EFFECT OF FOLIAR APPLICATION OF MICRONUTRIENTS ON POTATO PRODUCTION

By
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CERTIFICATE-I

This is to certify that this thesis entitled "Effect of foliar application of micronutrients on potato production" submitted for the degree of **Master of Science (Agriculture)** in the subject of **Horticulture - Vegetable Science** of the Chaudhary Charan Singh Haryana Agricultural University, Hisar is a bonafide research work carried out by **Mr. Ziauddin Hamidi, Admission Number 2015A148M** under my supervision and that no part of the thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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ABBREVIATIONS

%	Per cent	mm	Millimetre
°C	Degree Celsius	MT	Metric ton
°N	Degree North	No.	Number
°E	Degree East	No./m^2	Number per metre square
B:C	Benefit-cost ratio	RBD	Randomized block design
cm	Centimetre	NS	Non-significant
m	Metre	LSD	Least significant difference
CD	Critical difference	Fig.	Figure
SEm	Standard error of mean	kg/ha	Kilogram per hectare
DAP	Days after planting	q/ha	Quintal per hectare
dS/m	Deci-Siemens per metre	t/ha	Tons per hectare
EC	Electrical conductivity	*etc.*	et cetera
et al.	(et ali or et alia) and other people	*i.e.*	That is
viz.	(Videlicet) namely	*e.g.*	Example
var.	Variety	Rs./ha	Rupees per hectare
kg/fed.	kilogram per fedden	ppm	Part per million
g/m^3	Gram per metre cube	ppt	Part per trillion
kg	Kilogram	pH	Hydrogen ion activity
g	Gram	g/l	Gram per litre
ha	Hectare	mg/l	Milligram per litre
fed.	Fedden	mg/g	Milligram per gram
ml/l	Milliliter per litre	cv.	Cultivar
m^2	Square metre	pp.	Pages
@	At the rate		

CHAPTER–I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a dicotyledonous plant belonging to family Solanaceae is an important food crop of the world. The cultivated potato *Solanum tuberosum* is an autotetraploid with chromosome number, 2n=48. It is native of tropical South American where it grows as wild and present in widest diversity of forms like tuber shape, size, colour, taste *etc*. It is assumed that the cultivated potato originated from the wild species found near the lake Tritica basin in Peru Bolivian region. The potato was introduced in India in early 17^{th} century from Europe. Potato is the fourth most important food crop of the world after rice, wheat and maize. It occupies a pre-eminent place amongst the vegetable crops and known as the "king of vegetables" due to its great utility. It is the one of the major vegetable crop grown throughout the world. Among the potato growing countries of the world, China ranks first in area and production of potato followed by India, Russia and Ukraine. India produces 486.05 lakh MT potato from 21.79 lakh hectare area with productivity 22.31 tones/ha in 2016-17 (Anonymous, 2017). Potato is grown in almost all state of India except Kerala. The major potato growing states in India are Uttar Pradesh, West Bengal, Punjab, Bihar, Haryana, Madhya Pradesh, Gujarat and Maharashtra.

Potato can fulfill food requirements of the country in a substantial way. In India, it is considered as a staple food and used either alone or mixed with other vegetables. Potato is consumed in various forms such as boiled, baked, fried and cooked in sambhar and different curries of vegetable, fish and meat. Potato is commercially used for dehydrated, canned and fried products like, shredded potato, sliced potato, chips, flakes, French fries, finger chips, granules, disc, cubes, flour, *etc*. It is used for several industrial purposes such as production of starch, alcohol, dextrin, glucose, *etc*. This highly nutritious food containing 20.6% carbohydrates, 2.1% protein, 0.3% fat, 1.1% crude fiber and 0.9% ash also have good amount of essential amino acids like leucine, isoleucine and tryptophane (Khurana and Naik, 2003). Potatoes yield about 97 kilo-calories per 100 gm fresh weight, which is much higher than cereals. Potato starch is a large grained starch and contains 25% amylase and 73% amylopectin and high phosphate content. It also contains essential nutrients like, protein, minerals and vitamins. Major minerals present in potato are calcium, phosphorus and iron. It is quite rich source of vitamins especially B_1, B_2, B_6 and C.

Potato crop have many medicinal values. It is easy to digest and tasteful due to rich in carbohydrate content. The doctor prescribed boiled potato for babies, patient or for weak people who cannot take heavy diet as meal. Potato contains natural fiber that is helpful for appetite control and easy bowel movement. The raw pulps of crushed potato with honey make an excellent face and helps for removal of skin spots and pimple infections. Potato is good for patients suffering from high blood pressure due to rich source of potassium and sodium. Potato is helpful to prevent deposition of calcium in kidney due to high content of magnesium. Potato is safe and comfortable food for patient suffering from mouth ulcer and instant antidote for inflammation. Its consumption helps in supply of vitamin C and thus, it is effective against bleeding and spongy gums, frequent attack of cold, *etc*. Potato extract is a good natural healer for minor burn injury.

It is an herbaceous annual plant with spreading or erect habit; height varies from 30 cm to 90 cm, compact, medium compact or open. The crop is generally vegetatively propagated by means of tubers. Potato is a long-day crop and flowers sparingly, especially in certain favourable climates: cool climate, moderate humidity and long day conditions of more than 15 hours light period. Potato is mainly self-pollinated crop but some degree of cross-pollination occurs due to protruding stigma and self-incompatibility. Anthesis generally starts from 5.00 a.m. which continues up to 8.00 a.m. Anther dehiscence occur through the development of pores at the tip of anther just after anthesis. Stigma receptivity is maximum during anthesis, although it becomes receptive a day prior to anthesis.

Agricultural production of India depends heavily on fertilizer application, which results in greater nutrient lapse and soil health problems. Regular depletion of nutrient resources from soils has led to emergence of several nutrient deficiencies. Most of the Indian soils are deficient widely in micronutrients like Cu, Zn, Mn, B and Fe. In most of the productive zones of world the yield levels of different crops are showing declining trends in spite of addition of sufficient quantity of fertilizers carrying macro and micronutrients. The efficiency of applied inorganic micronutrients is rather low due to their fixation in the soil.

Among issues about increasing crop yield and improving the quality of agricultural products, the balanced plant nutrition is the most important and foliar application of nutrients has become an efficient way in this regard (Roemheld and El-Fouly, 1999). Potatoes are heavy nutrient feeding crop because of their bulk yields within a short time having shallow root systems. Micronutrients are essential for growth and development of plant like macronutrients. These are required in very small quantities as compared to the major nutrients N, P, K and they plays an important role in cells division and development of tissue, metabolism and respiration increased maturity speed (Kohraee *et al*., 2011). As micronutrients, mainly zinc (Zn), boron (B), iron (Fe) and manganese (Mn) are concerned with nutrient management of potato. Each of these micronutrients have specific role for the development of quality tuber. Among these, boron and zinc are the well-known essential micronutrients, which plays pivotal role in vegetative and reproductive cycles of plants.

Zinc is involved in hormone biosynthesis, cytoplasm synthesis, activation and function of different enzymes, protein synthesis, *etc*. Potato leaves are smaller, fold inwards giving a ‘fern like’ appearance and grayish brown to bronze colored blotches appear first on the middle leaves and later on all leaves due to deficiency of zinc in soil. Therefore, zinc is essential for better yield and quality of potato tuber and play a major role in nitrogen metabolism and deficient crops will have lower levels of protein and starch content is also affected by zinc. Alloway (2004) reported that the use of fertilizers containing zinc element lead to increasing the quantity and improving the quality of potato tubers when zinc activates enzymes.

Boron is an essential micronutrient for plant growth and plays an important role in cell wall synthesis, sugar transport, cell division, cell development, synthesis of amino acids and proteins, auxin metabolism and regulation of carbohydrate metabolism. Boron also helps in water and nutrient transportation from root to shoot (Ziaeyan and Rajaie, 2009). It influences root and shoot growth, plant development and pollination. Boron is an important element of cell wall that acts as cement between pectins, providing cohesive strength for cell tissues. Therefore, boron affects the tuber storage quality. Boron also affects calcium absorption, so supplies are important to ensure a balanced nutrition. The deficiency of boron occurs in a wider range of crops and climatic conditions than any other micronutrients (Reisenauer *et al.*, 1973). Boron deficient potato have short stem because of sprouting from the lateral bud and the plants look bushy. The youngest leaves become chlorotic, develop necrotic spots and die. The tuber skin is often rough and cracked with necrotic flesh underneath. Probably, boron is more important than any other micronutrient for obtaining high quality and crop yields. Spraying of boron significantly increased the growth parameters of potato plant (plant height, leaves per plant and shoot weight) as compared with control, furthermore, combined application of boron and manganese improved the growth of potato plants more than that recorded from single application of boron or manganese (Jafari-Jood *et al*., 2013).

Foliar spray of microelements is very helpful when the roots cannot provides all the necessary nutrients (Kinaci and Gulmezoglu, 2007; Babaeian *et al*., 2011). Moreover, soil application of micronutrients increases soil pollution. Crop roots are unable to absorb some important nutrients such as zinc, because of soil properties, such as high pH, lime or heavy texture, thus, in this situation, foliar spray is better as compared to soil application (Kinaci and Gulmezoglu, 2007). Foliar application of microelements improves the effectiveness of macronutrients (Narimani *et al*., 2010) and considered as the most important agricultural practices that affects the growing period of plant foliage and tuber formation as well as quality of produced yield (Gabr *et al*., 2001 and Bekhit *et al*., 2005).

Though, potato (*Solanum tuberosum* L.) is known to be highly susceptible to the deficiency of boron as well as of zinc, local research information on this aspect remains scarce. Therefore, keeping in view the above background the present investigation has been planned to study the response of foliar application of micronutrients on growth and yield of potato with the following objectives

- To study the effect of foliar application of micronutrients on growth and yield of potato
- To work out the economics of different treatment combinations

CHAPTER–II

REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is one of the most important tuber crops for high intensity cropping system because of its short duration and very wide regional and seasonal adaptability. It is a highly productive crop, removing huge quantity of nutrients from the soil. Thus, to maintain the sustainable use of nutrients and reduce the cost of cultivation in nutrient deficit soil, the crop needs to be tested with different macro and micronutrient supply system. Hence, the productivity of potato can be increased in sustainable way by the use of macro and micronutrients. Keeping in view the objectives of the present investigation, such literature information reported by earlier workers in India and abroad has been compiled, reviewed and presented here in this chapter. Since limited research findings are available on these aspects for potato, the research information on allied crops has also been included in this chapter.

2.1 Effect of zinc

2.1.1 Effect on plant growth parameters

Zinc is an essential component and activator of many enzymes involved in auxin biosynthesis and photosynthesis and therefore plays an important role in plant growth (Romheld and Marscher, 1991). Increase in plant height may be attributed to the role of zinc in auxin synthesis and association of boron with the development of cell wall and cell differentiation that help in root and shoot growth of plants (Basavarajeswari *et al*., 2008). The zinc application significantly increased the photosynthetic activity, which ultimately resulted in improving the plant growth. Under zinc application, improved root system helps the plant in better absorption of water and other nutrients dissolved in it, and consequently, they improved different organs and the entire plant. The entire favourable effect was also attributed to the fact that zinc was essential in nitrogen metabolism (Asana *et al*., 1971).

(Puzina, 2004) reported that potato-tuber treated with 3 mM zinc sulphate, 8 mM boric acid and water (control) significantly influenced the potato tuber yield under greenhouse condition. Zinc sulphate treatment gave highest chlorophyll content (0.46 mg/g), fresh leaf weight (83.5 g/plant), fresh haulms weight (106.7 g/plant) and fresh root weight (11.3 g/plant) as compared to boric acid and water (control). Furthermore, different fertilization methods of zinc sulphate significantly effects vegetative growth of potato plant. The average number of leaves per plant and number of haulms per plant was significantly increased with zinc sulphate treatments. The number of leaves per plant was recorded maximum when the tubers were soaked with 1% solution of $ZnSO_4$, while, maximum number of haulms per plant was recorded with the basal application of $ZnSO_4$ at 20 kg/ha. Foliar application of $ZnSO_4$ showed lowest number of haulms per plant due to lower efficiency of foliar application of zinc sulphate (Joshi and Raghav, 2007). According to Reshma *et al.* (2007), the growth parameters like plant height, number of shoots per plant, fresh weight of foliage per plant and per hectare were recorded maximum under 30 kg $ZnSO_4$/ha and 15 kg $FeSO_4$/ha .

Kumar *et al*. (2008) when work on potato reported that the potato growth parameters were significantly influenced with the application of different micronutrients. The highest plant height (45.8 and 62.9 cm), number of shoots/hill (2.94 and 4.39) and leaf area (40.7 and 55.0 cm^2) were obtained at 45 and 60 days after planting, respectively, as seed tubers treated with 0.05% $ZnSO_4$. Different concentrations of zinc sulphate (0.05, 0.10 and 0.15%) used for soaking of potato seed tubers significantly effects the growth and development of potato plant and highest vegetative growth was found under 0.10% zinc sulphate. The suitable concentration of zinc sulphate was 0.05 to 0.10% to accelerate the growth and development of potato (Li *et al*., 2010). Abd El-Baky *et al*. (2010) obtained the vegetative growth of sweet potato was significantly influenced with the application of four levels of potassium (120, 225, 300 and 375 kg/ha K_2O) and zinc fertilizer (0, 10, 20 and 30 ppm) and maximum value of vegetative growth of sweet potato was recorded at highest level of potassium and zinc fertilizer.

Potato plants grown under higher level of zinc generally exhibited rapid growth and often more biomass of plant than medium level of zinc treatments (Barben *et al*., 2010). Rahman *et al*. (2011) when working on potato observed that due to deficiency of zinc, performance and quality of potato will be decreased. The highest number of leaves/plant and main stem/hill (8.36) was produced by application of Zn at 4 kg/ha followed by 3 kg and 5 kg/ha, while the lowest number of main stem (7.28) was found in control. Foliar application of six active yeast extract (0, 1, 2, 3, 4 and 5 g/l) with four zinc fertilization rates (0, 100, 200 and 300 ppm) significantly enhanced vegetative growth of potato cv. *Valor*. Increasing concentration of zinc up to 300 ppm along with 5g/l yeast extract increased the vegetative growth characters, *i.e*., plant length, stem and leaves number per plant, leaf area per plant and fresh and dry weight of whole plant. Maximum plant height (52.0 cm), number of stems per plant (3.0), number of leaves per plant (35.0), leaf area per plant (1723.35 cm^3) average numbers of haulms (2.7), whole fresh (235.25 g) and dry weight of plant (12.3 g) were reported maximum with the foliar application of 300 ppm zinc in combination with 5 g/l yeast extract (Ahmed *et al*., 2011).

