient application differed significantly on seed index (g) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the seed index (20.85 g in 2023 and 21.50 g in 2024) which was statically similar with 70 % RDF with two foliar applications of plant extract (S_5) (20.75 g in 2023 and 21.43 g in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (20.70 g in 2023 and 21.38 g in 2024). The lowest seed index (g) was observed in control treatment (S_1) (20.50 g in 2023 and 20.83 seed index (g) in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to seed index (g) (Table 4.29b), during both the years, M_1S_2 increased seed index (g) (21.52 g in 2023 and 21.54 g in 2024) which was statistically similar with M_1S_5 (21.43 g in 2023 and 21.52 g in 2024), M_1S_4 (21.34 g in 2023 and 21.46 g in 2024), M_1S_3 (21.25 in 2023), M_3S_2 (21.52 g in 2024), M_3S_5 (21.45 g in 2024), M_5S_2 (21.44 g in 2024). The lowest seed index (g) was found in M_5S_1 (20.02 g in 2023 and 20.69 g in 2024).

4.4.3. Haulm yield (t ha^{-1})

The data on haulm yield (t) of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.29a).

The haulm yield (t ha^{-1}) of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased haulm yield (1.67 t ha^{-1} in 2023 and 1.80 t ha^{-1} in 2024) which was statistically similar with 1:1 row proportion of maize and soybean (M_3) (1.57 t ha^{-1} in 2023 and 1.72 t ha^{-1} in 2024). The lowest haulm yield (t ha^{-1}) was observed in 2:3 row proportion of maize and soybean (M_5) (1.19 t ha^{-1} in 2023 and 1.44 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on haulm yield (t ha^{-1}) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the haulm yield (t ha^{-1}) (1.55 t ha^{-1} in 2023 and 1.64 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (1.52 t ha^{-1} in 2023 and 1.66 t ha^{-1} g in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (1.52 t ha^{-1} in 2023 and 1.66 t ha^{-1} in 2024). The lowest haulm yield (t ha^{-1}) was observed in control treatment (S_1) (1.28 t ha^{-1} in 2023 and 1.58 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to haulm yield (t ha^{-1}) (Table 4.29c), during both the years, M_1S_2 increased haulm yield (t ha^{-1}) (1.75 t ha^{-1} in 2023 and 1.86 t ha^{-1} in 2024) which was statistically similar with M_1S_5 (1.73 t ha^{-1} in 2023 and 1.84 t ha^{-1} in 2024), M_1S_4 (1.72 t ha^{-1} in 2023 and 1.83 t ha^{-1} in 2024), M_1S_3 (1.71 t ha^{-1} in 2023 and 1.82 t ha^{-1} in 2024), M_3S_2 (1.78 t ha^{-1} in 2024. The lowest haulm yield (t ha^{-1}) was found in M_5S_1 (9.78 t ha^{-1} in 2023 and 1.40 t ha^{-1} in 2024).

4.4.4. Seed yield (t ha^{-1})

The data on seed yield (t ha^{-1}) of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.30a).

The seed yield (t ha^{-1}) of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased seed yield (t ha^{-1}) (2.32 q ha^{-1} in 2023 and 2.35 t ha^{-1} in 2024) which was statistically similar with 1:2 row proportion of maize and soybean (M_3) (2.13 t ha^{-1} in 2023 and 2.15 q ha^{-1} in 2024). The lowest seed yield (t ha^{-1}) was observed in 2:3 row proportion of maize and soybean (M_5) (1.57 t ha^{-1} in 2023 and 1.74 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on seed yield (t ha^{-1}) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the seed yield (t ha^{-1}) (2.22 t ha^{-1} in 2023 and 2.36 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (2.17 t ha^{-1} in 2023 and 2.25 t ha^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (2.16 t ha^{-1} in 2023 and 22.24 t ha^{-1} in 2024). The lowest seed yield (t ha^{-1}) was observed in control treatment (S_1) (1.27 t ha^{-1} in 2023 and 1.42 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to seed yield (t ha^{-1}) (Table 4.30b), during both the years, M_2S_2 increased seed yield (t ha^{-1}) (2.52 t ha^{-1} in 2023 and 2.64 t ha^{-1} in 2024) which was statistically similar with M_2S_5 (25.51 t ha^{-1} in

Table 4.30a. Effect of planting system and nutrient management on grain yield (t ha^{-1}), stover yield (t ha^{-1}) and biological yield (t ha^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

Treatment	Seed yield (t ha^{-1})		Stover yield (t ha^{-1})		Biological yield (t ha^{-1})		Harvesting index	
	2023	2024	2023	2024	2023	2024	2023	2024
Planting system								
M_2	2.32	2.35	3.37	3.48	5.68	5.83	40.52	40.25
M_3	1.88	1.98	3.12	3.28	4.99	5.26	37.40	37.49
M_4	2.13	2.15	3.21	3.32	5.34	5.47	39.40	38.98
M_5	1.57	1.74	2.71	3.00	4.28	4.74	36.47	36.49
SEm±	0.04	0.05	0.06	0.09	0.09	0.13	0.38	0.33
CD (P = 0.05)	0.14	0.17	0.22	0.31	0.33	0.47	1.35	1.16
Nutrient management								
S_1	1.27	1.42	2.53	2.79	3.79	4.20	33.43	33.54
S_2	2.22	2.36	3.32	3.49	5.53	5.85	39.97	40.36
S_3	2.06	2.01	3.14	3.21	5.20	5.22	39.49	38.48
S_4	2.16	2.24	3.27	3.42	5.42	5.66	39.54	39.54
S_5	2.17	2.25	3.26	3.44	5.43	5.69	39.82	39.58
SEm±	0.03	0.03	0.04	0.04	0.04	0.05	0.49	0.40
CD (P = 0.05)	0.08	0.07	0.10	0.12	0.13	0.18	1.41	1.15

4.30b. Interaction effect of planting system and nutrient management on seed yield (t ha^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_2	**M_3**	**M_4**	**M_5**	**Mean**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.60	1.34	1.24	0.90	**1.27**	1.70	1.37	1.36	1.23	**1.42**
S_2	2.52	2.19	2.37	1.80	**2.22**	2.64	2.25	2.57	2.00	**2.36**
S_3	2.46	1.90	2.20	1.67	**2.06**	2.36	1.91	2.13	1.65	**2.01**
S_4	2.49	1.98	2.42	1.73	**2.16**	2.52	2.20	2.35	1.89	**2.24**
S_5	2.51	1.98	2.43	1.77	**2.17**	2.53	2.20	2.35	1.92	**2.25**
Mean	**2.32**	**1.88**	**2.13**	**1.57**		**2.35**	**1.98**	**2.15**	**1.74**	
Subplot at same level of main plot										
SEm±	0.09					0.11				
CD (P = 0.05)	0.17					0.16				
Main plot at same or different level of subplot										
SEm±	0.06					0.07				
CD (P = 0.05)	0.20					0.22				

4.30c. Interaction effect of planting system and nutrient management on stover yield (t ha^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	3.08	2.60	2.66	1.77	**2.53**	2.86	2.74	2.80	2.74	**2.79**
S_2	3.65	3.23	3.38	3.01	**3.32**	3.78	3.50	3.54	3.12	**3.49**
S_3	3.34	3.03	3.27	2.90	**3.14**	3.23	3.28	3.32	3.01	**3.21**
S_4	3.41	3.36	3.36	2.94	**3.27**	3.76	3.43	3.47	3.00	**3.42**
S_5	3.35	3.37	3.37	2.94	**3.26**	3.77	3.43	3.51	3.07	**3.44**
Mean	**3.37**	**3.12**	**3.21**	**2.71**		**3.48**	**3.28**	**3.32**	**3.00**	
Subplot at same level of main plot										
SEm±	0.14					0.20				
CD (P = 0.05)	0.23					0.27				
Main plot at same or different level of subplot										
SEm±	0.09					0.11				
CD (P = 0.05)	0.28					0.38				

4.30d. Interaction effect of planting system and nutrient management on biological yield (t ha^{-1}) of soybean under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4.68	3.94	3.89	2.67	**3.79**	4.56	4.10	4.10	4.04	**4.20**
S_2	6.17	5.41	5.75	4.81	**5.53**	6.42	5.75	6.11	5.12	**5.85**
S_3	5.81	4.92	5.48	4.58	**5.20**	5.59	5.19	5.45	4.67	**5.22**
S_4	5.91	5.34	5.79	4.67	**5.42**	6.29	5.63	5.82	4.89	**5.66**
S_5	5.86	5.35	5.80	4.70	**5.43**	6.30	5.63	5.86	4.99	**5.69**
Mean	**5.68**	**4.99**	**5.34**	**4.28**		**5.83**	**5.26**	**5.47**	**4.74**	
Subplot at same level of main plot										
SEm±	0.21					0.30				
CD (P = 0.05)	0.25					0.35				
Main plot at same or different level of subplot										
SEm±	0.12					0.16				
CD (P = 0.05)	0.38					0.54				

4.30e. Interaction effect of planting system and nutrient management on harvest index (%) of soybean under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	34.12	34.05	33.83	31.70	**33.43**	37.31	33.31	33.11	30.42	**33.54**
S_2	40.92	40.41	41.15	37.38	**39.97**	41.14	39.13	42.03	39.15	**40.36**
S_3	42.89	38.53	40.32	36.61	**39.49**	42.37	36.78	39.15	35.61	**38.48**
S_4	42.21	36.97	41.89	37.08	**39.54**	40.16	39.09	40.38	38.52	**39.54**
S_5	42.45	37.05	41.82	37.57	**39.82**	40.24	39.12	40.22	38.74	**39.58**
Mean	**40.52**	**37.40**	**39.40**	**36.47**		**40.24**	**37.49**	**38.98**	**36.49**	
Subplot at same level of main plot										
SEm±	0.86					0.74				
CD (P = 0.05)	2.93					2.40				
Main plot at same or different level of subplot										
SEm±	0.95					0.79				
CD (P = 0.05)	2.86					2.36				

2023 and 2.53 t ha^{-1} in 2024), M_2S_4 (2.49 t ha^{-1} in 2023 and 2.52 t ha^{-1} in 2024), M_2S_3 (2.46 t ha^{-1} in 2023), M_2S_3(2.57 t ha^{-1}). The lowest seed yield was found in M_5S_1 (0.90 t ha^{-1} in 2023 and 1.23 t ha^{-1} in 2024).

4.4.5. Stover yield (t ha^{-1})

The data on stover yield (t ha^{-1}) of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.30a).

The stover yield (t ha^{-1}) of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased stover yield (3.37 t ha^{-1} in 2023 and 3.48 t ha^{-1} in 2024) which was statistically similar with 1:2 row proportion of maize and soybean (M_3) (3.21 t ha^{-1} in 2023 and 3.32 t ha^{-1} in 2024). The lowest stover yield (t ha^{-1}) was observed in 2:3 row proportion of maize and soybean (M_5) (2.71 t ha^{-1} in 2023 and 3.00 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on stover yield (t ha^{-1}) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the stover yield (t ha^{-1}) (3.32 t ha^{-1} in 2023 and 3.49 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (3.26 t ha^{-1} in 2023 and 3.44 t ha^{-1} in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (3.27 t ha^{-1} in 2023 and 3.42 t ha^{-1} in 2024). The lowest stover yield (t ha^{-1}) was observed in control treatment (S_1) (2.53 t ha^{-1} in 2023 and 2.79 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to stover yield (t ha^{-1}) (Table 4.30c), during both the years, M_2S_2 increased stover yield (t ha^{-1}) (3.65 t ha^{-1} in 2023 and 3.78 t ha^{-1} in 2024) which was statistically similar with M_2S_5 (3.35 t ha^{-1} in 2023 and 3.77 t ha^{-1} in 2024), M_2S_4 (3.41 t ha^{-1} in 2023 and 3.76 t ha^{-1} in 2024), M_3S_2 (3.23 t ha^{-1} in 2023 and 3.50 t ha^{-1} in 2024), M_3S_5 (3.37 t ha^{-1} in 2023). The lowest stover yield t ha^{-1} was found in M_5S_1 (1.77 t ha^{-1} in 2023 and 2.74 t ha^{-1} in 2024).

4.4.6. Biological yield (t ha^{-1})

The data on biological yield (t ha^{-1}) of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.30a).

The biological yield (t ha^{-1}) of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased biological yield (5.68 t ha^{-1} in 2023 and 5.83 t ha^{-1} in 2024) which was statistically similar with 1:2 row proportion of maize and soybean (M_4) (5.34 t ha^{-1} in 2023 and 5.47 t ha^{-1} in 2024). The lowest biological yield (q ha^{-1}) was observed in 2:3 row proportion of maize and soybean (M_5) (4.28 t ha^{-1} in 2023 and 4.74 q ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on biological yield (t ha^{-1}) during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the biological yield (t ha^{-1})

(5.53 t ha^{-1} in 2023 and 5.85 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) (5.43 t ha^{-1} in 2023 and 5.69 t ha^{-1} in 2024). The lowest biological yield (t ha^{-1}) was observed in control treatment (S_1) (3.79 t ha^{-1} in 2023 and 4.20 t ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to biological yield (t ha^{-1}) (Table 4.30d), during both the years, M_2S_2 increased biological yield (t ha^{-1}) (6.17 t ha^{-1} in 2023 and 6.42 t ha^{-1} in 2024) which was statistically similar with M_2S_5 (5.86 t ha^{-1} in 2023 and 6.30 t ha^{-1} in 2024), M_2S_4 (5.91 t ha^{-1} in 2023 and 6.29 t ha^{-1} in 2024. The lowest biological yield t ha^{-1} was found in M_5S_1 (2.67 t ha^{-1} in 2023 and 4.04 t ha^{-1} in 2024).

4.4.7. Harvesting index (%)

The data on harvesting index of soybean is influenced by cropping system and nutrient management at harvest during 2023 and 2024 (Table 4.30a).

The harvesting index of soybean differed significantly with cropping system. During both the years, sole soybean (M_2) increased harvesting index (40.52 in 2023 and 40.25 in 2024) which was statistically similar with 1:2 row proportion of maize and soybean (M_4) (39.40 in 2023 and 38.98 in 2024). The lowest harvest index was observed in 2:3 row proportion of maize and soybean (M_5) (36.47 in 2023 and 36.49 in 2024).

Similarly, the nutrient application differed significantly on harvesting index during 2023 and 2024. During both the years, 100% RDF (S_2) application increased the harvesting index (39.97 in 2023 and 40.36 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_2) (40.18 in 2023 and 39.41 in 2024) 70 % RDF with two foliar application of plant extract (S_5) (39.82 in 2023 and 39.58 in 2024), and 70% RDF with two foliar applications of Homemade NPK (S_4) (39.54 in 2023 and 39.54 in 2024). The lowest harvest index was observed in control treatment (S_1) (33.43 in 2023 and 33.54 in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to harvest index (Table 4.30e), during both the years, M_2S_3 increased harvest index (42.89 t ha^{-1} in 2023 and 42.37 in 2024) which was statistically similar with M_2S_5 (42.45 in 2023 and 40.24 in 2024). The lowest harvest index was found in M_5S_1 (31.70 in 2023 and 30.42 in 2024).

4.5. Growth parameter of oat crop under maize + soybean - oat cropping system (2023-24 and 2024-25)

4.5.1. Plant height (cm)

The data on plant height of fodder oat is influenced by residue of cropping system and nutrient management at 20, 40 and harvest during 2023-24 and 2024-25 (Table 4.31).

Table 4.31. Residual effect of planting system and nutrient management on plant height (cm) of fodder oat under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	20 DAS		60 DAS		At harvest	
	2023 - 24	2024 - 25	2023 - 24	2024 - 25	2023 - 24	2024 - 25
Planting system						
M_1	13.81	14.03	36.11	36.67	63.15	63.89
M_2	20.95	21.04	50.84	51.29	73.95	74.63
M_3	15.48	16.05	41.27	41.57	69.96	72.18
M_4	18.59	18.77	48.74	49.42	71.56	73.26
M_5	16.00	16.91	39.30	39.95	68.46	68.97
SEm±	1.04	1.15	1.47	1.63	1.41	1.29
CD (P = 0.05)	3.44	3.80	4.88	5.39	4.68	4.27
Nutrient management						
S_1	13.74	10.75	37.49	36.28	58.19	56.61
S_2	20.53	22.27	48.99	51.67	76.95	78.25
S_3	17.06	18.38	43.57	44.27	71.11	73.96
S_4	16.76	17.82	43.15	43.39	70.78	72.73
S_5	16.75	17.57	43.06	43.30	70.06	71.39
SEm±	1.02	0.74	1.45	1.41	1.24	0.99
CD (P = 0.05)	2.91	2.14	4.15	4.06	3.54	2.84

The plant height of fodder oat differed significantly with residue of cropping system at all the growth stages. During both the years, residue of sole soybean (M_2) cropping increased plant height at 20 DAS (20.95 cm in 2023 and 21.04 cm in 2024), at 40 DAS (50.84 cm in 2023 and 51.29 cm in 2024) and at harvest (73.95 cm in 2023 and 74.63 cm in 2024) which was statistically similar with 1:2 row proportion of maize and soybean residue (M_4) at 20 DAS (18.59 cm in 2023 and 18.77 cm in 2024), at 40 DAS (48.74 cm in 2023 and 49.42 cm in 2024) and at harvest (71.56 cm in 2023 and 73.26 cm in 2024). The lowest plant height was observed in sole maize (M_1) at 20 DAS (13.81 cm in 2023 and 14.03 cm in 2024), at 40 DAS (36.11 cm in 2023 and 36.67 cm in 2024) and at harvest (63.15 cm in 2023 and 63.89 cm in 2024).

Similarly, the residue of nutrient application differed significantly on plant height at 20, 40 and at harvest during 2023 and 2024. During both the years, residue of 100% RDF (S_2) application superior plant height at 20 DAS (20.53 cm in 2023 and 22.27 cm in 2024), at 40 DAS (48.99 cm in 2023 and 51.67 cm in 2024) and at harvest (76.95 cm in 2023 and 78.25 cm in 2024). 70 % RDF with two foliar application of nano NPK (S_3) was statically different with 70 % RDF with two foliar application of nano NPK (S_3) at 20 DAS (17.06 cm in 2023 and 18.38 cm in 2024), at 40 DAS (43.57 cm in 2023 and 44.27 cm in 2024) and at harvest (71.11 cm in 2023 and 73.96 cm in 2024), which was statically similar with 70% RDF with two foliar application of Homemade NPK (S_4) at 20 DAS (16.76 cm in 2023 and 17.82 cm in 2024), at 40 DAS (43.15 cm in 2023 and 43.39 cm in 2024) and at harvest (70.78 cm in 2023 and 72.73 cm in 2024), and 70 % RDF with two foliar application of plant extract (S_5) at 20 DAS (16.75 cm in 2023 and 17.57 cm in 2024), at 40 DAS (43.06 cm in 2023 and 70.06 cm in 2024) and at harvest (70.06 cm in 2023 and 71.39 cm in 2024) . The lowest plant height was observed in control treatment (S_1) at 20 DAS (13.74 cm in 2023 and 10.75 cm in 2024), at 40 DAS (37.49 cm in 2023 and 36.28 cm in 2024) and at harvest (58.19 cm in 2023 and 56.61 cm in 2024).

The interaction effect of residual cropping system and nutrient management differed, respect to plant height, there is no significant effect all the growth stage.

4.5.2. Dry matter accumulation (g m^{-2})

The data on dry matter accumulation (g m^{-2}) of fodder oat is influenced by residue of cropping system and nutrient management at 20, 40 and harvest during 2023-24 and 2024-25 (Table 4.32a).

The dry matter accumulation (g m^{-2}) of fodder oat differed significantly with residue of cropping system at all the growth stages. During both the years, residue of sole soybean (M_2) cropping increased dry matter accumulation (g m^{-2}) at 20 DAS (29.14 g in 2023 and 31.17 g in 2024), at 40 DAS (109.53 g in 2023 and 113 g in 2024) and at harvest (165.08 g in 2023 and 168.16 g in 2024) which was statistically similar with 1:2 row proportion of maize and soybean residue (M_4) at 20 DAS (27.52 g in 2023 and 29.42 g in 2024), at 40 DAS (106.22 g in 2023 and 106.65 g in 2024) and at

Table 4.32a. Residual effect of planting system and nutrient management on dry matter (g m^{-2}) of fodder Oat under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	20 DAS		40 DAS		A harvest	
	2023 - 24	2024 - 25	2023 - 24	2024 - 25	2023 - 24	2024 - 25
Planting system						
M_1	18.40	19.82	96.31	97.89	150.13	150.45
M_2	29.14	31.17	109.53	113.00	165.08	168.16
M_3	22.55	22.45	105.43	105.86	158.46	161.19
M_4	27.52	29.42	106.22	106.65	160.08	164.65
M_5	21.70	23.39	103.50	103.71	152.01	157.47
SEm±	2.16	2.21	2.40	2.66	2.14	2.21
CD (P = 0.05)	7.14	7.32	7.93	8.82	7.09	7.31
Nutrient management						
S_1	18.15	18.15	82.30	83.02	129.36	129.80
S_2	30.36	31.37	116.93	117.16	172.88	178.51
S_3	24.49	26.19	108.01	110.16	163.10	166.01
S_4	23.71	25.80	107.49	109.40	160.91	164.64
S_5	22.59	24.75	106.25	107.36	159.50	162.95
SEm±	1.48	1.51	1.85	3.08	1.46	1.44
CD (P = 0.05)	4.25	4.34	5.30	8.82	4.19	4.13

4.32b. Interaction effect of residue of planting system and nutrient management on dry matter accumulation (g m^{-2}) of fodder Oat at 40 DAS under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	112.65	146.21	124.52	138.04	125.37	**129.36**	107.99	142.19	128.26	138.17	132.39	**129.80**
S_2	169.31	179.11	173.01	175.68	167.32	**172.88**	169.19	189.01	177.32	184.66	172.37	**178.51**
S_3	156.99	168.25	168.66	164.90	156.69	**163.10**	158.46	173.53	167.69	169.20	161.18	**166.01**
S_4	157.32	165.45	161.96	164.08	155.74	**160.91**	157.87	169.77	167.17	167.39	161.01	**164.64**
S_5	154.37	166.37	164.13	157.71	154.94	**159.50**	158.74	166.29	165.50	163.85	160.38	**162.95**
Mean	**150.13**	**165.08**	**158.46**	**160.08**	**152.01**		**150.45**	**168.16**	**161.19**	**164.65**	**157.47**	
Subplot at same level of main plot												
SEm±	4.79						4.94					
CD (P = 0.05)	9.88						9.75					
Main plot at same or different level of subplot												
SEm±	3.62						3.63					
CD (P = 0.05)	10.95						11.00					

harvest (160.08 g in 2023 and 164.65 g in 2024). The lowest dry matter accumulation (g m^{-2}) was observed in sole maize (M_1) at 20 DAS (18.40 g in 2023 and 19.82 g in 2024), at 40 DAS (96.31 g in 2023 and 97.89 g in 2024) and at harvest (150.13 g in 2023 and 150.45 in 2024).

