"Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum*)."

Thesis

Submitted to the Lovely Professional University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
AGRONOMY

By

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Under the supervision of
Dr. Chandra Pandey

Transforming Education Transforming India

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2014

CERTIFICATE

This is to certify that **Ganesh Pawar** bearing Registration no. **11211980** is doing research titled, **"Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum*)."** Under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree at any University. This thesis is fit for submission and the partial fulfilment of the conditions for the award of degree of M.Sc. in Agronomy.

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DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled **“Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum)*"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Phagwara (**Pawar Ganesh Subhash**)

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ACKNOWLEDGEMENTS

In this highly complex society, no work can be accomplished by a single individual but it needs inspiration and sincere gratitude of intellectuals as well as the grace of that Almighty. Emotions cannot be adequately expressed in words because then emotions are transformed into a mere formality. My acknowledgements are many times more than what I am expressing here.

With unending humility, at the very outset, I would like to thank "The Almighty", who blessed with the limitless internal strength and favorable circumstances, to face and pass through all odds successfully at this juncture.

With an overwhelming sense of legitimate pride and genuine obligation, I seize this rare opportunity to express my deep sense of gratitude, indebtedness and personal regards to my esteemed teacher, *Dr. Chandra Pandey, Assistant Professor, Agronomy, LPU, Punjab (India)*, for his expert, invaluable, criticism during the entire course of my investigations.

I feel honored in expressing real appreciation and regards towards Dr. Chandra Pandey for their prompt anticipations, valuable suggestions and constant encouragement.

I am thankful to esteemed Dr. Balkrishna S Bhople (HOD, Agronomy), Dr. Madhu Sharma (HOD, Horticulture) and other faculty members of School of Agriculture and Food Technology, for their proper guidance during the entire course of present studies.

I am grateful to Dean, Dr Neeta Raj Sharma, School of Biosciences, Lovely Professional University for providing their full help and co-operation during the present investigation.

I expressed my heartfelt thanks to my friends Auwal, Bhanwar, Gajanan, Harinder, Gurvinder, F.Lalthasanga, Uday, Sonali, Nilam and…….. for their co-operation, encouragement, moral and timely help when demanded.

I avail the blessings, affection and moral encouragement of my gracious parents, constant moral encouragement inspired me to search ahead.

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LIST OF ABBREVIATIONS

@	At the rate of
ºC	degree celcius
i.e	that is
Agric	Agriculture
a.i	active ingredient
$CaCl_2$	Calcium chloride
CD	Critical Difference
cm	centimetre
conc	concentration
$CuSo_4$	Copper sulphate
DAP	Days After Planting
et al.	et al in (and others)
Fig	Figure
gm	gram
ha	hectare
Hort	Horticultural
ICAR	Indian Council of Agricultural Research
J	Journal
K	Potassium
kg	kilogram
lit	litre
$MgSo_4$	Magnesium Sulphte
MSL	Mean Sea Level
m	metre
ml	milli litre
mm	milli metre
N	North
N	Nitrogen
Newsl	Newsletter

N.S.	Non- Significant
P	Phosphorous
S	South
LPU	Lovely Professional University
SEm	Standard error mean
%	percentage
/	Per
q ha^{-1}	Quintal per hectare
viz.	Namely
W	West
$ZnSo_4$	Zinc Sulphate

ABSTRACT

ABSTRACT

The field experiment was conducted to study the effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato (*Solanum tuberosum*) at the departmental farm, School of Agricultural, LPU, Phagwara, during rabi season 2013-14. The experiment was laid out in split plot design consisting of 15 treatment combinations with 3 spacings as one factor and 5 foliar sprays of micronutrients as another factor.

Spacing of 60 x 40 cm resulted in maximum plant height (45.07 cm), leaf area (51.01 cm^2), total dry matter (84.75 gm), starch (17.06%), crude fibre (1.71 gm), and ash content (0.81 gm) while spacing of 60 x 20 cm resulted in maximum tuber yield (195.01 q/ha) and marketable yield (158.72 q/ha).

Among the various foliar application of micronutrients $ZnSo_4$ @ 8.5 kg/ha resulted in maximum plant height (46.14 cm), number of stem (2.84), tuber yield (182.34 q/ha), marketable yield (152.87 q/ha), total sugar (0.696%), ash content (0.718 gm), pH (3.67), starch (15.73%), specific gravity (0.83) and TSS (2.52^{o}Brix).

In terms of economics spacing of 60 x 20 cm and foliar spray of $ZnSo_4$ 8.5 kg/ha gave higher net returns of Rs. 1,42,404 per ha with the cost of tuber production of Rs. 73,467 per ha and a Cost Benefit Ratio of 1:93.

INTRODUCTION

Chapter

I

INTRODUCTION

Vegetables play a major role in the life of human beings. In India, tremendous progress has been made in recent past in the vegetable production and India emerged second largest production of vegetables in the world after China. Considering the demand to meet the requirement of 300g vegetables per capita per day for the burgeoning population with annual growth rate of 1.93 per cent and for processing industries and export market, India need to produce 170 million tonnes of vegetables by 2025 mainly through the enhancement in productivity (Prabhakar,1996).

India contributes 13.38% to the world population. More than 40 different kinds of vegetables are grown in Indian tropical, sub-tropical and temperate regions (Anonymous, 2010). Vegetables of vital source of minerals, vitamins and dietary fibres and thus, play an important role in human nutrition in supplying adequate quality of free radicals, antioxidants and micronutrients.

The genus Solanum (potato) belongs to the family Solanaceae which is grown in several parts of the world. The potato was first domesticated in the region of modern-day southern Peru and extreme northwestern Bolivia between 8000 and 5000 BC. It has since spread around the world and become a staple crop in many countries. It is the world's third-largest food crop, following rice and wheat. (Anonymous, 2011)

The potato is best known for its carbohydrate content (approx.26 grams in a medium potato). The predominat form of this carbohydrate is starch. A small but significant portion of this starch is resistant to digestion by enzymes in the stomach and small intestine. This resistant starch is considered to have similar physiological effects and health benefits as fiber. (Hylla *et al.*1998) The potato contains vitamins and minerals, as well as an assortment of phytochemicals, such as carotenoids and natural phenols. Chlorogenic acid constitutes up to 90% of the potato tuber natural phenols and trace amounts of thiamin, riboflavin, folate, niacin, magnesium, phosphorus, iron and zinc. (Ferretti, 2011)

India is placed 3rd in the list of major potato producing countries of the world. It produces around 423.39 lakh tonnes of potatoes that contribute to approximately 12.8% of the world's total produce. This crop is grown over 18.63 lakh hectare as compared to the productivity in the European countries that ranges between 30-40 tonnes per hectare. Major potato growing states are Uttar Pradesh, Punjab, Haryana, West Bengal, and Madhya Pradesh. (Anonymous, 2011)

Potatoes are used to brew alcoholic beverages such as vodaka, potcheen, or akvavitv. They are also used as food for domestic animals. Potato starch is used in the food industry as, for example, thickness and binders of soups and sauces, in the textile industry, as adhesives, and for the manufacturing of papers and boards.

Crop geometry is one of the important factors, which has to be maintained at optimum level to harvest maximum solar radiation and utilizes the soil resources effectively it helps maintaining optimum plant population it avoiding excessive crowding and thereby enabling cereals to utilize the resources and maintained micro climate in the cropping area.

Standardization of agro-techniques like spacing is one of the aspects which may increase the seed yield. One of the main factors affecting crop productivity is plant population which is mainly governed by the plant architecture, soil fertility, time of planting etc. Maintainace of optimum plant density assumes greater importance since it accounts for manifold increase in yield when other factors are non-limiting.

The beneficial effect of micronutrient on crop growth, reproductive phase, tuber yield and quality in several crops is well documented but information on macronutrients on potato is inadequate. Foliar spray of macronutrients usually penetrates through the cuticle of leaves or the stomata and enters the cells and results in higher tuber yield. Among the various macronutrients, Calcium is key component of cell walls, helping to build a strong structure and ensuring cell stability. Calcium-enriched cell walls are more resistant to bacterial or fungal attack. Calcium also helps the plant adapt to stress by influencing the signal chain reaction when stress occurs. It also has a key role in regulating the active transport of potassium for stomatal opening.

Adequate calcium is a critical aspect of the mineral nutrition of potatoes. Calcium is involved in both the structure and function of all plant cell walls and membranes. Inadequate supplies of calcium cause growth abnormalities like internal brown spot and hollow heart. Adequate calcium nutrition can also improve skin color in red potatoes. Abundant tissue calcium also increases the tuber's resistance to soft rot during storage and may improve the performance of seed potatoes (Waterer, 2005).

Magnesium has a central role in photosynthesis, as its atom is present in the center of each chlorophyll molecule. It is also involved in various key steps of sugar and protein production as well as transport of sugars in the form of sucrose from the leaves to the tubers. Yield increases of up to 10% were obtained in trials in which regular application of magnesium fertilizers has been practiced. Sharmila *et al.,*(2006) on potato found that application of magnesium at 24 and 48 kg per hectare resulted in significant higher growth, tuber grade and seed grade yield. Seed grade tubers contributed maximum to the tuber yield to extent of 50 to 68%. The proportion of higher-grade tubers did not vary greatly due to magnesium application at 240 N: 240 K_2O kg per hectare showing that at these levels of N, K and Mg did not influence the tuber grades.

Zinc is a micronutrient necessary for plant growth. Zinc promotes growth hormone biosynthesis, the formation of starch and seed production and maturation (Brady and Weil, 2002). Zinc has many important roles in plant growth and a constant and continuous supply is necessary for optimum growth and maximum yield. (Acquaah, 2002) Zinc is needed for plant's enzyme formation and associated with hormone (Indole acetic acid) formation. Deficiency of zinc has been found to reduce leaf size and shortened internodes and hence, limited plant growth. (Acquaah 2002 and Alloway, 2004)

Copper deficiency cause young leaves develop a pronounced rolling, and then leaf tips wilt and die. Leaves remain green and are of normal size.

The importance of good quality seed has been very well recognized for successful production of any crop. It can only be achieved through balanced and judicious application of micronutrients, proper plant spacing. However, very little scientific or scanty information is available on use of micronutrients with optimum spacing for tuber production of potato. Understanding the techniques of better tuber production is of great importance to increase the productivity and production of potato.

With this background, the present study is initiated to know the effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers is under taken with the following objectives:

1. To know the effect of planting geometry on plant growth, tuber yield and quality of potato.
2. To know the effect of foliar spray of micronutrients on plant growth, tuber yield and quality of potato.
3. To work out the economics of planting geometry and foliar spray of micronutrients on tuber production of potato.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

The literature pertaining to the performance of potato and other crops with different spacings and foliar spray of micronutrients on plant growth tuber yield and quality is reviewed here under.

2.1 Effect of planting geometry

In their studies on effect on spacing in okra, Plenet and Lemaire (2000) reported that okra planted 60cm x 20cm spacing contained maximum dry matter content.

In a trial on okra using three rates of phosphorus – 0, 33 and 60kgP205 /hand three planting densities – 11100, 37000 and 55500plants/ha, Amjad and Mohammed (2001) reported that the lowest planting density (37000plants/ha) resulted in maximum seed yield per plant while seed yield per hectare was highest at the highest planting density.

Yield of paprika pepper increased as the plant density increased. Fruit number and fruit weight per plant decreased with the increasing plant populations, and weight of fruit decreased slightly (Cavero *et al*. 2001).
(Mahmood et *al*. 2001) maximum grain yield (5.7 t ha^{-1}) was produced when plant spacing was kept as 20 cm and nitrogen was applied at the rate of 180 ka ha^{-1}.

Decreasing row spacing from 100 to 50 cm increased maize grain yield. The yield advantage provided by narrow rows was higher when maize was sown earlier. Differences in hybrid cycle and plant architecture did not alter maize response to row spacing reduction (Sangoi *et al.* 2001)

Highest fruit and seed yield of tomato (431.7 q per ha and 107.1 kg/ha respectively) was obtained by application of 150 kg N per ha with medium spacing of 60cm x 45cm than wider spacing of 60cm x 60cm and narrow spacing of 60cm x 30cm (Sharma *et al*. 2001).

Growth and dry fruit yield of pepper at different plant densities (20,000, 40,000 and 60,000 plants/ha) was evaluated by (Aliyu, 2002).They found that the plant density of 60,000 plants per hectare gave the highest fruit yield per ha but yield per plant decreased with increasing plant density.

While conducting spacing trails on chilli varieties for two years reported that plant height at harvest was maximum (98.18 cm) at closer spacing 60 cm x 60 cm. (Balaraj *et al.* 2002)

The maximum tuber yield, number of tubers, number of stems, multiplication rate and benefit:cost ratio were recorded in potato at a fertility level of 150:35:83 kg NPK per ha and a spacing of 60cm x 20cm (Kumar, 2002).