Taheri *et al*. (2012) reported that application of compost and manure with phosphorus and zinc influenced the growth and yield parameters of potato. The maximum dry weight of shoot (28.7 g/plant) was obtained with the application 225 kg/ha phosphorous along with 50 kg/ha zinc, which was significantly superior over other treatments. According to Panitnok *et al*. (2013) foliar application of various rates of zinc, magnesium and sulphur gave significant effect in fresh weight of stem and fresh weight of root of cassava plant. The zinc sulphate application gave significant effect on leaf area index (LAI) and root biomass at all stages of observation. The pooled data showed that leaf area index was maximum (5.13 and 5.33) with the application of zinc sulphate @ 25 kg/ha at the time of early stage planting, *i.e*. 45 and 60 days after planting, whereas, it was maximum (5.50) under zinc sulphate @ 12.5 kg/ha at the time of planting and 12.5 kg/ha at the time of earthing up + RDF at 75 DAP. Application of zinc sulphate @ 25 kg/ha at the time of planting gave maximum root biomass (5.68 g/plant) at 60 DAP as compared to other treatments (Sati *et al*., 2017).

2.1.2 Effect on yield parameters

Finding of Raghav and Singh (2003) revealed that potato yield and yield attributing characters were influenced with the basal as well as foliar application of zinc sulphate. The highest number of small tubers was produced with zinc at 2 kg/ha, whereas, maximum weight of small tubers was obtained with zinc at 5 kg/ha (applied during 30 and 45 days after planting). However, the highest number and weight of medium and large tubers were recorded with basal application of zinc at 8 and 10 kg/ha, respectively. The maximum tuber yield (32.21 t/ha) was obtained with soil application of zinc sulphate at 8 kg/ha as compared to foliar application of zinc sulphate in potato.

Seed-tuber treatment with 3 mM zinc sulphate, 8 mM boric acid and water (control) affects the potato tuber yield under greenhouse condition. Zinc sulphate treatment increased the tuber weight (344 g/plant) due to increased number of phellem (cork) cell layers (6.7) of potato tubers. The maximum number of tubers (13.5/plant) and fresh weight of large tubers per plant (51%) was obtained with 3 mM zinc sulphate application as compared to boric acid and water treatment (Puzina, 2004).

Singh and Rajini (2004) conducted a field experiment on sandy loam soil in Pantnagar, Uttaranchal, India to investigate the effect of Zn at 2, 4, 6, 8 and 10 kg/ha as basal and foliar application on potato. The highest tuber yield was obtained with Zn at 8 kg/ha as basal and this treatment produced 16% higher yield than the control and 4.5% higher than foliar spray. Thakare *et al.* (2007) reported that the growth and yield of potato was significantly influenced with different levels of zinc and iron application. The maximum number of tubers per plant, fresh weight of tubers per plant, total dry weight and tuber yield per hectare were obtained with application of $ZnSO_4$ at 30 kg/ha and $FeSO_4$ at 15 kg/ha.

Application of zinc and manganese increased all the yield and quality attributing characteristics of potato, *i.e*., tuber yield per plant, dry matter percentage, specific weight, protein and starch content of tuber. Application of zinc at 8 ppt increased the yield to 34.70 q/ha which was 25% higher over the control, while application of manganese at 4 ppt increased yield to 338.66 q/ha which was only 15% higher than control treatment. Maximum number of tuber per plant (12.00), tuber weight (79.16 g) and yield (389.50 q/ha) were obtained with the foliar application of mixture solution of 8 ppt zinc and 4 ppt manganese on potato crop which were 31, 17 and 64.93% higher as compared with control. Application of 8 ppt zinc and 4 ppt manganese together increased the protein (36.5%) and starch content (14.9%) of potato tuber as compared with control (Mousavi *et al*., 2007). According to the finding of Reshma *et al.* (2007) potato tuber yield parameters like number of tubers per plant, fresh weight of tubers per plant, total dry matter weight, yield of tubers per plot and tuber yield per hectare were recorded maximum under 30 kg $ZnSO_4$/ha and 15 kg $FeSO_4$/ha.

Soaking of seed tubers in different solution of $ZnSO_4$ (0.25%, 0.50%, 0.75%), 20 kg/ha $ZnSO_4$ as soil side dressing and 0.2% $ZnSO_4$ solution spray twice at 40 and 60 days after planting gave significant effect on productivity and quality of potato. Soaking of seed tubers in 0.50% $ZnSO_4$ solution for 3 hours gave higher productivity and superior quality of tubers (Brahmachari *et al*., 2010). Application of different levels of zinc on potato significantly influenced the weight of tubers per hill. The maximum weight of tubers per hill (431.50 g) was found with the application of zinc @ 4 kg/ha which was statistically at par with application of zinc at 3 kg and 5 kg/ha, while minimum weight of tubers per hill (393.80 g) was found in control (Rahman *et al*., 2011).

Foliar spray of 300 ppm zinc fertilizers along with 5 g/l yeast extract significantly increased the yield and quality of potato tuber. The maximum total tuber yield (18.769 and 19.055 ton/fed.) and dry matter (21.3 and 21.5%) was found with foliar spray of yeast at 5 g/l combined with foliar spray of zinc at 300 ppm in both seasons, respectively (Ahmed *et al*., 2011). Highest tuber weight (1.70 kg/m^2) was recorded under treatment with phosphorous at 150 kg/ha and zinc at 50 kg/ha, while, the maximum number of tubers (7.22 tubers/plant) was produced with the application of zinc at 50 kg/ha without phosphorous (Taheri *et al*., 2012). Khasti and Rana (2012) reported that the foliar feeding of Zn @ 4 mg/l significantly improved vegetative growth parameters, total yield and quality contents in bulb tissues in onion compared to other micronutrients and control. Foliar spraying of Zn gave the superiority in all measured parameters than other treatments.

Foliar application of Zn, Mn, Fe and Cu increased all plant characteristics relating to yield components, *i.e*., number of tuber per plant, yield and dry matter percentage of potato crop. Application of full micronutrients mixture (330 g $ZnSO_4$+ 330 g $MnSO_4$+ 150 g $FeSO_4$+ 80 g $CuSO_4$ dissolved in 1000 liter water) increased yield to 22.89 ton/ha, which was higher 8.74% in compare with control. However, application of half concentration of micronutrients mixture decreased yield of potato tuber to 20.01 ton/ha. Application of micronutrients mixture during flowering increased tuber yield in compare with application of micronutrient mixture at10 days before flowering and 20 days after flowering up to 13.74 and 16.18%, respectively. Application of full concentration of micronutrient mixture during flowering increased number of tubers (10.67) per plant, weight of tubers (82.02 g/plant) and dry matter 22.91 % in potato tubers as compared to control (Al-Jobori and Al-Hadithy, 2014). Saha *et al*. (2014) reported that two zinc fertilization rates 5 kg and 10 kg/ha significantly increased potato tuber yield. Whereas, Hadi *et al*. (2015) reported that application of iron and zinc fertilizers increased total numbers and weight of potato tubers but fertigation (zinc and iron fertilizers with irrigation) was more significant than spray application. Jam *et al*. (2015) observed that application of 40 ppm iron and 20 ppm zinc produced higher tuber number but the tuber yield (481 q/ha) and skin thickness were found maximum under treatment of 20 ppm iron and 80 ppm zinc.

Yield and quality attributes were significantly influenced with foliar application of 15 ppm zinc and 6 ppm manganese in potato. The highest tuber yield per plant (610.43 g), tuber yield per hectare (417.61 q) and quality parameters *viz*., reducing sugar (3.53%), non-reducing sugar (4.33%), total sugars (7.86%) and protein (2.60%) were recorded in crop which was sprayed with 15 ppm zinc and 6 ppm manganese (Parmar *et al*., 2016). Jawad (2016) studied the effect of foliar application of zinc and manganese on potato production and reported that application of combined solution of zinc and manganese increased mean weight of potato tubers to 94.03 g per tuber which was 65% higher, tuber yield 921.90 g per plant which was 56% higher and total tubers yield to 46.10 tonnes per ha which was 57% higher as compared to control. The interaction effect (spray of Zn+Mn × application date) was significant on yield parameters of potato, *i.e*., mean weight of potato tuber, tuber yield per plant and total tubers yield significantly increased with the combined application of zinc and manganese solution at vegetative growth stage which were 98.87 g tuber, 941.40 g per plant and 47.07 tonnes per ha, respectively.

The yield attributing characters (total number of tubers per plant and tuber weight) of potato plant was significantly increased with the application of zinc sulphate. Total number of tubers (9.63 and 10.42) as well as weight of tubers per plant (458.33 g and 516.67 g) at 60 and 75 days after planting was found maximum under treatment 25 kg/ha zinc sulphate at the time of planting, respectively. Application of 25 kg/ha zinc sulphate at the time of planting along with 160:100:120 kg/ha N:P_2O_5:K_2O gave higher tuber yield (35.55 and 37.35 t/ha) and benefit: cost ratio (2.18 and 2.28) during both the years, respectively, whereas, application of 12.5 kg/ha zinc sulphate at the time of planting and 12.5 kg/ha at the time of earthing up + RDF was found best with respect to potato tubers quality *viz*., dry matter (22.57 and 22.27 %), starch (18.56 and 19.11%) and protein (8.20 and 8.45%) during both the years, respectively (Sati *et al*., 2017). Application of different concentration of gibberellic acid (0, 100, 200 and 400 mg/litre) and zinc sulfate (0, 500, 1000 and 2000 mg/litre) significantly affected the number of seed tubers, fresh tuber weight (g), dry matter content (%), tuber starch and crude protein content (%) and tuber yield (q/ha). Foliar spray of 200 mg/litre gibberellic acid and 1000 mg/litre zinc sulfate at 20 and 50 days after tuber sprouting increased 38% total tuber yield as compared to control. The greatest tuber dry matter content (24.33 g/100 g fresh wt.) was obtained from 200 mg/litre GA_3 plus 2000 mg/litre zinc sulfate treatment, while the highest starch content (32.56% tuber fresh weight) was obtained from individual application of 2000 mg/litre zinc sulfate. Application of GA_3 at 400 mg/litre and zinc sulfate at 2000 mg/litre resulted in the highest tuber crude protein content (8.37% tuber dry weight) which was twice over the control treatment (Javanmardi and Rasuli, 2017).

2.2 Effect of Boron

2.2.1 Effect on plant growth parameters

(l-Dissoky and Abdel-Kadar (2013) in their studies reported that boron is an essential micronutrient required for normal plant growth and development. It performs a wide range of functions in potato plants. It is a very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. It is necessary for normal cell division, nitrogen metabolism and protein formation. It is essential for proper cell wall formation, translocation of sugar and carbohydrates and helps in maintaining balance between sugar and starch in plant body. Foliar spray of boron significantly affected potato growth parameters, *i.e.*, plant height, number of leaves per plant, fresh weight of plant, dry weight of plant and leaf area. Number of leaves per plant, fresh and dry weight of plant and leaf area were increased significantly with foliar application of boron up to level 60 mg/litre in both locations, while, the plant height was decreased with foliar application of boron. The highest fresh and dry weight of plant (324 and 330 g) and (33.79 and 34.85 g) were found with application of 60 mg/litre boron in first and second location, respectively. At the same time, the highest value of leaf area was 1946 cm^2 per plant in first location and 1960 cm^2 per plant in second location at 60 mg/litre boron level.

The growth parameters of potato plants, *viz.*, plant height, number of leaves per plant and shoot weight per plant were significantly enhanced with the spray of boron as compared with control, furthermore, combined application of boron and manganese improved the growth behavior of potato plants over the single application of boron or manganese. The maximum plant height (133.3 cm), number of leaves per plant (57.0) and shoot weight per plant (235.3 g) were found with the application of boron along with manganese on *Sprit* cultivar of potato (Jafari-Jood *et al.*, 2013). Combined foliar application of potassium (2% KCl) with boron (0.2% H_3BO_3) significantly enhanced most of plant growth parameters in potato, such as plant height, number of leaves, fresh and dry weight of shoots, whereas, the individual effect of boron was mostly at par with control. At 70 DAS, significant increase in fresh and dry weight of shoots was noticed by potassium application in the first season and by combined application of potassium and boron on shoot dry weight in the both seasons. At 90 DAS, growth parameters was increased with potassium or combined treatments of potassium and boron except of shoot dry weight in the second season, this effect reached the significance level by potassium application on shoot dry weight and combined treatments of potassium and boron on leaves number in the first season (Ibrahim *et al*., 2015).

2.2.2 Effect on yield parameters

Foliar application of boron significantly increased the total tuber yield, dry shoot yield and average weight of tubers. Potato tubers yield increased by 17.39% with foliar application of boron @ 60 mg/litre in the first location and by 16.95% with 90 mg/litre in the second location, whereas, dry shoot yield increased by 33.47 and 30.02 % in both locations, respectively with foliar spray of 60 mg/litre boron. The highest average weight of tubers was 267 g in the first location and 275 g in the second location at foliar spray of 60 mg/litre boron. Quality parameters such as dry matter, protein and starch percentage of potato tuber and uptake of N, P, and K significantly increased with foliar application of boron. Potato variety *valor* appeared superiority in plant growth, total tuber yield (19.90 mg/fed), dry shoot yield and total NPK-uptake (El-Dissoky and Abdel-Kadar, 2013). Total chlorophylls were only increased by the combined application of potassium and boron (2% KCl and 0.2% H_3BO_3) and total phenolic compounds by individual potassium treatment. Adversely, boron had significantly decreased most of the measured chemical parameters. Tubers yield was significantly increased in all treatments compared with control plants. Combined application of boron and potassium treatment increased seedling tubers yield by 53.11%, 46.03 % followed by individual treatment of potassium (29.85%, 20.03%) and boron (15.20%, 9.93%) over the control plants in both seasons, respectively (Ibrahim *et al*., 2015). Foliar spraying of potato plants with 75 ppm boron and 50 ppm of molybdenum significantly increased plant height, number of stems per plant, leaf area, number of tubers per plant, fresh weight of vegetative growth, total tuber yield, dry matter percent and recorded the highest concentrations of N, K and B in plants (El-Banna and Abd El-Salam, 2005). Bari *et al*., (2001) reported that application of 1.1 kg/ha boron from borax increased potato fresh haulm weight per hill, number of tubers per hill, percent dry matter and yield of tuber. Tubers yield was increased from 12.5 t/ha in control to 14.7 t/ha in boron treatment at 3 kg/ha. The response of spring crop to boron application was better than that of autumn. Basal application of boron also enhanced the dry matter content of tuber from 17.02 to 20.03% and starch from 10.75 to 13.07%.