Similarly, the residue of nutrient application differed significantly on dry matter accumulation (g $meter^{-1}$ row) at 20, 40 and at harvest during 2023 and 2024 (Table 4.32). During both the years, residue of 100% RDF (S_2) application superior the dry matter accumulation (g m^{-2}) at 20 DAS (30.36 g in 2023 and 31.37 g in 2024), at 40 DAS (116.93 g in 2023 and 117.16 g in 2024) and at harvest (172.88 g in 2023 and 178.51 g in 2024), which was statically different with 70% RDF with two foliar application of Nano NPK (S_4) at 20 DAS (24.49 g in 2023 and 26.19 g in 2024), at 40 DAS (108.01 g in 2023 and 110.16 g in 2024) and at harvest (163.10 g in 2023 and 166.01 g in 2024), which was at par with 70% RDF with two foliar application of Homemade NPK (S_4) at 20 DAS (23.71 g in 2023 and 25.80 g in 2024), at 40 DAS (107.49 g in 2023 and 109.40 g in 2024) and at harvest (160.91 g in 2023 and 164.64 g in 2024), and 70 % RDF with two foliar application of plant extract (S_5) at 20 DAS (22.59 g in 2023 and 24.75 g in 2024), at 40 DAS (106.25 g in 2023 and 107.65 g in 2024) and at harvest (159.50 g in 2023 and 162.95 g in 2024) . The lowest dry matter accumulation (g m^{-2}) was observed in control treatment (S_1) at 20 DAS (18.15 g in 2023 and 18.15 g in 2024), at 40 DAS (82.30 g in 2023 and 83.02 g in 2024) and at harvest (129.36 g in 2023 and 129.80 g in 2024).

The interaction effect of residual cropping system and nutrient management differed significantly with respect to plant height at harvest but there is no significant effect at 20 and 40 DAS (Table 4.32b) during both the years, residue of M_2S_2 increased dry matter accumulation (g m^{-2}) at harvesting (179.11g in 2023 and 189.01 in 2024) which was statistically similar with M_3S_2 at harvest (173.01 g in 2023), M_4S_2 at harvesting (175.68 g in 2023 and 184.66 g in 2024). The lowest dry matter accumulation was observed in M_1S_1 (112.65 g in 2023 and 107.99 g in 2024).

4.5.3. Number of tillers (meter^{-1} row)

The data on number of tillers of fodder oat is influenced by residue of cropping system and nutrient management at 40 DAS and harvest during 2023-24 and 2024-25 (Table 4.33a).

The number of tillers ($meter^{-2}$) of fodder oat differed significantly with residue of cropping system at all the growth stages. During both the years, residue of sole soybean (M_2) cropping increased number of tillers ($meter^{-2}$) at 40 DAS (138.23 in 2023-24 and 138.67 in 2024-25) and at harvest (177.04 in 2023-24 and 179.01 in 2024-25) which was statistically similar with 1:2 row proportion of maize and soybean residue (M_4) at 40 DAS (130.29 in 2023-24 and 132.93 in 2024-25) and at harvest (171.24 in 2023-24 and 171.22 in 2024-25). The lowest number of tillers was observed in residue of sole maize (M_1) at 40 DAS (113.55 in 2023-24 and 115.41 in 2024-25) and at harvest (151.88 in 2023-24 and 152.02 in 2024-25).

Table 4.33a. Residual effect of planting system and nutrient management on number of tillers (meter^{-1} row) of fodder oat under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	40 DAS		At harvest	
	2023 - 24	2024 - 25	2023 - 24	2024 - 25
Planting system				
M_1	113.55	115.41	151.88	152.02
M_2	138.23	138.67	177.04	179.01
M_3	124.11	126.51	165.57	167.62
M_4	130.29	132.93	171.24	171.22
M_5	122.31	122.93	159.19	163.22
SEm±	3.07	2.83	1.96	2.03
CD (P = 0.05)	10.16	9.36	6.50	6.72
Nutrient management				
S_1	87.13	87.52	104.05	99.56
S_2	143.79	147.37	189.25	193.06
S_3	133.46	135.78	177.80	180.83
S_4	132.83	133.20	177.60	179.61
S_5	131.28	132.59	176.24	180.04
SEm±	3.21	2.23	1.35	1.22
CD (P = 0.05)	9.20	6.39	3.87	3.51

4.33b. Interaction effect of residue of planting system and nutrient management on number of tillers (meter^{-1} row) of fodder Oats under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023-24						2024-25					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	100.81	112.25	103.45	101.25	102.45	**104.05**	93.55	108.65	96.19	103.20	96.19	**99.56**
S_2	173.68	205.51	188.57	196.84	181.63	**189.25**	182.35	202.57	193.53	194.61	192.23	**193.06**
S_3	162.51	188.85	178.91	186.33	172.38	**177.80**	163.07	195.48	181.54	186.95	177.08	**180.83**
S_4	162.43	189.37	178.51	186.31	171.36	**177.60**	158.94	194.97	182.72	185.85	175.56	**179.61**
S_5	159.97	189.22	178.39	185.49	168.11	**176.24**	162.20	193.38	184.11	185.47	175.04	**180.04**
Mean	**151.88**	**177.04**	**165.57**	**171.24**	**159.19**		**152.02**	**179.01**	**167.62**	**171.22**	**163.22**	
Subplot at same level of main plot												
SEm±	4.39						4.54					
CD (P = 0.05)	9.12						8.34					
Main plot at same or different level of subplot												
SEm±	3.34						3.18					
CD (P = 0.05)	10.09						9.69					

Similarly, the residue of nutrient application differed significantly on number of tillers (meter^{-2}) at 40 DAS and at harvest during 2023-24 and 2024-25. During both the years, residue of 100% RDF (S_2) application superior number of tillers at 40 DAS (143.79 in 2023-24 and 147.37 in 2024-25) and at harvest (189.25 in 2023-24 and 193.06 in 2024-25) which was statically different with 70 % RDF with two foliar application of nano NPK (S_3) at 40 DAS (133.46 in 2023-24 and 135.78 in 2024-25) and at harvest (177.80 in 2023-24 and 180.83 in 2024-25) which was at par with 70% RDF with two foliar application of Homemade NPK (S_4) at 40 DAS (132.83 in 2023-24 and 133.20 in 2024-25) and at harvest (177.60 in 2023-24 and 179.61 in 2024-25), and 70 % RDF with two foliar application of plant extract (S_5) at40 DAS (131.28 in 2023-24 and 132.59 in 2024-25) and at harvest (176.24 in 2023-24 and 180.04 in 2024-25) . The lowest number of tillers (meter^{-2}) was observed in control treatment (S_1) at 40 DAS (87.13 in 2023-24 and 87.52 in 2024-25) and at harvest (104.05 in 2023-24 and 99.56 in 2024-25).

The interaction effect of residual cropping system and nutrient management differed significantly with respect to number of tillers (meter^{-1} row) at harvest but there is no significant effect at 30 DAS (Table 4.33b) during both the years, residue of M_2S_2 increased number of tillers (meter^{-2}) at harvesting (205.51 in 2023-24 and 202.57 cm in 2024-25) which was statistically similar with M_4S_2 at harvest (196.84 in 2023-24 and 194.61 in 2024-25), M_2S_3 at harvesting (195.48 in 2024-25), M_2S_4 at harvesting (194.97 in 2024-25), M_2S_5 at harvesting (193.38 in 2024-25) . The lowest dry matter accumulation was observed in M_1S_1 (100.81 in 2023-24 and 93.55 in 2024-25).

4.5.4. Green fodder yield of oat crop under residue of maize + soybean - oat cropping system (2023-24 and 2024-25)

4.5.4. Green fodder Yield (t ha^{-1})

The data on green fodder yield (t ha^{-1}) of fodder oat is influenced by residue of cropping system and nutrient management at harvest during 2023-24 and 2024-25(Table 4.34a).

The green fodder yield (t ha^{-1}) of fodder oat differed significantly with residue of cropping system at harvest stages. During both the years, residue of sole soybean (M_2) cropping increased green fodder yield (t ha^{-1}) at harvest (29.13 t ha^{-1} in 2023 and 30.01 t ha^{-1} in 2024) which was statistically similar with 1:2 row proportion of maize and soybean residue (M_4) at harvest (28.25 t ha^{-1} in 2023 and 28.47 q ha^{-1} in 2024). The lowest green fodder yield (t ha^{-1}) was observed in residue of sole maize (M_1) at harvest (16.20 t ha^{-1} in 2023 and 16.88 t ha^{-1} in 2024).

Similarly, the residue of nutrient application differed significantly on green fodder yield (t ha^{-1}) at harvest during 2023 and 2024. During both the years, residue of 100% RDF (S_2) application superior the green fodder yield (t ha^{-1}) at harvest (30.60 t ha^{-1} in 2023 and 31.04 t ha^{-1} in 2024) which was statically different with 70 % RDF with two foliar application of nano NPK (S_3) at harvest (26.17

Table 4.34a. Residual effect of planting system and nutrient management on green fodder Yield ($t\ ha^{-1}$) of fodder oat under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	2023 - 24	2024 - 25
Planting system		
M_1	16.20	16.88
M_2	29.13	30.01
M_3	26.63	26.68
M_4	28.25	28.47
M_5	24.92	25.17
SEm±	0.50	0.57
CD (P = 0.05)	1.64	1.89
Nutrient management		
S_1	16.92	16.64
S_2	30.60	31.04
S_3	26.17	26.94
S_4	25.92	26.58
S_5	25.52	26.01
SEm±	0.54	0.56
CD (P = 0.05)	1.56	1.60

4.34b. Interaction effect of residue of planting system and nutrient management on green fodder yield ($q\ ha^{-1}$) of fodder oat under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	11.943	22.209	15.193	21.002	14.253	**16.92**	11.706	22.789	14.258	21.322	13.115	**16.638**
S_2	19.876	35.337	32.634	34.353	30.803	**30.601**	21.353	35.753	32.757	33.977	31.34	**31.036**
S_3	16.553	30.044	28.605	29.063	26.581	**26.169**	17.312	31.317	29.324	29.544	27.206	**26.941**
S_4	16.444	29.352	28.51	28.73	26.549	**25.917**	17.18	30.476	28.92	29.14	27.168	**26.577**
S_5	16.174	28.712	28.203	28.079	26.433	**25.52**	16.851	29.697	28.127	28.347	27.026	**26.01**
Mean	**16.198**	**29.131**	**26.629**	**28.246**	**24.924**		**16.88**	**30.007**	**26.677**	**28.466**	**25.171**	
Subplot at same level of main plot												
SEm±	1.19						1.28					
CD (P = 0.05)	3.51						3.69					
Main plot at same or different level of subplot												
SEm±	1.19						1.25					
CD (P = 0.05)	3.51						3.70					

t ha^{-1} in 2023 and 26.94 t ha^{-1} in 2024) which was at par with 70% RDF with two foliar application of Homemade NPK (S_4) at harvest (25.92 t ha^{-1} in 2023 and 26.58 t ha^{-1} in 2024), and 70 % RDF with two foliar application of plant extract (S_5) at harvest (25.52 t ha^{-1} in 2023 and 26.01 t ha^{-1} in 2024) . The lowest green fodder yield (t ha^{-1}) was observed in control treatment (S_1) at harvest (16.92 t ha^{-1} in 2023 and 16.64 t ha^{-1} in 2024).The interaction effect of residual cropping system and nutrient management differed significantly with respect to green fodder yield (t ha^{-1}) at harvest but there is no significant effect at 30 DAS (Table 4.34b) during both the years, residue of M_2S_2 increased green fodder yield (t ha^{-1}) at harvesting (35.34 t ha^{-1} in 2023 and 35.73 t ha^{-1} in 2024) which was statistically similar with M_3S_2 at harvest (32.63 t ha^{-1} in 2023 and 32.76 t ha^{-1} in 2024), M_4S_2 at harvesting (34.35 t ha^{-1} in 2023 and 33.98 t ha^{-1} in 2024). The lowest green fodder yield (t ha^{-1}) was observed in M_1S_1 (11.94 t ha^{-1} in 2023 and 11.71 t ha^{-1} in 2024).

4.6. Agro – physiological and biochemical attributes

4.6.1. Proline content (µg g^{-1} fresh weight)

The data on proline content (µg g^{-1} fresh weight) of maize is influenced by cropping system and nutrient management at 90 DAS 2023 and 2024 (Table 4.35).

The proline content (µg g^{-1} fresh weight) of maize crop was non- significant with the cropping system, during both the year, here was non-significant difference was noticed with the cropping pattern of maize crop.

The nutrient application differed significantly on proline content (µg g^{-1} fresh weight), during 2023 and 2024. During both the years, control treatment (S_1) increased proline content (1.127 µg g^{-1} in 2023 and 0.925 µg g^{-1} in 2024) which was statically different with 70 % RDF with two foliar application of nano NPK (S_3) (0.566 µg g^{-1} in 2023 and 0.549 µg g^{-1} in 2024) which was at par with and 70% RDF with two foliar applications of Homemade NPK (S_4) (0.563 µg g^{-1} in 2023 and 0.539 in 2024), and 70% RDF with two foliar applications of plant extract (S_5) (0.554 µg g^{-1} in 2023 and 0.531 in 2024) . The lowest proline content was observed in 100 % RDF treatment (S_2) (0.430 µg g^{-1} in 2023 and 0.393 µg g^{-1} in 2024).

The interaction effect of cropping system and nutrient management, there was no interaction effect respect to proline content (µg g^{-1} fresh weight)

4.6.2. Growing Degree Days (days)

There was considerable variation in availed of thermal units available for various growth stages in both crops. In the case of soybean, total thermal units availed up to harvests were 2520.20 and maize was availed at 2172.66 in 2023 and 2551.00 in 2024 (Table - 4.36). The magnitude of variation in availed of thermal units or GDD between flowerings and pod/cob formation was

Table 4.35. Effect of planting system and nutrient management on proline content (µg g^{-1} fresh weight) of maize under maize + soybean - oat cropping system (2023 and 2024)

Treatment	2023	2024
Planting system		
M_1	0.661	0.590
M_3	0.649	0.614
M_4	0.644	0.578
M_5	0.638	0.567
SEm±	0.006	0.018
CD (P = 0.05)	NS	NS
Nutrient management		
S_1	1.127	0.925
S_2	0.430	0.393
S_3	0.566	0.549
S_4	0.563	0.539
S_5	0.554	0.531
SEm±	0.014	0.026
CD (P = 0.05)	0.039	0.076

4.36. Effect of planting system and nutrient management on growing degree day (days) in maize + soybean - oat cropping system (2023 and 2024)

Stage	Maize crop		GDD			Soybean crop		GDD	
	Days	Duration	2023	2024		Days	Duration	2023	2024
Germination	12	12	195.50	286.67	**Germination**	70.00	70.00	1260.55	12055.26
Tasselling and Silking	65	53	1154.88	1154.88	**Flowering**	90.00	20.00	368.71	398.29
Cob/ Pod formation	72	7	129.5	135.90	**Pod formation**	105.00	15.00	265.41	499.97
Grain formation	80	8	150.00	163.11	**Seed formation**	115.00	10.00	165.04	199.89
Beginning the grain development	87	7	142.00	137.26	**Beginning the seed development**	128.00	7.00	189.26	240.11
Cob contains full size	98	11	216.66	221.09	**Pod contains full size**	140.00	12.00	151.91	201.69
Physiological maturity	110	12	209.18	259.06	**Physiological maturity**	156.00	16.00	119.34	156.80
Harvest maturity			156.77	192.99					
	Total GDD		**2172.66**	2158.98		2264.325		**2520.20**	**13752.00**

comparatively higher than that of other growth stages. For attaining the flowering stage, soybean had the highest thermal unit (12055 in soybean) and maize 1168 compared with the other growth stages.

4.6.3. Rain water use efficiency (mm ha^{-1})

The data on rain water use efficiency (mm ha^{-1}) of maize is influenced by cropping system and nutrient management during 2023 and 2024 (Table 4.37a). The rain water use efficiency of maize crop was significant differed with the cropping system, During both the year. 1:1 row proportion of the maize soybean (M_3) increased rainwater use efficiency (3.75 mm ha^{-1} in 2023 and 10.99-mm ha^{-1} in 2024). The lowest rain water use efficiency was recorded under the sole maize (M_1) (2.03 mm ha^{-1} in 2023- and 4.58 mm ha^{-1} in 2024).

The nutrient application differed significantly on rain water use efficiency (mm ha^{-1}), during 2023 and 2024. During both the years, 100% RDF (S_2) increased rain water use efficiency (13.34 mm ha^{-1} in 2023 and 9.52 mm ha^{-1} in 2024) which was statically different with 70 % RDF with two foliar application of plant extract (S_5) (3.24 mm ha^{-1} in 2023 and 9.38 in 2024) which was at par with the 70% RDF with two foliar applications of Homemade NPK (S_4) (3.23 mm ha^{-1} in 2023 and 9.24 in 2024). The lowest rainwater use efficiency was observed in control treatment (S_1) (2.30 mm ha^{-1} in 2023and 4.58 mm ha^{-1}in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to rain water use efficiency (mm ha^{-1}) (Table 4.37b), during both the years, M_3S_2 increased rain water use efficiency (4.06 mm ha^{-1} in 2023 and 12.19 mm ha^{-1} in 2024) which was statistically similar with M_3S_5 (4.01 mm ha^{-1} in 2023 and 11.83 in 2024), M_3S_4 (4.01 mm ha^{-1} in 2023 and 11.80 mm ha^{-1} in 2024). The lowest rain water use efficiency (mm ha^{-1}) was observed in M_1S_1 (1.76 mm ha^{-1} in 2023and 3.65 mm ha^{-1} in 2024).

4.7. Agronomic indices

4.7.1. Competition Index

The data on competition index of maize is influenced by cropping system and nutrient management during 2023 and 2024 (Table 4.38). The competition index of maize crop was significant differed with the cropping system, During both the year. Sole maize (M_1) and sole soybean (M_2) was highest compared to their intercropping system. The lowest competition index was recorded under the 1:1 row proportion of maize and soybean (M_3).

The nutrient application differed significantly on competition index, during 2023 and 2024. During both the years, control treatment was increased competition index (0.42 in 2023 and 0.42 in 2024) which was statically similar with 70 % RDF with two foliar applications of nano NPK (S_3) (0.42 in 2023 and 0.41 in 2024) which was at par with the 70% RDF with two foliar applications of

Table 4.37a. Effect of planting system and nutrient management on rain water use efficiency (mm ha^{-1}) in maize + soybean - oat cropping system (2023 and 2024)

Treatment	2023	2024
Planting system		
M_1	2.03	4.58
M_3	3.75	10.99
M_4	3.38	9.78
M_5	3.03	8.83
SEm±	0.02	0.19
C.D (0.05)	0.08	0.66
Nutrient management		
S_1	2.30	6.04
S_2	3.34	9.52
S_3	3.12	8.54
S_4	3.23	9.24
S_5	3.24	9.38
SEm±	0.04	0.11
C.D (0.05)	0.11	0.31

4.37b. Interaction effect of planting system and nutrient management on rainwater use efficiency (mm ha^{-1}) of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.76	2.71	2.54	2.18	**2.30**	3.65	7.89	6.6	5.96	**6.04**
S_2	2.12	4.06	3.76	3.41	**3.34**	5.02	12.19	11.12	9.76	**9.52**
S_3	2.06	3.84	3.49	3.07	**3.12**	4.38	11.25	9.68	8.85	**8.54**
S_4	2.10	4.01	3.55	3.23	**3.22**	4.87	11.80	10.7	9.59	**9.24**
S_5	2.10	4.01	3.57	3.23	**3.23**	4.98	11.83	10.79	9.92	**9.38**
Mean	**2.03**	**3.73**	**3.38**	**3.02**		**4.58**	**10.99**	**9.78**	**8.82**	
Subplot at same level of main plot										
SEm±	0.05					0.42				
CD (P = 0.05)	0.22					0.69				
Main plot at same or different level of subplot										
SEm±	0.07					0.27				
CD (P = 0.05)	0.20					0.86				

Table 4.38. Effect of planting system and nutrient management on competition index and land equivalent ratio of maize + soybean - oat cropping system (2023 and 2024)

Treatment	competition index		land equivalent ratio	
	2023 - 24	2024 - 25	2023 - 24	2024 - 25
Planting system				
M_1	1.00	1.00	1.00	1.00
M_2	1.00	1.00	1.00	1.00
M_3	0.01	0.01	1.77	1.81
M_4	0.02	0.02	1.63	1.63
M_5	0.05	0.03	1.37	1.44
SEm±	0.00	0.00	0.01	0.02
CD (P = 0.05)	0.01	0.01	0.04	0.07
Nutrient management				
S_1	0.42	0.42	1.29	1.34
S_2	0.41	0.41	1.39	1.40
S_3	0.42	0.41	1.35	1.36
S_4	0.41	0.41	1.38	1.39
S_5	0.41	0.41	1.38	1.39
SEm±	0.00	0.00	0.01	0.01
CD (P = 0.05)	0.01	0.01	0.03	0.03

Homemade NPK (S_4) (3.233 mm ha^{-1} in 2023 and 12.234 in 2024). The lowest competition index was observed in 100% RDF (S_2) (0.41 in 2023 - and 0.41 in 2024).

The interaction effect of cropping system and nutrient management, there is no significant with respect to competition index.

4.7.2. Land equivalent ratio (LER)

The data on land equivalent ratio (LER) was of maize is influenced by cropping system and nutrient management during 2023 and 2024 (Table 4.38). The LER of maize crop significant differed with the cropping system, during both the year 1:1 row proportion of maize and soybean (M_3) increased the LER (1.77 in 2023 and 1.81 in 2024) compared to other intercropping treatment. The lowest LER (1.37 in 2023 and 1.44 in 2024) was recorded under the 2:3 row proportion of maize and soybean (M_5).

Similarly, the nutrient application differed significantly on LER at harvest during 2023 and 2024. During both the years, 100% RDF (S_2) application superior the LER at harvest (1.39 in 2023 and 1.40 in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at harvest (1.38 in 2023 and 1.39 t ha^{-1} in 2024), 70% RDF with two foliar applications of Homemade NPK (S_4) at harvest (1.38 in 2023 and 1.39 in 2024). The lowest LER was observed in control treatment (S_1) at harvest 1.29 in 2023 and 1.29 in 2024).

The interaction effect of cropping system and nutrient management, there is no significant with respect to LER.

4.7.3. Maize Equivalent Yield (t ha^{-1}) MEY

The data on MEY of maize is influenced by cropping system and nutrient management during 2023 and 2024 (Table 4.39a).

The MEY of maize differed significantly with cropping system at harvest stages. During both the years, 1:1 row proportion of maize and soybean (M_1) at harvest (9.39 t ha^{-1} in 2023 and 9.88 t ha^{-1} in 2024) compared to other cropping treatment. The lowest MEY was observed in sole maize (M_1) at harvest (5.47 t ha^{-1} in 2023 and 5.68 t ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on MEY at harvest during 2023 and 2024. During both the years, 100% RDF (S_2) application superior the MEY at harvest (8.36 t ha^{-1} in 2023 and 8.84 t ha^{-1} in 2024) which was statically similar with 70 % RDF with two foliar application of plant extract (S_5) at harvest (8.23 t ha^{-1} in 2023 and 8.66 t ha^{-1} in 2024), 70% RDF with two foliar application of Homemade NPK (S_4) at harvest (8.20 t ha^{-1} in 2023 and 8.55 t ha^{-1} in 2024). The lowest MEY was observed in control treatment (S_1) at harvest (5.79 t ha^{-1} in 2023 and 6.34 in 2024).