Among the various spacings tried in soybean, wider row spacings of 45 cm with the application of 90 kg P per ha gave the highest yield (16.35 q/ha) of seeds (Kataria and sharma, 2006).

during their studies on response of african tall maize (*Zea mays*) to nitrogen application at varying levels of plant population (Kataria and sharma 2006) and reported that total grain yield (6.2 t/ha) per hectare increased with closer spacing by increasing the plant population 66,666 plants per hectare, but grain weight per plant was decreased.

In his studies the effect on spacing, Pandey *et al.* (2003) observed that higher process grade tubers were highest in wider spacing (75 cm x 30 cm) in Potato cv. Kufri Jyoti.

Capsicum cultivars California Wonder, Bharat and Pusa Deepti were grown at four level of spacing under shade house. Among the cultivars, California Wonder with a spacing 60 cm x 30 cm exhibited statistically significant values of plant height, number of leaves, and number of main branches per plant (Awani *et al.* 2004)

Studied the effect of three different plant spacing. They observed that plant spacing at 60x30 cm attained maximum plant height (176 cm) compared with spacing 60x20 cm (169cm) (Muhammad Rasheed *et al*. 2004)

Studies were conducted by Yenagi *et al.* (2004). They reported on the effect of potato yield was recorded with narrow spacing (45cm) and ‘A’ grade tubers were recorded with wider row spacing (60cm).

Even though all the spacing of capsicum were non significant with various characters studied but the plant height (140.77cm), number of leaves per plant (155.50), number of main branches (23.25) and fresh weight of plant biomass (436.52g/plant) were significantly higher at the wider spacing of 60 x 30cm compared to other spacings (Singh *et al.* 2004).

The effect of row spacing on the yield and yield components of okra and groundnut showed that the productive nodes increased with increasing row spacing. Row spacing of 90cm x 50cm had 77% nodes while row spacing of 75cm x 50cm and 60cm x 50cm had 69% and 66% nodes respectively. The closest row spacing (30cm x 50cm) suppressed weeds better, had low fruit yield when compared to other plat densities (Ibeawuchi *et al*. 2005).

Field experiment at Dharwad (Karnataka) and reported that plant height, number of functional leaves, and dry matter accumulation were significantly higher at 45cm x 20cm and 60cm x 30cm spacing during the growth period as compared to (45cm x30cm) and (60cm x15cm).The effect of spacing's on growth and development of maize. It was found that the spacing of 45 cm x 20 cm recorded the maximum plant height of 176.2 cm, which was significantly superior to wider row spacings of 60 cm x 15 cm (Agasibagil, 2006)

Maximum row spacing of 30cm in determinate type cowpea variety 'Swad' (DFC-1) gave maximum seed yield (743 kg ha^{-1}) and haulm yield (4198 kg ha^{-1}) compared to 45 cm Kurubetta (2006).

A study was conducted by Mantur *et al.* (2007) in capsicum under 50 per cent shade house during summer and *kharif* season. There were two planting geometry and studies revealed that, significantly more number of fruits per plant (8.94), average fruit weight (88.50g), fruit yield per plant (760.50g) and fruit yield per m2 (3.06kg) was recorded in 45cm x 30cm spacing during summer whereas during kharif significantly more number of fruits per plant (10.07), fruit yield per plant (931.60g) was recorded in 45cm x 45cm spacing while fruit yield per m2 (3.94kg) was significantly higher in 45cm x 30cm.

Field experiment was conducted by Thavaprakaash and Velyudham (2007) conducted field experiment on two differents crop geometry and reported that spacing of 60 cm x 19 cm produce higher yield (9507 kg ha-1) compared to second geometry level 45 cm x 25cm (8870 kg ha-1). They further that stated if row spacing was decreased it gradually decreased corn grain yield.

Reported if row spacing 15 inch to 30 inch Very little difference was found if row spacing increased 15 inch to 30 inch respectively decreased stalk diameter from 0.94 inch to 1.02 plant^{-1} Grosbach (2008).

The effect of three planting densities on okra (28,000, 56,000 and 111000plants/ha) on okra intercropped between or within maize rows showed that .plant height and leaf area index increased as the planting density increased in sole or intercropped okra while the number of branches per plant decreased with increasing planting density (Muoneke and Asiegbu, 2008).

An experiment was conducted by Zende (2008) to study the effect of planting geometry in capsicum cv. Orobelle under two growing environments *viz*., naturally ventilated poly house and plant height and leaf area per plant under both naturally ventilated Polly house and shade house. Wider spacing of 45 cm x 60 cm showed the early to 50 per cent flowering under both growing environments.

Plant density has an impact on marketable bulb size and the higher the plant density the smaller the marketable size (Seck and Baldeh, 2009).

Study undertaken to find out the influence of different spacings in potato by Khan *et al*. (2010) revealed that a wider spacings of 70cm x 20 cm and 50 x 20 cm were the best for producing higher number of large size tubers.

Maximum plant height (202.47 cm^2), leaf area per plant (3885 cm^2) dry matter yield (10.90 t/ha) and crude fiber (30.93%) was recorded in wide row spacing of 45cm (Ahmad *et al*., 2012).

In their studies on optimizing planting geometry of in vitro potato plants for growth and minitubers production in nethouse, Dhruv Kumar *et al*. (2012) reported that wider inter row spacing of 45 cm gave maximum plant height (34.3 cm), No. of stem per plant (2.1), leaf area (2.1): over other treatment and control.

Potato cultivars Kufri Bahar, Kufri Badshah and Kufri Chipsona-1 were grown at two level of spacing under net house. Among the cultivars, Kufri Chipsona at spacing 45 cm x 20 cm exhibited statistically significant values of growth parameters, yield parameters *viz*. harvest index (0.72), number of minitubers per plant (12.6), yield (110.2 g) and mean minituber weight (8.7g) (Kumar *et al.* 2012).

In their studies Soleymani and Shahrajabian (2012) reported that application of zinc at (10%) to forage sorghum recorded higher plant height (184 cm), stem diameter (2.2), Ash percentage (12.6%) over control.

According to Kashsay *et al.*(2013) widest intra row spacings of 10 cm recorded the maximum plant height , leaf number per plant, leaf biomass yield, leaf dry matter content but the lowest yield per hectare. Closer intra row spacing of 5 cm the highest total bulb yield of onion (36.14 t/ha).

In his studies Lyocks *et al.,* (2013), reported that maximum plant height of 158.8 cm was recorded at row spacing 75x25 cm which was significantly higher than height (119.3 cm) at spacing 40 x 20 cm.

The rectangular spacing of 45cm x 15cm consistently gave the highest seed yield of 908 kg ha^{-1} among the different spacings tried with KS 95010 variety of sesame (Sivagamy and Rammohan 2013).

2.2 Effect of foliar spray of micronutrient on growth, yield and quality.

During his research on effect on micronutrients, Ullagaddi (2000) indicated that, the foliar spray of $ZnSO_4$ (0.1%) plus Boron (0.1%) in combination with GA_3 (50 ppm) significantly increased the number of squares, flowers and matured bolls per plant and highest seed yield.

A field experiment was conducted by Barik and Chandel (2001) on silty clay loam soil at Pantnagar in UP to know the effect of copper levels on growth, grain yield and copper uptake by different varieties of soybean. They reported interaction effect between soybean varieties and different copper levels and stated that soil application of $CuSO_4$ at 5 kg ha^{-1} produced significantly higher grain (1785 kg ha^{-1}) yield over other treatments.

Among the treatments, soil application of 12.5 kg $ZnSO_4$ per ha along with three sprays of 0.2 per cent $ZnSO_4$ and 0.5 per cent FeSO4 thrice at weekly interval at later stages recorded significantly highest fruit yield of 37.7 t per ha with 23.6 per cent increased over control in brinjal cv. Bhagyamathi (Raj *et al.* 2001)

While evaluating the effect of magnesium fertilizer Swierczewska *et al.* (2001), Application of magnesium fertilizer increased crop yield in cereals (193 kg), winter rape seed (36 kg) and potato (361 kg).

In his field experiment on effect of nutrition and growth regulators on plant growth, seed yield and quality of bell pepper at Dharwad. Yoganand (2001) stated that maximum mean germination (64.81%), root length (4.86 cm) and shoot length (5.95 cm) were obtained when the plants were sprayed with $ZnSO_4$ (0.2%) at pre-flowering stage.

Application of 2.5 kg $CuSO_4$ ha^{-1} to soybean significantly increased nodules per plant, their dry weight and leghaemoglobin content by 10.9, 10.0 and 20.8 per cent, respectively over the control (Barik and Chandel, 2002).

A study was carried out in Giza, Egypt, to study the response of cotton plants to P and Zn application accompanied with VAM inoculation. Inoculation with VAM along with P and Zn applications significantly increased the survival of plants and gave the highest dry weight of shoots and roots, seed index, seed cotton yield and lint cotton yield by (Elwan *et al*. 2002).

A study conducted by Gundlur and Manjunathaiah (2002). A study on the different levels of copper ore tailings (COT) and copper sulphate on groundnut revealed that application of COT at 1000 kg ha^{-1} and copper sulphate at 30 kg ha^{-1} significantly increased pod yield of groundnut (24.03 and 21.14 q ha^{-1}) over control (17.48 q ha^{-1}).

In their studies on the effect of foliar spray of micronutrients on cotton Hallikeri *et al*. 2002 reported that foliar spray of MC + NAA + $ZnSO_4$ + $FeSO_4$ 5kg/ha significantly increased the seed cotton yield (1445 kg/ha) over other treatments and control.

In their studies, Khalate et *al*. (2002) reported that, application of copper at 1 per cent to onion recorded higher onion seed yield (1336.90 kg ha^{-1}) over control (1008.90 kg ha^{-1}).

Different versions of foliar fertilizing with the micro fertilizers Mo, Cu, Zn, Mn, B and the complex suspension fertilizers lactofol B and lactofol O were tested in field trails. Two controls were used. Nitrogen was incorporated with the pre sowing cultivation and water control. The results indicated that the independent effect of 800 g per ha of Zn sprayed during the budding stage of cotton is the best pronounced one. The yield from the first crop was increased by 12 per cent (Nikolov, 2002).

In their field experiment studies on the effect of foliar application of micronutrients on growth and yield of tomato Tamilselvi *et al.* 2002, there was reported maximum dry matter production (4732 kg ha^{-1}) with the foliar spray of Copper @ 100 ppm when compared to concentration (200 ppm) (4569 kg ha^{-1}) and control (4456 kg ha^{-1}).

Agrwal *et al*. (2004) observed significant increase in plant height (76.53 cm) with the foliar spray of Cu at 0.5 per cent under the drip irrigation over control (68.07 cm) in tomato.

A study was carried out by Chhabra *et al*. 2004 studied the effect of macro and micronutrients on the production of cotton genotypes. Results indicated that application of macro and micronutrients gave significantly higher values of fibre length, (24.4 mm) fibre strength (18.91 g/t), ginning outturn (36.74%), over control.

Application of micronutrients (B, Zn and Mo) significantly increased yield, oil content and growth parameters of groundnut (Niranjana *et al*. 2005).

A field experiment was conducted on clayey soil in Killikulm, Tamil Nadu to study the effect of individual and interactive effect of foliar spraying of Mg and Zn, along with the recommended N and P levels (40:20 kg/ha) on cotton yield, quality and nutrient uptake. Foliar application of 0.5% $ZnSO_4$ + 1% $MnSO_4$ at 45 and 60 DAS recorded higher value for halo length (24.7 mm), ginning percentage (37.1) and lint index (45.3) (Suresh and Kumar, 2005).

A field experiment was conducted at Annamalai University Experimental Farm, Tamil Nadu to evaluate the effect of foliar application of micronutrient mixture Micnelf MS-16 on yield and economics of cotton. Among the treatments, application of Micnelf MS-16 @ 1.5% has resulted in increased kapas yield (1510 kg/ha) over control (941 kg/ha) (Imayavaramban *et al*. 2006).

Soil application of 5 kg ha^{-1} Cu to soybean significantly increased grain yield by 9 per cent as compared to control and foliar application of $CuSO_4$ at 0.4 per cent significantly increased grain yield by 9.6 per cent over control. (Manchanda *et al.* 2006)

Santhosh Kumari and Sharma (2006) conducted a field experiment on the effect of micronutrient spray on tomato seed production. They concluded that application of Cu at 100 ppm resulted in the production of more seed yield as compared to other micronutrient sprays.

Foliar application of copper, magnesium and zinc and their different concentration resulted in maximum plant height (62.9 cm), dry matter (74.9 g), tuber yield (21.9 t/ha) and tuber size (218 g) (Kumar *et al.* 2007).