2.3 Effect of zinc and boron mixture

2.3.1 Effect on growth parameters

The growth characters like plant height, number of leaves, fresh shoot weight and dry shoot weight were significantly influenced with the individual and combined application of macro and micronutrients (Ca, Mg, S, Zn and B @ 7.2, 6.5, 12.6, 9.0 and 1.0 kg/ha, respectively) in potato. Soil application of calcium (Ca), magnesium (Mg), sulphur (S), zinc (Zn) and boron (B) gave maximum plant height (28.86 cm and 32.15 cm) and number of leaves per plant (80.72 and 90.67) at 50 and 70 DAP over the other treatment. The maximum fresh (277.17 g) and dry weight of shoot (45.83 g) was found under treatment of combined soil application of macro and micronutrients (Ca, Mg, S, Zn and B) over control with no macro and micronutrients applied (Chowdhury, 2017). Plant growth parameters of potato like plant height at 60 DAS and 90 DAS, number of leaves per plant and number of branches per plant were increased significantly with foliar application of micronutrient and macronutrient on potato plant. The maximum plant height (43.16 cm and 45.0 cm, respectively) at 60 DAS and 90 DAS, number of leaves per plant (82.0) and number of branches per plant (13.65) were recorded by application of micronutrient mixture of Zn, B, Fe, Mn and NPK together (Moinuddin *et al*., 2017).

3.3.2 Effect on yield parameters

Foliar application of micronutrient solution (330 g $ZnSO_4$ + 330 g $MnSO_4$ + 150 g $FeSO_4$ + 80 g $CuSO_4$ dissolved in 1000 liter water) sprayed at 10 days before flowering, during flowering and 20 days after flowering on potato crop in Iraq. The result showed that foliar spray of micronutrient solution significantly increased number of tubers per plant, tuber yield and dry matter percentage. The result also depicted that application time has a very strong influence on potato performance. Foliar spay of micronutrients solution during flowering caused to increase number of tubers per plant and mean weight of tubers, which improved tuber yield (Kamil and Saifedin (2014). The effect of soil application of Ca, Mg, S, Zn and B was also found to be significant on yield attributes like different size tubers, yield and quality. Soil application of calcium, magnesium, sulphur, zinc and boron recorded highest number of tubers per plant (6.78), total yield per plant (244.44 g) and tuber yield per hectare (191.52 q) over control treatment (Chowdhury, 2017). Foliar application of micronutrients alone or in combination with NPK significantly influenced the yield component and yield of potato. The maximum number of tubers per plant at 60 and 90 DAP (3.67 and 5.67, respectively), tuber diameter (13.93 cm), tuber weight (65.67 g) and tuber yield (22.45 t/ha) was found maximum with the foliar application of micronutrients (Zn, B, Fe and Mn) in combination NPK as compared to control treatment (Moinuddin *et al*., 2017).

3.4 Effect of vegetable special, potato specific nutrients formulations and mixtures

3.4.1 Effect on growth parameters

Awad *et al.* (2010) showed that the vegetative growth parameters, *i.e.*, plant height, number of main stems per plant, chlorophyll content, foliage fresh and dry weight per plant at 80 days after planting gave the highest values with foliar application of the micronutrients mixture of Fe, Zn and Mn as well as potassium sulphate in the two seasons of study. Mona *et al.* (2012) studied on effect of NPK levels and foliar nutritional compounds on different growth parameters grown in newly reclaimed soil. The obtained results showed that highest values of all the growth parameters at harvest and macro and micronutrients in potato shoots were obtained by using the highest NPK (120:80:100) as compared with the other two NPK levels (medium: 102:68:85 and low: 90:60:75). They also reported that foliar application of nutritional compounds *viz.*, folifertile, byfolane and fetrilon combi significantly increased growth parameters and nutrients content of shoots as compared with the control treatment.

Jasim (2013) conducted experiment to study the effect of Alaska foliar fertilizer (N: 12%, P_2O_5: 12%, K_2O%: 36%, Fe: 0.05%, Cu: 0.005%, Mn: 0.03%, Zn: 0.01%, B: 0.02%, Mo: 0.003%) on growth of seven potato cultivars in University of Babylon, Iraq. The obtained results showed that foliar fertilizer had a significant effect on plant height of potato plant and highest plant height was obtained from Red Brown, Provento and Draga cultivars. Channakeshava *et al*. (2017) reported that plant height at 90 DAS (63.10 cm) and number of branches at 60 and 90 DAS (4.65 and 6.0) was increased significantly with foliar spray of vegetable special at 5 g/litre along with RDF followed by vegetable special at 3 g/litre + RDF (62.95 cm and 4.25 and 5.1, respectively) and recommended practice (62.75 cm and 3.25 and 4.8, respectively) in potato.

3.4.2 Effect on yield parameters

In the two seasons of study conducted by Awad *et al.* (2010) showed that tuber number and tuber dry weight per plant and total tuber yield at harvest time gave the highest values with foliar application of the micronutrient mixture of Fe, Zn and Mn as well as potassium sulphate. Mona *et al.* (2012) studied on effect of NPK levels and foliar nutritional compounds on yield, chemical constituents and nutrients content of potato plants grown in newly reclaimed soil. The obtained results showed that highest values of all the yield parameters, photosynthetic pigments, chemical constituents of potato tuber at harvest and macro and micronutrients in potato shoots and tubers were obtained by using NPK 120:80:100 kg/ha as compared with the other NPK levels. They also reported that foliar application of nutritional compounds *viz.*, folifertile, byfolane and fetrilon combi significantly increased yield parameters, photosynthetic pigments, chemical constituents and nutrients content of shoots and potato tubers as compared with the control treatment.

Jasim (2013) conducted an experiment in University of Babylon, Iraq reported that foliar spray of Alaska fertilizer (N: 12%, P_2O_5: 12%, K_2O: 36%, Fe: 0.05%, Cu: 0.005%, Mn: 0.03%, Zn: 0.01%, B: 0.02%, Mo: 0.003%) had a significant effect on tuber weight and total tuber yield of potato. He also resulted that higher tuber yields were obtained from Red Brown, Provento and Draga cultivars of potato.

Channakeshava *et al*. (2017) in their experiment resulted that the yield and yield parameters differed significantly due to foliar application of vegetable special micronutrients mixture over other treatments in potato. The higher number of tubers per plant (9.7), tuber weight per plant (1.46 kg) and tuber yield (103.95 q/ha) were recorded with foliar application of vegetable special at 5 g/litre along with recommended dose of fertilizers over farmers practice (4.5, 0.62 kg and 91.3 q/ha) and recommended practice (5.6, 0.81 kg and 95.1 q/ha).

The increase in yield was 13.85% with foliar application of vegetable special @ 5 g/litre along with recommended dose of fertilizer as compared to farmers practice. Foliar application of vegetable special at 3 g/litre along with recommended dose of fertilizers and recommended practice increased 9.07% and 5.96% yield in comparison to farmers practice. With respect number of tubers per 10 m^2 area of different sizes, maximum number of tubers (426.75) of more than 75 g size was recorded with the foliar application of vegetable special at 5 g/litre along with RDF followed by 3 g/litre vegetable special + RDF (413.75), recommended practice (393.5) and farmers practice (326.5). Similar trend was also followed with respect other size groups like <25g, 25-50g and 50-75 g. As regard to micronutrient content in tubers, higher concentration of Zn, Cu, Mn, Fe, B and Mo (22.2, 8.3, 21.5, 25.0 and 16.6 ppm) were recorded in the treatment where foliar application of vegetable special at 5g/litre along with RDF than recommended practice and farmers practice. With respect of economics of crop, the higher B: C ratio was recorded with the foliar application of vegetable special @ 5 g/litre + RDF (1:2.44) followed by application of vegetable special at 3 g/litre with RDF (1:2.30) and recommended practice (1:2.26), while, lowest B:C ratio (1:2.23) in farmers practice.

Manjunath *et al.* (2017) conducted experiment in Karnataka on different micronutrients and their formulation on growth, yield and quality of potato cv. Kufri Jyoti. Among the different formulations, foliar spray of UHSB-3 micronutrient formulation (Zinc 200 ppm, Manganese 75 ppm, Iron 100 ppm, Boron 75 ppm, Copper 25ppm) @ 3 g/litre sprayed at 30, 45 and 60 days after sprouting of tubers along with RDF recorded significantly highest A- grade (>75g) tuber yield per plant (532.15 g), total yield per plant (687.87 g), A grade tuber yield per hectare (16.65 t/ha), total tuber yield per hectare (25.18 t/ha), dry matter content of tubers (19.76%) and total sugar (0.43%) as compared to control.

CHAPTER–III

MATERIALS AND METHODS

The present experiment entitled "Effect of foliar application of micronutrients on potato production" was conducted at Research Farms of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during winter (*Rabi*) season of the year 2016-17. The details of materials used and methods applied in the present study are given below:

3.1. Experiment site and location

The experiment was conducted at Research Farm, Department of Vegetable Science, CCS Haryana Agricultural University, Hisar in Haryana state at $29^{\circ}10^{'}$ N latitude, $75^{\circ}46^{'}$ E longitude and at an altitude of 215.2 meters above mean sea level. Hisar is situated in the semi-arid, sub tropical region of North Western India.

3.2 Climate

The Hisar has a typical semi-arid climate with hot dry summer and extremely cold winter. The mean monthly maximum and minimum temperature showed a wide range of fluctuation during summer as well as winter season. The maximum temperature around 47 $^{\circ}$C during summer month of May and June and minimum temperature around freezing point accompanied by frost during winter month of December and January is common in this region. There is a large variation in receiving of total rainfall as well as its distribution in the region. About 80 to 90 percent of the total rainfall (400 mm) is received through south west monsoon during July to September. Cyclonic rains occur during December and January or late spring. The rainfall is highly unpredictable with 20-30 percent annual and 30-50 percent seasonal distinction. From July to end of March, the mean morning relative humidity remains around 80-90 percent but decreases to about 40-50 percent by April to June end.

3.3 Meteorological observations

The mean weekly values for important weather parameters during the crop season (October, 2016 to April, 2017) influences the growth, development, yield and quality of the crop considerably, therefore the data on various meteorological aspects (maximum and minimum temperature, relative humidity, sunshine and precipitation) during the course of experimentation were recorded from the Meteorological Observatory at Research farm, Chaudhary Charan Singh, Haryana Agricultural University, Hisar are given in Table 3.1.

Table 3.1: Monthly meteorological data recorded during crop season 2016-17

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
October 2016	34.7	18.8	M	E	12.0
November 2016	29.4	10.7	84	42	0.0
December 2016	24.6	7.5	91	47	0.0
January 2017	18.6	6.9	97	56	41.2
February 2017	24.3	7.8	99	71	0.0
March 2017	29.0	11.3	92	46	7.5

Source: Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar.

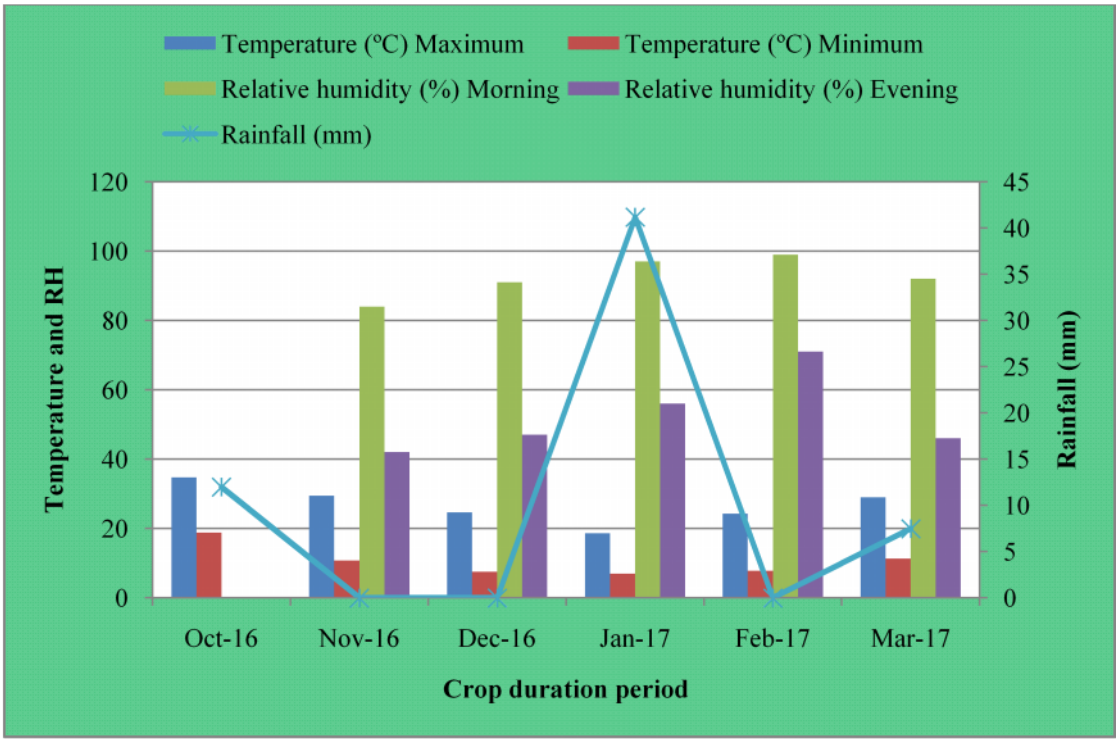


Figure 1: Agro-meteorological data during the period of experimentation on monthly basis from October 2016 to March 2017

3.4 Soil analysis

3.4.1 Mechanical analysis

For mechanical analysis soil samples from 0-15 cm depth were collected from different locations of the experimental field before experimentation. A representative composite sample was prepared by processing and mixing them together and then analysed for mechanical and chemical characteristics.

The mechanical analysis done by using International pipette method (Piper, 1966) showed that the texture of experimental area was loamy sand in nature as concluded from the results are presented in Table 3.2.

Table 3.2: Mechanical analysis of the soil of experimental field

Soil separates	Value	Method of determination
Sand (%)	61.98	International Pipette Method (Piper, 1966)
Silt (%)	22.02	-do-
Clay (%)	17.00	-do-

3.4.2 Chemical analysis

For chemical analysis of soil, the soil samples were taken from 0-15 cm depth at different places in the field. The samples from all the places were mixed thoroughly, dried under shade, ground into fine powdery mass and were analyzed for chemical constituents. The observations recorded and methods used are presented in Table 3.3.