Table 4.39a. Effect of planting system and nutrient management on maize equivalent yield (t ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	2023	2024
Planting system		
M_1	5.47	5.68
M_3	9.39	9.88
M_4	8.63	8.82
M_5	7.29	7.80
SEm±	0.11	0.15
CD (P = 0.05)	0.38	0.53
Nutrient management		
S_1	5.79	6.34
S_2	8.36	8.84
S_3	7.90	7.82
S_4	8.20	8.55
S_5	8.23	8.66
SEm±	0.24	0.05
CD (P = 0.05)	0.41	0.15

4.39b. Interaction effect of planting system and nutrient management on maize equivalent (t ha^{-1}) yield of maize under maize + soybean - oat cropping system (2023 and 2024)

M/S	2023					2024				
	M_1	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	4.74	6.99	6.14	5.30	**5.79**	4.97	7.64	6.56	6.19	**6.34**
S_2	5.71	10.46	9.32	7.95	**8.36**	5.99	10.80	9.96	8.60	**8.84**
S_3	5.57	9.61	8.86	7.58	**7.90**	5.51	9.64	8.66	7.49	**7.82**
S_4	5.66	9.95	9.41	7.77	**8.20**	5.88	10.65	9.40	8.27	**8.55**
S_5	5.68	9.96	9.44	7.86	**8.23**	6.03	10.68	9.51	8.44	**8.66**
Mean	**5.47**	**9.39**	**8.63**	**7.29**		**5.68**	**9.88**	**8.82**	**7.80**	
Subplot at same level of main plot										
SEm±	0.24					0.34				
CD (P = 0.05)	0.42					0.35				
Main plot at same or different level of subplot										
SEm±	1.59					0.18				
CD (P = 0.05)	0.50					0.60				

The interaction effect of cropping system and nutrient management differed significantly with respect to MEY (t ha^{-1}) at harvest (Table 4.39b) during both the years, M_3S_2 increased MEY at harvesting (10.46 t ha^{-1} in 2023 and 10.80 t ha^{-1} in 2024) which was statistically similar with M_3S_5 at harvest (10.68 t ha^{-1} in 2024), M_3S_4 at harvesting (10.65 t ha^{-1} in 2024). The lowest MEY was observed in M_1S_1 (4.74 t ha^{-1} in 2023 and 4.97 t ha^{-1} in 2024).

4.8. Soil health parameters

4.8.1. Available soil nitrogen (kg ha^{-1})

The data on soil nitrogen (kg ha^{-1}) as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 40a).

The soil nitrogen (kg ha^{-1}) of soil after maize + soybean - oat cropping system significantly influence on the soil. During both the years, sole soybean (M_2) cropping increased soil nitrogen at *Kharif season* (234.81 kg ha^{-1} in 2023 and 239.98 kg ha^{-1} in 2024), at *Rabi season* (204.62 kg ha^{-1} in 2024 and 206.74 kg ha^{-1} in 2024) which was statistically similar with 1:2 row proportion of maize and soybean at *Kharif season* (M_4) (229.83 kg ha^{-1} in 2023 and 232.24 kg ha^{-1} in 2024), at *Rabi season* (197.61 kg ha^{-1} in 2024 and 203.91 kg ha^{-1} in 2025). The lowest soil nitrogen (kg ha^{-1}) was observed in sole maize (M_1) *Kharif season* (178.55 kgha^{-1} in 2024 and 176.79 kg ha^{-1} in 2025), After oat cultivation (144.77 kgha^{-1} in 2024 and 142.50 kgha^{-1} in 2025)

Similarly, the nutrient application differed significantly on available nitrogen (kg ha^{-1}) of soil during 2023 - 24 and 2024 - 25. During both the years, 100% RDF (S_2) application increased the nitrogen at *Kharif season* (237.54 kg ha^{-1} in 2023 and 242.77 kg ha^{-1} in 2024), at *Rabi season* (203.80 kg ha^{-1} in 2024 and 213.69 kg ha^{-1} in 2025) which was statically different with 70 % RDF with two foliar application of nano NPK (S_5) at *Kharif season* (223.75 kg ha^{-1} in 2023 and 228.70 kg ha^{-1} in 2024), *Rabi season* (196.11 kg ha^{-1} in 2024 and 224.09 kg ha^{-1} in 2025), which was statically similar with 70% RDF with two foliar applications of Homemade NPK (S_4) at *Kharif season* (224.92 kg ha^{-1} in 2023 and 229.89 kg ha^{-1} in 2024), at *Rabi season* (196.05 kg ha^{-1} in 2024 and 201.87 kg ha^{-1} in 2025), 70% RDF with two foliar applications of plant extract (S_5) at *Kharif season* (223.75 kg ha^{-1} in 2023 and 228.70 kg ha^{-1} in 2024), at *Rabi season* (195.93 kg ha^{-1} in 2024 and 202.87 kg ha^{-1} in 2025). The lowest nitrogen (kg ha^{-1}) was observed in control treatment (S_1) at *Kharif season* (163.20 kg ha^{-1} in 2023 and 156.46 kg ha^{-1} in 2024), at *Rabi season* (128.27 kg ha^{-1} in 2024 and 115.03 kg ha^{-1} in 2025).

The interaction effect of cropping system and nutrient management differed significantly with respect to soil nitrogen (kg ha^{-1}) of soil (Table 4.40b-c), during both the years, M_2S_2 increased nitrogen at *Kharif season* (262.0 kg ha^{-1} in 2023 and 267.8 kg ha^{-1} in 2024), at *Rabi season* (226.6 kg ha^{-1} in 2023 and 235.1 kg ha^{-1} in 2024) which was statistically similar with M_2S_3 at *Kharif season* (249.7 kg

Table 4.40a. Effect of planting system and nutrient management on available soil nitrogen (kg ha-1) under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif*		*Rabi*	
	2023 - 24	**2024 - 25**	**2024**	**2025**
Planting system				
M_1	178.55	176.79	144.77	142.50
M_2	234.81	239.98	204.62	206.74
M_3	206.62	211.23	180.03	182.59
M_4	229.83	232.24	197.61	203.91
M_5	224.84	227.82	193.12	200.86
SEm±	3.18	3.23	2.80	2.72
CD (P = 0.05)	10.53	10.70	9.26	9.01
Nutrient management				
S_1	163.20	156.46	128.27	115.03
S_2	237.54	242.77	203.80	213.69
S_3	225.25	230.23	196.11	203.15
S_4	224.92	229.89	196.05	201.87
S_5	223.75	228.70	195.93	202.87
SEm±	2.84	2.76	1.99	2.37
CD (P = 0.05)	8.14	7.93	5.70	6.78
Initial value	180 kg ha^{-1}			

4.40b. Interaction effect of planting system and nutrient management soil nitrogen (kg ha-1) after maize + soybean intercropping under maize + soybean - oat cropping system (2023-24 and 2024-25).

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	162.7	163.5	162.5	163.3	163.8	**163.2**	140.3	166.8	165.8	153.3	156.1	**156.5**
S_2	193.3	262.0	226.8	255.8	249.8	**237.5**	197.2	267.8	232.0	261.5	255.4	**242.8**
S_3	181.0	249.7	214.6	243.6	237.3	**225.2**	184.6	255.3	219.5	249.1	242.7	**230.2**
S_4	180.6	249.4	214.5	243.2	237.0	**224.9**	184.2	254.9	219.4	248.7	242.3	**229.9**
S_5	174.2	249.5	214.6	243.2	237.3	**223.7**	177.7	255.1	219.5	248.6	242.6	**228.7**
Mean	**178.6**	**234.8**	**206.6**	**229.8**	**224.8**		**176.8**	**240.0**	**211.2**	**232.2**	**227.8**	
Subplot at same level of main plot												
SEm±	7.2						6.1					
CD (P = 0.05)	18.9						15.8					
Main plot at same or different level of subplot												
SEm±	6.5						5.5					
CD (P = 0.05)	19.4						16.3					

4.40c. Interaction effect of planting system and nutrient management soil nitrogen (kg ha-1) after oat crop under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	124.4	141.6	125.5	125.1	124.7	**128.3**	103.9	125.1	124.3	112.1	109.8	**115.0**
S_2	154.7	226.6	201.0	222.3	214.3	**203.8**	161.6	235.1	205.0	234.9	231.7	**213.7**
S_3	147.8	218.4	191.6	213.8	209.0	**196.1**	151.1	224.6	194.6	224.4	221.0	**203.1**
S_4	148.1	218.3	191.6	213.4	208.9	**196.0**	145.2	224.5	194.6	224.1	221.0	**201.9**
S_5	147.8	218.2	191.5	213.5	208.7	**195.9**	150.7	224.4	194.5	224.1	220.7	**202.9**
Mean	**144.8**	**204.6**	**180.0**	**197.6**	**193.1**		**142.5**	**206.7**	**182.6**	**203.9**	**200.9**	
Subplot at same level of main plot												
SEm±	6.3						6.1					
CD (P = 0.05)	13.4						15.8					
Main plot at same or different level of subplot												
SEm±	4.9						5.5					
CD (P = 0.05)	14.7						16.3					

ha^{-1} in 2023 and 255.3 kg ha^{-1} in 2024), at *Rabi season* (218.4 kg ha^{-1} in 2024 and 224.6 kg ha^{-1} in 2025) M_2S_4 at *Kharif season* (249.4 kg ha^{-1} in 2023 and 254.9 kg ha^{-1} in 2024), at *Rabi season* (218.3) kg ha^{-1} in 2024 and 224.5 kg ha^{-1} in 2025), M_2S_5 at *Kharif season* (249.5 kg ha^{-1} in 2023 and 255.1 kg ha^{-1} in 2024), at *Rabi season* (218.18 kg ha^{-1} in 2024 and 221.74 kg ha^{-1} in 2025), M_4 S_2 at after intercropping (285.82 kg ha^{-1} in 2023 and 291.53 kg ha^{-1} in 2024), at *Rabi season* (218.2 kg ha^{-1} in 2024 and 224.4 kg ha^{-1} in 2025), M_4S_3 at *Kharif season* (213.8 kg ha^{-1} in 2023), at *Rabi season* (213.8 kg ha^{-1} in 2024 and 224.4 kg ha^{-1} in 2025), M_4S_4 at *Kharif season* (243.2 kg ha^{-1} in 2023), at *Rabi season* (224.1 kg ha^{-1} in 2024) M_4S_5 at *Kharif season* (243.2 kg ha^{-1} in 2023), at *Rabi season* (234.9 kg ha^{-1} in 2024) and M_5S_2 at *Kharif season* (249.8 kg ha^{-1} in 2023 and 255.4 kg ha^{-1} in 2024), at *Rabi season* (214.3 kg ha^{-1} in 2024 and 231.7 kg ha^{-1} in 2025).The lowest soil nitrogen (kg ha^{-1}) was found in M_5S_1 at *Kharif season* (162.7 kg ha^{-1} in 2023 and 140.3 kg ha^{-1} in 2024), after oat crop (124.4 kg ha^{-1} in 2024 and 103.9 kg ha^{-1} in 2025).

4.8.2. Available soil phosphorus (kg ha^{-1})

The data on soil phosphorus (kg ha^{-1}) as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 4.41a).

The phosphorus (kg ha^{-1}) of soil after maize + soybean – oat cropping system significantly influence on the soil. During both the years, sole soybean (M_2) cropping increased phosphorus *at Kharif* (23.45 kg ha^{-1} in 2023 and 23.77 kg ha^{-1} in 2024), after oat cultivation (20.23 kg ha^{-1} in 2024 and 20.49 kg ha^{-1} in 2025) which was statistically similar with 1:2 row proportion of maize and soybean *at Kharif season* (M_4) (22.36 kg ha^{-1} in 2023 and 23.05 kg ha^{-1} in 2024), *at Rabi season* (18.06 kg ha^{-1} in 2024 and 18.26 kg ha^{-1} in 2025). The lowest phosphorus (kg ha^{-1}) was observed in sole maize (M_1) at *Kharif season* (18.07 kgha^{-1} in 2024 and 20.06 kg ha^{-1} in 2025), *at Rabi season* (15.23 kgha^{-1} in 2024 and 15.76 kgha^{-1} in 2025).

Similarly, the nutrient application differed significantly on phosphorus content (kg ha^{-1}) of soil during 2023 – 24 and 2024 - 25. During both the years, 100% RDF (S_2) application increased the soil phosphorus after the intercropping (23.51 kg ha^{-1} in 2023 and 24.65 kg ha^{-1} in 2024), *at Rabi season* (17.93 kg ha^{-1} in 2024 and 19.60 kg ha^{-1} in 2025) which was statically different with 70 % RDF with two foliar application of nano NPK (S_3) *at Kharif season* (21.81 kg ha^{-1} in 2023 and 24.07 kg ha^{-1} in 2024), *at Rabi season* (18.28 kg ha^{-1} in 2024 and 18.34 kg ha^{-1} in 2025), which was statically similar with 70% RDF with two foliar applications of Homemade NPK (S_4) after intercropping (27.76 kg ha^{-1} in 2023 and23.88 kg ha^{-1} in 2024), *at Rabi season* (18.01kg ha^{-1} in 2024 and 18.18 kg ha^{-1} in 2025), 70% RDF with two foliar applications of plant extract (S_5) *at Kharif season* (22.06 kg ha^{-1} in 2023 and 23.66 kg ha^{-1} in 2024), *at Rabi season* (18.13 kg ha^{-1} in 2024 and 19.04 kg ha^{-1} in 2025). The lowest soil phosphorus (kg ha^{-1}) was observed in control treatment (S_1) *at Kharif season* (15.49 kg ha^{-1} in 2023 and 15.61 kg ha^{-1} in 2024), *at Rabi season* (14.03 kg ha^{-1} in 2024 and 13.57 kg ha^{-1} in 2025).

Table 4.41a. Effect of planting system and nutrient management on available soil phosphorus (kg ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif*		*Rabi*	
	2023 - 24	**2024 - 25**	**2023 - 24**	**2024 - 25**
Planting system				
M_1	18.07	20.06	15.89	15.92
M_2	23.45	23.77	20.23	20.49
M_3	19.23	22.45	16.96	18.43
M_4	22.36	23.05	18.06	18.26
M_5	21.54	22.56	15.23	15.76
SEm±	0.33	0.35	0.29	0.43
CD (P = 0.05)	1.11	1.17	0.95	1.41
Nutrient management				
S_1	15.49	15.61	14.03	13.57
S_2	23.51	24.65	17.93	19.60
S_3	21.81	24.07	18.28	18.34
S_4	21.76	23.88	18.01	18.30
S_5	22.06	23.66	18.13	19.04
SEm±	0.30	0.15	0.35	0.34
CD (P = 0.05)	0.85	0.43	1.01	0.99
Initial value	22.5			

4.41b. Interaction effect of planting system and nutrient management available soil phosphorus (kg ha^{-1}) after maize + soybean intercropping under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	14.6	16.2	15.2	16.0	15.5	**15.5**	12.3	18.4	16.3	15.9	15.1	**15.6**
S_2	19.9	27.1	21.9	24.8	23.9	**23.5**	23.5	25.4	24.4	25.1	24.8	**24.7**
S_3	18.5	24.6	19.6	23.6	22.7	**21.8**	21.6	25.1	24.1	24.9	24.6	**24.1**
S_4	18.5	24.6	19.6	23.5	22.6	**21.8**	21.4	25.0	23.9	24.8	24.3	**23.9**
S_5	18.9	24.7	19.8	23.9	23.0	**22.1**	21.4	24.9	23.5	24.6	24.0	**23.7**
Mean	**18.1**	**23.4**	**19.2**	**22.4**	**21.5**		**20.1**	**23.8**	**22.4**	**23.0**	**22.6**	
Subplot at same level of main plot												
SEm±	0.7						0.8					
CD (P = 0.05)	2.0						1.1					
Main plot at same or different level of subplot												
SEm±	0.7						0.5					
CD (P = 0.05)	2.1						1.5					

4.41c. Interaction effect of planting system and nutrient management available soil phosphorus (kg ha^{-1}) after oat cultivation phosphorus under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	11.8	20.1	12.6	12.8	12.9	**14.0**	10.0	15.3	15.1	13.0	14.5	**13.6**
S_2	17.5	22.1	19.0	20.2	17.0	**17.9**	18.1	22.6	20.2	20.4	16.8	**19.6**
S_3	16.4	16.5	17.8	19.0	15.8	**18.3**	16.8	21.2	19.0	19.2	15.5	**18.3**
S_4	16.3	21.3	17.7	19.0	15.7	**18.0**	16.8	21.1	18.9	19.2	15.5	**18.3**
S_5	16.5	21.2	17.8	19.4	15.8	**18.1**	17.9	22.3	19.0	19.6	16.5	**19.0**
Mean	**15.9**	**20.2**	**17.0**	**18.1**	**15.2**		**15.9**	**20.5**	**18.4**	**18.3**	**15.8**	
Subplot at same level of main plot												
SEm±	0.6						1.0					
CD (P = 0.05)	2.3						2.3					
Main plot at same or different level of subplot												
SEm±	0.8						0.8					
CD (P = 0.05)	2.3						2.4					

The interaction effect of cropping system and nutrient management differed significantly with respect to soil phosphorus (kg ha^{-1}) of soil (Table 4.41b-c), during both the years, M_2S_2 increased soil phosphorus at *Kharif season* (27.1 kg ha^{-1} in 2023 and 25.4 kg ha^{-1} in 2024), *at Rabi season* (22.1 kg ha^{-1} in 2023 and 22.6 kg ha^{-1} in 2024) which was statistically similar with M_2S_3 *at Kharif season* (25.1 kg ha^{-1} in 2024), M_2S_4 *at Rabi season* (21.3 kg ha^{-1} in 2024 and 21.1 kg ha^{-1} in 2025) M_2S_4 *at Kharif season* (25.0 kg ha^{-1} in 2024), M_2S_5 *at Kharif season* (24.9 kg ha^{-1} in 2024), *at Rabi season* (21.2 kg ha^{-1} in 2024 and 22.3 kg ha^{-1} in 2025), M_4S_2 *at Kharif season* (25.1 kg ha^{-1} in 2024), *at Rabi season* (20.4 kg ha^{-1} in 2025), M_4S_3 *at Kharif season* (24.9 kg ha^{-1} in 2024), M_4S_4 *at Kharif season* (24.8 kg ha^{-1} in 2024), M_4S_5 (24.6 kg ha^{-1} in 2024), and M_5S_2 *at Kharif season* (24.8 kg ha^{-1} in 2024).The lowest phosphorus (kg ha^{-1}) was found in M_1S_1 *at Kharif season* (14.6 kg ha^{-1} in 2023 and 12.3 kg ha^{-1} in 2024), *at Rabi season* (11.8 kg ha^{-1} in 2024 and 10.0 kg ha^{-1} in 2025).

4.8.3. Available soil potassium (kg ha^{-1})

The data on available soil potash (kg ha^{-1}) as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 4.42a).

The available soil potassium (kg ha^{-1}) of soil after *Kharif* cropping system significantly influence on the soil. During both the years, sole soybean (M_2) cropping increased potash content at *Kharif season*(184.02 kg ha^{-1} in 2023 and 185.22 kg ha^{-1} in 2024), after oat cultivation (168.13 kg ha^{-1} in 2024 and 169.65 kg ha^{-1} in 2025) which was statistically similar with 1:2 row proportion of maize and soybean at *Kharif season* (M_4) (180.07 kg ha^{-1} in 2023 and 183.95 kg ha^{-1} in 2024), at Rabi *season*(167.42 kg ha^{-1} in 2024 and 168.15 kg ha^{-1} in 2025). The lowest soil potassium content (kg ha^{-1}) was observed in sole maize (M_1) *Kharif season* (173.66 kg ha^{-1} in 2024 and 177.36 kg ha^{-1} in 2025), After oat cultivation (161.27 kg ha^{-1} in 2024 and 163.30 kg ha^{-1} in 2025).

Similarly, the nutrient application differed significantly on available soil potassium (kg ha^{-1}) of soil during 2023 - 24 and 2024 - 25. During both the years, 100% RDF (S_2) application increased the soil potassium after the intercropping (188.91 kg ha^{-1} in 2023 and 192.12 kg ha^{-1} in 2024), at Rabi *season* (176.97 kg ha^{-1} in 2024 and 180.72 kg ha^{-1} in 2025) which was statically different with 70 % RDF with two foliar application of nano NPK (S_3) at *Kharif season* (178.24 kg ha^{-1} in 2023 and 184.58 kg ha^{-1} in 2024), at Rabi *season*(163.98 kg ha^{-1} in 2024 and 166.96 kg ha^{-1} in 2025), which was statically similar with 70% RDF with two foliar applications of Homemade NPK (S_4) *Kharif season*(171.55 kg ha^{-1} in 2023 and 184.12 kg ha^{-1} in 2024), at Rabi *season*(163.96 kg ha^{-1} in 2024 and 166.96 kg ha^{-1} in 2025), 70% RDF with two foliar applications of plant extract (S_5) *Kharif season*(178.46 kg ha^{-1} in 2023 and 183.48 kg ha^{-1} in 2024), at Rabi *season*(163.72 kg ha^{-1} in 2024 and 165.77 kg ha^{-1} in 2025). The lowest phosphorus content (kg ha^{-1}) was observed in control treatment (S_1) *Kharif season* (169.75 kg ha^{-1} in 2023 and 164.51 kg ha^{-1} in 2024), at Rabi *season* (158.96 kg ha^{-1} in 2024 and 154.92 kg ha^{-1} in 2025).

Table 4.42a. Effect of planting system and nutrient management on available soil potassium (kg ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif*		*Rabi*	
	2023 - 24	**2024 - 25**	**2023 - 24**	**2024 - 25**
Planting system				
M_1	173.66	177.36	161.27	163.30
M_2	184.02	185.22	168.13	169.65
M_3	176.75	180.93	164.30	166.81
M_4	180.07	183.95	167.42	168.15
M_5	172.40	181.35	166.48	167.05
SEm±	1.78	0.60	0.36	0.62
CD (P = 0.05)	5.90	2.00	1.20	2.06
Nutrient management				
S_1	169.75	164.51	158.96	154.92
S_2	188.91	192.12	176.97	180.78
S_3	178.24	184.58	163.98	166.96
S_4	171.55	184.12	163.96	166.53
S_5	178.46	183.48	163.72	165.77
SEm±	1.80	0.61	0.36	0.59
CD (P = 0.05)	5.15	1.76	1.02	1.70
Initial value	185.62 Kg ha^{-1}			

4.42b. Interaction effect of planting system and nutrient management on available soil potassium (kg ha^{-1}) after maize + soybean intercropping under maize + soybean - oat cropping system (2023-24 and 2024-25).