Mousavi *et al.* (2007) reported that, foliar application of zinc @ 8 ppm in combination with manganese @ 4 ppm in potato was resulted maximum yield (38950 kg/ha).

Ahmed *et al.* (2011) observed that, foliar application of active yeast extract and zinc with different concentrations increased the plant height, stem, leaves, specific gravity, protein (%), starch (%) and dry matter (%).

Kazemi (2013) studied the effects of Zn, Fe and their combination treatments on the growth and yield of tomato. Among all the treatments Zinc @ 100 mg and iron @ 200 mg per liter were found to be the most effective when applied alone or in combination and produced the highest vegetative growth and fruit quality.

A study on response of cucumber plants to foliar application of calcium chloride and paclobutrazol under greenhouse conditions. Indicated that paclobutrazol at 10 mg and calcium chloride at 7.5 mM per litre applied alone or in combination showed the best response in total yield (4.4 kg plant^{-1}) and fruit quality (Kazemi, 2013).

While evaluating the effect of foliar fertilization of calcium on potato Ulamin *et al.* (2013) reported that, foliar application of 3-6 mM calcium chloride significantly increased the relative growth rate (0.711 week^{-1}), water content (94.872%) and dry matter (695.568 μmoles g^{-1} Dry Wt.).

According to Al-Rashidi and Ahmad Zinc at 10 mg/kg gave maximum sugar percentage (14.4%) of sugar beet.

2.3 Economics

The maximum benefit: cost ratio was recorded in potato at a fertility level of 150:35:83 kg NPK per ha and a spacing of 60cm x 20cm (Kumar, 2002).

MATERIAL AND METHODS

Chapter III

MATERIALS AND METHODS

A field experiment was conducted to study the effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum).* The experiment was laid out during rabi 2013-14 under irrigated condition, in alluvial soil at research farm of Lovely Professional University, Phagwara. The details of the materials used and experimental techniques adopted during the course of investigation are described in this chapter.

3.1 General description

3.1.1 Location of the experimental site

The experiment site is located at research farm of Lovely Professional University, Phagwara having an elevation of 245 meters above the mean sea level (MSL) with 31^o 15’ N latitude and 75^o 41’ E longitude.

3.2 Soil properties of experimental site

The soil of experimental site at LPU, Phagwara is sandy clay loam in nature. The composite soil sample from the experimental site was drawn before commencement of the experiment and analysed for the different physical and chemical properties by following the standard procedure. The results are given in Table 1 (Fig. 3.1).

3.3 Climatic condition

The experimental farm of Lovely Professional University is situated in the (PB-3) Central Zone of the State. This zone receives rainfall from both South-West and North-East monsoons which is well distributed from June to September with lower coefficient of variation.

The data on weather parameters such as rainfall (mm), mean maximum and minimum temperature (^{0}C) and relative humidity (%) recorded at Meteorological Observatory, Main Agricultural Research Station, Punjab Agricultural University of Punjab during the experimental year and the mean are presented in Table 3.2.

3.4 Varietal description of *Solanum tuberosum* cv. Kufri Jyoti

Kufri Jyoti plants are tall, erect, compact and vigorous. Crop matures early in hills, average yield in hills 20 t/ha. In the plains region the tubers develop in 90 to 100 days and average yield in plains region is 30 t/ha. Flowers are in white colour and anthers are in orange-yellow colour with high pollen stainability. Shape of stigma is round and slightly notched. Tubers are large, oval in size and shape with white flesh and smooth skin. Moderately resistant to early and late blight. Slow rate of degeneration. It is suitable for processing purpose.

3.5 Experimental details

3.5.1 Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum*):

The experiment was conducted during rabi season of the year 2013-14. The experiment consisted of 15 treatment combination with 3spacing as one factor and 5 foliar spray of micronutrients as another factor. The details of the treatment are given below and the experiment was laid out in split plot design.

3.5.2 Treatment details

Factor 1: Main plots (Spacing) (M)

M_1: 60 cm × 30 cm

M_2: 60 cm × 20 cm

M_3: 60 cm × 40 cm

Factors 2 : Sub plots (Foliar spray of micronutrients) (S)

S_1 : Calcium chloride @ 1 kg per hectare

S_2 : Magnesium sulphate @ 7 kg per hectare

S_3 : Copper sulphate @ 1 kg per hectare

S_4 : Zinc sulphate @ 8.5 kg per hectare

S_5 : Control

Table3.1. Physical and Chemical properties of soil of the experimental site

Sr. No	Particulars	Values (0- 30 cm depth)	Method employed
I.	**Physical properties**		
1	Coarse sand (%)	17%	International pipette method (Piper, 1955)
2	Fine sand (%)	44%	
3	Silt (%)	7%	
4	Clay (%)	32%	
II.	**Chemical properties**		
1	pH	7.96	Buckmoric Hmeter (Piper,1955)
2	Electrical conductivity (dS/m)	0.33	Jackson (1973)
3	Organic carbon (%)	0.48	Wet oxidation method (Jackson, 1957)
4	**Available nutrient status**		
A	Available N (kg/ha)	764.72	Alkaline permagnate method (Subbaiah and Asija,1955)
B	Available P (Kg/ha)	418.3	Olsen's method (Jackson,1957)
C	Available K (kg/ha)	14.56	Flame photometer method (Tandon, 1993)

Table2. Meteorological data (mean standard monthly values) of winter season of (2013-14) during the crop growth period was recorded.

Months	Rainfall (mm)	Maximum Temperature (^oC)	Minimum Temperature (^oC)	Relative Humidity (%)
	2013-14	**2013-14**	**2013-14**	**2013-14**
October	75.94	30.5	17	83
November	23.11	26.4	9.9	74.8
December	3.56	20.6	6.2	89.1
January	18.04	19.1	4.4	86.1
February	8.87	20.2	5.8	79.9

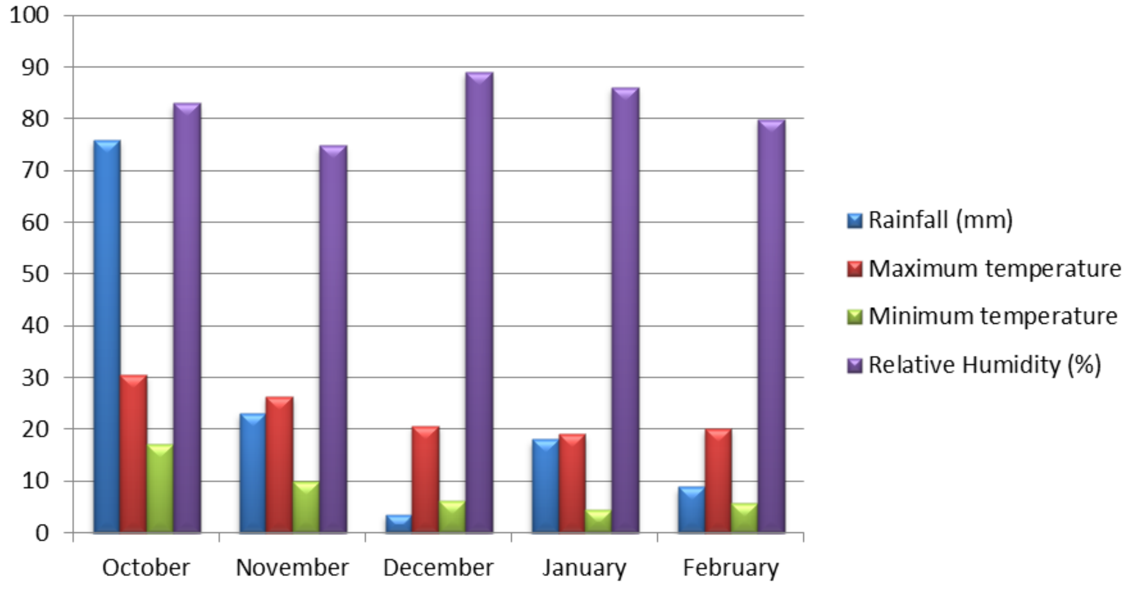

Fig. 3.1: Monthly meteorological data

R1

M1 S1	M1 S2	M1 S3	M1 S4	M1 S5
M2 S5	M2 S1	M2 S2	M2 S3	M2 S4
M3 S4	M3 S5	M3 S1	M3 S2	M3 S3

R2

M2 S3	M2 S2	M2 S5	M2 S4	M2 S1
M3 S1	M3 S5	M3 S4	M3 S3	M3 S2
M1 S2	M1 S1	M1 S5	M1 S4	M1 S3

R3

M3 S3	M3 S2	M3 S1	M3 S5	M3 S4
M1 S4	M1 S3	M1 S2	M1 S1	M1 S5
M2 S5	M2 S4	M2 S3	M2 S2	M2 S1

2.5 m

2.5 m

LEGEND

$M_1 S_1$ = 60 X 30 & Calcium Chloride

$M_1 S_2$ = 60 X 30 & Magnesium Sulfate

$M_1 S_3$ = 60 X 30 & Copper Sulfate

$M_1 S_4$= 60 X 30 & Zinc Sulfate

$M_1 S_5$ = 60 X 30 & Control

$M_2 S_1$ = 60 X 20 & Calcium Chloride

$M_2 S_2$ = 60 X 20 & Magnesium Sulfate

$M_2 S_3$ = 60 X 20 & Copper Sulfate

$M_2 S_4$ = 60 X 20 & Zinc Sulfate

$M_2 S_5$ = 60 X 20 & Control

$M_3 S_1$ = 60 X 40 & Calcium Chloride

$M_3 S_2$ = 60 X 40 & Magnesium Sulfate

$M_3 S_3$ = 60 X 40 & Copper Sulfate

$M_3 S_4$ = 60 X 40 & Zinc Sulfate

$M_3 S_5$ = 60 X 40 & Control

Fig. 3.2: Plan of layout of the experimental site

Plate 3.1

Plate 3.2

Plate 3.3

First foliar spray was given at 10 days after 100% emergence and second foliar spray was given after 15 days from first spray.

Following are the technical details of experiment.

1. Crop and Variety : Potato cv. Kufri Jyoti
2. Experimental design : Split plot design
3. Number of Treatments : 15
4. Number of Replications : Three
5. Gross plot size : 2.5m x 2.5m
6. Net plot size : 2.1m x 2.1m
7. Fertilizer dose : 180 :100 :150 NPK kg per ha
8. Season : Rabi 2013

3.5.3 Treatment combinations

M_1S_1	M_2S_1	M_3S_1
M_1S_2	M_2S_2	M_3S_2
M_1S_3	M_2S_3	M_3S_3
M_1S_4	M_2S_4	M_3S_4
M_1S_5	M_2S_5	M_3S_5

3.6 Cultural practices

3.6.1 Land preparation

The land was ploughed with the help of tractor by using mould board plough and disc plough then cultivator was passed to crush the big clods and one harrowing was done to get the fine tilth. The land was levelled and the field was laid out in to experimental plots as per the plan and then bunds were formed to all the plots.

3.6.2 Sprouting of potatoes

Potato tubers were kept for 10 to 12 days under the diffuse light condition for sprouting. Pre sprouting of tubers help to increase the number of stem and consequently the crop’s final yield.

3.6.3 Tuber treatment

The tubers were treated with boric acid 3% (1kg in 33litre of water) for protecting them from fungal diseases. The treatment was given for 30 minutes by dipping in solution.

3.6.4 Fertilizer application

Fertilizers were applied manually by adopting the ring method. In these rings fertilizers were placed and were thoroughly mixed in the soil. Recommended dose of N, P and K (180:100:150 kg N, P_2O_5 and K_2O ha^{-1}) were applied to the soil. Full dose of 'P' and 'K' were applied along with 50 per cent of N to potato crop at the same time of sowing and the remaining 50 per cent N was applied after one month.

3.6.5 Planting of tubers

The furrows were opened with the help of marker and manual as per the different spacing. Tubers were planted manually in the dated 21st October, 2013 and covered with the soil. Tubers of 'Kufri Jyoti' were used for planting with recommended tuber rate of 3500 kg ha^{-1}.

3.6.6 Cultural operations

The details of cultural operations were carried out during the course of investigations were as follows.

3.6.7 Gap filling

Gap filling was done 10 days after planting with tubers of same age to ensure optimum plant population.

3.6.8 Weeding and intercultivation

Intercultivation was carried out 20, 40 and 60 days after sowing followed by two hand weeding's at 30 and 50 days after sowing to keep the experimental plot weed free.

3.6.9 Earthing up

Earthing up was done at 40 DAP after the top dressing with nitrogenous fertilizer.

3.6.10 Irrigation

Four Irrigation were given at 5 DAP, second irrigation 20 DAP and third irrigation 45 DAP and last irrigation was applied 75 DAP.