Table 3.3: Chemical analysis of the soil of experimental field

Particulars	Content	Method used
pH	8.1	pH meter with glass electrode in 1:2 Soil Water Suspension (Jackson, 1973)
Electrical Conductivity ($dS\ m^{-1}$)	1.03	Conductivity Bridge Method (Richards, 1954)
Organic carbon (%)	0.31	Digestion Method (Walkley and Black, 1934)
Available nitrogen ($kg\ ha^{-1}$)	185	Alkaline Permanganate Method (Subbiah and Asija, 1956)
Available phosphorus ($kg\ ha^{-1}$)	12	Olsen's Method (Olsen *et al.,* 1954)
Available potassium ($kg\ ha^{-1}$)	268	Flame Photometric Method (Jackson, 1973)

3.5 Experimental materials

Treatment details:

Foliar spray of the below-mentioned micronutrients combinations was done three times at 30, 45 and 60 days after planting (DAP) of the crop in field.

1. Boron 50 mg/l
2. Boron 100 mg/l
3. $ZnSO_4$ 150 mg/l
4. $ZnSO_4$ 300 mg/l
5. $ZnSO_4$ 150 mg/l + Boron 50 mg/l
6. $ZnSO_4$ 300 mg/l + Boron 100 mg/l
7. Vegetable Special IIHR 5 g/l
8. Potato Specific Nutrients 4 g/l
9. Control (water sprayed)

The other details of the experimental material and design treatments are given as under:

Variety : Kufri Bahar

Design : Randomized Block Design

Replications : Three

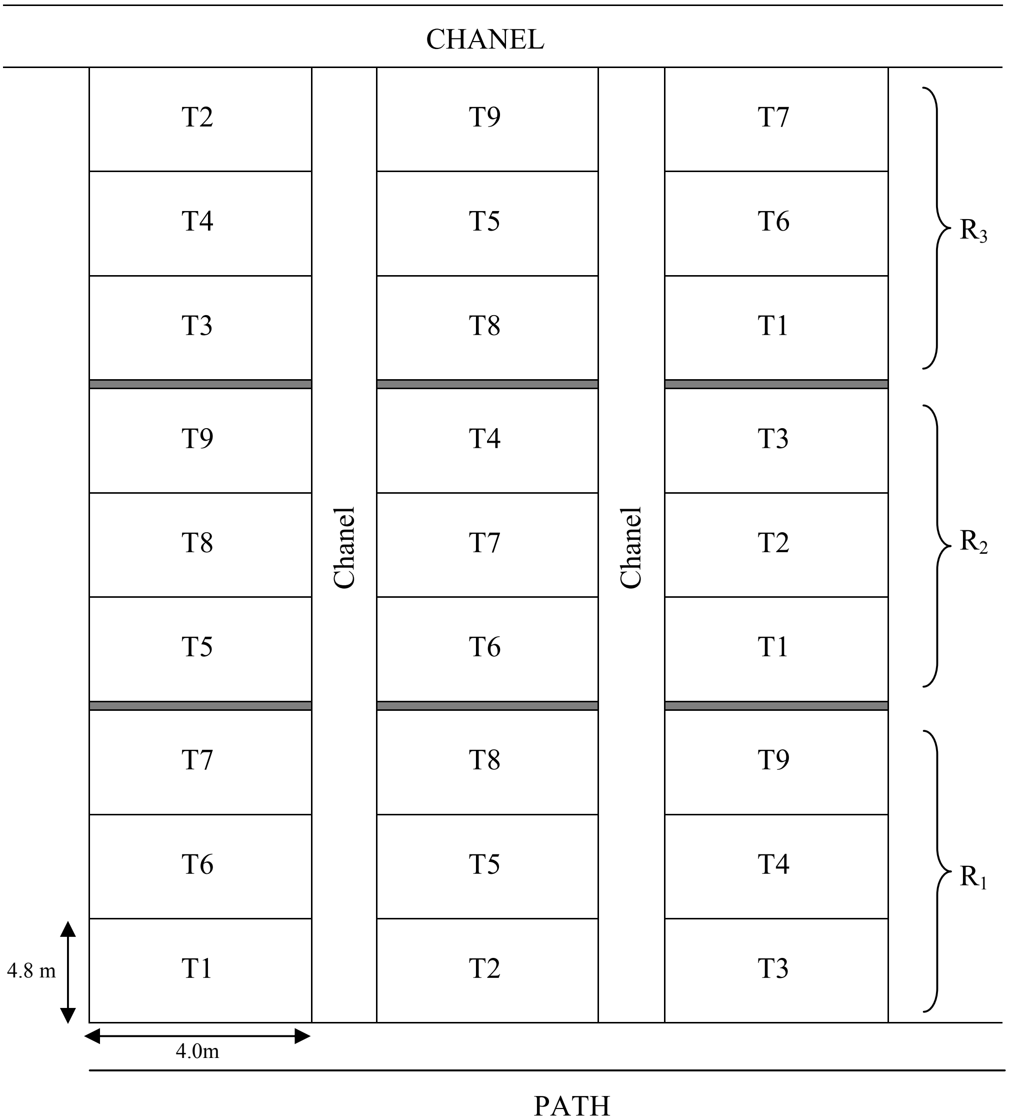
Gross plot size : 4.8 x 4.0 m^2

Net plot size : 3.6 x 3.6 m^2

Plant spacing : 60 x 20 cm (between and within rows)

Fertilizer (RDF) : NPK 150:50:100

LAYOUT PLAN OF EXPERIMENTAL FIELD



3.6 Cultural operations

3.6.1 Land preparation

Farmyard manure was incorporated @ 20 t/ha in soil before ploughing the field, and then, the experimental field was prepared by ploughing thrice followed by planking each time to prepare the suitable seedbeds of size 4.8 x 4.0 m^2.

3.6.2 Planting

In well prepared field, the plots of desired size as per the treatment were marked, and in each plot, the rows at a distance of 60 cm were demarcated with the help of rope. The uniformly well sprouted healthy tubers of optimum seed size (40-50 g) were placed on each marked row at a distance of 20 cm between tubers. The Recommended dose of fertilizers (NPK: 150:50:100 kg/ha) dressed on both sides of the rows about 4-5 cm away as band placement. Thereafter, the soil from both sides was placed on tubers in such a way that it made a uniform size ridge about 15-20 cm high leaving no part of the tubers exposed to light. Potato tubers were planted on 25th October, 2016.

3.6.3 Micronutrients application

The different levels of micronutrients were applied as foliar application as per the treatments in potato crop. Foliar spray schedule is common to all the treatments, *i.e.*, 30, 45 and 60 days after planting. Boron is supplied through boric acid (17.5%) and zinc through zinc sulphate (21.0%). Foliar Vegetable Special of IIHR and Potato Specific nutrients formulation were received from IIHR, Bangalore. The pH of the nutrients solution was adjusted to 6.5 before spraying by using the citric acid.

3.6.4 Irrigation and fertilizer application

First irrigation was supplied just after planting of potato tubers and subsequent irrigation was given as per requirement of the crop. Total seven irrigations were given during the entire crop period. Half dose of nitrogen and full dose of phosphorus and potash were given at the time of planting, while remaining half nitrogen was applied at the time of earthing up (30 days after planting). The other cultural operations were done as per the recommendations of Package of Practices of CCS Haryana Agricultural University, Hisar.

3.6.5 Harvesting

The crop was dehaulmed after 100 days of planting using paraquate (Gramoxone), which is a non-selective post emergence fast acting contact herbicide. All plots were harvested manually after ten days of dehaulming to allow tuber hardening (curing).

3.7 Observations recorded

During the course of experimentation the details methods followed for the recording of various observations are given below.

3.7.1 Growth parameters

3.7.1.1 Plant emergence percent at 30 days after planting

The count of plant emergence in each plot was recorded at 30 days after planting and was converted into percent by using following formula-.

$$\text{Plant emergence (\%)} = \frac{\text{Number of tubers sprouted per plot}}{\text{Total number of tubers planted per plot}} \times 100$$

3.7.1.2 Plant height (cm)

Ten plants from each plot were selected randomly and plant height was measured in centimeter. Height of the tallest shoot was measured from base of the plant to apex of last leaf at 45, 60, 75 and 90 days after planting and average was worked out.

3.7.1.3 Number of stems per hill

Ten plants (hills) were selected at random from each treatment replication wise at harvest and their stems were counted and then averaged number of stems per hill was worked out.

3.7.1.4 Number of leaves per stem

Stems of five selected plants were counted and their leaves were removed and counted at harvesting time. The total number of leaves was divided by total stems for working out average number of leaves per stem.

$$\text{Number of leaves per stem} = \frac{\text{Total number of leaves of selected stems}}{\text{Total number of stems}} \times 100$$

3.7.1.5 Leaf weight per hill at harvest

The fresh weight of leaves per hill was recorded in gram at final harvest. It was recorded by weighing the leaves of selected five plants (hills) as mentioned above and then average leaves weight per hill was worked out.

3.7.1.6 Stem weight per hill at harvest

Weight of stem per hill was recorded at final harvest for the plant selected earlier for leaves weight and their stems without leaf were weighed in gram, and then average was calculated.

3.7.1.7 Weight of foliage

Weight of foliage was recorded at final harvest. It was taken by weighing all the foliage (haulm) of each plot (net plot size) at 100 days after planting in kilogram and then worked out for one square meter by dividing total foliage weight with net plot size and also converted in to quintal per hectare.

3.7.2 Tuber yield parameters

3.7.2.1 Number of tubers per plot in different grade

Net plot was harvested and grade-wise number of tubers was counted. Tubers were divided into four different grades i.e. >75 g (A grade), >50-75 g (B grade), >25- 50 g (C grade) and up to 25 g (D grade).

3.7.2.2 Total number of tubers per plot

At the time of harvesting, the total number of potato tubers of different grade such as A grade (>75g), B grade (>50-75g), C grade (>25-50g) and D grade (upto 25g) from each plot were sum up and calculating total number of tubers per plot.

3.7.2.3 Total number of tubers per hectare

The total number of tubers per plot was divided by plot size to work out the total number of tubers in one square meter and then the number of tubers per hectare was calculated.

3.7.2.4 Weight of tubers (kg) per plot in different grade (0-25, >25-50, >50-75 and >75 g)

At the time of harvest, the potato tubers from each plot which were divided into four grades such as A grade (>75 g), B grade (51-75 g), C grade (26-50 g) and D grade (up to 25 g) for number of tubers were weighed separately and calculate for weight of different grades tubers per plot in kilogram.

3.7.2.5 Total tuber yield (kg/plot)

The total tuber yield per plot was obtained by summing up the weight of different grade tubers (0-25, >25-50, >50-75 and >75 g) plot wise as taken for weight of tubers of different grades in kilograms.

3.7.2.6 Total tuber yield (q/ha)

The total tuber yield in quintal per hectare was obtained by summing up the weight of A, B, C and D grade tubers plot wise and then the values were converted into quintal per hectare (taking effective area of 9000 m^2).

3.7.2.4 Marketable tuber yield (q/ha)

The tubers harvested from each plot were sorted out into four grades based on their weights as A (>75 g), B (>50-75 g), C (>25-50 g) and D- grade (up to 25 g) grade. The weight of each grade tubers per plot was recorded and tubers of above 25 g (A + B + C grade) were considered as marketable tuber yield and their values were summed up. Later, the values were converted into kilogram per square meter and quintal per hectare.

3.7.2.5 Biological yield (q/ha)

Biological yield is the total biomass of the crop and calculated by summing up of tuber yield and foliage weight per plot and later converted in to quintal per hectare.

3.7.2.5 Harvest index (%)

The harvest index was calculated by dividing the economic yield (total tuber yield) with biological yield (economic yield + foliage weight) per hectare and then expressed as percent.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7.2.6 Percent dry weight of tuber

For the estimation of dry matter accumulation, weighted sample of fresh tuber were chopped into pieces and Sun dried for 2 to 3 days in polyhouse and then kept in oven at 70^0 C for drying until the constant weight recorded. The dry matter accumulation in the tubers was calculated based on final dry weight and expressed in percentage.

$$\text{Dry weight of tuber (\%)} = \frac{\text{Dry weight of tuber}}{\text{Fresh weight of tuber}} \times 100$$

3.7.2.7 Economics of various treatments

Common cost of cultivation of crop was calculated and the cost of each of the treatment was calculated by taking into account all items as per standard procedure and prevailing market rates and both were added to get the total cost of cultivation of each treatment. The value of the produce i.e. tuber yield at market rate was taken as gross return and net return for each treatment was calculated by subtracting the total cost of cultivation for respective treatments. The benefit cost ratio was calculated by dividing the gross return values with total cost of cultivation.

3.8 Statistical analysis

The data observed for the various characters during the study were statistically analyzed following the technique of analysis of variance (ANOVA). The significance of difference between mean of two treatments were judge with the critical difference (C.D.) worked out using following formula:

$$\text{C.D.} = \text{SE} \times \text{‘t’}$$

Where,

S.E. is a standard error of the difference of treatment means, which was calculated as follows:

S.E. = $\sqrt{(2EMS/r)}$

C.D. : Critical difference

EMS : Error mean sum of squares

r : Number of replication

‘t’ : Tabulated ‘t’ value at error degrees of freedom at 5% level of significance

CHAPTER–IV

EXPERIMENTAL RESULTS

The present investigations entitled "**Effect of foliar application of micronutrients on potato production**" conducted during Rabi season 2016-17 are presented in this chapter with the help of appropriate tables. The data related to different parameters were statistically analyzed by using Randomized Block Design method. The data recorded on plant emergence, plant height, number of shoots per hill, number of leaves per stem, leaf weight per hill at harvest, stem weight per hill at harvest, foliage weight, yield of tubers in different grade, number of tuber per plot in different grade, total tuber yield, marketable yield, biological yield, harvest index, percent dry weight of tuber and economics of various treatments have been interpreted and described in this chapter under the following headings:

4.1 Plant emergence percent

The plant emergence percent recorded at 30 days after planting has been presented in the Table 4.1 the data showed that plant emergence at 30 days after planting was found non-significant with the foliar application of different micronutrients alone or their combinations on potato crop. However, plant emergence was recorded in the range of 93.5 to 96.0%.