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	168.02	173.06	168.86	169.66	169.16	**169.75**	154.02	171.85	166.09	165.62	164.95	**164.51**
S_2	183.07	194.77	186.57	190.57	189.57	**188.91**	190.33	194.70	190.07	194.74	190.78	**192.12**
S_3	172.43	184.17	175.90	179.93	178.77	**178.24**	181.77	186.73	183.27	187.02	184.09	**184.58**
S_4	172.20	184.17	176.07	179.88	145.40	**171.55**	181.02	186.67	182.87	186.36	183.70	**184.12**
S_5	172.57	183.93	176.36	180.31	179.12	**178.46**	179.63	186.15	182.37	186.01	183.24	**183.48**
Mean	**173.66**	**184.02**	**176.75**	**180.07**	**172.40**		177.36	185.22	180.93	183.95	181.35	
Subplot at same level of main plot												
SEm±	3.99						1.35					
CD (P = 0.05)	11.88						4.05					
Main plot at same or different level of subplot												
SEm±	4.01						1.37					
CD (P = 0.05)	11.86						4.03					

4.42c. Interaction effect of planting system and nutrient management available soil potassium (kg ha^{-1}) after oat crop potash under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	**2023**						**2024**					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	157.94	159.67	158.73	145.40	160.34	**156.79**	145.40	160.34	156.79	156.35	155.72	**154.92**
S_2	172.08	180.07	175.37	179.68	182.76	**179.42**	179.68	182.76	179.42	181.95	180.10	**180.78**
S_3	158.96	167.19	162.43	164.72	168.59	**166.35**	164.72	168.59	166.35	168.01	167.13	**166.96**
S_4	158.74	167.20	162.59	164.02	168.52	**165.97**	164.02	168.52	165.97	167.39	166.76	**166.53**
S_5	158.61	166.50	162.39	162.71	168.03	**165.51**	162.71	168.03	165.51	167.05	165.57	**165.77**
Mean	**161.27**	**168.13**	**164.30**	**163.30**	**169.65**	**166.81**	163.30	169.65	166.81	168.15	167.05	
Subplot at same level of main plot												
SEm±	0.81						1.39					
CD (P = 0.05)	2.35						3.94					
Main plot at same or different level of subplot												
SEm±	0.80						1.34					
CD (P = 0.05)	2.36						3.97					

The interaction effect of cropping system and nutrient management differed significantly with respect to available potassium (kg ha^{-1}) of soil (Table 4.42 b-c), during both the years, M_2S_2 increased potash content at *Kharif season*(194.77 kg ha^{-1} in 2023 and 194.70 kg ha^{-1} in 2024), at Rabi *season*(180.07 kg ha^{-1} in 2023 and 182.76 kg ha^{-1} in 2024) which was statistically similar with M_2S_3 at *Kharif season*(184.17 kg ha^{-1} in 2023), M_2S_4 at *Kharif season*(184.17 kg ha^{-1} in 2023), M_2S_5 at *Kharif season*(183.93 kg ha^{-1} in 2023), M_4S_2 at *Kharif season*(190.57 kg ha^{-1} in 2023 and 194.74 kg ha^{-1} in 2024), at Rabi *season*(179.68 kg ha^{-1} in 2024 and 181.95 kg ha^{-1} in 2025), M_5S_2 at *Kharif season* (189.57 kg ha^{-1} in 2023 and 194.74 kg ha^{-1} in 2024), at Rabi *season*(182.76 kg ha^{-1} in 2024 and 180.10 kg ha^{-1} in 2025). The lowest soil potassium (kg ha^{-1}) was found in M_1S_1 at *Kharif season* (168.02 kg ha^{-1} in 2023 and 154.02 kg ha^{-1} in 2024), at Rabi *season* (157.94 kg ha^{-1} in 2024 and 145.40 kg ha^{-1} in 2025).

4.8.4. Soil pH

The data on soil pH as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 4.43). In cropping pattern and nutrient management there was no significant value of soil pH was observed under during both years.

4.8.5. Electric conductivity (EC) (dS m^{-1})

The data on soil EC as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 4.44).

There was no interaction observed under cropping system and nutrient management respect to soil electric conductivity (EC).

4.8.6 Soil organic carbon (%)

The data on soil organic carbon (%) as influenced by cropping system and nutrient management at harvest during 2023-24 and 2024-25 (Table 4.45).

The soil organic carbon (%) of soil after maize + soybean – oat cropping system significantly influence on the soil. During both the years, sole soybean (M_2) cropping increased soil organic carbon (%) at *Kharif season* (0.44 % in 2023 and 0.45% in 2024), after oat cultivation (0.32 % in 2024 and 0.33% in 2024). The lowest soil organic carbon (%) was observed in sole maize (M_1) *Kharif season* (0.37 % in 2023 and 0.37% in 2024), After oat cultivation (0.25 % in 2024 and 0.25% in 2025)

Similarly, the nutrient application differed significantly on nitrogen content (kg ha^{-1}) of soil during 2023 – 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the soil organic carbon (%) after the intercropping (0.45 % in 2023 and 0.46 % in 2024), *Rabi season* (0.32 % in 2024 and 0.33% in 2025) which was statically different with 70 % RDF with two foliar applications of nano NPK (S_5) at *Kharif season* (0.43% in 2023 and 0.44 % in 2024), *Rabi season* (0.32 % in

Table 4.43. Effect of planting system and nutrient management on soil pH under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif*		*Rabi*	
	2023 - 24	**2024 - 25**	**2023 - 24**	**2024 - 25**
Planting system				
M_1	7.51	7.58	7.50	7.51
M_2	7.51	7.59	7.51	7.54
M_3	7.52	7.59	7.51	7.52
M_4	7.52	7.58	7.50	7.51
M_5	7.50	7.58	7.50	7.48
SEm±	0.02	0.01	0.01	0.01
CD (P = 0.05)	NS	NS	NS	NS
Nutrient management				
S_1	7.50	7.57	7.50	7.50
S_2	7.52	7.59	7.51	7.51
S_3	7.50	7.59	7.51	7.52
S_4	7.51	7.59	7.51	7.52
S_5	7.52	7.60	7.51	7.52
SEm±	0.03	0.01	0.01	0.01
CD (P = 0.05)	NS	NS	NS	NS
Initial value	7.52			

Table 4.44. Effect of planting system and nutrient management on electrical conductivity (dS m^{-1}) of soil under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif*		*Rabi*	
	2023 - 24	**2024 - 25**	**2023 - 24**	**2024 - 25**
Planting system				
M_1	0.29	0.34	0.24	0.28
M_2	0.35	0.35	0.26	0.28
M_3	0.30	0.35	0.23	0.28
M_4	0.31	0.35	0.24	0.28
M_5	0.29	0.35	0.24	0.28
SEm±	0.00	0.00	0.01	0.00
CD (P = 0.05)	NS	NS	NS	NS
Nutrient management				
S_1	0.26	0.33	0.23	0.28
S_2	0.33	0.35	0.24	0.28
S_3	0.31	0.35	0.24	0.28
S_4	0.33	0.35	0.24	0.28
S_5	0.30	0.35	0.25	0.28
SEm±	0.01	0.00	0.00	0.00
CD (P = 0.05)	NS	NS	NS	NS
Initial value	0.32			

Table 4.45. Effect of planting system and nutrient management on soil organic carbon (%) under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	*Kharif season*		*Rabi season*	
	2023 - 24	**2024 - 25**	**2023 - 24**	**2024 - 25**
Planting system				
M_1	0.37	0.37	0.25	0.25
M_2	0.44	0.45	0.32	0.33
M_3	0.40	0.44	0.28	0.30
M_4	0.42	0.42	0.29	0.30
M_5	0.40	0.41	0.28	0.29
SEm±	0.01	0.01	0.01	0.01
CD (P = 0.05)	0.02	0.03	0.02	0.03
Nutrient management				
S_1	0.35	0.35	0.23	0.23
S_2	0.45	0.46	0.32	0.33
S_3	0.43	0.44	0.30	0.32
S_4	0.41	0.43	0.29	0.31
S_5	0.40	0.41	0.28	0.29
SEm±	0.01	0.00	0.01	0.00
CD (P = 0.05)	0.02	0.01	0.02	0.01

2024 and 0.33% in 2025), and 70% RDF with two foliar applications of Homemade NPK (S_4) *Kharif season* (0.41 % in 2023 and 0.43% in 2024), *Rabi season* (0.30 % in 2024 and 0.32% in 2025), 70% RDF with two foliar applications of plant extract (S_5) *Kharif season* (0.40 % in 2023 and 0.41% in 2024), *Rabi season* (0.28 % in 2024 and 0.29 % in 2025). The lowest soil organic carbon (%) was observed in control treatment (S_1) *Kharif season* (0.35 % in 2023 and 0.35% in 2024), *Rabi season* (0.23 % in 2024 and 0.23% in 2025).

4.8.7. Microbial population colony-forming units (cfu g^{-1})

The data on soil microbial population as influenced by cropping system and nutrient management during 2023-24 and 2024-25 (Table 4.46a).

The microbial population colony forming unit (cfu g^{-1}) of soil after maize + soybean – oat cropping system significantly influence on the soil. During both the years, sole soybean (M_2) cropping increased microbial population (11.52 cfu g^{-1} in 2023 and 11.83 cfu g^{-1} in 2024), which was statistically similar with 1:2 row proportion of maize and soybean at after intercropping (M_4) (11.26 cfu g^{-1} in 2023 and 11.52 cfu g^{-1} in 2024). The lowest microbial population was observed in sole maize (M_1) after intercropping (10.38 cfu g^{-1} in 2023 and 10.42 cfu g^{-1} in 2024).

Similarly, the nutrient application differed significantly on microbial population colony forming unit (cfu g^{-1}) of soil during 2023 – 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the microbial population (11.61 cfu g^{-1} in 2023 and 12.00 cfu g^{-1} in 2024), which was statically different with 70 % RDF with two foliar applications of nano NPK (S_3) (11.36 cfu g^{-1} in 2023 and 11.72 cfu g^{-1} CFU in 2024). The lowest soil organic carbon (%) was observed in control treatment (S_1) (10.22 cfu g^{-1} in 2023 and 10.04 cfu g^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significantly with respect to microbial population colony forming unit (cfu) of soil (Table 4.46a), during both the years, M_2S_2 increased microbial population (cfu g^{-1}) (12.1 cfu g^{-1} in 2023 and 12.5 cfu g^{-1} in 2024), which was statically similar with M_2S_3 (11.8 cfu g^{-1} in 2023 and 12.2 cfu g^{-1} in 2024) and M_4S_2 (11.8 cfu g^{-1} in 2023 and 12.2 cfu g^{-1} in 2024). The lowest microbial population was found in M_1S_1 at after intercropping (9.4 cfu g^{-1} in 2023 and 8.6 cfu g^{-1} in 2024).

4.9. Economic study

4.9.1. Cost of cultivation (₹ ha^{-1})

The data on cost of cultivation (COC) (₹ ha^{-1}) of maize and soybean is influenced by cropping system and nutrient management 2023-24 and 2024-25 (Table 4.47a).

The COC (₹ ha^{-1}) of maize + soybean cropping system significantly influence during both the years, 1:1 row proportion of the maize and soybean (M_3) increased COC (97563 ₹ ha^{-1}in 2023 and

Table 4.46a. Effect of planting system and nutrient management on soil microbial count cfu g^{-1} (10^6) of soil under maize + soybean - oat cropping system (2023-24 and 2024-25)

Treatment	2023 - 24	2024 - 25
Planting system		
M_1	10.38	10.42
M_2	11.52	11.83
M_3	11.11	11.42
M_4	11.26	11.52
M_5	10.91	11.19
SEm±	0.09	0.10
CD (P = 0.05)	0.30	0.32
Nutrient management		
S_1	10.22	10.24
S_2	11.61	12.00
S_3	11.36	11.72
S_4	11.12	11.46
S_5	10.86	11.18
SEm±	0.05	0.07
CD (P = 0.05)	0.14	0.19

4.46b. Interaction effect of planting system and nutrient management soil microbial population (cfu g^{-1} (10^6) of soil after oat crop under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
S_1	9.4	10.8	9.9	10.7	10.3	**10.2**	8.6	10.9	10.1	10.6	9.9	**10.0**
S_2	11.0	12.1	11.8	11.8	11.4	**11.6**	11.3	12.5	12.1	12.2	11.9	**12.0**
S_3	10.8	11.8	11.4	11.6	11.2	**11.4**	11.1	12.2	11.8	11.9	11.6	**11.7**
S_4	10.6	11.6	11.3	11.2	10.9	**11.1**	10.9	12.0	11.6	11.5	11.3	**11.5**
S_5	10.1	11.2	11.1	11.1	10.8	**10.9**	10.3	11.6	11.4	11.4	11.2	**11.2**
Mean	**10.4**	**11.5**	**11.1**	**11.3**	**10.9**		**10.4**	**11.8**	**11.4**	**11.5**	**11.2**	
Subplot at same level of main plot												
SEm±	0.20						0.21					
CD (P = 0.05)	0.33						0.44					
Main plot at same or different level of subplot												
SEm±	0.13						0.16					
CD (P = 0.05)	0.40						0.49					

Table 4.47a. Effect of planting system and nutrient management on economic attributes under maize + soybean - oat cropping system (2023-24 and 2024-25)

Economic study								
Treatment	Cost of cultivation (₹ ha^{-1})		Gross return (₹ ha^{-1})		Net return (₹ ha^{-1})		B:C ratio	
	2023	2024	2023	2024	2023	2024	2023	2024
Planting system								
M_1	93,543	94,376	1,82,458	1,95,756	88,915	1,01,380	1.95	1.88
M_2	91,623	92,456	1,76,613	1,87,233	84,990	94,776	1.92	1.50
M_3	97,563	98,397	2,96,029	3,28,608	1,98,465	2,30,212	3.03	3.04
M_4	96,381	97,214	2,77,018	2,93,551	1,80,637	1,96,336	2.87	2.76
M_5	94,415	95,248	2,40,328	2,63,551	1,45,914	1,68,303	2.54	2.59
SEm±	90	70	2,344	3,486	2,344	3,491	0.03	0.02
CD (P = 0.05)	297	233	7,763	11,546	7,764	11,560	0.09	0.07
Nutrient management								
S_1	90,057	90,890	1,74,572	1,93,705	84,515	1,02,815	1.93	1.99
S_2	97,080	97,913	2,59,789	2,84,654	1,62,709	1,86,741	2.66	2.52
S_3	95,943	96,776	2,42,573	2,53,126	1,46,630	1,56,350	2.52	2.36
S_4	95,195	96,028	2,47,731	2,67,956	1,52,536	1,72,928	2.59	2.47
S_5	95,250	96,083	2,47,781	2,69,258	1,52,531	1,73,174	2.59	2.50
SEm±	66	88	1,657	1,398	1,654	1,405	0.02	0.02
CD (P = 0.05)	189	253	4,752	4,010	10,745	14,029	0.09	0.06

4.47b. Interaction effect of planting system and nutrient on cost of cultivation (COC) (₹ ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
S_1	89,128	87,987	91,992	91,063	90,112	**90,057**	89,962	88,821	92,826	91,897	90,946	**90,890**
S_2	95,821	93,423	1,00,414	99,125	96,614	**97,080**	96,655	94,257	1,01,248	99,959	97,448	**97,913**
S_3	94,688	92,667	99,041	97,760	95,558	**95,943**	95,522	93,501	99,875	98,594	96,392	**96,776**
S_4	94,013	91,992	98,151	96,947	94,868	**95,195**	94,847	92,826	98,985	97,781	95,702	**96,028**
S_5	94,063	92,042	98,217	97,007	94,919	**95,250**	94,897	92,876	99,051	97,841	95,753	**96,083**
Mean	**93,543**	**91,623**	**97,563**	**96,381**	**94,415**		**94,376**	**92,456**	**98,397**	**97,214**	**95,248**	
Subplot at same level of main plot												
SEm±	200						157					
CD (P = 0.05)	444						577					
Main plot at same or different level of subplot												
SEm±	160						190					
CD (P = 0.05)	480						556					

4.47c. Interaction effect of planting system and nutrient on gross return (₹ ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
S_1	1,50,933	1,28,774	2,13,961	2,06,163	1,73,028	**1,74,572**	1,61,804	1,38,862	2,39,114	2,27,054	2,01,692	**1,93,705**
S_2	1,96,290	1,99,358	3,31,771	3,04,670	2,66,858	**2,59,789**	2,13,249	2,13,883	3,70,848	3,31,281	2,94,006	**2,84,654**
S_3	1,87,061	1,85,001	3,06,004	2,84,288	2,50,509	**2,42,573**	1,94,855	1,89,454	3,30,916	2,91,029	2,59,378	**2,53,126**
S_4	1,88,891	1,85,367	3,14,246	2,95,552	2,54,597	**2,47,731**	2,02,872	1,97,498	3,51,486	3,08,505	2,79,417	**2,67,956**
S_5	1,89,114	1,84,567	3,14,161	2,94,416	2,56,648	**2,47,781**	2,06,001	1,96,466	3,50,677	3,09,883	2,83,262	**2,69,258**
Mean	**1,82,458**	**1,76,613**	**2,96,029**	**2,77,018**	**2,40,328**		**1,95,756**	**1,87,233**	**3,28,608**	**2,93,551**	**2,63,551**	
Subplot at same level of main plot												
SEm±	5,241						7,796					
CD (P = 0.05)	11,174						9,810					
Main plot at same or different level of subplot												
SEm±	4,058						4,469					
CD (P = 0.05)	12,242						14,025					

4.47d. Interaction effect of planting system and nutrient management on net return (₹ ha^{-1}) under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	61,805	40,787	1,21,969	1,15,100	82,916	**84,515**	71,843	50,042	1,46,288	1,35,158	1,10,747	**1,02,815**
S_2	1,00,468	1,05,934	2,31,356	2,05,545	1,70,243	**1,62,709**	1,16,594	1,19,626	2,69,601	2,31,323	1,96,559	**1,86,741**
S_3	92,372	92,333	2,06,963	1,86,528	1,54,951	**1,46,630**	99,333	95,953	2,31,041	1,92,436	1,62,986	**1,56,350**
S_4	94,878	93,374	2,16,095	1,98,605	1,59,729	**1,52,536**	1,08,026	1,04,672	2,52,501	2,10,724	1,83,716	**1,71,928**
S_5	95,051	92,524	2,15,944	1,97,408	1,61,729	**1,52,531**	1,11,104	1,03,590	2,51,626	2,12,042	1,87,509	**1,73,174**
Mean	**88,915**	**84,990**	**1,98,465**	**1,80,637**	**1,45,914**		**1,01,380**	**94,776**	**2,30,212**	**1,96,336**	**1,68,303**	
Subplot at same level of main plot												
SEm±	5,242						7,805					
CD (P = 0.05)	16,157						17994					
Main plot at same or different level of subplot												
SEm±	6,054						7,481					
CD (P = 0.05)	17,231						18,058					

4.47e. Interaction effect of planting system and nutrient management benefit cast ratio (B:C ratio) under maize + soybean - oat cropping system (2023-24 and 2024-25)

M/S	2023						2024					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**Mean**
S_1	1.69	1.46	2.33	2.26	1.92	**1.93**	1.80	1.56	2.58	2.47	2.22	**2.13**
S_2	2.05	2.13	3.30	3.07	2.76	**2.66**	2.21	2.27	3.66	3.31	3.02	**2.89**
S_3	1.98	1.99	3.09	2.91	2.62	**2.52**	2.04	2.02	3.31	2.95	2.69	**2.60**
S_4	2.01	2.01	3.20	3.05	2.68	**2.59**	2.14	2.12	3.55	3.15	2.92	**2.78**
S_5	2.01	2.00	3.20	3.04	2.71	**2.59**	2.17	2.11	3.54	3.17	2.96	**2.79**
Mean	**1.95**	**1.92**	**3.03**	**2.87**	**2.54**		**2.07**	**2.02**	**3.33**	**3.01**	**2.76**	
Subplot at same level of main plot												
SEm±	0.06						0.08					
CD (P = 0.05)	0.12						0.13					
Main plot at same or different level of subplot												
SEm±	0.04						0.05					
CD (P = 0.05)	0.13						0.15					

98397 ₹ ha^{-1} in 2024). The lowest COC was observed in sole soybean (M_2) (91623 ₹ ha^{-1} in 2023 and 92456 ₹ ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on COC (₹ ha^{-1}) of maize and soybean during 2023 - 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the gross return (97080 ₹ ha^{-1} in 2023 and 97913 ₹ ha^{-1} in 2024). The lowest COC was observed in control treatment (S_1) (90057 ₹ ha^{-1} in 2023 and 90890 ₹ ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significant with respect to COC (₹ ha^{-1}) (Table 4.47b), during both the years, M_3S_2 increased gross return (100414 ₹ ha^{-1} in 2023 and 101248 ₹ ha^{-1} in 2024). The lowest COC was found in M_2S_1 (91992 ₹ ha^{-1} in 2023 and 88821 ₹ ha^{-1} in 2024).

4.9.2. Gross return (GR) (₹ ha^{-1})

The data on GR (₹ ha^{-1}) of maize and soybean is influenced by cropping system and nutrient management 2023-24 and 2024-25 (Table 4.47a).

The GR (₹ ha^{-1}) of maize + soybean cropping system significantly influence during both the years, 1:1 row proportion of the maize and soybean (M_3) increased GR (296029 ₹ ha^{-1}in 2023 and 328608 ₹ ha^{-1} in 2024). The lowest GR was observed in sole soybean (M_2) (176613 ₹ ha^{-1} in 2023 and 187233 ₹ ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on GR (₹ ha^{-1}) of maize and soybean during 2023 - 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the GR (2,59,789 ₹ ha^{-1} in 2023 and 2,84,654 ₹ ha^{-1} in 2024). The lowest GR was observed in control treatment (S_1) (174572 ₹ ha^{-1} in 2023 and 193705 ₹ ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significant with respect to GR (₹ ha^{-1}) (Table 4.47c), during both the years, M_3S_2 increased gross return (3,31,771 ₹ ha^{-1} in 2023 and 3,70,848 ₹ ha^{-1} in 2024). The lowest GR was found in M_1S_2 (1,28,774 ₹ ha^{-1} in 2023 and1,38,862 ₹ ha^{-1} in 2024).

4.6.3. Net return (NR) (₹ ha^{-1})

The NR (₹ ha^{-1}) of maize + soybean cropping system significantly influence during both the years, (Table 4.47), 1:1 row proportion of the maize and soybean (M_3) increased NR (1,98,465 ₹ ha^{-1}in 2023 and 2,30,212 ₹ ha^{-1} in 2024). The lowest NR was observed in sole soybean (M_2) 36032 ₹ ha^{-1} in 2023 and 43260 ₹ ha^{-1} in 2024).

Similarly, the nutrient application differed significantly on NR (₹ ha^{-1}) of maize and soybean during 2023 - 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the NR (1,62,709 ₹ ha^{-1} in 2023 and 1,86,741 ₹ ha^{-1} in 2024) which was statically similar with 70% RDF with two foliar application of plant extract (S_5) (1,52,531 ₹ ha^{-1} in 2023 and 1,73,174 ₹ ha^{-1} in 2024) and 70% RDF with two foliar application of Homemade NPK (S_4) (1,52,536 ₹ ha^{-1} in 2023 and 1,72,928 ₹ ha^{-1} in 2024). The lowest NR was observed in control treatment (S_1) (1,72,928 ₹ ha^{-1} in 2023 and 1,02,815 ₹ ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significant with respect to NR (₹ ha^{-1}) (Table 4.47d), during both the years, M_3S_2 increased NR (2,31,356 ₹ ha^{-1} in 2023 and 2,69,601₹ ha^{-1} in 2024) which was similar with M_3S_5 (2,15,944 ₹ ha^{-1} in 2023 and 2,51,626 ₹ ha^{-1} in 2024) and 70% RDF with two foliar application of Homemade NPK (S_4) (2,16,095 ₹ ha^{-1} in 2023 and 2,52,501₹ ha^{-1} in 2024). The lowest NR was found in M_2S_1 (40,787 ₹ ha^{-1} in 2023 and 50,042 ₹ ha^{-1} in 2024).

4.6.4. Benefit-Cost ratio (BCR)

The data on BCR of maize and soybean is influenced by cropping system and nutrient management 2023-24 and 2024-25 (Table 4.47a).

The BCR of maize + soybean cropping system significantly influence during both the years, 1:1 row proportion of the maize and soybean (M_3) increased BCR (3.03 in 2023 and 3.04 in 2024). The lowest BCR was observed in sole soybean (M_2) 1.92 in 2023 and 1.50 in 2024).