3.6.11 Plant protection measures

The proper schedule of different plant protection measures was taken to keep the crop pests/diseases free. The crop was regularly sprayed with neem oil (5ml per Litre) at 30, 60 days after sowing to control aphids, thrips, and mites. The Dithane M-45 was sprayed at 2kg/ha to control fungal attack.

3.6.12 Application of micronutrients

The quantity and type of micronutrients as mentioned in the treatment details were dissolved in known quantity of water and were sprayed to the crop at two intervals, once at one week after 100% emergence, second at 15 days after first spray.

Collection of experimental data

For analysing the growth pattern of the crop, four plants were selected randomly from the net plot area in each treatment and various observations were recorded at 40, 60, 80 days after sowing. The parameters and procedures followed are given below.

3.7 Growth parameters

3.7.1 Plant height (cm)

The plant height of the four randomly tagged plants were recorded at 40, 60, 80 DAP and at harvest and the average was expressed in cm.

3.7.2 Number of stem

Total number of stem per plant in four labelled plants was recorded at 40, 60 and 80 DAP and the mean values were computed.

3.7.3 Stem diameter (cm)

The circumference measured at the ground of stem was taken as the girth of the stem and expressed in centimetre (cm).

3.7.4 Leaf area per plant (cm^2)

The length of the fully opened leaf lamina was measured from the base to the tip of the leaf. The leaf breadth was taken at the widest point of the leaf lamina. The product of the length and breadth was multiplied by the factor 0.75 (Singh and Saxena, 1965) and the sum of all the leaves was expressed as leaf are in dm^2 per plant. Leaf area was measured by the following formula.

Leaf area = leaf length (cm) × leaf width (cm) × 0.75

3.7.5 Total dry matter (gm/plant)

The plant samples collected at 40, 60 and 80 DAP were separated into stem and tubers were dried in the oven at 65^0 to 70^0C till the constant weight was reached and then mean dry matter per plant in different parts was recorded in grams.

3.8 Yield and yield attributes

3.8.1 Number of tubers per plant

The number of tubers per plant was calculated from same three randomly selected plants meant for plant height and number of stems per hill in each plot. The average values were worked out at harvest time.

3.8.2 Tuber yield (q ha^{-1})

The tubers obtained from the net plots were separated and weighed. Total tuber yield was computed and recorded as quintals per hectare.

3.8.3 Marketable yield (q ha^{-1})

Tuber diameter between 40 mm to 80 mm was considered as marketable; there were souted out after harvest with help of vernier caliper. Then there average weight was calculated as per different treatments and expressed in q/ha.

3.8.4 Non marketable yield (q ha^{-1})

The tuber below 40 mm was considered as non-marketable was calculated as. Non-marketable yield = Total yield – Marketable yield

3.9 Quality parameters

3.9.1 Reducing sugar (%)

The per cent reducing sugar of tuber on dry weight basis was estimated by adopting Shaffer Somogy's micro method (Nelson, 1944) for all treatments and each estimation was done in duplicate and mean was computed.

To 1ml of ethanolic extract. I ml of fresh copper reagent prepared by mixing copper tartarate and copper sulphate solution (25:1 vlv) was added. The mixture was heated for 20 min in a boiling water-bath and cooled. One ml of arsenomolybdate reagent was added and the contents incubated for15 min. The solution was then diluted to 25 ml with distilled water and the colour intensity was read at 500 nm in Systronics Spectrophotometer. The content of the reducing sugar was calculated using the standard graph for glucose.

3.9.2 Non reducing sugar (%)

The amount of non-reducing sugars was determined by following the formula suggested by Loomis and Shull (1937).

Non-reducing sugars = Total sugars - free reducing sugars x 0.95

3.9.3 Total sugar (%)

The total sugars were estimated by the method proposed by Dubois *et al.* (1956).

Four ml of cold anthrone reagent was added to 1 ml of ethanolic extract. This mixture was shaken vigorously and boiled for 10 min in a boiling water bath. After cooling in running tap water, the absorbance was read at 620 nm in Systronics Spectrophotometer. A standard curve was prepared with known amounts of glucose.

3.9.4 Ash (gm)

Total ash content tuber samples were determined according to AOAC (2000) using sub component 923.03 by incineration of known weights of the samples in a muffle furnace (Carbolite CSF 1200) at 550^0C until a white ash was obtained. About 2.000g of tuber samples of each treatment in triplicates were added into each dish. The dishes were placed on a hot plate under a fume hood, and the temperature was slowly increased until smoking ceases, and the samples become thoroughly charred. The charred samples were placed inside the Muffle Furnace (Carbolite CSF 1200), and ashed at 550^0C for 3 hrs. The charred samples were removed from a Muffle Furnace and cooled, seen to be clean and white in appearance. Few drops of de-ionized water and concentrated nitric acid were added, dried, and return to a Muffle Furnace. Then checked until traces of carbon are fully ashed. Finally taken out of the Muffle Furnace placing immediately in a desiccators till cooled to room temperature, and each dish plus ash was reweighed. Weight of total ash was calculated by difference, and expressed as percentage of sample.

3.9.5 pH values

pH values was measured by electronic pH meter (model: Knick 646) according to Anon., (1990).

3.9.6 Starch content (%)

Starch content in tubers was estimated by taking the residual material of tubers remaining after extraction of tubers with 80% alcohol as suggested by Powell and Gains (1973) on dry weight basis and expressed in per cent.

3.9.7 Crude fibre (gm)

Crude fiber content of tubers samples were determined according to AOAC, (2000) using sub component 962.09 in which the steps of digestion, filtration, washing, drying and combustion were involved. About 1.500 gm of tubers samples of each treatment (raw or control, boiled after peeling, and boiled before peeling) in triplicates were placed into a 60ml beaker, and about 200 ml of 1.25% H_2SO_4 was added, and boiled gently exactly for 30 minutes placing a watch glass over the mouth of the beaker. During boiling, the level of the sample solution was kept constant with hot distilled water. After 30 minute boiling, 20 ml of 28% KOH was added and boiled gently for a further 30 minute, with occasional stirring.

The bottom of a sintered glass crucible was covered with 10 mm sand layer, and wetted with a little distilled water. The solution was poured from beaker into sintered glass crucible, and then the vacuum pump was turned on. The wall of the beaker was rinsed with hot distilled water several times; washings were transferred to crucible, and filtered. The residue in the crucible was washed with hot distilled water, and filtered (repeated twice).

The residue was washed with 1% H_2SO_4 and filtered, and then washed with hot distilled water, and filtered; and again washed with 1% NaOH and filtered. The residue was washed with hot distilled water and filtered and again washed with 1% H2SO4 and filtered. Finally the residue was washed with water- free acetone.

The crucible with its content was dried for 2 hours in an electric drying oven at 130 0C and cooled for 30 min in the Desiccator (with fresh granular silica gel dessicant), and then Weighed. The crucible was transferred to a Muffle Furnace (Gallenkamp, size 3) and incinerated for 30 min at 5500 C. Finally, it was cooled in the Desiccators, and re-weighed.

3.9.8 Specific gravity

Specific gravity was calculated by weighing the cleaned tubers in air (W_1) and then completely immersed in a container of water ($W_{2)}.$ Calculation was made by the formula given by Talburt and Smith (1959).

Specific gravity = $W_1 / (W_1 - W_2)$

3.9.9 Total soluble solid (TSS) (^{o}Brix)

The total soluble solid (TSS) of harvested tubers were measured by digital refractometer (model: FG 103) at room temperature and expressed as ^{o}Brix value.

3.10 Economics

Additional cost involved and returns obtained with different chemical fertilizers was worked out on the basis of market rate of all the applied inputs during experimentation as per hectare basis (Appendix I).

3.10.1 Economic analysis

The net return per hectare was worked out for all the treatments by subtracting the cost of cultivation from the gross returns. The return per rupee invested (B: C ratio) was also calculated as follows.

Net returns (Rs.) = Gross income – Total cost of cultivation

$$\text{B: C ratio} = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$$

3.11 Statistical analysis

The data collected in respect of various parameters on growth, tuber yield and other attributes were analysed statistically as described by Sundarraj *et al.* (1972) and Panse and Sukhatme (1978). The critical difference (CD) values were calculated at 5 per cent probability level whenever ‘F’ test was significant.

RESULTS AND DISCUSSION

Chapter **IV**

RESULT AND DISCUSSION

The results of the present investigation entitled "Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum).* cv. Kufri Jyoti" have been presented and discussed in this chapter under the appropriate heads and sub-heads:

4.1 Plant growth parameters

4.1.1 Plant height

The data on plant height at 40, 60 and 80 day after planting and at harvest as influenced by spacing levels, foliar spray of micronutrients and their interactions are presented in Table 4.1.1.

Plant height varied significantly with different spacing. The spacing of 60 cm x 40 cm (M_3) recorded highest plant height (45.07 cm) while lowest plant height (43.58cm) was recorded at a spacing of 60x 30 cm (M_1) at 80 days after planting.

Micronutrient sprays were found to have a significant effect on plant height. Spray of Zinc sulphate @ 8.5 kg/ha (S_4) recorded significantly highest plant height (46.14 cm) at 80 days after planting while minimum plant height (26.72cm) was recorded in controlled plot (S_5).

As clear from the data, interaction between spacing and foliar spray of micronutrients had a significant effect on plant height. Maximum (47.18 cm) plant height at 80 days after planting was observed in M_3S_1 and lowest plant height was recorded in 39.75 cm in M_1S_5.

Higher plant height might be due to the more availability of nutrients and space for plant growth and development. These results are in agreement with the finding of Mohammad Rasheed *et al.* (2004) who observed that maximum plant height (176 cm) was recorded in wider spacing of 60 x 30 cm. Further the results are in accordance with Balaraj *et al.* (2002) where maximum plant height (98.18cm) was recorded at spacing of 60 x 60 cm.

4.1.2 Number of stem per plant

The data on number of stem per plant at 40, 60 and 80 days after planting as influenced by spacing's and micronutrients are presented in Table 4.1.2.

Table 4.1.1. Effect of planting geometry and foliar spray of micronutrients on plant height at 40, 60, 80 DAP of Potato.

Treatments	Plant height (cm)											
	40 DAP				60 DAP				80 DAP			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	28.79	27.19	31.93	29.30	38.36	36.66	40.77	38.6	43.5	41.75	47.18	44.14
S_2	27.71	26.37	29.99	28.03	37.86	38.35	38.68	38.30	42.68	40	44.97	42.55
S_3	27.99	25.21	28.32	27.17	37.13	40.33	39.87	39.11	45.21	43.41	44.37	44.33
S_4	30.83	28	32.16	30.33	39.73	38.41	42.07	40.07	46.78	45.26	46.37	46.14
S_5	27.78	24.98	27.40	26.72	35.79	35.43	37.06	36.09	39.75	41	42.46	41.07
Mean	28.62	26.35	29.96		37.77	37.84	39.69		43.58	42.28	45.07	
For comparing the means of	**S.Em±**		**CD at 5%**		**S.Em±**		**CD at 5%**		**S.Em±**		**CD at 5%**	
MP	0.61		2.13		0.39		1.36		0.49		1.70	
SP	0.35		1.00		0.38		1.09		0.50		1.45	
MP×SP	0.60		NS		0.66		1.89		0.88		2.52	

NS – Non significant DAP –Days after planting

Main Plots (M)
M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)
S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

Spacing was observed to have a significant effect on number of stems per plant. M_1 (60 x 30cm) gave maximum number of stem at 40 (1.44) and 60 (2.08) days after planting while M_3 (60 x 40 cm) gave maximum number of stem (2.76) at 80 days after planting.

Micronutrients foliar applications also show significant effect on number of stems. Highest number of stems 1.56, 2.17 and 2.84 was recorded in S_4 (Zinc sulphate@) at 40, 60 and 80 day after planting respectively. Lowest number of stem (2.297) was obtained in control (S_5) at 80 days after planting.

Interaction between spacing levels and foliar spray of micronutrients affected number of stems significantly. At 80 day after planting maximum number of stem (3.025) were recorded in M_3S_4 and M_2S_1 (2.137) gave minimum number of stems.

In conformity to above results, Kumar, (2012) reported that wider spacing (45 cm) gave more number of stems as compared to those obtained at closer spacing (30 cm). Similar result was also reported by Ahmed *et al.* (2008) in potato.

4.1.3 Stem diameter

The data on stem diameter at 40, 60 and 80 day after planting as influenced by spacing levels and foliar sprays of micronutrients are presented in Table 4.1.3.

60 x 20 cm (M_2) spacing recorded maximum stem diameter (3.54 cm) at 40 days after planting and at 60 days (4.13 cm) after planting. Spacing of 60x 40 cm (M_3) recorded maximum stem diameter (3.95cm) at 80 days after planting.

Foliar spray of micronutrients had a non-significant effect on stem diameter; however maximum stem diameter was recorded in the control plot (4.17, 3.81 cm) at 60, 80 day after planting respectively. Lowest stem diameter (3.37cm) was obtained from S_2 (Magnesium sulphate @ 7 kg/ ha).