Table 4.1: Effect of foliar application of micronutrients on plant emergence (%) at 30 DAP and plant height at 45 DAP in potato cv. Kufri Bahar

Sr. No.	Treatments	Plant emergence %	Plant height 45 DAP
1	Boron 50 mg/l	94.4	59.1
2	Boron 100 mg/l	96.0	60.5
3	$ZnSO_4$ 150 mg/l	95.7	61.9
4	$ZnSO_4$ 300 mg/l	93.5	61.5
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	94.1	63.0
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	96.0	65.0
7	Vegetable Special IIHR 5 g/l	94.4	62.7
8	Potato Specific Nutrients 4 g/l	94.4	62.1
9	Control (water sprayed)	94.4	58.9
C.D. at 5%		**N.S.**	**N.S**

4.2: Plant height (cm)

Plant height at 45 days after planting (DAP) was recorded in the range of 58.9 to 65 cm. The foliar application of different micronutrients, alone and in combinations, has non-significant effect on plant height recorded at 45 DAP (Table 4.1). The data pertaining to plant height at 60, 75 and 90 days after planting was significantly influenced by foliar application of different micronutrients are presented in Table 4.2. The plant height was recorded maximum (72.7, 76.4

and 77.5 cm, respectively) at 60, 75 and 90 DAP in treatment where combined foliar application of zinc sulphate @ 300 mg/litre and boron @ 100 mg/litre was applied, which was statistically at par with the foliar application of zinc sulphate 150 mg/litre in combination with boron 50 mg/litre (70.7, 74.9 and 74.3 cm, respectively). Whereas, minimum plant height (63.3, 68.7 and 68.8 cm at 60, 75 and 90 DAP) was recorded in control treatment.

Table 4.2: Effect of foliar application of micronutrients on plant height at 60, 75 and 90 DAP in potato cv. Kufri Bahar

Sr. No.	Treatments	Plant height (cm)		
		60 DAP	**75 DAP**	**90 DAP**
1.	Boron 50 mg/l	64.3	70.1	70.2
2.	Boron 100 mg/l	65.2	70.7	72.1
3.	$ZnSO_4$ 150 mg/l	67.9	72.1	73.1
4.	$ZnSO_4$ 300 mg/l	69.3	72.7	73.6
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	70.7	74.9	74.3
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	72.7	76.4	77.5
7.	Vegetable Special IIHR 5 g/l	68.5	70.5	71.1
8.	Potato Specific Nutrients 4 g/l	69.1	72.5	72.8
9.	Control (water sprayed)	63.3	68.7	68.8
C.D. at 5%		**3.5**	**2.7**	**3.2**

4.3 Number of stems per hill

Number of stems per hill (plant) was significantly influenced by different foliar application of micronutrients like boron, zinc, vegetable special IIHR and potato specific nutrients formulations (Table 4.3). The number of stems per hill was observed highest (5.4) with the foliar application of zinc sulphate 300 mg/litre + 100 mg/litre boron on potato, which was statistically at par with lower dose of zinc sulphate (150 mg/litre) + boron (50 mg/litre), while, number of stems was recorded the minimum (4.1) in water sprayed control.

Table 4.3: Effect of foliar application of micronutrients on number of stems per hill and number of leaves per stem at harvest in potato cv. Kufri Bahar

Sr. No.	Treatments	Number of stems per hill	Number of leaves per stem
1.	Boron 50 mg/l	4.2	15.4
2.	Boron 100 mg/l	4.4	15.1
3.	$ZnSO_4$ 150 mg/l	4.6	15.4
4.	$ZnSO_4$ 300 mg/l	4.8	15.0
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	5.0	15.8
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	5.4	16.1
7.	Vegetable Special IIHR 5 g/l	4.7	15.8
8.	Potato Specific Nutrients 4 g/l	4.8	15.4
9.	Control (water sprayed)	4.1	14.9
C.D. at 5%		**0.7**	**NS**

4.4 Number of leaves per stem

The effect of different micronutrients application on number of leaves per stem was found non-significant (Table 4.3). The highest number of leaves per stem (16.1) was observed with the foliar application of zinc sulphate 300 mg/litre + boron 100 mg/litre on potato, while the minimum number of leaves per stem (14.9) was recorded in water sprayed crop (control treatment).

4.5 Leaf weight per hill

The effect of foliar application of micronutrients on leaf weight per hill was recorded significant and showed in Table 4.4. Among all the treatments, combined application of zinc sulphate 300 mg/litre and boron 100 mg/litre gave maximum (190.3 g) leaf weight per hill followed by zinc sulphate 150 mg/litre and boron 50 mg/litre (180.5 g/hill) and minimum values of leaf weight per hill (150.3 g) was found in control treatment.

4.6 Stem weight per hill

Stem weight per hill was recorded significant with the foliar application of different micronutrients applied alone and in combinations on potato crop (Table 4.4). Among all the treatments, combined application of zinc sulphate 300 mg/litre and boron 100 mg/litre gave maximum stem weight per hill (111.3 g) closely followed by zinc sulphate 150 mg/litre and boron 50 mg/litre (108.7 g), while, the minimum values (96.7 g) of stem weight per hill was found in control treatment.

Table 4.4: Effect of foliar application of micronutrients on leaf and stem weight per hill at harvest in potato cv. Kufri Bahar

Sr. No.	Treatments	Leaf weight per hill (g)	Stem weight per hill (g)
1.	Boron 50 mg/l	151.3	97.1
2.	Boron 100 mg/l	154.5	97.9
3.	$ZnSO_4$ 150 mg/l	156.3	100.5
4.	$ZnSO_4$ 300 mg/l	168.7	103.3
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	180.5	108.7
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	190.3	111.3
7.	Vegetable Special IIHR 5 g/l	175.6	105.5
8.	Potato Specific Nutrients 4 g/l	178.2	106.2
9.	Control (water sprayed)	150.3	96.7
C.D. at 5%		**11.3**	**2.6**

4.7 Weight of foliage kg/m^2 and quintal per hectare

Foliage weight was significantly affected due to foliar application of different micronutrients applied alone and in combinations (Table 4.5). The maximum foliage weight (2.28 kg/m^2 and 204.9 q/ha) was recorded in treatment where combined application of zinc sulphate (300 mg/litre) and boron (100 mg/litre) was applied followed by lower dose of zinc sulphate 150 mg/litre + boron 50 mg/litre (2.19 kg/m^2 and 196.8 q/ha) on potato crop, while, the minimum foliage weight (1.96 kg/m^2 and 176.2 q/ha) was recorded in control.

Table 4.5: Effect of foliar application of micronutrients on foliage weight at harvest in potato cv. Kufri Bahar

Sr. No.	Treatments	Weight of foliage (kg/m^2)	Weight of foliage (q/ha)
1	Boron 50 mg/l	2.00	179.7
2	Boron 100 mg/l	2.05	184.8
3	$ZnSO_4$ 150 mg/l	2.08	186.9
4	$ZnSO_4$ 300 mg/l	2.13	191.8
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	2.19	196.8
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	2.28	204.9
7	Vegetable Special IIHR 5 g/l	2.16	194.4
8	Potato Specific Nutrients 4 g/l	2.17	195.3
9	Control (water sprayed)	1.96	176.2
C.D. at 5%		**0.09**	**9.4**

4.8 Number of different grade tubers per plot

Data pertaining to foliar application of micronutrients on number of different grade, *i.e.*, A grade (>75 g), B grade (>50-75 g), C grade (>25-50 g) and D grade (up to 25 g) tubers per plot in potato have been presented in Table 4.6. Number of tubers of A, B and C grades were significantly affected by foliar application of micronutrients, whereas, D grade tubers was not affected by foliar application of various micronutrients. Maximum number of A, B and C grade tuber per plot (168.0, 228.0 and 294.3, respectively) was recorded with foliar application of Zinc sulphate 300 mg/litre + boron 100 mg/litre, which was statistically at par with application of lower dose of zinc sulphate 150 mg/litre + boron 50 mg/litre, while, the minimum number of A, B, C grade tubers per plot (130.7, 194.0 and 252.7, respectively) was obtained in water sprayed crop (control treatment).

Table 4.6: Effect of foliar application of micronutrients on number of different grade tubers per plot at harvest in potato cv. Kufri Bahar

Sr. No.	Treatments	Number of tubers per plot (12.96 m^2)			
		A- grade (> 75 g)	B- grade (>50-75 g)	C- grade (>25-50 g)	D- grade (upto 25 g)
1.	Boron 50 mg/l	132.3	195.3	267.0	312.3
2.	Boron 100 mg/l	137.0	198.0	273.3	311.3
3.	$ZnSO_4$ 150 mg/l	147.3	203.3	279.7	312.0
4.	$ZnSO_4$ 300 mg/l	150.3	208.7	285.3	316.0
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	159.0	218.7	289.3	311.7
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	168.0	228.0	294.3	296.7
7.	Vegetable Special IIHR 5 g/l	149.5	206.3	283.0	314.7
8.	Potato Specific Nutrients 4 g/l	157.7	212.0	284.7	300.0
9.	Control (water sprayed)	130.7	194.0	252.7	318.3
C.D. at 5%		**9.8**	**11.6**	**8.8**	**NS**

4.9 Total number of tubers per plot

Foliar application of micronutrients showed significant variation in total number of tubers per plot as demonstrated in Table 4.7. The combined foliar application of zinc sulphate and boron sprayed at 30, 45 and 60 DAP produced the highest total number of tubers per plot as compared to all other treatments. Maximum number of total tubers per plot (987.0) was obtained in crop received foliar spray of zinc sulphate 300 mg/litre + boron 100 mg/litre, which was statistically at par with foliar application of zinc sulphate 150 mg/litre + boron 50 mg/litre (978.7 tubers per plot). However, the lowest value of total number of tubers was recorded in control treatment.

4.10 Total number of tubers per hectare

Nnumber of tubers per hectare, which has been presented in Table 4.7, was significantly influenced by various treatments. The number of total tubers per hectare was recorded maximum (685417) with combined foliar application of zinc sulphate 300mg/litre and boron 100 mg/litre closely followed by zinc sulphate 150 mg/litre + boron 50 mg/litre (679630). However, the lowest value (621991) of total number of tubers per hectare was recorded in control.

Table: 4.7 Effect of foliar application of micronutrients on total number of tubers per plot and per hectare in potato cv. Kufri Bahar

Sr. No.	Treatments	Total number of tubers per plot	Total number of tuber per hectare
1	Boron 50 mg/l	907.0	629861
2	Boron 100 mg/l	919.7	638657
3	$ZnSO_4$ 150 mg/l	942.3	654398
4	$ZnSO_4$ 300 mg/l	960.3	666898
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	978.7	679630
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	987.0	685417
7	Vegetable Special IIHR 5 g/l	953.5	662153
8	Potato Specific Nutrients 4 g/l	954.3	662731
9	Control (water sprayed)	895.7	621991
C.D. at 5%		**14.2**	**10434**

4.11 Tuber yield per plot of different grades

The data recorded for potato yield of different grades *i.e.*, A grade (>75 g), B grade (50-75 g), C grade (25-50 g) and D grade (up to 25 g) have been demonstrated in the Table 4.8, which illustrated that application of different micronutrients, individually or combined, significantly influenced the yield of different grade tubers. Maximum tuber yield of A- grade (24.02 kg), B-grade (16.43 kg) and C- grade (15.00 kg) per plot was produced with foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre, which was statistically higher over all other treatments except lower dose of zinc sulphate 150 mg/litre +

boron 50 mg/litre. While, lowest yield of A, B and C- grade tubers was recorded with control treatment. However, foliar application of different micronutrients had non-significant effect on D- grade (up to <25 g) tubers yield per plot.

Table: 4.8 Effect of foliar applications of micronutrients on tuber yield of different grade (<25 g, 25-50 g, 50-75 g and > 75 g) in potato cv. Kufri Bahar

Sr. No.	Treatments	Tuber yield per plot (kg)			
		A- grade	B- grade	C- grade	D- grade
1.	Boron 50 mg/l	19.20	14.69	12.87	6.04
2.	Boron 100 mg/l	19.26	14.79	13.63	6.09
3.	$ZnSO_4$ 150 mg/l	20.51	15.00	13.84	5.84
4.	$ZnSO_4$ 300 mg/l	21.45	15.64	14.65	5.62
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	23.08	15.73	14.83	5.22
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	24.02	16.43	15.00	4.51
7.	Vegetable Special IIHR 5 g/l	21.04	15.33	14.36	5.07
8.	Potato Specific Nutrients 4 g/l	22.00	15.40	14.62	4.96
9.	Control (water sprayed)	18.90	14.63	12.84	6.11
C.D. at 5%		**1.75**	**0.72**	**0.33**	**N.S.**

4.12 Total tuber yield per plot and per hectare

The data pertaining to total tuber yield per plot and per hectare with respect to foliar application of different micronutrients has been presented in Table 4.9, which illustrated that foliar application of zinc sulphate 300mg/litre in combination with boron 100 mg/litre produced maximum total tuber yield per plot (59.96 kg) and per hectare (416.4 q) closely followed with application of zinc sulphate 150 mg/litre + boron 50 mg/litre (58.86 kg/plot), while, control treatment (only water sprayed crop) gave minimum total tuber yield per plot (52.48 kg) and total tuber yield per hectare (364.4 q).

Table 4.9 Effect of foliar application of micronutrients on total tuber yield (per plot and per hectare), marketable yield in potato cv. Kufri Bahar

Sr. No.	Treatments	Total yield per plot (kg)	Total yield (q/ha)	Marketable yield (q/ha)
1	Boron 50 mg/l	52.80	366.7	324.7
2	Boron 100 mg/l	53.78	373.4	331.2
3	$ZnSO_4$ 150 mg/l	55.19	383.3	342.7
4	$ZnSO_4$ 300 mg/l	57.36	398.3	359.2
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	58.86	408.7	372.5
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	59.96	416.4	385.0
7	Vegetable Special IIHR 5 g/l	55.81	387.6	352.4
8	Potato Specific Nutrients 4 g/l	56.99	395.8	361.3
9	Control (water sprayed)	52.48	364.4	322.0
C.D. at 5%		**2.49**	**16.1**	**14.5**

4.13 Marketable yield

The data pertaining to marketable yield (q/ha) with respect to foliar application of different micronutrients has been presented in Table 4.9 showed that application of zinc sulphate 300mg/litre in combination with boron 100 mg/litre produced maximum marketable yield (385.0 q/ha), which was statistically at par with lower dose of zinc sulphate 150 mg/litre + boron 50 mg/litre (372.5 q/ha), while, minimum marketable yield (322.0 q/ha) was recorded in control treatment.

4.14 Biological yield (q ha^{-1})

The data on biological yield were observed to be in range of 540.6 to 621.3 q ha^{-1}. Significant variation in biological yield was obtained due to the foliar application of different micronutrients applied three times at 30, 45 and 60 DAP (Table 4.10). The highest biological yield (621.3 q/ha) was obtained with foliar application of zinc sulphate 300 mg/ha + boron 150 kg/ha, which was significantly superior to rest of the treatments except lower dose of zinc sulphate 150 mg/ha + boron 50 mg/ha (605.5 q/ha). The lowest value of the biological yield (540.6 q/ha) was observed in control plot where only water was sprayed on the crop.