Similarly, the nutrient application differed significantly on BCR of maize and soybean during 2023 - 24 and 2024 - 25. During both the years, 100 % RDF (S_2) application increased the BCR (2.33 in 2023 and 2.45 in 2024) which was statically similar with 70% RDF with two foliar application of plant extract (S_5) (2.31 in 2023 and 2.50 in 2024) and 70% RDF with two foliar applications of Homemade NPK (S_4) (2.31 in 2023 and 2.47 in 2024). The lowest NR was observed in control treatment (S_1) (1.93 ₹ ha^{-1} in 2023 and 1.99 ₹ ha^{-1} in 2024).

The interaction effect of cropping system and nutrient management differed significant with respect to BCR (Table 4.47e), during both the years, M_3S_2 increased BCR (3.30 in 2023 and 3.66 in 2024) which was similar with M_3S_4 (3.20 ₹ ha^{-1} in 2023 and 3.54 in 2024) and M_3S_4 (3.20 in 2023 and 3.55), The lowest NR was found in M_1S_1 (1.07 in 2023 and 1.16 ₹ ha^{-1} in 2024).

CHAPTER 5

DISCUSSION

The significant findings of the present field investigation, titled **"Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oats in a maize + soybean–oats cropping system"** are presented in this chapter. This chapter discusses the growth parameters, yield attributes, yield, economics, and soil properties with due discussion and supporting evidences in respect of growth. The chapter aims to explain and confirm the experimental results by establishing cause effect relationships wherever possible, and to support these results with relevant findings from earlier researchers when necessary.

5.1. Growth attributes of maize

Maize crop sowing in the second year (2024) showed notably higher values for various growth parameters, including plant height, the number of leaves per plant, dry matter accumulation (DMA), and crop growth rate (CGR), in comparison to those grown in the first year (Table – 4.1- 4.10). The growth parameters of soybeans remained constant across the study years. Frequent and intense rainfall during the critical stage led to an optimal supply of moisture, resulting in a favorable balance of salts and nutrients in the rhizosphere zone (an improved microclimate) of the crop. This congenial environment promoted higher crop growth, contributing to enhanced photosynthetic efficiency and the efficient translocation of nutrients toward growing points. Consequently, the growth attributes of maize showed improvement during the second year of the study.

5.1.1 Plant height

Parameters of growth and growth attributes for maize, such as plant height, leaves per plant, leaf area, leaf area index, dry matter accumulation, and chlorophyll index (SPAD value), were monitored at regular intervals. In all these characteristics, the sole maize (M_1) showed the highest values, followed by the 1:1 row proportion of maize and soybean intercropping.

In comparison to other cropping systems, maize grown under sole cropping (M_1) showed substantial improvements in growth metrics, including plant height was statistically comparable to the 1:1 row arrangement of maize-soybean intercropping (M_3 1:1), (Table - 4.1). The enhanced growth of maize under sole cropping is likely due to the development of both temporal and spatial complementarity, resulting in reduced competition for essential resources such as nutrients, water, and light. This is consistent with the findings of Wang *et al.* (2021), who discovered that mono cropped maize exhibited the greatest significant plant height compared to different intercropping row ratios, primarily due to the direct impact of solar interception on maize plant height. A wide-row proportional cropping system resulted in lower plant heights than a narrow-row cropping pattern. Plants that are tall with more leaves per plant and a higher leaf area index at tasseling demonstrate a faster crop growth rate from the knee-high to tasseling stage, resulting in greater plant height and a higher dry matter production (DMP). Greater space between rows and more compact planting within rows may have led to an increased spread of the roots, ultimately allowing the plants to more efficiently utilize water, nutrients, space, and light resources. A study by Kou *et al.* (2024) found that, on average, the plant height of intercropped maize was decreased by 7.94% compared to monocropped maize over a two-year period. Plant height for maize increased as the number of maize rows grew. Plant heights showed a significant response to the presence of shade.

5.1. 2. Dry matter accumulation

We observed a greater dry matter accumulation in maize under the sole cropping system at 30, 60, and 90 days after sowing, and at the time of harvesting. The low competition between plant rows and increased light interception in the lower parts of maize plants were responsible, and the accumulation of dry matter in the lower parts of maize was significantly higher in sole crops compared to intercropping. This difference could be attributed to increased light capture and photosynthetic product accumulation in the singular treatment as opposed to the remainder of the treatments. Raza *et al.* (2022), observed different treatments significantly affected the total dry matter production of maize. Across different sampling stages and treatments, maize plants accumulated higher dry matter in their sole cropping compared to intercropping treatments. In addition, different maize planting density treatments in intercropping not only affected dry matter production of intercrops but also changed dry matter partitioning in various plant parts of maize. A similar result was reported by Begam *et al*. (2024) and Kou *et al*. (2024)

5.1.1.3. Number of leaves plant^{-1}

The highest number of leaves per plant was recorded under the sole treatment, surpassing the other intercropping treatments, which were statistically comparable to the 1:1 row proportional maize and soybean (M_3) intercropping. This may be due to the optimum spacing, which allows for better nutrient uptake and aeration, resulting in a higher number of leaves. Researchers led by Deng *et al*. (2024) found that compared with intercropping methods, sole maize cultivation exhibited the greatest number of leaves due to greater light absorption. Leaves from this plant had lower stomatal conductance than comparable leaves from the sole maize crop. Sun leaf adaptations were uniquely observed at specific leaf positions and developmental stages in intercropping systems, whereas Kou *et al*. (2024) reported that sole maize had the highest significant leaves compared to intercropping treatments over a period of two cropping *season*s. The number of leaves increase with increasing height of the maize, as the number of leaves showed a substantial response to height. The varying numbers of leaves among the different intercropping patterns can be attributed to the intercropping ratios that support maize growth through reduced light competition. This occurs because taller plants absorb more light energy, leading to an increased rate of photosynthesis and subsequent production of assimilates by leaves.

5.1.1.4. Leaf area and leaf area index

Result revealed that, the sole maize cropping system exhibited the highest leaf area and leaf area index in comparison to the maize and soybean intercropping systems with row proportions of 1:1, 1:2, and 2:3 row proportion of maize and soybean. In both years, 2023 and 2024, maize and soybean intercropping with a 1:1 row proportion showed statistically similar leaf areas and leaf area index when compared to other treatments. Efficient use of available resources will likely increase the leaf area index (LAI) and consequently plant dry matter production. This potential issue can be attributed to the source-sink relationship and nutrient competition among maize plants. Maize cultivated in an intercropping system drew nutrients from the same soil layer and depth, thereby impairing the physical properties of the soil to some extent, ultimately hindering plant development. A study by Dong *et al.* (2024) found that compared with intercropping methods, sole maize cultivation resulted in the largest leaf area, primarily due to greater light interception in its monoculture system. Research by Raza *et al*. (2022) discovered that under various planting conditions, the Leaf Area Index (LAI) of maize grown in intercropping scenarios was substantially lower than that of maize grown alone. It is possible that maize grown alone was linked to greater light utilization efficiency, water use efficiency, nutrient accumulation, and adaptability in edge-row plants. The result was followed by Wang X *et al*., 2020 and Raza *et al*., 2021.

5.1.1.5. Growth development (CGR, RGR and NAR)

Crop growth and biomass are closely related to the amount of radiation intercepted by the crop canopy. Research indicates that sole maize cultivation resulted in the highest crop growth rate. In contrast, 2:3 row proportion of maize and soybean intercropping exhibited the lowest crop growth rate. This observation aligns with the findings of Begam *et al.* (2024), they found crop growth rate (CGR) of maize increased positively until 70 – 90 DAS, after which it declined towards maturity. Notably, treatment M_1 (sole maize) exhibited significantly higher CGR, and relative growth rate (RGR) throughout all periodic measurements, followed by treatment C_4 (2 M:1 C) due to less competition for nutrients and higher interception of the light which was create the higher amount of dry matter in sole crop compared to mixed plot crop. We observed that relative growth rate of maize during the 30-60 and 60-90 days after sowing (DAS) periods was influenced by the different crop arrangements. The 2:3 maize-soybean intercropping system demonstrated the maximum relative growth rate during both periods. This suggests a potential synergistic interaction between soybean and maize during these growth phases. The period between 30 and 60 DAS showed maximum overall plant growth, leading to a higher relative growth rate, while the subsequent period of 60-90 DAS showed comparatively lower growth. Similar result was found by Pandey *et al*. (2017). The net assimilation rate (NAR) was highest under the 1:1 row proportion of maize and soybean at 30-60 DAS, attributed to the enhanced plant growth observed in this arrangement. These findings likely reflect the synergistic effects of intercropped soybean and maize on plant development during this stage. In the later growth phase of 60-90 DAS, a comparatively lower and non-significant NAR was observed across the treatments, a result consistent with the findings of Pandey *et al*. (2017).

5.1.1.6. Stem diameter

The highest stem diameter and internode length was recorded under the sole maize cropping system at the 30, 60 and 90 DAS, compared to rest of treatment. 1:1 row proportion was recorded statically similar stem girth, which was due to higher light interception and less competition of light occurred under the sole cropping system compared to rest of treatment. Similar result was found Legba *et al*. (2025), They found stem diameter significantly affected by the tested sowing patterns of sole maize, (1:1), (2:2) and (1:3). Highest significant stem girth was recorded under their monocropping due to higher light interception and less competition of light and proper spacing.

5.1.1.7. Chlorophyll index (SPAD)

The highest reading of the chlorophyll index (SPAD) value was observed in the sole maize treatment compared with the other treatments. This might be due to its higher light interception and optimum nutrient management. The use of 100% RDF with optimal spacing and reduced competition from the crop may influence higher SPAD values in sole maize cultivation. This was statistically comparable to a 1:1 row proportion of maize + soybean intercropping. In contrast to the results of Wei *et al*. (2022), the SPAD value for intercropping maize differed significantly from that of monocropping maize. Intercropping maize and soybean exhibited a higher SPAD value. Intercropping maize and soybean are more beneficial than monocropping because it allows for greater SPAD levels, enhances photosynthesis, and ultimately contributes to increased yields.

Maize and soybean fertilized through 100% RDF showed significantly greater growth parameter values (including plant height, DMA, number of leaves, leaf area, LAI, length, CGR, RGR and NAR stem girth and internode length and SPAD) compared to other fertility practices (Table 1). The possible justification for the higher growth attributes of 100% RDF is the optimization of essential nutrient supply to the crop. The result indicated that the yields of 70% RDF with two foliar applications of plant extract (S_5) and 70% RDF with two foliar applications of homemade NPK were statistically similar to that of the RDF treatment. The enhanced micronutrient levels in plant extract and homemade NPK may contribute to improved plant metabolism, as evidenced by better nutrient uptake and reduced environmental nutrient losses. This outcome is consistent with the findings of Begam *et al.* (2024). A sufficient supply of nutrients (both macro and micronutrients) promotes increased nutrient uptake, leading to rapid leaf growth, and subsequently increased plant growth parameters due to enhanced cell division and expansion, as well as a higher photosynthetic rate (Begam *et al*., 2024). Besides this same growth parameters of maize reported to achieve higher values with high fertilizer dose applied *i.e.* 100%, this could be attributed to a mere fact that higher rates o of nitrogen may have caused rapid cell division and elongation. Maize being an exhaustive crop, responded well to the fertilizer application. Increase in its yield and growth parameters with increased application of NPK fertilizer was also reported by Usman *et al*., (2015). Raza *et al.,* 2022 was reported optimum recommended of doses application was found to boost chlorophyll levels and electron transport capacity in photosystems I and II of crop leaves, while also slowing down the aging process of lower and middle leaves and prolonging the period of high photosynthetic activity in those leaves. The photosynthetic performance of the crops was significantly enhanced, resulting in increased growth and growth attributes character of the maize crop. Hussein *et al.* (2021), observed that maximum growth of the maize crop, was recorded in foliar application of sea weed extract treatment compared to rest of the nutrient management treatment. Sea weed extract was enhanced root and shoot growth of the plant and also improves their stress, resulting maximum height was observed due to probably seaweeds include distinctive types of polysaccharides either being reserve materials or cell wall components as alginates which represent the main constituent of brown seaweed cell walls and are essential in stimulating plant growth.

5.2. Growth attributes of Soybean

Soybean crop that was sowed in the second year showed a significant increase in growth parameters (Table - 4.13). The microclimate became more favourable due to an optimal moisture supply. This favourable environment was the result of several factors, including frequent and abundant rainfall, higher sunshine hours, and relative humidity. As a result, the conditions were ideal for increased crop growth and photosynthetic activity. The increased photosynthetic activity led to the translocation of photosynthates, ultimately resulting in higher productivity in soybean during the second year of the study, as compared to the first year.

5.2.1. Plant height

Soybean growth metrics were monitored every 30 days until the crop was harvested. The 2:3 row proportion, (two rows of maize and three rows of soybean) (M_5), produced the tallest plants. This was closely followed by the 1:2 row proportion of maize and soybean intercropping (M_4). In contrast, the shortest plants were recorded in a sole soybean (M_2) plot. It is possible that intercropping with a higher population of plants led to soybean plants growing taller due to competition for light. This study confirmed the findings of numerous researchers, (Table- 4.13). According to Li *et al*. (2020) observed that soybean plants in sole cropping had a height, while those in intercropping. This indicates that intercropped soybean was taller than sole soybean, likely due to competition with maize. According to Liu *et al.* (2017) investigated the changes in light environment, morphology, growth, and yield of soybean in maize-soybean intercropping systems. They found that soybean plant height in the two intercropping treatments was 51% higher than that in the monoculture. The changes in the light environment led to increased plant height, these morphological changes enabled relatively more light interception and increased light use efficiency (LUE) of soybean due to the shading effect caused by maize.

5.1.2.2. Dry matter accumulation

The sole cropping of soybean (M_2) may potentially experience a more favorable microclimate that promotes healthier root development. This is due to the acquisition of more essential nutrients and water. In comparison to intercropped soybean with maize, solo soybean had a greater dry matter accumulation per plant, which was statistically similar to the 1:2 row proportion of maize and soybean intercropping (M_3). Conversely, the 2:3 row proportion of maize and soybean intercropping showed the lowest values. The improved use of nutrients, light, and space by plants in the sole soybean (M_2) create contributed to this result. Under an intercropping system, soybean plants experienced reduced vegetative growth due to shading from taller maize plants. Notable decreases in the specified parameters were observed in soybean intercropped with other crops, with lower values recorded particularly in the 2:3 maize to soybean row proportion and the 1:2 maize to soybean row proportion compared to other crop arrangements. According to Shen *et al*. (2021) observed, the intercropping of maize and soybeans is a weak competition system. Interspecific facilitation in maize-soybean intercrops may be due to increased efficiency of resource use. The maximum dry matter accumulation of soybean recorded under their monoculture, compared to intercropping due to less competition and light interception. Another study conducted by Liu *et al*. (2017). They found that SS (sole soybean) always caused higher dry matter level than the other treatments. The RI resulted in higher dry matter level than the other intercropping treatments before 50 DAS. After 70 DAS, the dry matter showed a trend of SS>SI1>SI2>SI3>RI due to higher light interception under the sole cropping of soybean.

5.1.2.3 Number of leaves

The highest number of leaves was found in sole soybeans, followed by 1:1 row proportion of maize and soybean, and the lowest value was obtained from the 2:3 row proportion of maize and soybean. It might be maize had a significant influence over the growth of soybean. In terms of foliage, sole soybean exhibited higher values for the number of leaves. Furthermore, the sole soybean cropping not only produced the greatest number of nodules and nodule dry weight but also exhibited the highest dry matter accumulation. Dong *et al*. (2024). They found sole soybean wear highest number of leaves compared to intercropping treatments because of optimum light interception. These leaves had lower SLA than corresponding leaves in sole maize. However, sun leaf adaptations were not found at other leaf positions and at other developmental stages in intercropping. Similarly, Kou *et al*. (2024) reported that sole soybean wear the highest significant leaves compared to intercropping treatments. The number of leaves of maze increased with height of soybean. It was clear that number of leaves responded significantly to height.

5.1.2.4. Leaf area and leaf area index

Result revealed that highest leaf area and LAI was found in sole soybeans, followed by 1:1 row proportion of maize and soybean, and the lowest value was obtained from the 2:3 row proportion of maize and soybean. It might be maize had a significant influence over the growth of soybean. It might due to b higher light interception and less competition between plant. Dong *et al*. (2024) observed that sole soybean was recorded highest leaf area compared to intercropping treatments because of less competition and higher light interception of soybean in their monoculture respectively. Khonde *et al* (2022) indicated that the leaf of soybean decreased in maize-soybean intercropping, negatively impacting its growth. The highest leaf area was recorded in their sole crop due to higher light interception on soybean leaves. Gu *et al.* (2024). The found that the leaf area index of soybean was 14.81% lower in the four rows of maize and six rows of soybean in the narrow-wide row planting pattern (D-M_4S_6), 18.01% lower in the six rows of maize and six rows of soybean in the narrow-wide row planting pattern (D-M_6S_6), and 26.56% lower in the four rows of maize and four rows of soybean in the narrow-wide row planting pattern (D-M_4S_4) than in the soybean monoculture in the narrow-wide row planting pattern (D-S) due to improve the light transmittance ratio of soybean but also increased the photosynthetic area of crops under the monoculture. Dudwal *et al.* (2021) indicated, the intercropping patterns significantly affected the LAI, higher LAI was recorded their sole crop respectively, due to low competition between the plant. Similarly, Issahaku *et al.* (2010), reported that the leaf area index LAI values of legume intercrops were lower compared to legume mono-crops, indicating dominance of corn in the grain legumes. The differences LAI can be attributed to the variations in canopy configuration, resulting in differences in leaf area. The sole soybean crop had a significantly higher LAI compared to all other treatments, indicated more effective in capturing light than the intercropped soybean.

5.1.2.5. Growth and development (CGR, RGR and NAR)

Result revealed that highest crop development attributes like CGR, RGR and NAR was recorded under the sole soybeans (M_2), followed by 1:1 row proportion of maize and soybean, and the lowest value was obtained from the 2:3 row proportion of maize and soybean. It might be maize had a significant influence over the growth of soybean. It might due to less competition and good environment condition under the sole soybean compared to other intercropping. Result was closely followed by Raza *et al.,* 2022. According to Ross *et al*. (2018) observed that crop growth rate (CGR), Relative growth rate (RGR) and Net assimilation rate (NAR) of soybeans in the intercropping system was negatively impacted, with yields 2 to 11% lower than monocrop. This reduction was associated with lower intercepted radiation (IPAR) and CGR, RGR, NAR in border rows during critical growth periods. Mohan *et al*. (2023) investigated the observed that, significantly highest crop growth rate, relative growth rate, and net assimilation rate at 30-60 DAS, were recorded at sole soybean. Sole soybean crop exhibited significantly higher CGR than soybean as an intercrop. A higher relative growth rate of soybean was observed in monoculture compared to intercropping systems might be due to no intercrop competition for light, nutrients, moisture, and space.

5.1.2.6. Number of branches plant^{-1}

We observed that highest number of branches of soybean was recorded under their sole cropping compared to rest of cropping treatment. It might be due to less competition and optimum light utilization under the sole treatment. Result was similar to Wang *et al.,* 2023. Legba *et al*. (2025) observed that, highest branches of moong been recorded under sole crop (3.4) compared to Maize + moong bean intercropping (1:2), (1:3) and (2:2), cropping pattern. The spacing and the spatial arrangement contributed to creating specific microclimatic conditions, including light interception, temperature, humidity, and wind patterns for each sowing pattern, which could explain the difference in moong bean growths. According to Wang *et al*. (2023) observed that maximum number of branches was recorded under the sole soybean treatment compared to maize -soybean due to intercropping reduced photosynthetic active radiation in the soybean canopy within the maize-soybean relay strip intercropping system influenced soybean morphogenesis, resulting in slender and weak stems that are prone to lodging and ultimately leading to a decline in soybean branches.

5.1.2.7. Number of nodules plant^{-1}

Highest significant number of nodules plant^{-1} was recorded under the sole soybean which was statically similar with 1:1 row proportion of maize and soybean (M_3). It might be excellent rhizosphere condition as well as less competition between plant. Shumet *et al*. (2022), they observed that, rhizobium inoculation treatment on the sole plot resulted in the highest average number of nodules plant^{-1} (51.9). When intercropping resulted in the lowest number of nodule plant^{-1}.The increased number of nodules in sole cropping might be due to the reduced competition for resources from the maize crop. Mandal *et al*. (2014) and Ijoyah (2013) observed that intercropping significantly reduced the number of nodules per plant significantly lower than that of sole soybean crops. This decline in these parameters was primarily due to competition between maize and soybean for essential nutrients, light, and physical space. Research has found that an increase in the population of maize plants has a negative impact on soybean growth. It is possible due to the depressing effect of a high population of maize, which can lead to the overcrowding of both species in a given area. This can have a negative impact on aboveground and belowground soybean biomass.

5.1.2.8. Nodules dry weight

Result revealed that significantly highest nodules dry weight was observed under the sole treatment(M_2) compared to other cropping system. It might be due to good condition of rhizosphere less shade effect by maize plant and less competition of light water and nutrient. Shumet *et al*. (2022) observed that, the highest nodule dry weight (0.64 g $plant^{-1}$) was recorded planted on sole cropping with inoculated treatment. The lowest nodule dry weight was recorded by in the intercropping treatments regardless of the inoculation. The increment in nodule dry weight under sole cropping with inoculation may be due to the higher infection and compatibility between the variety and the inoculant, and better light use than uninoculated and sole cropping. Effective light use might be due to better soil nutrition for more nodule formation. Lin *et al*. (2024) investigated the sole soybean promotes nodules development and nitrogen fixation by root exudates deposition. They found that planting pattern significantly influenced on nodule dry weight. Compared with monocrop, nodule dry weight in intercropped soybean was reduced by 19% and 26%.

Result revealed that soybean exhibited a positive response to various fertilizer doses. As the fertility level rose from 70% RDF to 100% RDF in both crops, all growth parameters increased.

We notice that significant higher growth attributes (like plant height, number of leaves, number of branches, Dry matter, CGR, RGR and NAR) was recorded under the 100% RDF (S_2) treatment which was statically similar with 70% RDF with two foliar application of plant extract (S_5) and 70% RDF with two foliar applications of Homemade NPK (S_4). It was probably due to availability of essential nutrients provide by the 100% RDF. In case of 70% RDF with two foliar application of plant extract (S_5) and 70% RDF with two foliar applications of Homemade NPK (S_4) have some micronutrients and stimulator which are help to improve the plant metabolism system which can be enhanced the nutrient uptake from the soil resulting statically similar growth attributes was found under S_5 and S_4 treatment. In absolute control treatment there was no any fertilizer applied resulting lowest values of growth parameter was occurred, it was probably due to deficiency of the essential nutrients which can't be well growth of soybean occurred under the control treatment. Similar result was found by the Nasar *et al.* (2022).

According to Racz *et al*. (2021) reported maximum soybean growth was recorded under the base and foliar nutrient application treatment, suggest that foliar fertilization is only a supplemental method that may correct nutrient deficiencies but cannot replace soil-applied fertilizers of major nutrients. They observed joint treatment of nutrient and foliar fertilization (which also contained N) may have resulted in the best N supply conditions for maize resulting obtained higher growth attributes of soybean crop. According to Shen *et al*. (2021) observed that the maximum dry matter accumulation of soybean recorded under their nutrient management compared to their control treatment. It was happened due to higher nutrient availability in 100% RDF treatment. Nasar *et al.* (2022) reported intercropping without fertilizer application showed lower trends in the growth indices of soybean crops such as leaf area (cm^2) and growth attributes of soybean. However, with fertilizer application, intercropping showed significant ($p< 0.05$) improvement in these indices of the soybean crop. However, with fertilizer application, intercropping showed significant ($p< 0.05$) improvement in these indices of the soybean crop. Singh *et al*. (2024), reported, better nutrition, as indicated by higher growth attributes, improved photosynthetic rate when 122 kg N ha^{-1} was applied at LCC 5 over fixed time application of 125 kg N ha^{-1}. This could be attributed to better synchronization of N supply with crop N demand leading to higher N uptake due to real time application of 125 kg N ha^{-1} based upon need.