Interaction between plant spacing and foliar spray micronutrient gave non-significant result. However highest stem diameter (4.1cm) was recorded in M_3S_5 treatment at 80 days after planting while minimum stem diameter (3.567cm) was recorded in M_1S_2 at 80 day after planting.

The results are in consonance with those of Grosbach (2008) who reported that the wider spacing gave maximum (1.02 inch) stem diameter.

Table 4.1.2. Effect of planting geometry and foliar spray of micronutrients on number of stem at 40, 60, 80 DAP of Potato.

Treatments	Number of stem											
	40 DAP				60 DAP				80 DAP			
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	1.42	1.22	1.5	1.38	2.06	1.96	2.12	2.05	2.62	2.42	2.75	2.6
S2	1.21	1.12	1.31	1.21	1.97	1.75	2.07	1.93	2.45	2.33	2.65	2.47
S3	1.37	1.3	1.5	1.39	2.12	2.11	2.22	2.15	2.82	2.42	2.92	2.72
S4	1.57	1.37	1.75	1.56	2.28	1.87	2.36	2.17	2.9	2.61	3.02	2.84
S5	1.62	1.03	1.06	1.24	1.97	1.82	2.12	1.97	2.30	2.13	2.45	2.29
Mean	1.44	1.21	1.42		2.08	1.90	2.18		2.62	2.38	2.76	
For comparing the means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
MP	0.04		0.15		0.04		0.16		0.06		0.23	
SP	0.05		0.16		0.03		0.09		0.04		0.13	
MP×SP	0.09		0.28		0.05		0.16		0.08		NS	

NS – Non significant DAP –Days after planting

Main Plots (M)

M_1: 60 cm × 30 cm

M_2: 60 cm × 20 cm

M_3: 60 cm × 40 cm

Sub Plots (S)

S_1: Calcium chloride @ 1 kg per hectare

S_2: Magnesium sulphate @ 7 kg per hectare

S_3: Copper sulphate @ 1 kg per hectare

S_4: Zinc sulphate @ 8.5 kg per hectare

S_5: Control

Table 4.1.3. Effect of planting geometry and foliar spray of micronutrients on stem diameter at 40, 60, 80 DAP of Potato.

Treatments	Stem diameter (cm)											
	40 DAP				60 DAP				80 DAP			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	2.88	3.47	3.32	3.22	3.33	3.50	4.2	3.68	3.67	3.9	3.88	3.81
S_2	3.55	3.6	2.9	3.35	3.3	3.95	4.5	3.91	3.6	3.79	3.81	3.37
S_3	3.12	3.97	2.97	3.35	3.6	4.17	3.61	3.79	3.82	3.76	4	3.86
S_4	3.46	3.08	3.12	3.22	3.65	3.61	3.97	3.7	3.83	3.83	4	3.93
S_5	2.92	3.58	3.25	3.2	3.36	5.45	3.69	4.17	3.56	3.93	4.1	3.81
Mean	3.18	3.54	3.11		3.45	4.13	3.99		3.72	3.81	3.95	

For comparing the means of	40 DAP S.Em±	40 DAP CD at 5%	60 DAP S.Em±	60 DAP CD at 5%	80 DAP S.Em±	80 DAP CD at 5%
MP	0.09	0.33	0.12	0.43	0.05	0.17
SP	0.14	N.S.	0.71	N.S.	0.05	N.S.
MP×SP	0.25	N.S.	0.29	0.84	0.10	N.S.

NS – Non significant

DAP –Days after planting

Main Plots (M)

M_1: 60 cm × 30 cm

M_2: 60 cm × 20 cm

M_3: 60 cm × 40 cm

Sub Plots (S)

S_1: Calcium chloride @ 1 kg per hectare

S_2: Magnesium sulphate @ 7 kg per hectare

S_3: Copper sulphate @ 1 kg per hectare

S_4: Zinc sulphate @ 8.5 kg per hectare

S_5: Control

4.1.4 Leaf area (cm^2)

The data on leaf area at 40, 60, 80 day after planting as influenced by different spacings, micronutrients and their interactions are presented in Table 4.1.4.

Perusal of data clearly indicates that the spacing had a significant effect on the leaf area. Maximum leaf area was recorded at a spacing of 60 x 40 cm (M_3) at 40 (29.50 cm^2), 60 (37.58cm^2) and 80 (51.01 cm^2) days after planting. Leaf area increased with the increase in number of growing days.

As clear from the data foliar spray of micronutrients affected leaf area significantly, S4 (Zinc sulphate @ 8.5 kg/ha) recorded maximum leaf area at 40 (30.89 cm^2), 60 (38.21cm^2) and 80 (51.46cm^2) days after planting.

Interaction between spacing and foliar spray significantly influenced the leaf area. Maximum leaf area (53.99cm^2) was recorded in M_3S_4 and minimum leaf area (45.79cm^2) was recorded in M_2S_5.

Almost similar result was reported by Zende, (2008) who recorded higher leaf area of capsicum at a wider spacing (45 x 60 cm).

4.1.5 Total dry matter (gm)

The data on total dry matter at 40, 60 and 80 day after planting as influenced by spacing, micronutrients and their interactions are presented in Table 4.1.5.

60 x 40cm (M_3) recorded maximum dry matter (84.75 gm) at 80 days after planting while minimum dry matter (81.51) has been recorded in spacing 60 x 20 cm at 80 days after planting.

Micronutrient foliar sprays also had a significant effect on the total dry matter production. S_4 (Zinc sulphate @ 8.5 kg/ha) gave 86.97 gm at 80day after planting and lowest dry matter (80.11 gm) was recorded at 80 days after planting from S_5 (control).

Among all the treatments of spacing and micronutrients, M_3S_4 recorded the highest dry matter production (89.11 gm) at 80 days after planting however M_1S_5 reported lowest dry matter (78.90 gm) at 80 days after planting.

Table 4.1.4. Effect of planting geometry and foliar spray of micronutrients on leaf area at 40, 60, 80 DAP of Potato.

Treatments	**Leaf area (cm^2)**											
	40 DAP				**60 DAP**				**80 DAP**			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
S_1	29.56	27.5	30.36	29.14	36.95	35.88	38.47	37.16	48.76	47.04	50.66	48.81
S_2	28.83	26.06	28.23	27.71	35.88	34.38	36.22	35.49	48.65	48.11	50.95	49.24
S_3	29.05	29.08	30.05	29.39	36.19	36.37	38.30	36.96	49.47	49.01	51.40	49.96
S_4	30.32	30.38	31.97	30.89	37.82	37.32	39.50	38.21	50.31	50.07	53.99	51.46
S_5	27.06	25.77	26.9	26.57	34.02	34.02	35.43	34.49	47.32	45.79	48.06	47.06
Mean	28.96	27.76	29.50		36.17	35.59	37.58		48.9	48.00	51.01	
For comparing the means of	**S.Em±**		**CD at 5%**		**S.Em±**		**CD at 5%**		**S.Em±**		**CD at 5%**	
MP	0.35		1.23		0.37		1.31		0.52		1.82	
SP	0.40		1.16		0.34		0.99		0.39		1.12	
MP×SP	0.70		N.S.		0.59		N.S.		0.68		N.S.	

NS – Non significant

DAP –Days after planting

Main Plots (M)

M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)

S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

Table 4.1.5. Effect of planting geometry and foliar spray of micronutrients on total dry matter at 40, 60, 80 DAP of Potato.

Treatments	Total dry matter (gm /plant)											
	40 DAP				60 DAP				80 DAP			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	9.71	7.95	10.58	9.41	53.25	51.06	54.03	52.81	81.54	80.51	82.21	81.42
S_2	8.55	7.88	10.45	8.96	51.36	50.08	54.26	51.90	80.5	80.91	84.89	82.1
S_3	10.11	9.03	8.69	9.27	54.52	52.35	55.25	54.10	83.42	82.09	86.40	83.97
S_4	11.01	9.62	11.40	10.68	56.27	55.19	57.28	56.25	85.87	83.8	89.11	86.97
S_5	8.43	7.01	8.49	7.97	46.36	43.73	47.69	45.93	78.90	80.25	81.17	80.11
Mean	9.56	8.30	9.927		52.37	50.48	53.74		82.05	81.51	84.75	
For comparing the means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
MP	0.31		1.08		0.54		1.89		0.75		2.61	
SP	0.26		0.75		0.75		2.16		0.83		2.40	
MP×SP	0.47		1.31		1.30		N.S.		1.45		N.S.	

NS – Non significant DAP –Days after planting

Main Plots (M)
M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)
S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

The obtained results are in accordance with those reported by Ahmed and Mousavi *et al.* (2007). Similar result was also obtained by Vinod Kumar who observed that maximum total dry matter (73.5 g) in zinc sulfate at 60 day after planting.

4.2 Yield parameter

4.2.1 Number of tubers

The data on number of tubers influenced by spacing levels and foliar spray of micronutrients along with their interactions are presented in Table 4.2.1.

The total number of tubers per plant differed significantly with spacing. Spacing of 60 x40cm (M_3) gave maximum number of tubers per plant (5.7) and the lowest numbers of tubers (4.76) were recorded at a spacing of 60x20cm (M_2).

Foliar spray of micronutrients significantly influenced the total number of tubers per plant. Spray of Zinc sulphate @ 8.5 kg per hectare (S_4) recorded highest number of tubers per plant (5.59) whereas lowest numbers of tubers (4.82) were obtained from untreated control.

Interaction between spacing and foliar spray of micronutrients was found to have a significant effect on total number of tubers per plant. Maximum number of tubers per plant was recorded in M_3S_4 (6.2) and less number of tubers per plant was recorded in M_2S_5 (4.55).

Khan *et al.* (2010) reported that wider spacing (70 x 20cm) significantly increased the number of tubers and similar result were also found by Mousavi *et al.*(2007), where maximum number of tubers per plant was increased by 31% by applying zinc at 8 ppt over control.

4.2.2 Tuber yield per hectare (q ha^{-1})

The data on yield per hectare influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.2.1.

Tuber yield per hectare varied significantly with spacing's. The M_2 (60 x20 cm) spacing recorded significantly higher tuber weight per hectare (175.28 q ha^{-1}) over M_1 (60 x30) (170.74 q ha^{-1}) and M_3 (60 x40) spacing (154.30 q ha^{-1}) respectively.

Foliar spray of micronutrients influenced the tuber yield per hectare significantly. The treatments S_4 (Zinc sulphate @ 8.5 kg per hectare) recorded highest tuber yield (182.34 q ha^{-1}) while minimum yield (153.81 q ha^{-1}) was obtained in S_5 (Control).

Interaction between spacing and foliar spray of micronutrients had a significant effect on tuber yield (q ha^{-1}). Highest tuber yield (195.01 q ha^{-1}) was recorded in M_2S_4 and minimum tuber yield (144.55 q ha^{-1}) in M_3S_5.

Above results are in agreement with the finding of Mahmood *et al.*(2001) who observed that intra row spacing of 20cm gave significantly maximum grain yield (5.7 t ha^{-1}). Almost similar results were reported by Ullagaddi (2000) who reported that the foliar spray of Zinc sulfate (0.1%) significantly increased the seed yield of cotton.

4.2.3 Marketable yield (q ha^{-1})

The data on reducing sugar influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.2.1.

Spacing differs significantly for marketable yield of tubers. The spacing of 60 x 30cm (M_1) recorded highest marketable yield (141.95 q ha^{-1}) while lowest (130.15 q ha^{-1}) was recorded from plants spaced at 60 x40 cm.

Foliar spray of micronutrients significantly influenced the marketable yield. The treatment S_4 (Zinc sulphate @ 8.5 kg per hectare) recorded significantly higher marketable yield (152.87q ha^{-1}) where lowest (125.09 q ha^{-1}) was recorded from S_5 (Control).

Interaction between spacing levels and foliar spray of micronutrients had significant effect on marketable yield. Maximum marketable yield (158.72 q ha^{-1}) was recorded in M_2S_4 followed by M_1S_4 (157.59 q ha^{-1}) while minimum (118.48 q ha^{-1}) was recorded in M_3S_4.

Plant density had an impact on marketable bulb size, higher the plant density the smaller the marketable size (Seck and Baldeh, 2009). Yenagi, (2004) also reported that higher marketable tuber yield (4.62 t/ha) obtained in wider row spacing.

Table 4.2.1. Effect of planting geometry and foliar spray of micronutrients on yield parameters of Potato.