Table: 4.10 Effect of foliar application of micronutrients on biological yield, harvest index and percent dry weight of tuber in potato cv. Kufri Bahar

Sr. No.	Treatments	Biological yield (q/ha)	Harvest index	Percent dry weight of uber
1.	Boron 50 mg/l	546.4	67.1	16.05
2.	Boron 100 mg/l	558.3	66.9	16.17
3.	$ZnSO_4$ 150 mg/l	570.2	67.2	16.34
4.	$ZnSO_4$ 300 mg/l	590.1	67.5	16.81
5.	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	605.5	67.5	17.28
6.	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	621.3	67.0	17.38
7.	Vegetable Special IIHR 5 g/l	582.0	66.6	16.50
8.	Potato Specific Nutrients 4 g/l	591.1	67.0	16.74
9.	Control (water sprayed)	540.6	67.4	16.03
C.D. at 5%		**18.6**	**N.S.**	**0.52**

4.15 Harvest index

The harvest index is defined here as total tuber fresh weight (economic yield) expressed as a proportion of total plant fresh weight (biological yield). The data recorded in Table 4.10 showed obviously that foliar application of different micronutrients applied alone or in combinations at 30, 45 and 60 DAP on potato crop had non- significant effect on harvest index percent. The data on harvest index (%) were observed to be in range of 66.6 to 67.5 q ha^{-1}.

4.16 Percent dry weight of tuber

The percent dry weight of tuber was significantly influenced by foliar application of different micronutrients (Table 4.10). The perusal of the data reveals that combined foliar application of zinc sulphate and boron had significantly increased the dry matter content of tuber as compared to other treatments. The maximum percent dry weight (17.38%) of tubers was found with the foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre which was statistically at par with zinc sulphate 150 mg/litre and boron 50 mg/litre (17.28 %), whereas, the minimum value (16.03%) for tubers dry matter percent was recorded with control treatment.

4.17 Economic of treatments

The total cost of cultivation of potato varied from Rs. 1,15,015 to 1,17,839 ha^{-1} due to the use of different micronutrients. The cost of cultivation was the lowest in the control (only water sprays, no application of micronutrients) and highest in the treatment where foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre was applied (Table 4.11). The highest gross return (Rs. 208200) and net returns (Rs. 90361) per hectare were obtained from the crop receiving foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre followed by the crop receiving zinc sulphate 150 mg/litre and boron 50 mg/litre. The crop in control plots paid very less gross and net returns (Rs. 182200 and Rs. 67185 per hectare, respectively) mainly due to low productivity. The highest benefit cost ratio (1.77) was received from the potato crop where zinc sulphate 300 mg/litre and boron 100 mg/litre was applied as foliar application closely followed by treatment zinc sulphate 150 mg/litre + boron 50 mg/litre (1.76).

Generally, from the one year's study it is concluded that potato variety Kufri Bahar when treated with zinc sulphate + boron as foliar application is best for higher productivity and profitability of potato over all other treatments.

Table 4.11: Effect of foliar application of micronutrients on economics of various reatments in potato cv. Kufri Bahar

Sr. No.	Treatments	Common cost (Rs./ha)	Treatment cost (Rs./ha)	Total cost (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
1	Boron 50 mg/l	114815	672	115487	183350	67863	1.59
2	Boron 100 mg/l	114815	1344	116159	186700	70541	1.61
3	$ZnSO_4$ 150 mg/l	114815	840	115655	191650	75995	1.66
4	$ZnSO_4$ 300 mg/l	114815	1680	116495	199150	82655	1.71
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	114815	1512	116327	204350	88023	1.76
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	114815	3024	117839	208200	90361	1.77
7	Vegetable Special IIHR 5 g/l	114815	1706	116521	193800	77279	1.66
8	Potato Specific Nutrients 4 g/l	114815	1365	116180	197900	81720	1.70
9	Control (water sprayed)	114815	200	115015	182200	67185	1.58

Boric acid: Rs. 1200/kg, Zinc sulphate: Rs. 600/kg, Vegetable Special IIHR: Rs. 175/kg,
Potato Specific Nutrients: 175/kg, Seed potato: 1000/q, Potato sale: Rs. 500/q,

CHAPTER–V

DISCUSSION

Potato is a short season crop with a high yielding potential. Hence, it needs application of heavy amount of macro and micro nutrients to exploit the high yielding potentiality of the crop. The continuous and imbalance use of fertilizers is adversely affecting the sustainability of crop production besides causing environmental pollution. The major issue for the sustainable crop production is management of micronutrients besides the major nutrients. However, since major nutrients alone cannot meet the total nutrient need of modern agriculture, integrated use of macro and micro nutrients will be the need of the time. Keeping this in view, the results of the present investigation carried out to evaluate the "Effect of foliar application of micronutrients on potato production" have been explained in previous chapter. During presentation of the experimental results, significant variation was noticed due to the experimental treatments. Here in this chapter, the efforts have been made to create cause and association among various parameters, which were found to be significantly influenced by foliar application of different micronutrients in potato. In doing so, the relevant findings of researchers have also been quoted in order to support the results of present study.

The data recorded on plant emergence, plant height, number of shoots per hill, number of leaves per stem, leaf weight per hill at harvest, stem weight per hill at harvest, foliage weight, tuber number and tuber yield in different grades, total tuber yield, marketable yield, harvest index, percent dry weight of tuber and economics of various treatments have been interpreted and described in this chapter under the following headings:

5.1 Growth parameters

The favourable effect of micronutrients on plant growth might be due to its important role in many physiological processes and cellular functions within the plants. In addition, they also play an essential role in improving plant growth, through the biosynthesis of endogenous hormones, which is responsible for better plant growth (Hansch and Mendel, 2009).

5.1.1 Plant emergence percent

Emergence is a developmental stage, when first leaves of plant emerge from the soil. After two weeks of planting, the plants started emerge out from several tubers in each plot. Within a month, the emergence was almost completed. Emergence count was done at 30 days after planting during the year 2016-17. The data pertaining to the emergence percent have been presented in Table 4.1, which showed that plant emergence percent of potato at 30 DAP did not significantly influenced by various treatments. It might be due to the fact that food material already stored in the seed tubers gave initial boost to the emerging plants, furthermore, the application of micronutrients was started at 30 DAP and has no effect on plant emergence. Bari *et al*. (2001) reported that plant emergence was not influenced by application of micronutrients. The results of the present study are in agreement with the findings of Singh and Lal (2012) and Verma *et al.* (2013), they reported that the emergence of seed tubers in potato was not affected by fertilizer treatments.

5.1.2 Plant height (cm)

As micronutrients, mainly zinc (Zn) and boron (B) have specific role for the development of quality tubers. However, these elements are required in trace amount for different physiological processes of potato crop. Zinc is involved in hormone biosynthesis, cytoplasm synthesis, activation and function of different enzymes, protein synthesis etc. Boron (B) is a micronutrient necessary for plant growth. It plays an active role in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, good pollination and fruit set, seed development, synthesis of amino acids and proteins and regulation of carbohydrate metabolism. Boron also helps in water and nutrient transportation from root to shoot (Ziaeyan *et al.*, 2009). The plant height was significantly influenced with the foliar application of different micronutrients. The tallest plant at 60, 75 and 90 DAP was recorded in plots where combined of zinc sulphate 300 mg/litre and boron 100 mg/litre applied three times at 30, 45 and 60 days after planting (Table 4.2 and Figure 2). This might be because of these micronutrients (zinc and boron) play an active role in cell wall synthesis, cell division, cell development and activation of different enzymes which finally increased the plant height. Whereas, plant height recorded at 45 DAP was not influenced by different micronutrients application (Table 4.1). This may be due to that fact that micronutrients after their application takes some time for boosting the growth of the potato plant. These results are in confirmity with the findings of Kiran *et al.* (2010) and Rahman *et al.* (2011).

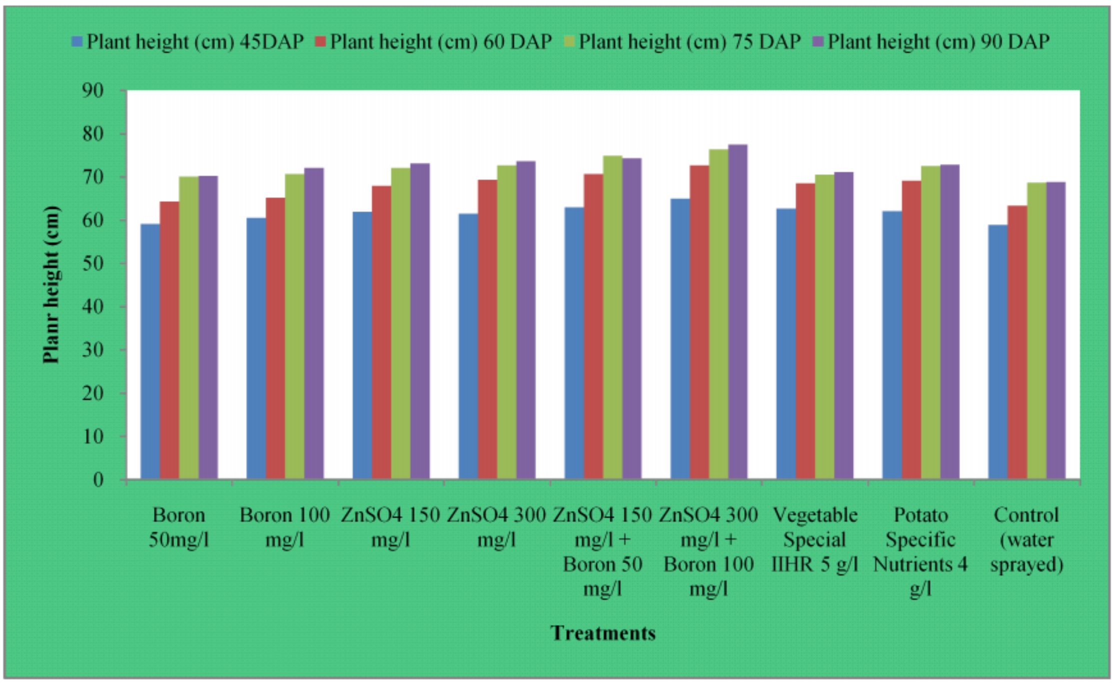


Figure 2: Effect of foliar application of micronutrients on plant height at 45, 60, 75 and 90 DAP in potato

5.1.2 Number of stems per hill and number of leaves per stem

Number of stems per hill was recorded maximum in potato crop which received foliar application of micronutrients mixture of zinc sulphate 300 mg/litre and boron 100 mg/litre followed by treatments with zinc sulphate 150 mg/litre and boron 50 mg/litre (Figure 3). This is due to increased rate of mineralization, which released phytohormones that stimulated plant growth and photosynthetic processes which enhanced number of main stems. These, results are in harmony with those reported by Ahmed *et al*. (2015) and Kumar *et al*. (2017) on potato. Present results also indicated that influence of foliar application of micronutrients on number of leaves per stem (Table 4.3) was found non-significant. Similar findings were obtained by application of zinc (Kiran *et al*., 2010) and micronutrients mixture (Hatwar *et al*., 2003).

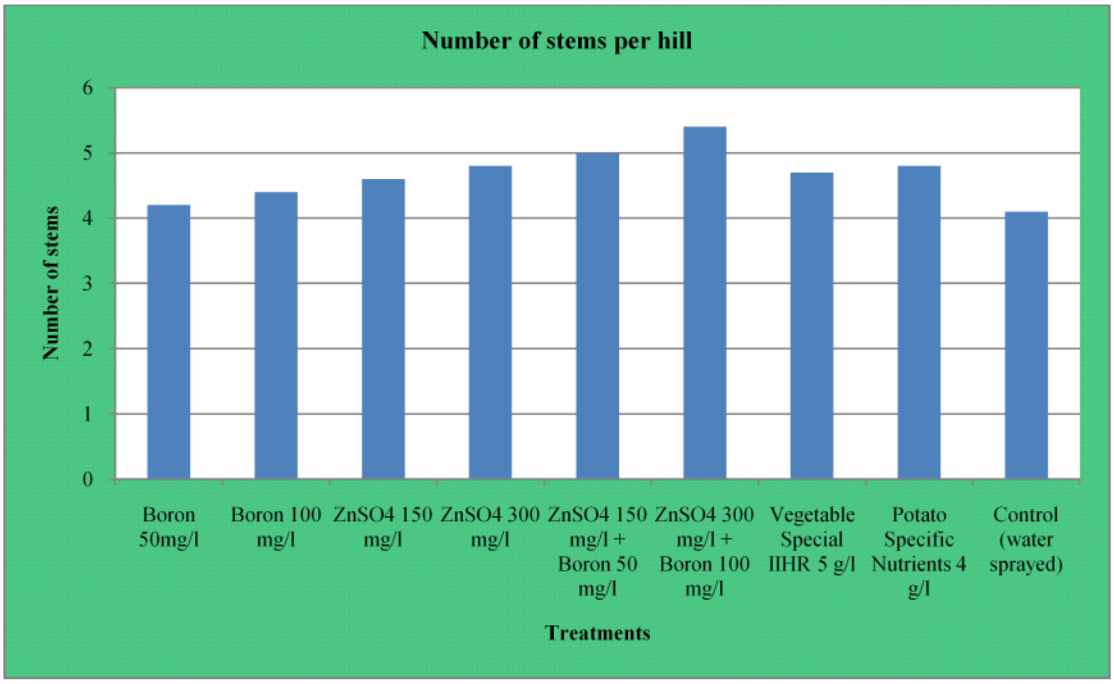


Figure 3: Effect of foliar application of micronutrients on number of stems per hill in potato

5.1.3 Leaf and stem weight per hill (g)

Leaf and stem weight per hill was recorded at harvesting time. Data revealed that combined zinc sulphate and boron application gave significant higher results on weight of leaf and stem per hill. Effect of foliar application of micronutrients on leaf and stem weight per hill has been shown in Table 4.4. The maximum leaf and stem weight per hill was observed in treatment where the zinc sulphate 300 mg/litre and boron 100 mg/litre was applied, which was statistically at par with treatment zinc sulphate 150 mg/litre and boron 50 mg/litre application (Table 4.4 and Figure 4). Higher leaf and stem fresh weight can be attributed to more number of green leaves and stems per plant that enhancement fresh weight of leaves and stems per hill. Weight of potato leaves and stems per hill increased with the application of zinc sulphate and boron because of zinc improves the rate of photosynthesis as well as tryptophan content (precursor of IAA) may be due to activation of key enzyme of photosynthesis, *i.e.*, ribulose-1, 5- diphosphate carboxylase. Both these factors helped to increase plant growth, which is directly correlated with fresh weight of plant. These findings were partially in agreement with the results of Ahmed *et al*. (2011) who reported that foliar spray of zinc increased fresh weight of potato plant. Whereas, El-Haddad and Awad (2007) reported that fresh weight of leaves and stems in potato increased with the application of micronutrients (Zn, B, Fe and Mn).