Jaybhay *et al*. (2021) observed the chlorophyll index (SPAD value) was significantly affected due to different foliar nutrition treatments. Chlorophyll index (SPAD value) was significantly high in treatment RDF + 2% Urea over control and RDF + water spray and was followed by RDF + 2% DAP and RDF + 0.5% MOP foliar spray at pod initiation stage. Jarecki *et al*. (2024). They confirmed that the 100 % RDF of soybean seeds significantly increased the number of nodules and nodules dry weight on the roots compared to nitrogen the untreated control. Singh *et al*. (2024) reported, Soybean shows shy nodulation and needs nitrogen to boost up the nodulation, therefore under 125% RDF soybean recorded higher dry weight as well as number of nodules. This is the reason why nodule number decreased with the deceasing fertility level. A positive correlation between growth parameters of soybean except plant height with its seed yield was reported. This confirms that these parameters exert beneficial effect on seed yield of soybean.

5.3. Growth of fodder oat

5.1.3.1 Plant height

The cropping system where oats were seeded under the residue of sole-soybean (M_2) resulted in significantly greater plant height compared to systems with residue from maize-soybean intercropping in 1:1 (M_3), 1:2 (M_4), and 2:3 (M_5) row proportions (as indicated in Tables 4.25 to 4.27). This enhanced growth is likely attributable to the cultivation of oats following a legume (soybean), which improved the soil's physical, biological, and chemical environment. The residual effect of the soybean likely enhanced nutrient availability, leading to increased crop growth. Notably, the residue from the 1:2 row proportion of maize-soybean intercropping (M_4) produced statistically similar growth attributes to the residue from sole soybean. This could be due to the higher number of soybean plants in the M_4 treatment compared to the M_3 and M_5 treatments. In contrast, the nutrient-exhaustive maize crop likely left a smaller quantity of nutrients for subsequent crops, resulting in lower growth. These findings align with previous research by Congreves *et al*. (2015) and Parihar *et al.* (2016), which also reported improvements in crop growth with the inclusion of legumes in cropping systems.

5.1.3.2. Dry matter accumulation

Result revealed that highest dry matter accumulation of fodder Oats was observed under the residue of sole soybean, followed by the 1:2 row proportion of maize and soybean (M_4). It might be soybean plant have capability to enhance the soil organic carbon as well as fixed the atmospheric nitrogen in to the soil which was utilized by the succeeding crop. Result was followed by the Reddy *et al*., 2023 and Mallu *et al.*, 2020. Jangir *et al.* (2022) reported the maximum dry matter of succeeding crop was observed under the residual legume treatment compared to rest of treatment due to residual N is obtained from rhizodeposition and recoverable debris which become part of the active soil organic matter pool that derives the N pool in soil for the long term. The ability of legumes to fix atmospheric nitrogen as well as produce biomass and sequester carbon (C) is a crucial factor in reducing greenhouse gases emissions utilized by the succeeding crop. Mukhametov *et al.* (2024), reported that sole maize as a preceding crop has a nonsignificant impact on the succeeding crop. They observed legume intercropping can enhance nutrient cycling and improve soil health, the direct residual effects on oats growth can vary significantly based on management practices and environmental conditions.

5.1.3.3. Number of tillers

We noticed that highest number of tillers was recorded under the residue of sole soybean which was statically similar with the 1:2 row proportion of the maize and soybean (M_4). The lowest number of tillers was recorded under the residue of sole maize. It might be due to low availability of nutrient under the residue of sole maize (M_1) and higher nutrient availability under the residue of sole soybean (M_2). Result was followed by Parihar *et al.,* 2016. Geijersstam *et al.* (2006) recorded positive effect of number of tillers and their growth attributes influenced by preceding legumes residue. It was due to field pea fixed the atmospheric nitrogen into the soil, these nitrogens retain in soil and provide nutrient for succeeding oats crop and improved their growth attributes. In the case of legume incorporation in the cropping system, these are positively impacted on the succeeding fodder oats.

Regarding nutrient management, the application of 100% Recommended Dose of Fertilizers (RDF) (S_2) to the preceding crop resulted in significantly higher values for all growth parameters of oats at the initial stages. This was statistically different from the treatment residue of 70% RDF with two foliar applications of nano NPK (S_3), but remained statistically comparable to the treatments residue of 70% RDF with two foliar applications of Homemade NPK (S_4) and 70% RDF with two foliar applications of plant extract (S_5) residue application (as shown in Tables 4.27 to 4.27a). Conversely, the control treatment (S1) exhibited the lowest values for all growth attributes of fodder oat. The superior growth observed with the residue of the 100% RDF application at the initial crop growth stage could be attributed to the rapid availability of macronutrients, which likely facilitated rapid foliage expansion, a subsequent increase in cell division and expansion, an enhanced photosynthetic rate, and ultimately improved plant growth and dry matter accumulation (Hui *et al.*, 2017). The increase in all growth attributes of the succeeding fodder oats due to the S_2 (100% RDF) treatment applied to the preceding soybean could be ascribed to the addition of nitrogen and the leftover residual nitrogen and phosphorus applied to the chickpea. This residual effect likely contributed to a significant improvement in growth and yield attributes, ultimately leading to higher dry matter accumulation in the succeeding fodder oat. Furthermore, this improvement might also be attributed to the addition of nitrogen to the soil through a higher number of root nodules on the soybean plants and the soybean residues. This clearly highlights the vital role of legumes in cropping systems. Similar results have also been reported by Chaudhary *et al.* (2022).

5.3. Yield parameter

5.3.1 Yield attributes and yields of Maize

The yield attribute of a crop plays a crucial role in determining its overall productivity. In the context of maize, several yield parameters contribute directly to grain yield. These parameters include cobs plant^{-1}, number of seeds row^{-1}, number of seeds row cob^{-1}, number of grains cob^{-1}, weight of cob plant^{-1}, weight of grain cob^{-1}, and hundred seed weight. Research has shown that crop arrangements significantly impact these yield parameters in maize. This research examined the effects of different crop arrangements on maize yield under the maize + soybean – oat cropping system (2023-24) and found that sole maize (M_1) exhibited the highest values for these parameters. Notably, the 1:1 row proportion of the maize and soybean (M_3) intercropping system was statistically similar to M_1 in terms of yield parameter values. On the other hand, the lowest values for these yield parameters were recorded under the 2:3 row proportion of the maize and soybean (M_4) cropping system. This highlights the importance of crop arrangement in optimizing maize yield parameters. To further understand the relationship between crop arrangement and maize yield parameters, it is essential to consider the underlying factors that contribute to these parameters. For instance, cobs plant^{-1} and number of seeds row^{-1} are influenced by factors such as plant density, row spacing, and crop management practices. Similarly, number of grains cob^{-1}, weight of cob plant^{-1}, and weight of grain cob^{-1} plant^{-1} are affected by factors such as cob length, and grain weight. 100 seed weight, on the other hand, is influenced by factors such as seed size.

The yield of any crop is largely influenced by the crop's biomass. This biomass is determined by the amount of radiation that the crop canopy intercepts. Improved growth in plants, which resulted in higher leaf numbers, leaf areas, and leaf area indices in the sole maize, directly increased the photosynthetic area. This allowed the crop to absorb lighter and produce greater biomass. Additionally, the expansion of healthy root systems facilitated the use of nutrients belowground by these treatments. In conclusion improvements in both source efficiency and sink capacity are key factors. The yield of maize crop is primarily influenced by the crop biomass, which is itself determined by the amount of radiation that the crop canopy intercepts. The increased grain yields of maize in sole cropping systems can be attributed to the higher plant populations compared to intercropping. 1:1 row proportion of maize and soybean intercropping (M_3) was statically similar due to higher population of maize compared to other intercropping arrangements. In (M_3) cropping system had same population of maize compared to their sole cropping. It was additive series where maize plant was same as sole cropping and addition one row of soybean sowed between the two rows of maize crop. Our result is in close agreement with Raza *et al.* (2022) and Manasa *et al*. (2020). Gidey *et al*. (2024) reported grain yields of each sole crop were greater grain yield than intercrops this could be because of a better compatibility of the component crops at this specific population density on use of essential growth resources such as space, water, nutrients, and light. Kou *et al*. (2024) observed the intercropping significantly reduced grain yields of maize, but all intercropping systems had higher population grain yields than monocropped maize, creating an intercropping advantage. The overall grain yield reduction of maize was smaller, ranging from 7% to 25%, This suggests that wide and narrow rows in intercropped maize increase side row dominance, which in turn reduces yield losses. Mandal *et al.,* (2014) the intercropping system of maize and soybean resulted in the highest recorded number of grains cob^{-1} in their sole cropping system. This outcome was statistically on par with both sole maize and groundnut (1:2) and maize with groundnut (2:4) intercropping treatment. Manasa *et al*. (2020) reported the maximum maize grain yield (5669 kg ha^{-1}) was noted with sole maize due to no competition, optimum nutrient management practices and better light interception and translocated sink to sources, but the highest system yield was recorded in intercropping system compared to their monoculture.

The yield parameters of maize showed significant improvement as fertility levels increased from 70% of recommended dose of fertilizer (RDF) to 100% RDF. Parameters such as cob yield plant^{-1}, length and girth of cobs plant^{-1}, number of rows cobs^{-1}, grains row cobs^{-1}, number of grains cob^{-1}, and seed index (100 Seed weight) for maize increased with a subsequent increase in fertilizer dose. The highest values were recorded at 100% RDF. Which was statically similar with 1:1 row proportional of maize and soybean cropping (M_3). It was probably due to higher nutrient availability and higher source 0%to sink activity was observed under the 100% RDF (S_2) treatment followed by the 70% RDF with two foliar application of plant extract (S5) and 70% RDF with two foliar applications of Homemade NPK (S_4) treatment. It might be plant extract and Homemade NPK have bio stimulant and micronutrient which are improved the plant health and root system which's improved their nutrient uptake and higher activity of source to sink process resulting higher yield was observed. Result was followed by the Begam *et al*., 2024. The lowest yield and yield attributes parameter were observed under the control treatment (S_1). It was probably due to low nutrient availability under the control treatment. Our result is closely followed by the Pandey *et al.* (2017). Krishna *et al*. (2024) observed that nutrient management, the treatment NE@10t ha^{-1} (153:58:79 kg ha^{-1} of N: P_2O_5:K_2O) produced the highest number of grain row^{-1}, relation to fertilizer doses. Afrida *et al*. (2023) reported nutrient omission techniques fertilization significantly affected maize grain weight per cob. Among all omission techniques fertilization, P_2 (un-fertilizer of nitrogen) showed the highest inhibition of maize seed weight by 14.71; 18.85; 12.61; and 30.48%, respectively compared to completely fertilized. Yasari *et al*. (2024) found the fertilizer combination (N_2K_1) produced the highest average grain yield (9.84 t ha^{-1}) with an increase of 78.00% versus the control treatment (N_0K_0), which gave the lowest average grain yield (5.53 t ha^{-1}). Paul *et al*. (2023) reported, the highest grain and stover yield was recorded in F_3 (100% RDF), while the lowest values of the mentioned parameters were observed in the one irrigation and poultry manure (5 t ha^{-1}) treatment. This might be due to the fact that optimum nutrient supply increased the turgidity of cells, stomatal opening, increased net assimilation and ultimately resulted in better cob development. Duvvada *et al.* (2024) observed nutrient management had a significant effect on grain yield and stover yield. The higher grain and stover yield were with 100% RDF (F_2), F_3 – P_2O_5 (F5), and F_3 - K_2O (F_6), and the lower stover yield was noticed in control (F_0). The higher stover yield attributes and physiological indices recorded under SSNM (sole cropping + 100% RDF) lead to better crop health and a better source-sink relationship, which might result in enhanced maize yield over other nutrient management practices. Getnet *et al.* (2019) recorded the highest maize grain yield of 6155 kg/ha, which was achieved by applying the highest levels of nitrogen (120 kg/ha) and phosphorus (60 kg/ha) in combination. Gheith *et al.* (2022) reported that high nitrogen concentrations had the greatest impact on the development of the vegetative parts of plants. This suggests that the beneficial effect of increasing nitrogen supply on yield could be due to better ear growth, more filled kernels per ear, and larger kernels. Nitrogen increased the assimilate supply for component development and yield set, as evidenced by the significant rise in yield components.

5.3.2. Yield attributes and Yield of Soybean

The soybean yield attributes, (Table 4.31-33), were significantly impacted by the crop arrangements. Notably, the sole soybean (M_2) produced significantly higher values for yield attributes such as pods plant-[1], seed index, seed yield, stover yield, and biological yield, which was statically similar with 1:2 row proportion of maze and soybean(M_3) cropping system. It might be due to low competition between plants. The higher number of pods from sole soybeans can be attributed to its increased number of branches and leaves. This view is supported by Kebebew *et al.* (2014), who also noted an increase in seeds per pod with increased soybean plant densities. On the other hand, the lowest recorded values for all yield and yield attributes parameters were observed in the 2:3 row proportion of the maize and soybean cropping system. This is due to low population and inter-specific competition between the maize and soybean plants spaced between rows. Sole soybean cropping (M_2) exhibited greater growth due to significantly higher total dry matter accumulation in comparison with intercropped soybean. The leaf area index in intercropped soybeans is decreased due to the shading effect, which negatively impacts the photosynthetic rate and the delivery of assimilates to various plant organs. This reduction in leaf area index can be attributed to the competition for light between the two crops, resulting in a decrease in photosynthetic activity. The highest yield in sole soybean cultivation, as opposed to intercropping, can also be attributed to the higher plant population and the lack of competition between different species. In an intercropping system, the presence of multiple crops can lead to competition for resources such as water, nutrients, and light, resulting in reduced growth and yields. The decrease in light intensity caused by the maize plant in an intercropping system impairs the photosynthetic ability of the second crop, specifically soybean. This is because photosynthesis is a light-dependent process, and reduced light intensity can limit the rate of photosynthesis, resulting in reduced growth and yields. Improved root growth and nodulation in the soybean plant also enabled it to produce a higher yield. The nodulation process allows the soybean plant to form symbiotic relationships with nitrogen-fixing bacteria, which can provide the plant with a source of nitrogen. This can be particularly beneficial in soils with low nitrogen availability, allowing the soybean plant to thrive and produce higher yields. Result was followed by Zhang *et al*. (2015). Shen *et al*. (2021) reported that, intercropping reduces the number of pods plant^{-1} compared to their monoculture of soybeans, resulting in lower soybean yields. This study believes that the main reason for the reduction of soybean production by about 50-60% is that the shading of soybeans by maize will reduce the formation of soybean photosynthesis. Shumet *et al.* (2022). They found highest number of seed per pods was recorded from inoculated under sole cropping, whereas the lowest number of pods per plant$^{−1}$ was recorded in uninoculated and intercropped treatments of both varieties. It might be due to the microclimate effects of maize as the main crop which caused a reduction in photosynthetically active radiation (PAR). Singh *et al*. (2023a) reported the highest number of pods plant^{-1} was recorded from sole soybean (238.75) and sole green gram (29.96). Reduction in number of pods per plant due to intercropping might be attributed to shorter plant height in intercropping and could utilize lower percentage of incoming solar radiation might be due to plant height variation, the legumes could not able to receive the incoming solar radiation efficiently which affected the rate of photosynthesis. According to Feng *et al*. (2019) observed that significant differences were noted in the seed yield of soybean in their sole cropping compared to in 2M2S, 1M1S, for both years in field conditions. These variations in yield are likely due to the differences in light interception and planting arrangements. Anushree *et al*. (2024) reported sole soybean recorded significantly higher grain, stover, biological yield and harvesting index compared to their intercropping treatment due to competition free environment for growth resources *viz*., light, soil moisture, air, nutrients and better agronomic practices which helped the crop to exhibit their full production potential.

Soybeans responded positively to increased fertilizer application rates. When given 100% of the recommended dose of fertilizer, they showed enhanced productivity. This resulted in a higher number of pods per plant, improved test weight, and increased yields of seed, stover, and biological yield compared to the control treatment. The yields achieved under the 100% RDF (S_2) were comparable to 70% RDF with two foliar applications of plant extract (S_5) and 70% RDF with two foliar applications of homemade NPK (S_4). The control treatment (S_1), which received no fertilizer, notice the lowest productivity among the five nutrient management practices. Using 70% RDF as split and foliar applications refer to the direct application of a substance to the leaves of the plant. Plant extract and Homemade NPK have beneficial micronutrients and bio stimulant which enhance the metabolic activity of the plant and improved the all over yield attributes resulting higher yield was occurred. Our findings closely agreed with Begam *et al*., 2024. The maximum harvest index was recorded under the 70% RDF with two foliar applications of nano NPK (S_4) It might be higher seed and stover ratio of the soybean crop. Singh *et al*. (2023). They found that the highest seed yield, stover yield and biological yield of soybean, were observed with the treatment of 100% RDF of soybean. The increase in a 100 seed weight, might be due to the increased supply of almost all plant essential nutrients by translocation of the photosynthates accumulated under the influence of the sources of organic nutrients. Zewide *et al*. (2023) reported treatment of mixed NPS fertilizer at the rate of 150 kg NPS ha^{-1} produced the highest seed yield, while 0 kg NPS ha^{-1} produced the lowest yield (5.0). The increase in seeds yield observed with increasing NPS fertilizer application rates may result from an adequate supply of nutrients facilitating the formation of maximum seed. Jaybhay *et al*. (2020) reported, increase in seed yield with application of 2% Urea along with 100% RDF was 14.57% over control. Sireesha *et al.,* 2025 was reported 100% RDF was produce higher seed yield of soybean. Purohit *et al.,* 2022 reported that the varied fertilizer doses applied to soybean significantly improved the yield attributes such as number of pods per plant and number of seeds per pod and this increase was observed up to 100% RDF.

5.3.3. Green fodder yield of Oat

The green fodder yield of the succeeding fodder oats remained numerically similar during both study years at the harvest stage (Table 4.33). Across the different cropping systems, oats sowing under the sole-soybean-oats (M_2) system exhibited significantly higher green fodder production along with greater overall crop productivity compared to oats seeded under the other cropping systems. This higher green fodder production of oats sown after a legume might be attributed to a more favorable soil environment with increased available soil nutrients resulting from the residual effect of the legume. This improved soil condition likely led to enhanced crop growth, which in turn resulted in an improved source-to-sink relationship, as evidenced by the higher values of all growth parameters of oats. Furthermore, the enhanced growth and yield-contributing characteristics of oats collectively resulted in higher crop productivity, total biomass yield (green fodder yield). In contrast, the cultivation of oats in the cereal-dominated sole maize-oats (M_1) cropping system recorded lower values of green fodder yield. This might be due to the fact that both maize and oats are nutrient-exhaustive crops, and their continuous cultivation may degrade the soil environment, leading to lower growth and yield attributes, which ultimately resulted in reduced crop productivity. The carryover benefits of legumes are typically associated with their nitrogen contribution to succeeding cereal crops. A portion of the biologically fixed nitrogen becomes available to the next crop after the decomposition of legume roots in the soil. Legumes enrich the soil with nitrogen, which not only reduces the reliance on external chemical fertilization but also creates a more favorable environment, thereby initiating a cascading effect on other soil and system processes. These processes ultimately boost the fodder yield of the subsequent crop. Resulting higher positive residual effect observed under sole ma soybean treatment, which was statically similar with 1:2 row proportional of maize soybean intercropping system. However, all intercropping maize soybean intercropping influenced the positive impact of residue on growth and yield attributes of succeeding fodder oats compared to residue of sole maize treatment. The enhancement in the green fodder yield of succeeding cereals due to the inclusion of legumes has also been reported by several other researchers (Shukla *et al.,* 2024; Chaudhary *et al*., 2022).

In context of nutrient management, green fodder yield is influenced by the residual effects of nutrient applications in the preceding maize-soybean intercropping system. A significantly higher green fodder yield was observed with 100% RDF residue, differing significantly from other nutrient combinations. The 100% RDF applied to the preceding crop may not have been fully utilized, becoming retained in the soil in a less available form. However, the inclusion of legumes facilitates the release of root-derived chemicals that convert these nutrients from an unavailable to an available state, enhancing their utilization by the subsequent fodder crop. Consequently, soils with higher residual nutrient levels exhibit improved nutrient availability over a prolonged period due to the slow release of these nutrients. Additionally, nitrogen application promotes vegetative growth and influences key physiological processes, including cell division and elongation, resulting in the higher green fodder yield observed, compared to other nutrient combinations. Green fodder yield is influenced by the residual effects of nutrient applications in the preceding maize-soybean intercropping system. A significantly higher green fodder yield was observed with 100% RDF residue, differing significantly from other nutrient combinations. The 100% RDF applied to the preceding crop may not have been fully utilized, becoming retained in the soil in a less available form. However, the inclusion of legumes facilitates the release of root-derived chemicals that convert these nutrients from an unavailable to an available state, enhancing their utilization by the subsequent fodder crop. Consequently, soils with higher residual nutrient levels exhibit improved nutrient availability over a prolonged period due to the slow release of these nutrients. Additionally, nitrogen application promotes vegetative growth and influences key physiological processes, including cell division and elongation, resulting in the higher green fodder yield observed, compared to other nutrient combinations.

5.3. Physiological parameters

5.3.1. Proline content

We noticed no effect of the proline content of maize with different cropping patterns of maize and soybean cropping system. Significant difference was observed for various nutrient management systems. We noticed that higher significant value of proline content was found under the control treatment (S_1). This may be due to deficient nutrients in plants go under stress (Racz *et al.* (2021). Higher nutrient availability leads to low proline content. We found a significantly different proline content (µg g^{-1} fresh weight) with 70% RDF with two foliar applications of nano NPK, which was at par with 70% RDF with two foliar applications of Homemade NPK and 70% RDF with two foliar applications of plant extract, while the lowest value was observed under the 100% RDF treatment. Perhaps higher nutrient availability suppresses the stress resulting least proline content was occurred. Our results are in close agreement with those of Senthilkumar *et al.* (2023) and Racz *et al.* (2021). According to the present knowledge about the function of proline, it is a multifunctional amino acid that helps to stabilize sub-cellular structures (e.g., membranes and proteins), as well as scavenge free radicals under stress. Elshamly *et al.* (2024) reported that proline is a widely used indicator that accumulates to high levels as a response to stresses. especially water deficit. salinity and proline also accumulate under nutrient deficiency, such as N.

5.3.2. Rainfall water use efficiency

We noticed that highest Rainwater use efficiency was recorded under the 1:1 row proportion of maize and soybean (M_3) which was followed by the 1:2 row proportion of maize and soybean intercropping (M_4). It might be 1:1 row proportion of maize and soybean intercropping have higher efficiency to utilisation of rain water due to less competition between plant and optimum utilisation of space. The lowest rain water use efficiency was recorded under the sole maize (M_1) Result was followed by Sharma *et al.,* 2016. The nutrient management was also influenced the rain water use efficiency, we observed that, higher nitrogen content in the soil enhances the rain water use efficiency. 100% RDF (S_2) treatment was recorded higher Rain water use efficiency compared to their control.