Treatments	Yield Parameters															
	No of tubers				Tuber yield per hectare (q/ha)				Marketable yield (q/ha)				Non marketable yield(q/ha)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	5.43	4.81	5.75	5.33	170.06	177.43	156.45	167.98	141.72	145.12	131.51	139.45	28.34	32.31	24.94	28.53
S_2	5.18	4.75	5.37	5.10	163.82	169.49	149.65	160.99	137.18	136.05	125.28	132.84	26.64	33.44	24.37	28.15
S_3	5.25	4.75	6	5.33	175.73	172.9	157.59	168.74	146.26	137.75	133.22	139.07	29.47	35.14	24.37	29.66
S_4	5.63	4.93	6.2	5.59	188.77	195.01	163.26	182.34	157.59	158.72	142.28	152.87	31.17	36.28	20.97	29.47
S_5	4.75	4.55	5.17	4.82	155.32	161.56	144.55	153.81	126.98	129.81	118.48	125.09	28.34	31.74	26.07	28.71
Mean	5.25	4.76	5.7		170.74	175.28	154.30		141.95	141.49	130.15		28.79	33.78	24.14	
For comparing the means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
MP	0.04		0.16		2.75		10.81		2.52		9.89		0.47		1.87	
SP	0.08		0.25		1.14		3.32		1.36		3.96		0.90		NS	
MP×SP	0.14		0.43		1.97		5.76		2.35		6.87		1.57		4.59	

NS – Non significant DAP –Days after planting

Main Plots (M)
M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)
S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

4.2.4 Non marketable yield (q ha^{-1})

The data on non-marketable yield as influenced by spacing's and micronutrients are presented in Table 4.2.1.

Non marketable yield varied significantly with different spacing levels. The spacing of 60 x 20cm (M_2) recorded significantly higher non marketable yield (33.78 q ha^{-1}) and minimum (24.14 q ha^{-1}) was obtained at a spacing of 60 x40cm (M_3).

Perusals of presented data clearly indicate a non-significant effect of micronutrients on non-marketable yield. However, maximum non marketable yield (29.47 q ha^{-1}) was recorded in Zinc sulphate @ 8.5 kg per hectare (S_4) while minimum (28.15 q ha^{-1}) was recorded by spray of Magnesium sulphate @ 7 kg per hectare.

Interaction between spacing and foliar spray of micronutrients affected the non marketable yield significantly. M_2S_4 recorded significantly higher non marketable yield (36.28 q ha^{-1}) while lowest non marketable yield (35.14 q ha^{-1}) was recorded in M_2S_3.

4.3 Quality parameter

4.3.1 Reducing sugar

The data on reducing sugar influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.3.1.

Reducing sugar percentage varied significantly with spacing. Spacing of 60 x 20cm (M_2) noticed highest reducing sugar (0.171%) and plants spaced at 60X40cm (M_3) recorded lowest (0.088%) reducing sugar.

Foliar spray of micronutrients significantly influenced the reducing sugar content. Untreated control (S_5) noticed significantly highest reducing sugar (0.142%) over the rest of the treatments while minimum (0.107%) was obtained in S_4 ($ZnSo_4$ @8.5 kg/hectare).

Interaction between foliar spacing and foliar spray of micronutrients ha a significant effect on reducing sugar content. Maximum reducing sugar (0.19%) was noticed in M_2S_5 and minimum reducing sugar content (0.069%) was recorded in M_3S_4.

4.3.2 Non reducing sugar

The data on non reducing sugar influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.3.1.

Non reducing sugar varied significantly with spacing. Spacing of 60 x 40cm (M_3) recorded significantly higher non reducing sugar (0.610%) over all the spacing followed in the present research. Minimum non reducing sugar (0.464%) was obtained at a spacing of 60 x 20cm (M_2).

Foliar spray of micronutrients influenced the non reducing sugar significantly. Zinc sulphate @ 8.5 kg per hectare (S_4) recorded highest non reducing sugar (0.589%) while minimum (0.509 %) was obtained in control.

Interaction between spacing and foliar spray of micronutrients also had a significant effect on non reducing sugars. Maximum reducing sugar was noticed in M_3S_4 (0.664%) and minimum (0.420%) in M_3S_5.

4.3.3 Total sugar

The data on total sugar influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.3.1.

The total sugar of tuber values differed significantly with spacing. The spacing of 60x 40cm (M_3) recorded higher total sugar (0.698%) while minimum (0.635%) was recorded at spacing of 60x 20cm (M_2).

Similarly the total sugar differed significantly with foliar spray of micronutrients. Zinc sulphate @ 8.5 kg per hectare (S_4) recorded higher total sugar (0.696%) and lower total sugar (0.645) was recorded in Calcium chloride @ 1 kg per hectare (S_1).

Interaction between spacing and foliar spray of micronutrients also affected total sugar content significantly. Treatment M_3S_4 recorded maximum total sugar (0.733%) while minimum (0.610%) was recorded in M_2S_5.

Almost similar effect of zinc on total sugar content has been observed by Al-Rashidi and Ahmad, who reported that maximum sugar percentage (14.5%) was obtained by application of Zinc @ 10 mg/kg.

Table 4.3.1. Effect of planting geometry and foliar spray of micronutrients on reducing sugar, non–reducing sugar and total sugar.

Treatments	Reducing Sugar (%)				Non Reducing Sugar (%)				Total Sugar (%)			
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	0.09	0.16	0.08	0.11	0.54	0.45	0.59	0.53	0.63	0.62	0.67	0.64
S2	0.10	0.16	0.09	0.12	0.54	0.45	0.59	0.53	0.64	0.62	0.69	0.65
S3	0.09	0.17	0.07	0.11	0.57	0.47	0.62	0.55	0.67	0.65	0.70	0.67
S4	0.09	0.15	0.06	0.10	0.59	0.51	0.66	0.58	0.68	0.66	0.73	0.69
S5	0.12	0.19	0.11	0.14	0.53	0.42	0.57	0.50	0.66	0.61	0.68	0.65
Mean	0.10	0.17	0.08		0.55	0.46	0.61		0.66	0.63	0.69	
For comparing the means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
MP	0.0018		0.0071		0.0022		0.0087		0.0249		0.097	
SP	0.0022		0.0066		0.0029		0.0085		0.0339		0.099	
MP×SP	0.00397		0.0116		0.0050		0.0148		0.0588		0.171	

NS – Non significant DAP –Days after planting

Main Plots (M)
M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)
S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

4.3.4 Ash

The data on ash influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.3.2.

Spacing of 60 x 40 cm (M_3) spacing recorded maximum ash content 0.744 gm while the spacing 60 x 20 cm (M_2) gave lowest (0.718 gm) ash content.

Foliar spray of micronutrient influenced the ash content significantly. The treatment S_4 ($ZnSo_4$ @ 8.5 kg per hectare) recorded highest ash content (0.718 gm) while minimum ash content (0.623 gm) was obtained in control (S_5).

Interaction between spacing and foliar spray of micronutrient was significant. M_3S_4 reported maximum ash content (0.818gm) while M_2S_5 reported lowest (0.583gm) ash content.

Similar to above results, Soleymani *et al*. (2012) reported that Zn (10%) increased ash percentage (12.6%) compared to control (12.0%).

4.3.5 pH

The data on pH influenced by spacing levels and foliar spray of micronutrients are presented in Table 4.3.2.

pH value showed maximum value (3.683) at a spacing of 60 x 40 cm (M_3) while the lowest pH value (3.30) was observed from spacing of 60 x 20 (M_2).

Micronutrients foliar applications had a significant effect on pH values. Zinc sulphate @ 8.5 kg per hectare (S_4) gave highest pH value (3.67) while minimum pH Value (3.279) was recorded in control.

Interaction between spacing and foliar spray of micronutrients gave significant result. Maximum pH (3.9) was recorded in M_3S_4 while lowest pH value (3.168) was observed in M_2S_5.

Similar result was found by Kazemi (2013), he stated that highest pH (2.38) was obtained with foliar application of Zinc @ 100 mg/l.

4.3.6 Starch

The data on starch as influenced by spacing's and micronutrients are presented in Table 4.3.2.

Table 4.3.2. Effect of planting geometry and foliar spray of micronutrients on ash, pH and starch

Treatments	Ash (%)				pH (%)				Starch (%)			
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	0.66	0.62	0.69	0.66	3.58	3.45	3.83	3.62	14.09	13.81	15.75	14.55
S2	0.65	0.60	0.73	0.66	3.46	3.21	3.60	3.43	14.44	13.41	15.68	14.51
S3	0.67	0.62	0.81	0.70	3.50	3.21	3.71	3.47	14.12	13.93	14.93	14.33
S4	0.69	0.63	0.81	0.71	3.67	3.45	3.9	3.67	16.19	13.93	17.06	15.73
S5	0.62	0.58	0.66	0.62	3.3	3.16	3.36	3.27	13.68	11.75	14.56	13.33
Mean	0.66	0.61	0.74		3.50	3.30	3.68		14.50	13.37	15.6	

For comparing the means of	Ash S.Em±	Ash CD at 5%	pH S.Em±	pH CD at 5%	Starch S.Em±	Starch CD at 5%
MP	0.0021	0.0084	0.0174	0.068	0.111	0.439
SP	0.0032	0.0096	0.0280	0.081	0.097	0.285
MP×SP	0.0057	0.0166	0.0486	0.141	0.169	0.493

NS – Non significant DAP –Days after planting

Main Plots (M)

M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)

S_1: Calcium chloride @ 1 kg per hectare
S_2: Magnesium sulphate @ 7 kg per hectare
S_3: Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

Among all the main treatments, Plants spaced at 60 x 40 cm (M_3) recorded maximum starch content (15.6%) while minimum starch (13.371) was recorded at a spacing of 60 x 20 cm (M2)

Micronutrient sprays affected starch content of tubers significantly. Foliar spray of Zinc sulphate @ 8.5 kg per hectare (S_4) gave highest starch content (15.732%) and lowest starch content (13.333%) was noticed in S_5 (control).

Interaction between spacing and foliar treatments was also significant. M_3S_4 gave maximum starch content (17.062%) and lowest starch content (11.75%).was recorded in treatment M_2S_5

The results are in conformity with those of Mousavi *et al*. (2007) who reported that the maximum starch percentage (7.1%) was obtained due to the higher application of Zinc (8ppt).

4.3.7 Crude fibre

The data on starch as influenced by spacing's and micronutrients are presented in Table 4.3.3.

Crude fiber percentage varied significantly with spacing. Spacing of 60 x 20cm (M_2) noticed highest crude fiber content (1.571 gm) and plants spaced at 60x40cm (M_3) recorded lowest (1.371 gm) crude fiber.

Foliar spray of micronutrients also had significant influence on crude fibre content of tuber. Higher crude fibre content (1.591 gm) was noticed with foliar spray of Zinc sulphate @ 8.5 kg per hectare (S_4) and minimum (1.343 gm) in control.

Interaction between spacing and foliar spray significantly influenced crude fibre content. Highest crude fibre content (1.718 gm) was noticed with M_3S_4 while lowest crude fibre (1.243 gm).was noticed with M_2S_5.

This result are in line with those reported by Ahmad *et al.* (2012) who stated that more crude fibre (30-93%) was obtained at a wider spacing (45 cm apart double row strip).

4.3.8 Specific gravity

Table represents the data on specific gravity as influenced by spacing's, micronutrients and their interactions are presented in Table 4.3.3.

Specific gravity varied significantly with different spacing levels. The spacing of 60x40cm (M_3) recorded significantly higher specific gravity (0.826) while minimum (0.820) was recorded at a spacing of 60x 30cm (M_1).

Foliar spray of micronutrients significantly influenced the specific gravity. The treatment S_4 (Zinc sulphate @ 8.5 kg per hectare) recorded significantly higher specific gravity (0.831) while untreated control (S_5) recorded minimum (0.793) specific gravity.

Interaction between spacing level and foliar spray of micronutrients had a significant effect on specific gravity. Maximum specific gravity (0.837) was recorded in M_3S_4 and minimum (0.774) was recorded in M_2S_5 combination.

Similar trend was reported by Ahmad *et al.* (2012) who obtained maximum specific gravity (1.0822) by the application of Zinc @ 300 g/L

4.3.9 TSS

The data on specific gravity as influenced by spacing's and micronutrients are presented in Table 4.3.3.

TSS varied significantly with spacing. Planting at a spacing of 60x 40cm (M_3) resulted in significantly higher (2.675^{o}Brix) TSS content while minimum (2.210^{o}Brix) was recorded at 60x 20cm (M_2) spacing.

Foliar spray of micronutrients significantly influenced the TSS content. The treatment S_4 (Zinc sulphate @ 8.5 kg per hectare) recorded significantly highest TSS (2.523^o Brix) over other treatments.

Interaction between spacing and foliar spray of micronutrient significantly influenced the TSS content. Maximum TSS (2.675^{o}Brix) was recorded in M_3S_4 followed by M_1S_4 for TSS (2.58^{o}Brix) while minimum TSS (2.118^{o}Brix) found in M_2S_2 combination.