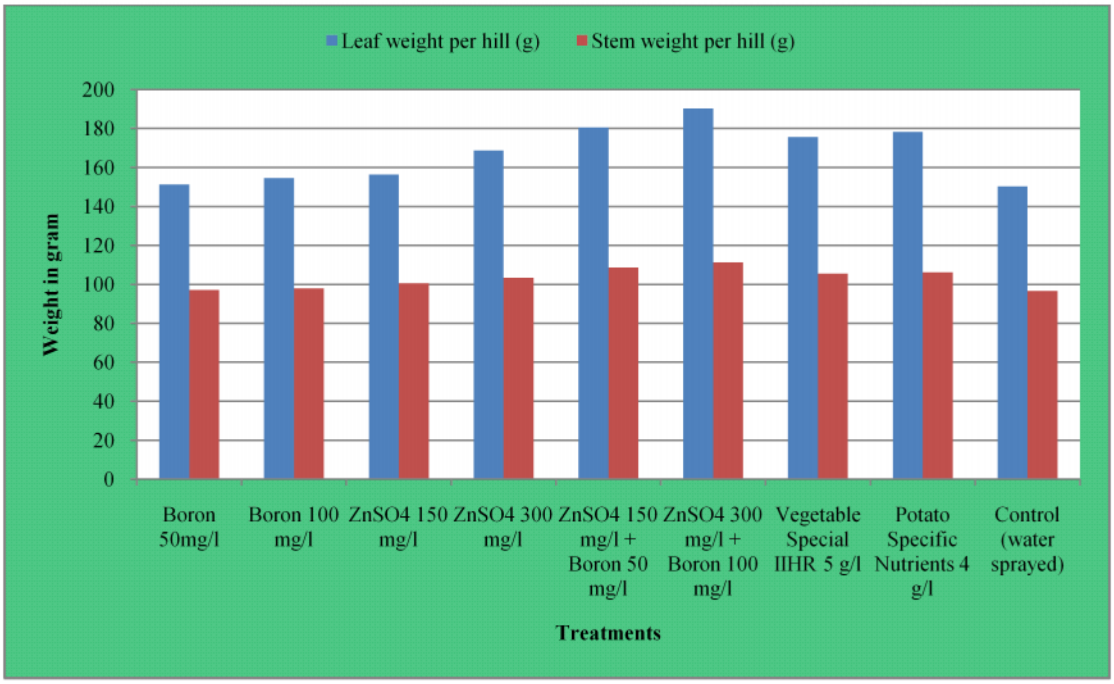


Figure 4: Effect of foliar application of micronutrients on leaf and stem weight per hill at harvest in potato

5.1.4 Foliage weight

Weight of foliage was significantly differed due to foliar application of different micronutrients applied alone or in combinations on potato crop (Table 4.5). The foliage weight (per square meter and per hectare) was recorded maximum in treatment where the zinc sulphate (300 mg/litre) and boron (100 mg/litre) was applied in combination at 30, 45 and 60 DAP followed by lower dose of zinc sulphate 150 mg/litre + boron 50 mg/litre on potato crop (Figure 5). The foliage weight is the combined result of leaves weight and stems weight. The higher foliage weight might be due to maximum number and weight of leaves and stems under these treatments, which increased the foliage weight per square metre and ultimately per hectare. These results are in harmony with the findings of Rahman *et al*. (2011), Ahmed *et al*. (2011) and Taheri *et al*. (2012).

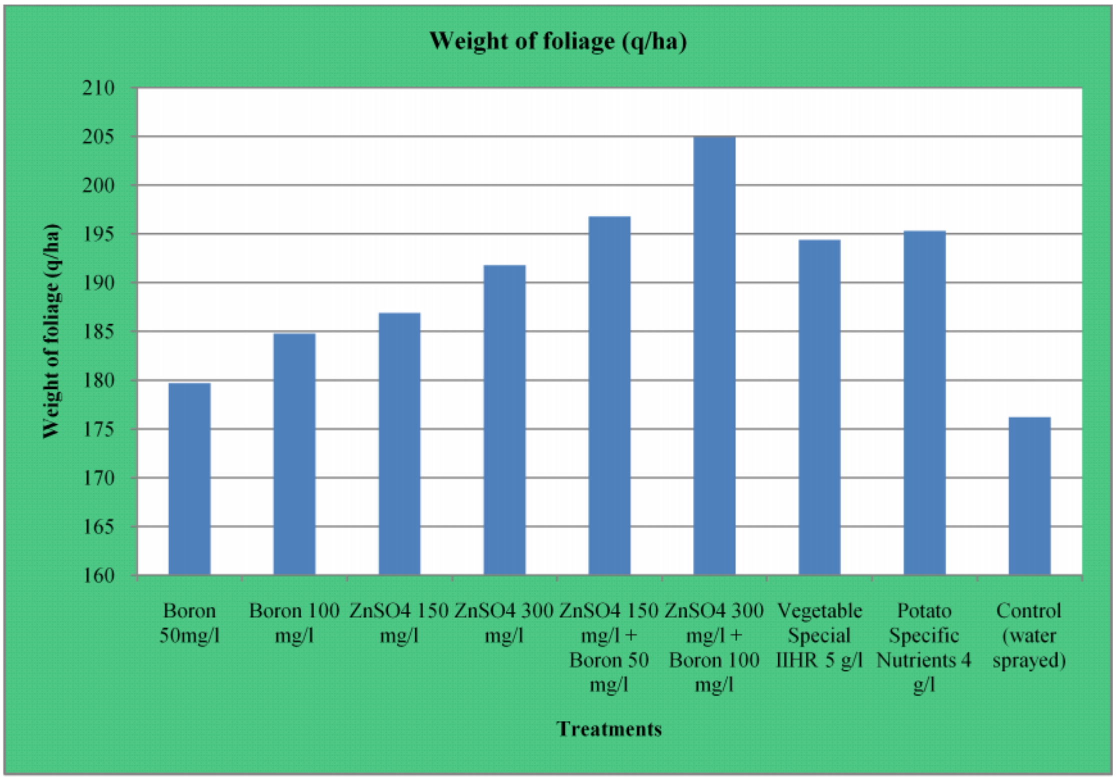


Figure 5: Effect of foliar application of micronutrients on foliage weight at harvest in potato

5.2 Yield parameters

5.2.1 Number of different grade tubers

Data pertaining to foliar application of micronutrients on number of different grade, *i.e.*, A grade (>75 g), B grade (>50-75 g), C grade (>25-50 g) and D grade (up to 25 g) tubers per plot in potato have been presented in Table 4.6 and Figure 6. Number of A, B and C grade tubers was significantly affected by foliar application of different micronutrients and maximum number was recorded with foliar application of Zinc sulphate 300mg/litre + boron100 mg/litre closely followed with zinc sulphate 150 mg/litre + boron 50 mg/litre, whereas, D grade tubers was not affected by foliar application of various micronutrients. The increase in A, B and C-grade tubers with foliar application of zinc sulphate and boron, might be cause of more vegetative growth which produced more photosynthates and resulted more number of different grade tubers per plot and per hectare. Raghav and Singh (2003) found that the highest number and weight of medium and large tubers were recorded with basal application of zinc at 8 and 10 kg/ha, respectively. The maximum tuber yield (32.21 t/ha) was obtained with soil application of zinc sulphate at 8 kg/ha as compared to foliar application of zinc sulphate These results were also confirmed by the findings of *Bari et al*. (2001), Al-Jobori and Al-Hadithy (2014), Taheri *et al*. (2012) and Mousavi *et al*. (2007) in potato.

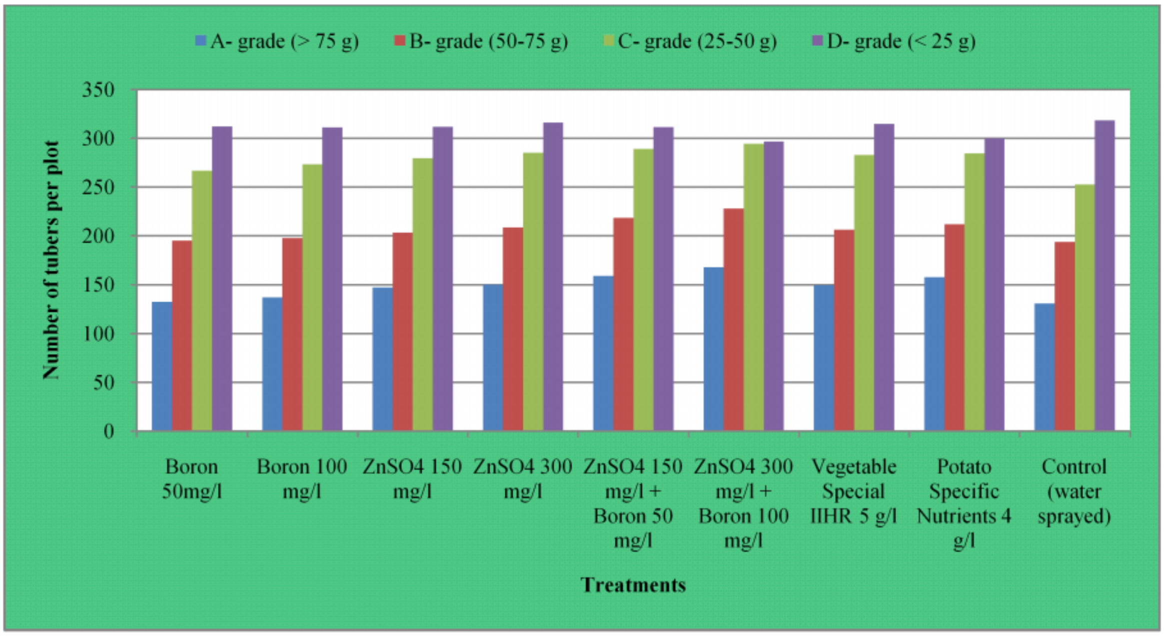


Figure 6: Effect of foliar application of micronutrients on number of different grade tubers per plot at harvest in potato

5.2.2 Total number of tubers

Effect of foliar application of different micronutrients on total number of tubers per plot and per hectare has been presented in Table 4.7 and Figure 7. The number of tubers were recorded maximum with combined application of zinc sulphate 300 mg/litre and boron 100 mg/litre followed by lower dose of 150 mg/litre zinc sulphate and boron 50 mg/litre, which were significantly higher over to other treatments.

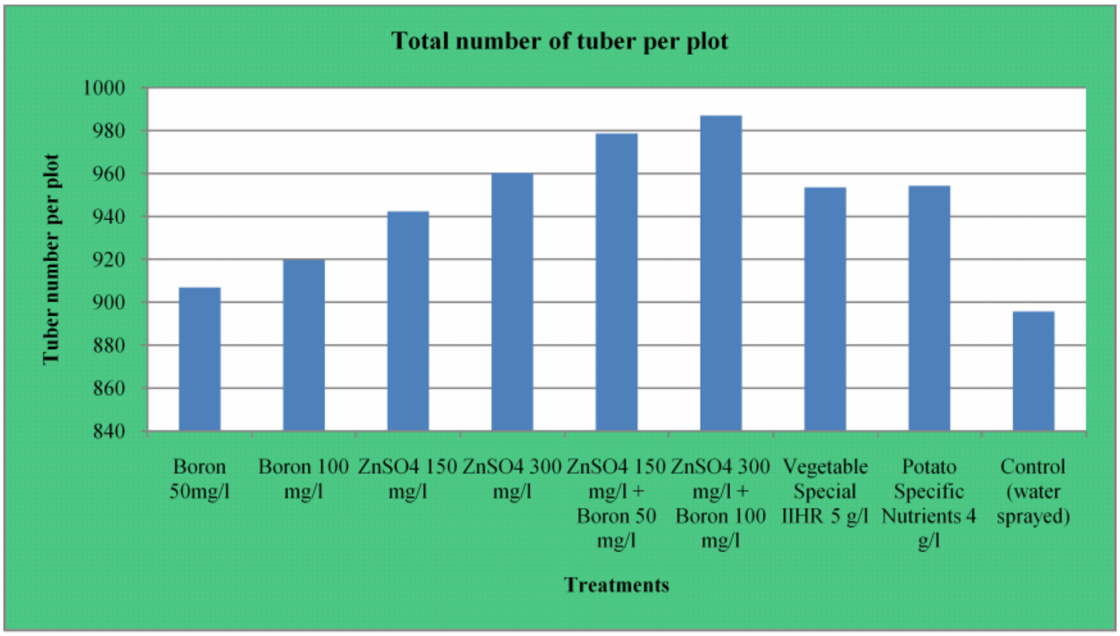


Figure 7: Effect of foliar application of micronutrients on total number of tubers per plot at harvest in potato

Total number of tubers of potato plant increased with the combined application of zinc sulphate and boron due to fact that zinc affected the hormonal status of potato plant. On the other hands, zinc improved the IAA/ABA and cytokinin/ABA ratio, which is responsible for formation and growth of stolons. This is mainly due to decrease in ABA content with increase in gibberellins content of plant (Puzina, 2004). These results were confirmed by the findings of *Bari et al*. (2001), Mousavi *et al*. (2007), Taheri *et al*. (2012) and Al-Jobori and Al-Hadithy (2014) in potato.

5.2.3 Tuber yield of different grades

The data recorded on potato yield of different grades *i.e.*, A grade (>75 g), B grade (50-75 g), C grade (25-50 g) and D grade (up to 25 g) have been demonstrated in the Table 4.8 and Figure 8. The obtained results showed that application of different micronutrients, individually or combined, significantly influence the yield of different grade tuber. Maximum yield of A, B and C- grade per plot was produced with foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre, which was statistically higher than all other treatments except zinc sulphate 150 mg/litre + boron 50 mg/litre. However, foliar application of different micronutrients had non-significant effect on D- grade (up to <25 g) tuber yield (Figure 8). The improved vegetative growth of plant and yield attributing characters due to zinc and boron application has also direct relation in improvement in tuber development and increase in tuber yield of medium and large size. The results were in agreement with the finding of Parmar *et al*. (2016) and Thakare *et al*. (2007).