5.4. Soil health parameter

Soil pH and EC

We observed a higher pH reading in the sole crop of maize, whereas the pH slightly decreased in the intercropping system. The lowest soil pH was recorded under a 2:3 row proportion of maize and soybean (M_5). This may be attributed to root-releasing compounds, such as acid phosphatases and phytases, and changes in soil pH. Notably, there were no significant effects of nutrient management and cropping pattern on soil pH. In terms of electric conductivity, the maximum EC was recorded under the sole soybean compared to the intercropping treatment, followed by the 1:2 row proportion of maize and soybean (M_4). It is possible that sole maize enhanced soil nitrogen, which directly influenced EC. The lowest EC value was recorded under the sole maize (M_1). Furthermore, higher nutrient (NPK) application enhanced soil EC compared to the control treatment. It can be inferred that when maize is grown, especially in sole culture, from the crop harvest, the absence of nutrient uptake, as seen in the soil nitrate dynamics, led to more concentrated soil solutions. This is supported by a decrease in the amount of rainfall. Our results are consistent with those of Ariel *et al.* (2013). Additionally, our findings are in line with those of Nasar *et al*. (2024).

5.4.1 Available soil nitrogen

The availability of nutrients in soil under an intercropping system was significantly influenced by the treatments imposed. Different crop arrangements and nutrient management strategies had a notable impact on the availability of mineral nitrogen, phosphorus, and potassium in the soil. The maximum available nitrogen was recorded in sole soybean cropping (M_2), followed by the 1:2 row proportion of maize and soybean crop (M_4). In contrast, the lowest nutrient availability of nitrogen was observed in sole maize cropping (M_1). The increased availability of nitrogen in the maize root zone may be attributed to the formation of hyphal bridges between maize and soybean roots. These bridges facilitate the transfer of nitrogen fixed by soybean roots to the maize root zone, and the absorption of nitrogen in soybean soil by maize stimulates the growth of root nodules. Additionally, maize and soybean can transform insoluble soil nitrogen by secreting extracellular enzymes, resulting in the transformation of insoluble soil nitrogen into a more available form. Studies by Li *et al.* (2024) and Kebeney *et al.* (2015) reported similar findings, with higher nitrogen fertilizer application rates leading to increased nitrogen concentrations in soils under an intercropping system. In terms of nutrient management, 100% recommended dietary fertilizer (RDF) was associated with higher nutrient availability following maize and soybean cultivation. Lu *et al.* (2023) reported that 100% RDF resulted in significantly increased concentrations of available nitrogen, soil organic matter, and available phosphorus in the rhizosphere soil of maize and soybean crops. The control treatments recorded the lowest soil nitrogen availability.

5.4.2. Available soil phosphorus

In case of phosphorus availability, the availability was observed higher during 2024 in comparison to 2023, this was due to building-up of the phosphorus from one years to the next year. Higher availability of phosphorus was reported in maize + soybean intercropping system than the sole maize. Similar result was also found by Owusu and Sadick (2016). Their result of study indicated that sole soybean and intercropping of maize with soybean caused increase in organic carbon and phosphorus of the soil. The increase in available phosphorus was attributed largely to the addition of P from NPK. They also found that all nutrients were low before the onset of experimentation and were largest in the maize-soybean intercropped plot compared to the quantities recorded in pure maize plot. The increase in nutrient content of maize intercropped with soybean might be due to the substantial role of legume component with respect to transfer of atmospheric fixed N and mobilization P and micronutrients towards the maize. The cultivation of deep-rooted soybean with shallow rooted maize in the intercropping might help in extraction of sub-surface nutrients to surface through solubilization effect of their root rhizosphere. This in turn increases the nutrient availability in surface soil layers where maximum concentrations of maize roots were found. The legume rhizosphere also helps in formation of chelating agent forms which enhancing the micronutrients content in cereals. Contrast to this, maize planted under sole stand recorded significantly higher total K uptake which might be due to the fact that the cereals are more efficient with regards to uptake monovalent nutrients (K) as compared with legumes. Zhou *et al*. (2024) observed that intercropping boosted the available P and K fractions while reducing the insoluble P fractions (conc. HCl-Pi) and mainly organic P fractions (NaOH-Po and conc. HCl-Po). This may be due to maize/soybean system may facilitate P turnover the various P fractions, and interspecific interactions may facilitate maize and soybean crops to increase the effective P concentration by secreting organic acids or phosphatases to mobilize and hydrolyse insoluble forms of Phosphorus.

5.4.3. Available soil potassium

The results show that higher available potassium levels were recorded under sole soybean cropping compared to the 1:2 row proportion of maize and soybean (M_4). This result was statistically significant and was attributed to the higher application of potassium. The increased availability of potassium resulted in a significant increase in available potassium records, reaching 100% of the recommended dietary fertilizer (RDF). The inclusion of legumes in the intercropping system facilitated symbiotic N_2 fixation and enhanced soil health by supplementing the system with nutrients. This process was achieved via the root exudation of sugars, organic compounds, amino acids, and secondary metabolites such as flavonoids, phenolic compounds, and terpenoids. Changes in soil-accessible available potassium in intercropping were most likely due to root-releasing compounds, such as acid phosphatases and phytase. Chen *et al.* (2023) reported maximum available potassium levels recorded under maize-soybean intercropping compared to monocropping. Among the available nutrients, potassium accounted for a 7% increase in potassium content under intensive intercropping. This suggests that intensive intercropping results in greater nutrient utilization efficiency in regions with poor soil phosphorus and potassium fertility.

5.4.4. Soil organic carbon

The highest level of soil organic carbon was found in the sole soybean crop (M_2), which was statistically similar to the 1:2 row proportion of maize and soybean (M_4). Conversely, the lowest soil organic matter (SOM) was recorded under the sole maize crop. In terms of nutrient management, the application of 100% recommended dietary fertilizer (RDF) (S_2) resulted in the highest SOM among all nutrient treatments. On the other hand, the lowest SOM was recorded under the control treatment. The crop roots in the intercropping system can provide a more diverse carbon source for soil microorganisms. This diversity increases the abundance and variety of microorganisms involved in carbon source utilization, thus promoting the utilization and fixation of straw residual microbial biomass carbon (MBC). This result is consistent with the findings of Zhang *et al.* (2024). Lu *et al.* (2023) observed that the maize rhizosphere soil and the concentrations of SOM in soybean rhizosphere soil were higher compared to monocropping. The increased SOM concentrations in soybean soil may be related to the increase of root exudates and enzyme activities. This can be attributed to intercropping, which increases the metabolic activity of maize and soybean roots and their penetration into soil. This, in turn, improves the microbial habitat and increases soil permeability, thus increasing soil enzyme activity.

5.4.5. Soil microbial activity

The significantly highest microbial population was recorded under the sole soybean crop which was statically similar to 1:2 row proportion of the maize and soybean crop(M_4). In 100% RDF was recorded higher microbial population because of higher organic content under 100% RDF and these are positively influenced the microbial activity. Result was followed by the Raza *et al.,* 2022. Wang *et al*. (2023). They observed comprehending alterations in the soil microbial community composition in response to maize and soybean cultivation is vital for the sustainability of intercropping systems. The aforementioned groups might be more common colonizers in the rhizosphere soil of maize/soybean intercropping. However, while the abundance of soil microbial communities at the phylum and genus levels can provide insights, it may not always fully reveal the functional characteristics that vary under different agricultural systems. Liu *et al*. (2023) reported the N fertilization had a strong effect on the microbial α-diversity of maize rhizosphere soil, but there were different effects on bacterial and fungal α-diversity. The bacterial Shannon and Simpson indices in both intercropping and monocropping treatments showed an increasing trend with N fertilization, but the fungal α-diversity of maize rhizosphere soil in both intercropping and monocropping treatments was significantly lower than that in the unfertilized treatments. They observed intercropping enhanced the activity of nitrogen-cycling microorganisms despite the absence of N fertilization.

5.4.6. Soil dehydrogenase activity

We observed the highest dehydrogenase activity under the sole soybean treatment compared to the rest of the cropping arrangements. This was significantly different from the other cropping system treatments. On the other hand, the lowest dehydrogenase activity was recorded under the sole maize cropping system. The low dehydrogenase activity observed under the sole maize cropping system may be due to the ability of maize to absorb maximum nutrients from the soil, creating a barrier to microbial populations. Without a sufficient microbial population, the carbon assimilation rate becomes very slow, resulting in low dehydrogenase activity compared to soybean and intercropping treatments. In the case of soybean, many substances are released from its roots, attracting microbial populations and enhancing soil organic carbon. There is a positive correlation between dehydrogenase activity and soil organic carbon, as reported by Rautaray *et al.* (2005). The highest dehydrogenase activity was also recorded under the 100% RDF (S_1) treatment, which was statistically similar to the 70% RDF with two foliar applications of plant extract (S_5) and the 70% RDF with two foliar applications of Homemade NPK (S_4). This may be due to higher nitrogen accumulation, which leads to a higher microbial population and maximum soil organic carbon, thereby enhancing dehydrogenase activity. Legume plants also accumulate soil organic carbon, which directly influences microbial activity and dehydrogenase activity in soil. Higher soil microbial enzymatic activity is enhanced by legume crops and higher nitrogen doses, as reported by Kumar *et al.* (2018). Dehydrogenase activity closely follows the pattern of organic matter and available NPK buildup in soil under various treatments, as reported by Adak *et al.* (2014). Dehydrogenase is an enzyme that exists as an integral part of intact cells, but it does not accumulate extracellularly in soil. It achieves the oxidation of soil organic matter by transferring protons and electrons from substrates to an acceptor and is linked to the respiration pathway of microorganisms, as reported by Das and Verma (2011). The availability of organic matter, soil temperature, nutrients, and soil moisture significantly affect the dehydrogenase activity of soil.

5.6. Economic Study

5.6.1. Cost of cultivation

Among the different planting ratios, the 1:1 row proportion of maize and soybean (M_3) recorded the highest cost of cultivation (COC). In contrast, the lowest cost of cultivation was recorded under the sole soybean. This discrepancy may be attributed to the fixed and variable input costs. A similar result was reported by Legba *et al.* in 2025, and Ali *et al.* in 2024. They observed that the maximum cost of cultivation was obtained in intercropped fields compared to monocropped fields. This was due to the inclusion of fixed costs (such as land preparation, fertilizer, irrigation, herbicide, labor, and land value) and variable costs that were higher in intercropping compared to monocropping. Legba *et al.* (2025) also found that maize-based intercropping generated a higher cost of cultivation than sole cropping. This was primarily due to higher labour involvement and fixed costs. Yogesh *et al.* (2014) reported that the cost of cultivation of sole maize and sole soybean was less than that of intercropped maize. This was attributed to the additional cost of intercropping with soybean. Among intercropping options, the highest cost of cultivation was recorded for the maize: soybean, 1:1 (60 x 20 cm) planting ratio.

5.6.2. Gross return

The maximum gross return was recorded as a 1:1 row proportion of maize and soybean (M_3) among the cropping systems. It might be due to higher yield of maize and soybean intercropping pattern(M_3), which showed the highest gross return compared to their sole system. The results are attributed to the synergetic impact of maize and soybean plants and their optimum resource utilization by both crops. This finding was consistent with the results of Kou *et al*. (2024), who observed higher gross returns recorded under intercropping than monocropping in both years. However, M_3S_4 and M_4S_6-MN plants showed higher economic efficiency than monocrops in 2022. Kou *et al.* (2024) suggested that although land productivity increases in all intercropping systems, not all intercropping patterns are suitable for promotion from the point of view of economic efficiency. Raza *et al.* (2021) conducted an economic analysis of soybean and maize production under maize/soybean relay intercropping and sole cropping systems. The results of Raza *et al.* (2022) also supported the findings of the synergetic impact of maize and soybean plants in intercropping systems.

5.6.3. Net Return

The highest net return was observed under the 1:1 row proportion of the maize and soybean (M_3), compared to their sole crop. We noticed that all intercropping treatment had recorded higher net return compared to their sole. It might be higher maize equivalent yield was recorded under the 1:1 row proportion of maize and soybean (M_3). In nutrient context maximum net return was recorded under the 100% RDF compared to their control and 70% RDF with two foliar applications of plant extract was statically similar was observed. Result was followed by Begam *et al.,* 2024. Fu *et al*. (2024) reported the Maize–soybean relay intercropping (IMS) achieved a net ecosystem economic benefit (NEEB) 133.5% higher than monoculture maize, primarily due to increased economic gains and reduced greenhouse gas costs, with optimal nitrogen application enhancing yield without raising environmental costs. According to Raza *et al.* (2022) recorded the maximum net profit in maize soybean intercropping over the sole maize and sole soybean under semi-arid conditions. Additionally, the higher net profit of intercropping over sole cropping suggested that farmers could plant soybean and maize together in intercropping with a minimal overall yield penalty.

5.6.4. Benefit Cost Ratio (B:C Ratio)

The maximum benefit cast ratio was recoded under the 1:1 row proportion of maize and soybean (M_3) compared to their sole crop. The whole intercrop has higher B:C ratio recorded compared to their sole crop. It might be due to higher input cast and lower gross return of under the sole crop. In nutrient management higher B:C ratio was recorded under the 70% RDF with two foliar application of plant extract (S_5) and 70% RDF with two foliar applications of Homemade NPK(S_4). The lowest B:C ratio was recorded under the control treatment. It might be higher fertilizer cast in S_2 treatment and lower input cast in 70% RDF with two foliar application of plant extract (S_5) treatment. Jaswal *et al.* (2023) observed the intercropping maize + black gram (1:3) had the maximum (2.18) B:C ratio because of less cost of cultivation and maximum net return as compared to other cropping pattern, while lowest benefit cast ratio was observed in their sole maize due to higher cost of cultivation and low net return. Paudel *et al.,* (2015) obtained highest gross return from two rows of soybean intercropped with two rows of maize contributed B: C ratio (2.53) over sole cropping. This was due to high compensation add by the soybean in maize - soybean intercropping.

CHAPTER 6

SUMMARY AND CONCLUSION

A field experiment titled "**Nutrient management studies in maize + soybean intercropping and its residual effect on the succeeding fodder oat in maize + soybean – oat cropping system**" was conducted over a two-year period from 2023-24 to 2024-25 at the Agriculture Farm, School of Agriculture, Lovely Professional University, Phagwara, Punjab. The experimental plot had a sandy loam texture, with a slightly alkaline soil pH of 7.52. The soil contained 0.34% organic carbon (SOC), and had available levels of nitrogen, phosphorus, and potassium at 180, 22.5, and 185.2 kg ha^{-1} respectively. The experiment was structured in a split plot design, featuring four main plot treatments: sole maize oat (M_1), sole soybean - oat (M_2), Intercropped maize + soybean (1M:1S) - oat (M_3), Intercropped maize + soybean (1M:2S) - oat (M_4) and Intercropped maize + soybean (2:3) - oat. The five subplot treatments used were: Absolute control (S_1); 100% RDF (S_2); 70% RDF with two foliar applications of nano NPK (S_3); 70% RDF with two foliar applications of Homemade (S_4); 70% RDF with two foliar applications of plant extract (S_5). The key results of the current investigation are outlined in this chapter under the following headings and subheadings.

6.1. Growth attributes of maize

- Maize planted during the second year of the study showed improved growth in terms of plant height, dry matter accumulation (DMA), and crop growth rate (CGR) compared to the first year.
- Among the different cropping systems, maize planted under sole maize recorded significantly higher growth attributes such as plant height, number of leaves, leaf area, leaf area index, and stem girth compared to the other systems.
- However, dry matter accumulation and crop growth rate were observed to be significantly higher under sole planted maize.
- The relative growth rate (RGR) was observed to be significant under the 1:1 row proportion of maize soybean intercropping (M_3), which was statistically similar to the sole maize cropping system (M_1). The net assimilation rate (NAR) was recorded to be significantly superior under the 1:1 row proportion of maize soybean intercropping (M_3) at 30-60 days after sowing (DAS) and non-significant at 60-90 DAS.
- Among the cropping systems, the SPAD value (chlorophyll index) was recorded under the sole maize crop, which was at par with the 1:1 row proportion of the maize and soybean cropping system, and the lowest values were recorded under the 2:3 row proportion of maize and soybean intercropping system.

- In most cases, all growth parameters of the maize crop were recorded to be highly significant in their sole cropping system, which was statistically similar to the 1:1 maize and soybean intercropping system.
- Among the nutrient management practices, 100% RDF showed significantly higher growth parameters, such as plant height, dry matter, number of leaves, leaf area, leaf area index, stem girth, and crop growth rate (CGR), compared to the other treatments.
- In nutrient management, the growth parameters of maize under 100% RDF were statistically similar to those obtained with 70% RDF with two foliar applications of plant extract (S_5) and 70% RDF supplemented with two foliar applications of homemade NPK. The lowest values were observed in the absolute control treatment.
- In terms of relative growth rate (RGR) and net assimilation rate (NAR), significantly higher values were recorded under 100% RDF from 30 to 60 days after sowing (DAS). However, the highest values of RGR and NAR at 60 - 90 DAS were obtained with 70% RDF supplemented with two foliar applications of nano NPK.

6.1.2. Growth attributes of soybean

- Growth attributes of soybean like dry matter, number of leaves plant^{-1}, leaf area, leaf area index, number of branches, number of nodules plant^{-1} and dry weight of nodules was recorded under their sole cropping system, which was statically similar with the 1:1 row proportion of the maize and soybean cropping system.
- The significantly highest CGR, RGR and NAR values were recorded under the sole cropping system of soybean which was statically at similar with the 1:1 row proportion of the maize and soybean intercropping while lowest values were recorded under the 2:3 row proportion of maize and soybean intercropping.
- Similarly, highest significant SPAD vale was recorded under the sole soybean cropping system which was followed by the 1:1 row proportion of the maize and soybean intercropping system. The lowest SPAD values was recording under the 2:3 row proportion of the maize and soybean intercropping.
- All the aforesaid parameters recorded highest values under 100% RDF (S_2) and it was followed by 70% RDF with two foliar applications of the plant extract and 70% RDF with two foliar applications of the Homemade NPK (S_4) but the lowest values of these characters were obtained from absolute control treatment.

6.1.3. Growth attributes of fodder oat crop

- Growth attributes of fodder oat were significantly differed from residue effect of maize and soybean cropping system. The highest growth attributes like plant height, dry matter accumulation and number of tillers was recorded under the residue of sole soybean which was statically similar with the residue of 1:2 row proportion of maize soybean intercropping.
- In the nutrient management, there was observed statically highest nutrient residue found under the 100% RDF (S_2) treatment, which was statically different with residue of 70% RDF with two foliar applications of nano NPK (S_3), 70% RDF with two foliar applications of the Homemade NPK (S_4) and 70% RDF with two foliar applications of the plant extract (S_5). The lowest growth attributes of the fodder oat were recorded under the residue of sole maize crop.

6.2.1. Yield attributes of maize

- The yield attributing characters of maize, such as cobs per plant, length and diameter of cob, number of grains per row, number of grains per cob, weight of cob, grains weight per cob, and 100 grains weight, were significantly superior under the sole maize cropping system. This system was statistically similar to the 1:2 row proportion of the maize and soybean intercropping.
- On the other hand, the lowest yield attributes were recorded under the 2:3 row proportion of maize and soybean intercropping. Grain Yield and Harvest Index the highest grain yield (t ha^{-1}), stover yield (t ha^{-1}), and biological yield were recorded under the sole cropping system of maize crop, which was statistically similar to the 2:3 row proportion of the maize and soybean intercropping (M_4).
- The highest harvested index was recorded under the sole maize due to a higher grain and stover ratio, which was statistically similar to the 1:1 row proportion of the maize and soybean intercropping (M_4). In contrast, the lowest harvested index was recorded under the sole maize cropping system (M_1).
- In terms of nutrient management, the highest grain attributes, such as cobs per plant, length and diameter of cob, number of grains per row, number of grains per cob, weight of cob, grains weight per cob, and 100 grains weight, were significantly superior under the 100% RDF treatment. This was statistically similar to the 70% RDF with foliar application of plant extract (S_5) and 70% RDF with foliar application of plant extract (S_4). The lowest values were recorded under the control treatment (S_1).
- In nutrient management, the highest grain yield, stover yield, biological yield, and harvest index were recorded under the 100% RDF treatment (S_2), which was statistically similar to the 70%

RDF with foliar application of plant extract (S_5) and 70% RDF with foliar application of plant extract (S_4). Interestingly, a higher harvest index was recorded under the 70% RDF treatment, followed by the 70% RDF with foliar application of nano NPK (S_5).

6.2.2. Yield Attributes of soybean

- The yield attributes of soybean, including pods per plant, 100 seed weight, and seed yield, were significantly affected by crop arrangements. Notably, the sole soybean (M_2) produced significantly higher values for these yield attributes compared to intercropped soybean plants. This was consistent with the 1:2 row proportion of the maize and soybean intercropping system, which also showed similar results.
- Conversely, the lowest yield attributes were observed in the 2:3 row proportion of the maize and soybean intercropping system. Furthermore, the sole soybean (M_2) produced the highest seed yield, stover yield, and biological yield compared to the intercropping systems, which were statistically similar to the 1:2 row proportion of the maize and soybean intercropping system.
- In terms of nutrient management, the highest yield and yield attributes of soybean were recorded under the 100% RDF treatment. Notably, this was statistically similar to the 70% RDF treatment combined with two foliar applications of plant extract (S_5) and the 70% RDF treatment combined with two foliar applications of homemade NPK (S_4). In contrast, the absolute control treatment (S_1) produced the lowest yield and yield attributes.

6.2.3. Yield of green fodder oat

- The significantly highest green fodder yield of oat was recorded under the residue of sole soybean (M_2), which was statistically similar to the 1:2 row proportion of maize and soybean intercropping (M_4).
- In terms of nutrient management, the highest green fodder yield of oat was recorded under the residue of 100% RDF (S_2) compared to all other nutrient combinations. The lowest green fodder yield was recorded under the control treatment (S_1).

6.2.4. Proline content

- There was observed non-significant values of proline content with the cropping system but significant different was observed with respect to nutrient management. The highest proline content was observed under the absolute control treatment(S_1) compared to intercropping. The lowest proline content was recorded under the 100% RDF treatment.

6.3. Agronomic indices

6.3.1. Competition indices

- Land equivalent ratio of maize + soybean intercropping system, the significantly higher LER value was recorded under the 1:1 row proportion of maize and soybean (M_3) which was statically similar with 1:2 row proportion of maize and soybean intercropping (M_4) and 2:3 row proportion of maize and soybean intercropping system (M_5).
- In case of competition index there was observed higher competition was recorded under the 2:3 row proportional of maize and soybean cropping system (M_5).
- In nutrient management in 2023 there was no significant values observed but in 2024 there was recorded significantly highest LER in 100% RDF (S_2) treatment which was statically similar with 70% RDF with two foliar applications of plant extract (S_5), 70% RDF with two foliar applications Homemade NPK (S_4) and 70% RDF with two foliar applications of nano NPK(S_3) while the lowest values was recorded in their control (S_1). In case of competition index higher competition was recorded under the absolute control (S_1).

6.3.2. Maize equivalent yield (MEY)

- The highest significant MEY was recorded under the 1:1 row proportional of maize and soybean intercropping (M_3) compared to another cropping system treatment. In nutrient management 100% RDF was recorded highest maize equivalents yield which was statically similar with 70% RDF with two foliar applications of plant extract.