The results are further supported by Kazemi (2013) who stated that highest percentage of TSS (5.87^{o}Brix) was obtained with application of foliar spray of zinc @100 g/l.

Table 4.3.3. Effect of planting geometry and foliar spray of micronutrients on crude fibre, specific gravity and TSS.

Treatments	Crude Fibre (%)				Specific Gravity				TSS (^{o}Brix)			
	M1	**M2**	**M3**	**Mean**	**M1**	**M2**	**M3**	**Mean**	**M1**	**M2**	**M3**	**Mean**
S1	1.50	1.41	1.57	1.498	0.82	0.80	0.82	0.81	2.35	2.23	2.50	2.36
S2	1.44	1.31	1.57	1.445	0.82	0.81	0.82	0.82	2.31	2.11	2.37	2.27
S3	1.4	1.39	1.52	1.439	0.82	0.82	0.83	0.82	2.49	2.25	2.53	2.42
S4	1.56	1.48	1.71	1.591	0.83	0.82	0.83	0.83	2.58	2.31	2.67	2.52
S5	1.32	1.24	1.46	1.343	0.79	0.77	0.81	0.79	2.36	2.12	2.38	2.29
Mean	1.44	1.37	1.57		0.82	0.81	0.82		2.421	2.21	2.49	

For comparing the means of	Crude Fibre S.Em±	Crude Fibre CD at 5%	Specific Gravity S.Em±	Specific Gravity CD at 5%	TSS S.Em±	TSS CD at 5%
MP	0.024	0.097	0.0007	0.0028	0.0078	0.030
SP	0.033	0.099	0.0010	0.0029	0.0090	0.026
MP×SP	0.058	NS	0.0017	0.0051	0.0155	0.045

NS – Non significant   DAP –Days after planting

Main Plots (M)
M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)
S_1 : Calcium chloride @ 1 kg per hectare
S_2 : Magnesium sulphate @ 7 kg per hectare
S_3 : Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

Table 4.4. Effect of planting geometry and foliar spray of micronutrients on economics of potato cv. Kufri Jyoti tuber production.

Treatment	Tuber yield (q ha^{-1})	Gross returns (Rs./ha) A	Total cost of cultivation (Rs./ha) B	Net returns (A-B Rs./ha)	Cost benefit ratio
M_1S_1	229.02	183216	71437.14	111778.86	1.56
M_1S_2	219.95	175960	71570.14	104389.86	1.45
M_1S_3	238.09	190472	71267.14	119204.86	1.67
M_1S_4	253.96	203168	71847.14	131320.86	1.82
M_1S_5	208.61	166888	71077.14	95810.86	1.34
M_2S_1	240.36	192288	73057.64	119230.36	1.63
M_2S_2	229.02	183216	73190.64	110025.36	1.50
M_2S_3	233.56	186848	72887.64	113960.36	1.56
M_2S_4	269.84	215872	73467.64	142404.36	1.93
M_2S_5	217.68	174144	72697.64	101446.36	1.39
M_3S_1	217.68	174144	70628.64	103515.36	1.46
M_3S_2	204.08	163264	70761.64	92502.36	1.30
M_3S_3	213.15	170520	70458.64	100061.36	1.42
M_3S_4	222.22	177776	71038.64	106737.36	1.50
M_3S_5	199.54	159632	70268.64	89363.36	1.27

Main Plots (M)

M_1: 60 cm × 30 cm
M_2: 60 cm × 20 cm
M_3: 60 cm × 40 cm

Sub Plots (S)

S_1 : Calcium chloride @ 1 kg per hectare
S_2 : Magnesium sulphate @ 7 kg per hectare
S_3 : Copper sulphate @ 1 kg per hectare
S_4: Zinc sulphate @ 8.5 kg per hectare
S_5: Control

4.4 Economics on potato tuber production

The data on total cost of cultivation, gross returns, net returns and cost Benefit ratio due to spacing's and foliar spray of micronutrients in potato tuber production are presented in Table 4.4.

The spacing of M_2 (60 cm x 20 cm) and foliar spray of S_4 ($ZnSo_4$) had high gross and net returns of Rs.215872 and 142404.36 respectively and B: C ratio of 1.938327677 followed by spacing of M_1 (60 cm x 30cm) and foliar spray of S_4 ($ZnSo_4$) has net returns of Rs.131320.86.

The spacing of M_3 (60 cm x 40cm) and (control) had lower net returns of Rs. 89363.36 and B: C ratio of. 1.27.

Similar trend of the obtained results were reported by Kumar (2002) who obtained maximum B: C ratio of potato tubers with 60 x 20cm.

SUMMARY AND CONCLUSIONS

Chapter

V

SUMMARY AND CONCLUSION

Field studies entitled, **"**Effect of planting geometry and foliar spray of micronutrients on plant growth, tuber yield and quality of potato tubers (*Solanum tuberosum).***"** were conducted during *rabi* season 2013-14 at the departmental Farm , School of Agriculture , LPU, Phagwara . The experiment was laid out in split plot design with 15 treatments of spacing as main plot and foliar spray of micronutrients as sub plot along with absolute control, replicated 3 times. In case of fertilizer applications half dose of recommended nitrogen and full dose of P and K was supplied at planting and remaining half dose of nitrogen was applied after one month. The results presented and discussed in previous chapter are summarized here.

Spacing significantly influenced plant growth, tuber yield and quality attributes of potato. Highest plant height (45.07 cm), stem diameter (2.76 cm), leaf area (51.01 cm^2) and total dry matter (84.75 gm) were recorded significantly in the spacing of 60 x 40 cm (M_3). The spacing of 60 x 40 cm produced maximum number of tubers (5.7) while highest marketable yield (141.95 q/ha) was recorded at 60 x 30 cm spacing (M_1). Highest tuber yield (175.28 q/ha) and non-marketable yield (33.78 q/ha) were recorded at a spacing of 60 x 20cm (M_2).

Maximum plant height (46.14 cm), number of stem (2.84), leaf area (51.46 cm^2) and total dry matter (86.97) were recorded by spray of $ZnSo_4$ @8.5 kg/ha. The maximum number of tubers (5.59), tuber yield (182.34 q/ha), marketable yield (152.87 q/ha) were obtained from $ZnSo_4$ @8.5 kg/ha. Quality parameters like non reducing sugar (0.589%), total sugar (0.696%), ash content (0.718 gm), pH (3.67), starch (15.73%), crude fibre (1.59 gm), specific gravity (0.83) and TSS (2.52^{o}Brix) were recorded maximum by spraying $ZnSo_4$@ 8.5 kg/ha.

The interaction between spacing and foliar application had significant effect on the growth, yield and quality parameters. The result shows that M_3S_1 gave highest plant height (47.18cm) and M_3S_4 recorded maximum number of stem (3.02). Highest number of tubers per plant was recorded in M_3S_4 (6.2) while maximum tuber yield (195.01 q/ha), marketable yield (158.72 q/ha) and non-marketable yield (36.28 q/ha) were obtained from M_3S_4. Among the various quality parameters highest reducing sugar (0.19%) was obtained from M_2S_5 while non-reducing sugar (0.66%), total sugar (0.73%), ash content (0.81 gm), pH (3.9), starch (17.06%), crude fibre (1.71 gm), specific gravity (0.83) and TSS (2.67^{o}Brix) was recorded from the treatment M_3S_4.

Crop grown under spacing of 60 x 20cm and sprayed with $ZnSo_4$ @ 8.5 kg/ha (S_4), gave higher gross income (2,15,872 Rs.) and net income (1,42,404 Rs.) compared with other treatments. Benefit cost ratio (1.93) also was significantly higher than other treatments.

Conclusion

1. Result of present trial indicate that the spacing of 60 x 40 cm resulted in better growth and quality parameters while plant spaced at 60 x 20 cm were superior in terms of yield parameters.
2. Among the various foliar micronutrient sprays, application of $ZnSo_4$ @ 8.5 kg/ha proved best for enhancing growth, yield and quality parameters.
3. Hence it can be concluded that the spacings at 60 x 40 cm and 60 x 20 cm and spray of $ZnSo_4$ @ 8.5 kg/ha holds potential for improving growth, yield and quality parameters in potato.

REFFERENCE

REFERENCES

Agasibagil,A.B., 2006. Response of maize (*Zea mays L*) genotypes to planting density in drill sown paddy tract. M.Sc.(Ag) Thesis. Dept. of Agronomy, C.A., D.U.O.A.S. **8:** 17-25.

Acquaah, G., 2002. Horticulture principles and practices. 2nd Ed. Upper Saddle River, New Jersy: Prentice Hall.

Ahmad, W., Ahmad, A.U.H., Zamir, M.S.I., Afzal., M., Mohsin, A. U., Khalid, F., Gillani, S. M. W., 2012. Qualitative and quantitative response of forager maize cultivars to sowing methods under subtropical conditions. *The J. of Animal and plant Sci*., **22**(2): 318-323.

Ahmed,A.A., El-Baky., Zaki,M.F., and Eaten,S.A., 2011.Effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato plant (*Solanum tuberosum L.). J. of Applied Sci. Research.* **7**(12):2479-2488.

Al-Rashidi, S.M. and Ahmad. Effect of zinc and potassium application on yield and quality of sugar beet (*Beta Valgaris* L.) M.Sc. (Agri.). Thesis, College of Agril., Mosul, Univ., Iraq.

Aliyu, I., 2002, Growth and yield of pepper (*Capsicum annuum* L.) as affected by nitrogen and phosphorous application and plant density. *Crop Res.*,**23**(3):467-475.

Alloway, B.J., 2004. Zinc in soils and crop nutrition. International Zinc Association (IZA). www.zincworld.org.

Amjad, Muhammed and Muhammed, Akbar, Anjum., 2001. Effect of phosphorus and density on seed production of okra (*Abelmoschus esculentus Moench*). *J. of Agric. and Bio*. **3**(4): 380 – 383.

Anonymous, 2010. Hand book of Horticulture, Indian Council of Agricultural Research, New Delhi, India, pp.7.

Anonymous, 2011. Vegetable statistics, Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India, pp.250.

AOAC (2000). Association of Official Analytical Chemists. Official methods of Analysis (Vol. II 17th edition) of AOAC International. Washington, DC, USA. Official methods 925.09, 923.03, 979.09, 962.09, 4.5.01 and 923.05.

Awani,K., Singh,A., Singh,K., Gupta, M. J., and Shrivastava,R., 2004, Effect of variety and spacing on growth, yield and economics of capsicum under greenhouse condition. *Prog. Hort*., **36**(2):321-330.

Balaraj ,R., Kurdikeri, M. B., Patil, S. A., and Shekhargouda, M., 2002. Effect of fertilizer doses and spacings on seed yield and quality in chilli (*Capsicum annuum* L.). *Seed Res*., **30**(2): 234-238.

Barik, K. C. and Chandel, A. S., 2001, Effect of copper levels on growth, grain yield and copper uptake in different varieties of soybean (*Glycine max*). *Indian J. Agric. Sci*., **71** (2): 118-120.

Barik, K. C. and Chandel, A. S., 2002, Effect of copper nutrition on nodulation, leghaemoglobin content and nitrogen uptake in different varieties of soybean (*Glycine max*). *Indian J. Agric. Sci*., **72**(12): 739-741.

Brady, N.C. and R.R. Weil, 2002. The nature and properties of soils. 13th Ed. Upper Saddle River, New Jesrsey: Prentice Hall.

Cavero, J., Gil Ortega and Gutierrez, M., 2001, Plant density affects yield, yield components and colour of direct seeded Paprika pepper. *Hort. Sci*., **36**(1):76-79.

Chhabra,K.L., Bishoni,L.K. and Bhattoo,M.S., 2004, Effect of macro and micronutrientson the productivity of cotton genotypes. *Int. Symp. "Strat. Sust. Cot. prod.- A G. Vis."2 Crop Prod*. 23-25.

Kumar, D., Singh, O.P., Lal, S.S., Singh, B.P and Singh, U., 2012. Optimizing planting geometry of in vitro potato plants for growth and minitubers production in nethouse. *Potato J.* **39** (1): 69-74.

Dubois,M.,. Gilles, K. A ., Hamilton, J. K., Rebers, P.A. and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. *Anal. Chem*. **28**:350-356.

Elwan, I. M., Mohamed, H. Z., Omran, S. E., 2002, Response of cotton plants to phosphatic and zinc fertilization. *Annals Agric. Sci*. Cairo, **47**(3): 1159-1178.

Ferretti,F. (2011).The correspondence between Élisée Reclus and Pëtr Kropotkin as a source for the history of geography". *J. of Historical Geography* **37**(2): 216.

Galavi,S.R., Mousavi, Ahamadvand, G., 2007. Effect of zinc and manganese foliar application on yield, quality and enhancement on potato. *Asian J. of plant sci.* **6**(8): 1256-1260.

Grosbach, 2008. The Effect of Row Spacing on the Yield and Plant Growth of Popcorn (*Zea mays*) Cantaurus, *McPherson College Division of Sci. and Tech.* **16**:9-12.

Gundlur,S.S. and Manjunathaiah,H,M., 2002, Influence of copper ore tailings and copper sulphate on groundnut nodulation. *Karnataka J. Agric. Sci.*, **15** (3): 504-508.

Hallikeri, S. S., Halemani, H. L., Khadi, B. M., 2002, Integrated foliar nutrition for yield maximization of rainfed cotton. *Karnataka J. Agric. Sci*. **15**(3): 562-565.

Hylla,S., Gostner,A., Duse,l.G., *et al.* (1998). Effects of resistant starch on the colon in healthy volunteers: possible implications for cancer prevention. *Am. J. Clin. Nutr.* **67** (1): 136–42.

Ibeawuchi, Matthews, Edna, Ofor, Miriam, Chinyere and Onyia, Anyanwu Plant Spacing, Dry Matter Accumulation and Yield of Local and Improved Maize Cultivars. *J. of American Sci*. **4**(1)1545-1003.

Imayavaramban, V., Sundaravel Rajan, G., Murugan, S. and Thanunathan, K., 2006, Effect of micronutrients on yield and economics of LRA 5166 cotton. *Res. Crops*, **7** (2):384-385.

Jackson, M. L., 1957. Soil Chemical Analysis, Prentice Hall of India Private Ltd., New Delhi, pp. 66-90.

Jackson, M. L., 1973. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., NewDelhi. pp. 66-90.

Kazemi, M., 2013. Effect of Zn, Fe and their combination treatments on the growth and yield of tomato. *Bull. Env. Pharmacol Life Sci.* **3**(1):109-114.

Kazemi, M., 2013. Response of cucumber plants to foliar application of calcium chloride and paclobutrazol under greenhouse conditions. *Bull. Env. Pharmacol. Life Sci*. **2**(11):15-18.

Kataria,R.K., Sharma,H.L., 2006. Seed yield and quality of soybean (*Glycine max L. Merril)* as influenced by row spacing and phosphorus under mid hill conditions of Himachal Pradesh. *Himachal J. of Agric. Res.* **32**(1):25-27.

Kashay,Y., Belew,D., Abay,F., 2013. Effect of intra row spacing on yield and quality of some onion varieties (*Allium cepa L.)* at Aksum, Northern Ethopia. *Afr. J. Plant Sci*. **7**(12):613-622.

Khalate,S.P., Sanghavi,K.U. and Kadam,J.R., 2002, Effect of some micronutrients on seed yield and seed quality of onion (Cv. Baswant-780). *South Indian Hort*., **50**: 248-250.

Khan,S.A., Jamro,M.M.R., Arain,M.Y., 2010. Determination of suitable planting geometry for different true potato seed tuberlet grades. *Pakistan J. Agric. Res.* **23**:1-2.

Kumar,D., Lal,S.S., 2006. Effect of planting geometry, N and P levels and haulms cutting on the production of small size tubers of potato. *Potato J.* **33** (1/2) : 97-98.

Kumar,V., Vyakarnahal,B.S., Basavaraj,N., Kulkarni,S., Shekhargouda,M., 2007. Influence of micronutrients on growth and yield of potato *(Solanum tuberosum L.)* cultivars. *Indian J. of Agric. Sci.* **78**(9):752-756.

Kumar,D., Singh,O., lal,S.S., Singh,B.P., Singh,V., 2012. Optimizing planting geometry of in vitro potato plants for growth and minitubers production in nethouse, *Potato J.* **39**(1):69-74.

Kurubetta,K.D., 2006. Effect of time of sowing, spacing and seed rate on seed production potentiality and quality of fodder cowpea (*Vigna unguiculata L. Walp.).* M.Sc.(Ag.) Thesis. Dept. of Agronomy, C.A., D.U.O.A.S. p:85.

Lyocks, Tanimu, Dauji and Ogunleye, Dainiel, (2013), Evaluation of the effects of different intra-row spacing on the growth and yield of maize (*zea mays* L). *Agric. and Bio. J. of North America* **4**(3): 3-4.

Loomis,W.E. and C.A. Shull, 1937. Methods in plant physiology. McGraw hill book co. New York. 276.

Mahmood, M. T., Maqsood, M., Awan, T. H. And Rashid Sarwar, 2001, Effect of different levels of nitrogen and intra row plant spacing on yield and yield components of maize. Pakistan Journal of Agricultural Sciences, **38** (1/2) : 48- 49.

Manchanda,J.S., Bansal,R.L. and Nayyar,V.K., 2006, Mode of copper fertilization in a typic ustipsamment under soybean-wheat cropping sequence. *J. Res. Punjab Agric. Univ*., **43** (4): 303-307.

Manjappa, K. and Satyanarayana Rao, 2001, Response of cotton to soil and foliar application of secondary and micronutrients and irrigated conditions. *J. Cot. Res. Devp.* **15**(2): 233-234.

Mantur, S. M., Patil, H. B., Biradar, D. P., Patil, S. R and Patil, D. R., 2007, Effect of planting geometry and nutrient sources for capsicum under shade house during summer and kharif. *Karnataka J. Agric. Sci*., **20**(3): 578-580.

Mousavi,S.R., Galavi,M., Ahmadvand,G., 2007. Effect of zinc and manganese foliar application on yield, quality and enrichment on potato. (*Solanum tuberosum). Asian J. of Plant Sci.* **6**(8):1256-1260.

Muhammad,R., Javad,K., Muhammad,H., 2004. Biological Response of Maize (*Zea mays* L.) to Variable Grades of Phosphorus and Planting Geometry. *Int. J. of Agric. and Biology*.**6** (3): 462-464.

Muoneke,C.O. and Asiegbu,J.E., 2008. Effect of okra planting density and spatial arrangement in intercrop with maize on the growth and yield component. *J. of Agron. and Crop Sci.* **179**: 201- 207.

Nelson,N., 1944. *J. Biol.Chem.***195**:19-23.

Nikolov,G., 2002, Independent effect of cotton's foliar micro-fertilizing. Pochvoznante, Agrokhimiya, I-Ekologiya, **35**(3): 13-15.

Niranjana, S.S., Prakash, Basavegowda, Yelladhalli, N.A. And Chandranath, H.T., 2005, Effect of micronutrient seed treatment on growth and yield of groundnut. *Seed Research*, **33** (2): 138-141.

Pandey,P., Lal,S.K., Rawal,S., Kumar,D., 2003. Effect of crop geometry and plant density on processing grade tuber yield of potato cv. Kufri Jyoti. *J. of the Indian Potato association.* **30**(1/2): 93-34.

Panse,V.G. and Sukhatme,P.U., 1978, *Statistical Methods for Agricultural Workers*, Indian Council of Agriculture Research, New Delhi.

Piper,C.S., 1955. Soil and Plant Analysis, Academic Press, New York, p. 236.

Plenet and Lemaire, 2000. Relationships between dynamics of nitrogen uptake and dry matter accumulation in maize crops. *Determination of critical N conc. Kluwer Academic Publishers Plant and Soil.* **216**: 65-82.

Prabhakar, B.S., 1996. Phosphate and potash use in vegetable crops. Better Crops International, **10**(2): 16-18.

Raj, G. B., Patnaik, M. C., Reddy, I. P. And Rao, A. P., 2001, Response of brinjal (*Solanum melongena* L.) to zinc and iron. *Vegetable Science,* **28**(1): 80-81.

Sangoi, L., 2001. Understanding plant density affects on maize growth and development an important issue to maximize grain yield. *Ciencia Rural*, **31**(1): 159-168.

Kumari, S. and Sharma, S. K., 2006, Effect of micronutrient sprays on tomato (*Lycopersicon esculentum*) seed production. *Indian J. Agric. Sci*., **76**(10): 676- 678.

Seck, A., Baldeh, A., (2009). Studies on onion bulb yield and quality as influenced by plant density in organic and intensive cropping systems in The Gambia (West Africa).African Crop Science Conference Proceedings, **9**:69- 173, Printed in Uganda.

Sharma, D. K., Chaudary, D. R. and Verma, T. S., 2001, Growth and seed yield of tomato (*Lycopersicon esculentum* Mill.) cv. Roma as influenced by levels of nitrogen plant spacing. *Harayana J. Hort. Sci*., **30**(1&2): 95-96.

Sharmila B. S. M., Malarvizhi P. P., Thiyagarajan T.M. and T. Nagendra Rao (2006). Effect of nitrogen, potassium and magnesium on tuber yield, grade and quality of potato cv. Kufri Giriraj. 18th World Congress of Soil Science July 9-15, 2006- Philadelphia, Pennsylvania, USA.

Singh,A.K., Singh,A.K., Gupta, M.J. and Shrivastava, R., 2004, Effect of variety andspacing on growth, yield and economics of capsicum under greenhouse condition. *Progressive Hortic*., **36**(2): 321-330.

Sivagamy,K., Rammohan, J., 2013. Effect of sowing date and crop spacing on growth, yield attributes and quality of sesame. *IOSR J. of Agric. and Veterinary Sci.* **5**(2):38-40.

Soleymani,A., Shahrajabian., M.H., (2012). The effect of Fe, Mn and Zn foliar application on yield, ash and protein percentage of forage sorghum. *International J. of. Bio*., **4**(3):2012

Subbaiah, B. B. and Asija, G. L., 1956. A rapid producer for the estimation of available nitrogen in soils. Current Sci., **25**: 259-260.

Suresh, S. and Kumar, S.D., 2005, Magnesium and zinc effects on yield and nutrients uptake by cotton. *Adv. Pl. Sci.* **18** (1): 249-252.

Swierczewska,M., Sztuder, H., Warszawa, 2001. Response of cultivated plant to foliar magnesium fertilization. *Polska ,6-7 Wrzesnia* .235-238.

Talburt,W.F. and Smith,O. 1959. Potato processing. AVI west port. Connecticut U.S.A.

Tamilselvi, P., Vijayakumar, R. M. and Nainar, P., 2002, Studies on the effect of foliar application of micronutrients on growth and yield of tomato (*Lycopersicon esculentum* Mill.) Cv. pkm-1. *South Indian Hort.,* **53**: 46-51.

Tandon, H. L. S., 1993, Fertilizer use efficiency system components and their status. *Fertilizer News*, **28**(12): 46-56.

Thavaprakaash,N., and Velayudham,K., (2007), Effect of crop geometry, intercropping systems and INM practices on cob yield and nutrient uptake of baby corn, *Asian J. of Agric. Res.* **1** (1): 10-16.

Ulamin,N., Sanga,G., Ara,N., Shah,S.H., Farhatullah, 2013. Effect of various concentrations of calcium chloride on callus growth and potassium nutrition of calli cultures of potato (*Solanum tuberosum L.). Pak. J. Bot.* **45**(1):209-214.

Ullagaddi, M. S., 2000, Effect of dates of sowing and chemicals on seed yield and quality of Male parent SB (YF)-425 cotton (*Gossypium barbadonse* L.). M.Sc. (Agri.) Thesis, Univ. of Agril. Sci., Dharwad, Karnataka, India.

Waterer, D., 2005. Calcium nutrition of potatoes, problems and potential solutions. *Manitoba Agri*., pp. 1-3.

Yenagi,B.S., Meli,S.S., Agadi,S.S., 2004. Effect of row spacing, planting date and nitrogen level on tuber grade, yield and economics of potato. *Karnataka J. Agric. Sci.*, **17**(2):220-223.

Yoganand, D. K., 2001, Effect of mother plant nutrition and growth regulators on plant growth, seed yield and quality of Bell pepper cv. California Wonder. M. Sc. (Agri.) Thesis, Univ. of Agril. Sci., Dharwad, Karnataka, India.

Zende,U.M., 2008, Investigation on protected techniques in capsicum under protected cultivation. M.Sc. (Agri.) Thesis, Univ. of Agril. Sci., Dharwad, Karnataka, India.

APPENDICES

Appendix I: Prices of inputs

1) Tubers:	Rs. 650 per qntl.
2) Urea:	Rs. 483 per qntl.
3) Single super phosphate:	Rs. 935 per qntl.
4) Murate of potash:	Rs. 445 per qntl.
5) labours:	Rs. 150 per day
6) Machinery charges:	Rs. 5000
7) Calcium Chloride:	Rs. 120 per Kg.
8) Magnesium Sulphate:	Rs. 110 per kg
8) Copper Sulphate	Rs. 190 per Kg.
9) Zinc sulphate:	Rs. 58 per Kg
10) Land rent:	Rs. 8000/ha per season
11) Miscellaneous:	Rs. 2500
12) Plant protection:	Rs. 2000

VITA

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