6.3.3. Rain water use efficiency

- In cropping system significantly higher rain water use efficiency was recorded under the 1:1 row proportion of maize and soybean intercropping system, which was statically similar with 1:2 row proportion of maize and soybean intercropping system (M_4) and 2:3 row proportion of maize and soybean intercropping system.
- In nutrient management study we observed that significantly highest rain water use efficiency was recorded under the 100% RDF (S_2) which was statically similar with the 70% RDF with two foliar applications of plant extract and (S_5) and 70% RDF with two foliar applications of Homemade NPK(S_4). The lowest Rainwater use efficiency was recorded under the control treatment (S_1) respectively.

6.4. Soil health parameter

6.4.1. Soil physical properties

- In intercropping there was slightly pH enhanced compared to their sole cropping system. There was no significant different was observed under the nutrient management system.

- In electric conductivity EC there was recorded significantly highest in sole soybean (M_2) cropping system which was statically similar to 1:2 row proportion of the maize and soybean intercropping.
- In nutrient management 100% RDF (S_2) treatment have record highest EC values compared to among nutrient management. The lowest EC was found under the control treatment (S_1).

6.4.2. Available and residual soil nutrient

- Availability of nutrients (nitrogen, phosphorus and potash) in soil were significantly influenced by crop arrangements as well as nutrient management. the maximum available nutrient was recorded under the sole soybean (M_2) treatment at par with 1:2 row proportion of maize and soybean cropping system(M_4). The lowest available nutrient was recorded under the sole maize cropping system (M_1).
- In nutrient management highest residual nutrient (available Nitrogen, phosphorus and potash) was recorded under the 100% RDF compared to rest of nutrient combination. The lowest residual nutrient was observed under the control (S_1) respectively.

6.4.3. Biological properties

- Among the cropping system and nutrient management sole maize with 100% RDF (M_2S_2) was recorded highest microbial count in soil which was statically similar with 1:2 row proportion of maize and soybean cropping system(M_4). Lowest microbial population was recorded under the sole maize with control(M_1S_1).
- The second year recorded significantly higher microbial counts (bacteria) as well as soil enzymatic activity (dehydrogenase) as compared to first year. The sole soybean cropping system and application of 100% RDF and 70% RDF with to foliar application plant extract (S_5) to fodder-food cropping system indicated significantly higher microbial counts as well as activity of soil.

6.5. Economic Studies

- Among the planting ratios, 1:1 row proportional of maize soybean cropping system (M_3) recorded significantly higher gross return, net returns and benefit cost ratio as compared to sole maize and soybean.
- The application of 100% RDF and 70% RDF with two foliar applications of plant extract (S_5) recorded significantly higher gross return amongst nutrient management practices. However, remarkably higher net return and benefit cost ratio were noted under 100% RDF.

Conclusion

- Our experimental results show that varying planting methods and nutrient management strategies have a substantial impact on the yield of maize, soybean, and oat green biomass, as well as farm profitability and soil health. The following conclusions could be drawn as per the objective sat for the present study.

i. During both the seasons, cropping system and nutrient management significantly influenced growth and development, yield attributes and yield of crop, economic returns and soil properties.

ii. Application of 100% RDF in sole maize and soybean produced maximum growth attributes and productivity. However, “maize + soybean (1:1)” at par with their sole cropping.

iii. Significantly higher gross return, net return and benefit cost ratio was found in maize + soybean (1:1) row proportion followed by the 1:2 row proportion. However, 100% RDF achieved maximum gross return, net return and benefit cost ratio which was at par with 70% RDF + Homemade NPK and 70% RDF + plant extract treatment.

iv. Residual effect of sole soybean with 100% RDF on oat was significant and higher growth and biomass yield was obtained followed by the 1:2 row proportion. However, 70% RDF with Nano NPK and Homemade NPK and plant extract are statistically similar with each other.

It may be concluded that maize + soybean (1:1) with 70% RDF and application of plant extract or homemade NPK (as supplement) was found to be better for obtaining higher yield, profit and better soil health in maize + soybean - oat systems under Punjab conditions.

CHAPTER 7

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APPENDIX -I

Meteorological data during crop growth period (4 June 2023 - 4 February 2024)

Standard weeks	T. Max (°C)	T. Min (°C)	RH Max (%)	RH Min (%)	Wind speed (km hr^{-1})	Rain (mm)	Evaporation (mm)	Sunshine (hrs)
***Kharif* season 2023**								
23	37.57	22.14	81.86	34.57	5.29	22.8	40.4	11.34
24	36.29	23.71	82.43	45.86	3.57	41.2	34.6	9.56
25	37.86	27.57	82	51.57	2.57	16.2	43.4	5.86
26	35.71	27	82.86	56.14	2.57	2.2	33.2	4.71
27	33.57	25.29	86.71	65.57	3	53.2	15.3	4.57
28	33.57	25.86	88.43	66.14	7	11.2	27.2	2.5
29	34.57	27.43	86.43	70	5.71	49.6	23.5	2.01
30	33.57	27	90.86	72.71	4.29	60	12.5	3.27
31	35.43	27.59	90.86	68.71	5.57	60.6	15.5	5.91
32	34.29	26.86	90.29	73	4.29	5.8	3.23	4.21
33	34.71	27.29	90.57	72.14	5.57	1.8	28.4	5.79
34	34.71	26.86	92	70	4.43	0	18.7	5.01
35	33.57	26.48	91.71	64.29	5.16	11	22.1	8.91
36	34.92	24.71	92	60.86	5.2	0	32.4	10.27
37	34.24	25.99	91	70	4.28	4	19.7	3.01
38	31.65	23.93	92	71.08	3.96	15.9	18.4	3.07
39	33.76	21.21	93	60.23	4.37	2.4	24.1	9.3
40	33.79	17.79	92.51	48.48	5.76	0	4.4	9.83
41	32.33	18.7	91.89	53.21	4.47	6.6	22.1	8.39
42	28.19	15.46	92.01	52.2	4.94	2	20.3	8.44
43	30.27	13.71	92.59	47.06	5.4	0	20.1	7.96
***Rabi* season 2024**								
44	30.27	14.14	93.42	46.67	3.39	0.6	14.2	6.99
45	26.9	12.94	92.1	53.96	5.5	0	12.3	4.53
46	27.11	10.03	93.83	49.9	5.04	0	13.2	8.79
47	26.19	9.89	93.1	46.93	4.78	0	13.4	5.94
48	23.52	11.17	91.56	59.72	4.53	6.6	7.5	3.61
49	23.55	7.97	94.62	52.46	4.63	0	9.4	7.83
50	22.02	4.46	93.95	50.21	3.75	0	9	7.3
51	21.23	4.33	94.26	55.66	4.22	0	8.2	6.87
52	18	7.45	94.26	70.63	2.68	0	5.6	2.55
1	12.4	6.59	95	85.86	3.08	0	3.1	5.74
2	11.76	6.43	94.29	78.29	2.92	0	4.5	7.43
3	13.14	5.57	94.57	78.86	3.19	0	5.3	7.04
4	14.14	5.57	93.57	75	4.91	0	6.6	3.49
5	17.71	9	93.43	72.86	5.06	8.8	6.9	1.89

APPENDIX -II

Meteorological data during crop growth period (4 June 2024 - 4 February 2025)

Standard weeks	T. Max (°C)	T. Min (°C)	RH Max (%)	RH Min (%)	Wind speed (km hr^{-1})	Rain (mm)	Evaporation (mm)	Sunshine (hrs)
***Kharif season* 2024**								
23	39.81	23.25	75.9	28.6	8.85	9.3	76.1	6.28
24	43.36	25.66	71.07	26.66	12.45	0	90.1	6.48
25	39.85	27.05	72.69	39.72	10.13	0	91.5	8.23
26	36.99	27.33	85.34	58.41	7.62	2.8	77.3	9.2
27	33.92	26.62	88.29	70.12	10.13	3.8	28.1	3.43
28	36.06	27.11	90.59	62.8	6.07	0	42.4	4.7
29	37.37	28.47	88.04	64.92	4.89	1.4	39.5	5.47
30	35.44	27.46	89.72	72.14	4.89	0	38.1	5.32
31	35.88	28.01	93.15	76.09	5.07	10.7	33	5.79
32	33.9	27.05	90.78	73.5	6.48	15.6	28	5.76
33	32.79	26.77	93.54	74.98	5.61	33.6	18	5.32
34	34.76	26.14	94.78	73.06	4.37	28.2	33.1	6
35	33.65	25.31	94.33	72.38	5.04	3.3	33.8	5.85
36	33.69	26.38	95.12	74.81	4.06	11.4	29.3	6.6
37	34.74	25.15	93.95	69.54	4.11	2.4	29.1	7.51
38	34.54	24.35	94.08	64.34	2.83	0	31.5	7.34
39	33.93	24.82	94.08	68.96	3.5	1.4	33	6.8
40	35.45	21.87	94.24	61.64	4.01	10	25.5	9.23
41	33.6	18.13	93.33	50.96	3.91	0	25.3	9.26
42	34.13	17.81	93.39	46.93	3.24	0	22.9	9.36
43	32.8	16.47	93.64	50.9	4.27	0	20.7	9.11
***Rabi season* 2025**								
44	32.61	15.27	93.14	47.22	3.29	0	16.2	8.84
45	29.24	15.73	94.2	68.12	2.21	0	16.4	8.43
46	24.16	15.33	96.06	68.64	2.26	0	15.8	8.43
47	26.82	9.54	94.27	44.26	3.2	0	11.6	7.7
48	26.48	7.68	93.11	44.32	3.14	0	8.1	7.89
49	16.34	7.22	92.55	68.51	4.06	0	16.2	8.31
50	20.73	2.73	91.07	47.07	5.15	0	15.7	8.44
51	20.35	5.71	92.58	45.83	3.25	0	8.5	3.76
52	17.16	8.25	93.82	66.95	4.43	2	7.1	1.99
1	15.26	8.7	94	80.57	3.43	1	5.2	1.99
2	15.41	8.24	96.71	75.71	3.27	5.8	4.6	2.53
3	19.29	8.31	92.29	54.86	4.09	0	7.7	4.31
4	21.66	6.14	92.57	41.57	9.04	0	1.86	9.24
5	20.77	9.26	94.59	70.09	4.05	0	1.5	6.93

APPENDIX - III

Variable cost of seed ha^{-1} for cultivation of maize and soybean under maize + soybean intercropping system during 2023 – 24

Cropping system	Seed rate kg ha^{-1}		Prize rate Rs ha^{-1}		Total cast (Rs ha^{-1})
	Maize	Soybean	Maize	Soybean	
(M_1) Sole Maize	25		6575		6575
(M_2) Sole Soybean		75		5233.8	5233.8
(M_3) Maize + Soybean (1:1)	25	23.84	6575	1664.34	8239.34
(M_4) Maize + Soybean (1:2)	18.75	34.08	4931.25	2378.76	7310.01
(M_5) Maize + Soybean (2:3)	18.75	20.45	4931.25	1427.25	6358.5
Fodder Oats	80		78		6240

APPENDIX-IV

Variable cost of fertilizer ha^{-1} of soybean under maize + soybean intercropping system during 2023 – 24

Nutrient combination	Quantity of fertilizers				Rate of fertilizers				Total amount
	Urea (kg ha^{-1})	SSP (kg ha^{-1})	MOP (kg ha^{-1})	Spray (ml l^{-1})	Urea (₹ ha^{-1})	SSP (₹ha-^{1})	MOP (₹ ha^{-1})	Spray (₹ l^{-1})	
Soybean crop									
S_1 -(Absolute control)	Nill	Nill	Nill	Nill	Nill	Nill	Nill	Nill	0
(S_2)100 % RDF	70.52	514.06	Nill		8.36	9.43	Nill		5437.13
(S_3)70 % RDF + two foliar applications of nano NPK	49.4	359.84	Nill	2				875	4680.6
(S_4)70 % RDF + two foliar applications of Homemade NPK	49.4	359.84	Nill	8				200	4005.61
(S_5)70 % RDF + two foliar applications of Plant extract	49.4	359.84	Nill	8				250	4055.61

APPENDIX-V

Variable cost of seed rate ha^{-1} under maize + soybean-oat intercropping system during 2023 – 24 and 2024-25

Cropping system	Seed rate kg ha^{-1}		Prize rate ₹ ha^{-1}		Total cast (₹ ha^{-1})
	Maize	Soybean	Maize	Soybean	
(M_1) Sole Maize	25		6575		6575
(M_2) Sole Soybean		75		5233.8	5233.8
(M_3) Maize + Soybean (1:1)	25	23.84	6575	1664.34	8239.34
(M_4) Maize + Soybean (1:2)	18.75	34.08	4931.25	2378.76	7310.01
(M_5) Maize + Soybean (2:3)	18.75	20.45	4931.25	1427.25	6358.5
Fodder Oat	80		6240		6240

APPENDIX-VI

The fixed, variable, and total costs of maize + soybean - oats cropping system cultivation, as well as the economics incurred, were treated as constants for 2023- 2024 year of the experiment

Particulars treatments	**M_1S_1**	**M_1S_2**	**M_1S_3**	**M_1S_4**	**M_1S_5**	**M_2S_1**	**M_2S_2**	**M_2S_3**	**M_2S_4**	**M_2S_5**	**M_3S_1**	**M_3S_2**	**M_3S_3**	**M_3S_4**	**M_3S_5**	**M_4S_1**	**M_4S_2**	**M_4S_3**	**M_4S_4**	**M_4S_5**	**M_5S_1**	**M_5S_2**	**M_5S_3**	**M_5S_4**	**M_5S_5**
A. Variable cost (Rs/ha)																									
land preparation	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250
seed rate	12815	12815	12815	12815	12815	11473.8	11474	11473.8	11473.8	11473.8	14479.3	14479.34	14479	14479.3	14479.34	13550	13550.01	13550	13550	13550	12598.5	12598.5	12598.5	12598.5	12598.5
Seed treatment	0	0	0	0	0	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
4.Ridge/bund making	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
5.Fertilizers	0	6693	5560	4885	4935	0	5436.6	4680.6	4005.61	4055.61	0	8421.832	7048.4	6158.78	6224.684	0	8061.719	6697	5883.98	5944.21	0	6502.305	5446.4	4756.08	4807.215
6.Irrigation	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
7.Herbicide	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00
8.Plant protection	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580
9.Harvesting/threshing	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
B. Fixed cost (Rs/ha)																									
1.Rental value	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
2.Supervision and mgt charges	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
3.Transport	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
Total cost	88895	95588	94455	93780	93830	87753.8	93190	92434.4	91759.4	91809.4	91759.3	100181.2	98808	97918.1	97984.02	90830	98891.73	97527	96714	96774.2	89878.5	96380.81	95324.9	94634.6	94685.71
maize grain yield(q)	47.45	57.10	55.66	56.58	56.76						40.37	56.45	54.39	55.91	55.91	34.16	41.11	40.08	40.74	40.87	33.21	39.97	38.96	39.60	39.73
maize by product (q)	55.77	74.38	75.24	75.51	76.28						56.78	73.28	74.54	75.08	75.74	53.15	58.56	59.17	59.37	58.37	55.04	57.07	57.67	57.86	58.39
soybean seed yield (q)						16.00	25.20	24.61	24.94	25.09	13.42	21.87	18.97	19.80	19.83	12.37	23.68	22.03	24.24	24.32	9.00	17.97	16.72	17.29	17.67
soybean by product yield(q)						30.78	36.47	33.45	34.11	33.47	25.99	32.27	30.27	33.61	33.71	26.57	33.84	32.75	33.62	33.73	17.68	30.08	29.05	29.37	29.37
sale prize of maize grain yield	2090	2090	2090	2090	2090						2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090
Sale prize of maize by product	500	500	500	500	500						500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
sale prize of soybean seed yield						4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600
Sale prize of soybean by product						350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Sale prize of fodder oats	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Sale prize	119.43	198.76	165.5267	164.443	161.737	222.0867	353.37	300.443	293.52	287.12	151.93	326.34	286.05	285.097	282.03	210.023	343.5333	290.63	287.303	280.787	142.53	308.0267	265.81	265.493	264.33
Gross return (GR)(Rs/ha)																									
1. Maize	127046.9	156538	153955.4	156002	156767						112762	154622.5	150954	154399	154722.2	97973.7	115207.1	113348	114822	114597	96932.81	112076.3	110269	111702	112236.9
2.soybean						84356.5	128683	124912	126663	127143	70813.2	111880	97840	102828	103033	66185	120756.7	112815	123270	123661	47589.17	93175.83	87078.3	89797	91545
3. Fodder Oat	23886	39752	33105.33	32888.7	32347.3	44417.33	70674	60088.7	58704	57424	30386	65268	57211	57019.3	56406	42004.7	68706.67	58125	57460.7	56157.3	28506	61605.33	53162	53098.7	52866
Total gross return	150932.9	196290	187060.7	188891	189114	128773.8	199357	185001	185367	184567	213961	331770.5	306004	314246	314161.2	206163	304670.4	284288	295552	294416	173028	266857.5	250509	254597	256647.9
Net Return	62037.87	100702	92605.7	95110.9	95284.4	41020.03	106167	92566.6	93607.1	92757.3	122202	231589.3	207197	216328	216177.2	115333	205778.7	186761	198838	197642	83149.47	170476.7	155184	159963	161962.2
B-C ratio	1.70	2.05	1.98	2.01	2.02	1.47	2.14	2.00	2.02	2.01	2.33	3.31	3.10	3.21	3.21	2.27	3.08	2.91	3.06	3.04	1.93	2.77	2.63	2.69	2.71

APPENDIX-VII

The fixed, variable, and total costs of maize + soybean - oats cropping system cultivation, as well as the economics incurred, were treated as constants for 2024- 2025 year of the experiment

Particulars treatments	M_1S_1	M_1S_2	M_1S_3	M_1S_4	M_1S_5	M_2S_1	M_2S_2	M_2S_3	M_2S_4	M_2S_5
A. Variable cost (Rs/ha)										
1 Preparatory tillage and sowing	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
seed rate	12815	12815	12815	12815	12815	11473.8	11474	11473.8	11473.8	11473.8
Seed treatment	0	0	0	0	0	200	200	200	200	200
4.Ridge/bund making	400	400	400	400	400	400	400	400	400	400
5.Fertilizers	0	6693	5560	4885	4935	0	5436.6	4680.6	4005.61	4055.61
6.Irrigation	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
7.Herbicide	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00
8.Plant protection	580	580	580	580	580	580	580	580	580	580
9.Harvesting/threshing	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500
B. Fixed cost (Rs/ha)										
1.Rental value	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
2.Supervision and mgt charges	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
3.Transport	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
Total cost	88895	95588	94455	93780	93830	87753.8	93190	92434.4	91759.4	91809.4
maize grain yield(q)	49.67	59.93	55.11	58.77	60.30					
maize by product (q)	65.77	75.91	71.15	74.76	75.61					
soybean seed yield (q)						17.02	26.40	23.61	25.22	25.32
soybean by product yield(q)						28.59	37.79	32.29	37.63	37.68
sale prize of maize grain yield	2225	2225	2225	2225	2225					
Sale prize of maize by product	500	500	500	500	500					
sale prize of soybean seed yield						4892	4892	4892	4892	4892
Sale prize of soybean by product						350	350	350	350	350
Sale prize of fodder oats	200	200	200	200	200	200	200	200	200	200
fodder yield	117.06	213.53	173.12	171.80	168.51	227.89	357.53	313.17	304.76	296.97
Gross return(Rs/ha)										
1. Maize	143393.7	171309	158185	168137	171967					
2.soybean						93283.48	142376	126819	136547	137071
3. Fodder Oats	23412.67	42705.3	34623.33	34359.3	33702	45578.67	71507	62634.7	60951.3	59394.7
Total gross return	166806.3	214014	192808.4	202496	205669	138862.1	213883	189454	197498	196466
Net Return	77911.33	118426	98353.36	108716	111839	51108.35	120693	97019.4	105739	104656
B-C ratio	1.88	2.24	2.04	2.16	2.19	1.58	2.30	2.05	2.15	2.14

Particulars treatments	M_3S_1	M_3S_2	M_3S_3	M_3S_4	M_3S_5	M_4S_1	M_4S_2	M_4S_3	M_4S_4	M_4S_5	M_5S_1	M_5S_2	M_5S_3	M_5S_4	M_5S_5
A. Variable cost (Rs/ha)															
1 Preparatory tillage and sowing	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250	4250
seed rate	14479.3	14479.34	14479	14479.3	14479.34	13550	13550.01	13550	13550	13550	12598.5	12598.5	12598.5	12598.5	12598.5
Seed treatment	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
4.Ridge/bund making	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
5.Fertilizers	0	8421.832	7048.4	6158.78	6224.684	0	8061.719	6697	5883.98	5944.21	0	6502.305	5446.4	4756.08	4807.215
6.Irrigation	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
7.Herbicide	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00	4250.00
8.Plant protection	580	580	580	580	580	580	580	580	580	580	580	580	580	580	580
9.Harvesting/threshing	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
B. Fixed cost (Rs/ha)															
1.Rental value	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
2.Supervision and mgt charges	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
3.Transport	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
Total cost	91759.3	100181.2	98808	97918.1	97984.02	90830	98891.73	97527	96714	96774.2	89878.5	96380.81	95324.9	94634.6	94685.71
maize grain yield(q)	46.40	58.51	54.41	58.19	58.40	35.76	43.15	39.68	42.31	43.41	34.77	41.95	49.90	50.24	51.25
maize by product (q)	62.54	74.50	70.46	74.19	74.40	57.51	58.82	55.38	57.99	58.60	55.88	58.25	55.42	61.03	61.51
soybean seed yield (q)	13.66	22.50	19.08	21.99	22.00	13.59	25.66	21.33	23.49	23.51	12.34	20.02	16.53	18.92	19.17
soybean by product yield(q)	27.35	35.04	32.84	34.30	34.28	27.44	35.41	33.16	34.74	35.09	28.04	31.19	30.13	29.99	30.70
sale prize of maize grain yield	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225	2225
Sale prize of maize by product	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
sale prize of soybean seed yield	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892	4892
Sale prize of soybean by product	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Sale prize of fodder oats	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
fodder yield	142.58	327.57	293.24	289.20	281.27	213.22	339.77	295.44	291.40	283.47	131.15	313.40	272.06	271.68	270.26
Gross return(Rs/ha)															
1. Maize	134512	167429.6	156300	166560	167130.5	108323	125422.3	115973	123138	125896	105296	122472.8	138731	142300	144786.5
2.soybean	76380.9	122316.5	104832	119563	119622	76086.3	137904.7	115969	127087	127292	70166.14	108854.3	91425.4	103037	104542.1
3. Fodder Oats	28516	65514	58647	57839.3	56254	42644.7	67954	59087	58279.3	56694	26230	62679.33	54412.7	54335.3	54052
Total gross return	239409	355260.2	319779	343961	343006.5	227054	331281	291029	308505	309883	201692.1	294006.4	284569	299672	303380.6
Net Return	147649	255079	220972	246043	245022.5	136224	232389.3	193502	211791	213109	111813.6	197625.6	189244	205038	208694.9
B-C ratio	2.61	3.55	3.24	3.51	3.50	2.50	3.35	2.98	3.19	3.20	2.24	3.05	2.99	3.17	3.20

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Publications

- Copy Right: 3
- Patent: 6
- Full length paper/review paper: 14
- Abstracts: 5
- Extended summery: 2
- Popular article: 32
- Participation in National/International Conferences: 5

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