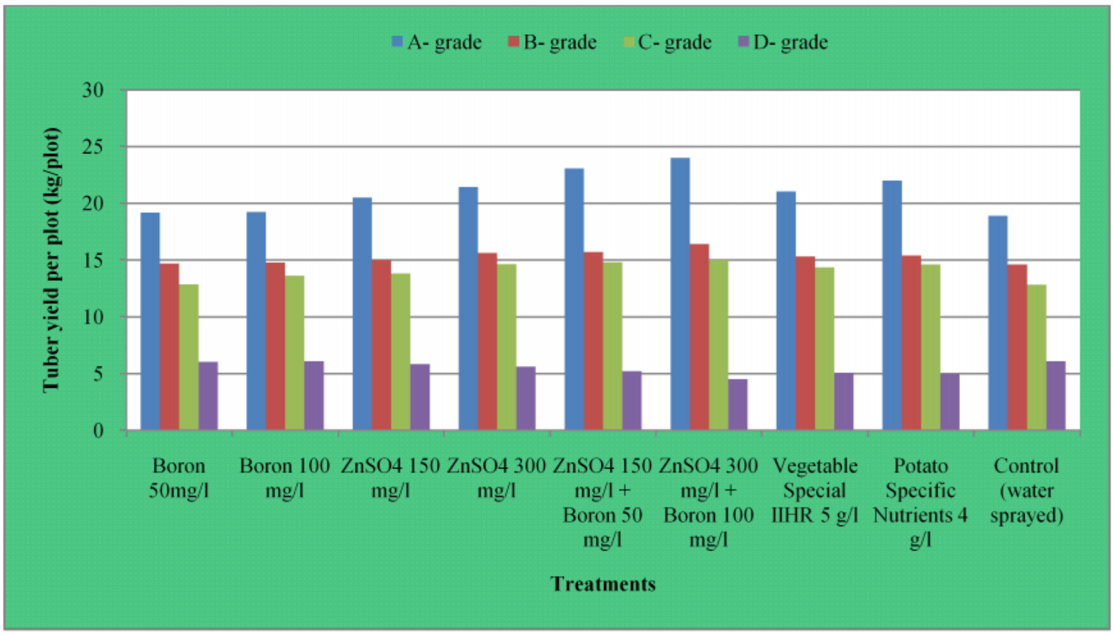


Figure 8: Effect of foliar application of micronutrients on tuber yield of different grade, *i.e.*, A-grade (>75 g), B-grade (>50-75 g), C-grade (>25-50 g) and D-grade (up to 25 g) in potato

5.2.4 Marketable yield and total tuber yield

The results pertaining to marketable yield and total tuber yield per hectare was significantly influenced with the foliar application of micronutrients on potato as presented in Table 4.9. The maximum marketable yield and total tuber yield per hectare was recorded with foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre sprayed at 30, 45 and 60 DAP, which was statistically higher than all other treatments except zinc sulphate 150 mg/litre + boron 50 mg/litre (Figure 9). The increase in marketable as well as total tuber yield might be attributed to the role of zinc in regulating the permeability of cell wall, which allowed the mobilization of more water and minerals to sink resulting in increase the size of tuber and ultimately increased the tuber yield. Zinc as an essential catalyst in the synthesis of auxin from tryptophan would have encouraged the auxin biosynthesis in the active sink, which would lead to higher transport and accumulation of photosynthates in the tuber. The improved vegetative growth of plant and yield attributing characters due to foliar application of zinc sulphate + boron has also direct relation in improvement in tuber development and increase in tuber yield. The results were in agreement with the finding of Bari *et al*. (2001) Thakare *et al*. (2007), Ahmed *et al*. (2011) and Parmar *et al*. (2016).

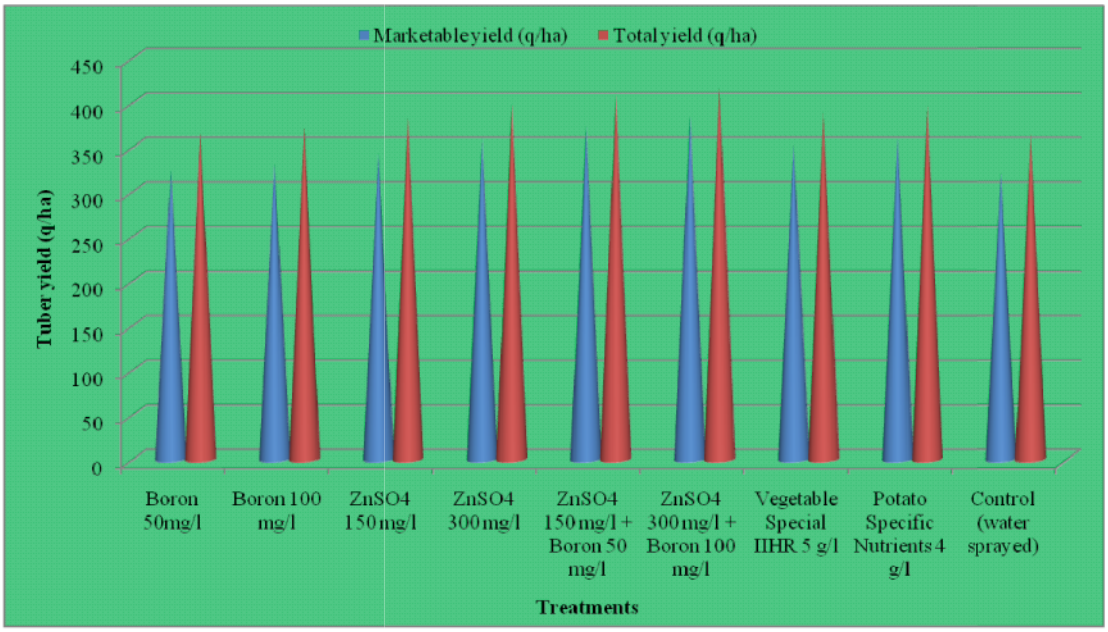


Figure 9: Effect of foliar application of micronutrients on marketable and total tuber yield (q/ha) in potato

5.2.5 Biological yield and harvest index

Significant variation in biological yield was obtained due to the foliar application of different micronutrients applied three times at 30, 45 and 60 DAP (Table 4.10). The highest biological yield was obtained with foliar application of zinc sulphate 300 mg/ha + boron 150 kg/ha, which was significantly superior to rest of the treatments except lower dose of zinc sulphate 150 mg/ha + boron 50 mg/ha. The highest biological yield might be due to more fresh foliage weight and tuber yield under these treatments. The superiority of crop performances under foliar application of micronutrients could be attributed to the beneficial effect of combined use of zinc sulphate and boron in precise proportions that led to increased biological yield (Singh and Kushwah, 2006). Mohapatra *et al*. (2008), Zaman *et al*. (2008), Narayan *et al*. (2013) as well as Narayan *et al*. (2014) also reported similar type of findings.

The harvest index is defined here as total tuber fresh weight (economic yield) expressed as a proportion of total plant fresh weight (biological yield). The data recorded in Table 4.10 showed obviously that foliar application of different micronutrients applied alone or in combinations at 30, 45 and 60 DAP on potato crop had non- significant effect on harvest index percent. The data on harvest index (%) were observed to be in range of 66.6 to 67.5 q ha^{-1}.

5.2.6 Percent dry weight of tuber

Dry matter content is a very important quality parameter of potato tubers when they used for processing potato product including chips, French fries, a wide range of frozen and chilled products. The high dry matter content led to a high yield of chips and French fries, low fat content results a high crispness level for final product. Also, dry matter content has proved the most practical property of potato for predicting cooking behavior.

Foliar application of micronutrient mixture significantly increased dry matter percentage in potato tubers (Table 4.10 and Figure 10).

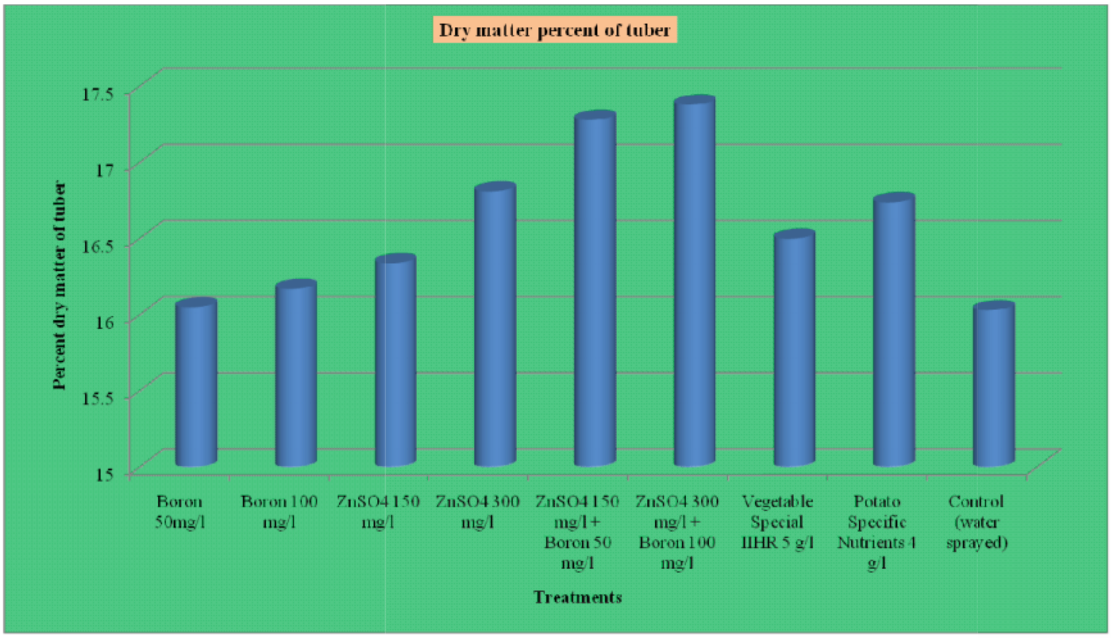


Figure 10: Effect of foliar application of micronutrients on percent dry matter of tubers in potato

The highest result of dry matter content was achieved by foliar application of zinc sulphate and boron (300+100 mg/litre) closely followed by treatment zinc sulphate 150 mg/litre + boron 50 mg/litre. It might be due to enhance assimilates partitioning and synchronization of physiological processes as movement of carbohydrates from leaves to tubers. The effects of foliar spray of zinc and boron may be attributed to their role on transport of photosynthesis to parts of storage (tubers), and also its role in synthesis of proteins and regulation of carbohydrate metabolism (Mengel and Kirkby, 2001 and Trehan and Grewal, 1981). These results are in accordance with that obtained by Bari *et al.*, (2001) and El-Banna and Abd El-Salsm (2005), Yourtchi *et al*. (2013) and Narayan *et al*. (2014) on potato.

5.2.7 Economics of treatments

The cost of cultivation of potato varied due to the use of different micronutrients. The cost of cultivation was the lowest in the control (only water sprays and no application of micronutrients) and highest in the treatment where foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre was applied (Table 4.11 and Figure 10). The highest gross and net returns per hectare were obtained from the crop receiving foliar application of zinc 300 mg/litre in combination with boron 100 mg/litre sprayed three times at 30, 45 and 60 DAP followed by the crop receiving zinc 150 mg/litre and boron 50 mg/litre, might be due to high economic yield. The crop at control plots paid very low gross and net returns mainly due to low productivity. The highest benefit cost ratio (1.77) was received from the potato crop where zinc sulphate 300 mg/litre and boron 100 mg/litre was applied as foliar application closely followed by treatment zinc 150 mg/litre + boron 50 mg/litre (1.76). Narayan *et al*. (2014) reported that the maximum benefit: cost ratio and net returns were evidenced with 75% RDF + 8 t ha^{-1}vermicompost + Azotobacter and PSB. Kumar *et al*. (2017) also revealed that maximum benefit-cost ratio invested were obtained by applying Tata geo green @ 3.75 t ha^{-1} along with 75% recommended dose of chemical fertilizers. As well as Ahmed *et al*. (2011) indicated that combined use of chemical fertilizer with manure could increase economic returns compared with fertilizer or manure alone.

Generally, from the one year's study it is concluded that potato variety Kufri Bahar when treated with zinc sulphate + boron as foliar application three times at 30, 45 and 60 days after planting is best for higher productivity and profitability of potato compare to all other treatments.

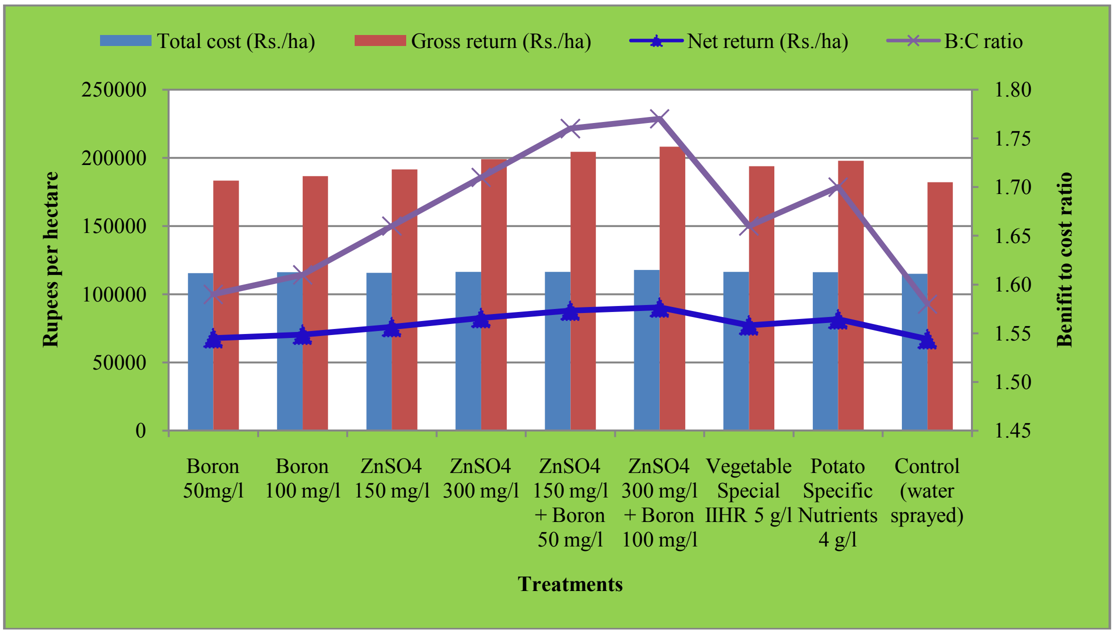


Figure 11: Effect of foliar application of micronutrients on economics of different treatments

CHAPTER–VI

SUMMARY AND CONCLUSION

Potato is undoubtedly one of the most important crop and also a highly input intensive crop, fertilization with macro and micro nutrients plays an important role for its higher production. But soil application of major nutrients (N,P,K) not fulfill the nutritional requirements of potato crop, hence, supplementing the nutrients through foliar spray of micro nutrients like zinc and boron has become necessary to sustain production and to improved food quality. Thus, a wide gap has been created between the nutrients removed from the soil and the nutrients applied. This gap can be bridged with the foliar spray of nutrients on the crop.

Keeping in view the importance of foliar spray of micronutrients, the present study was carried out at the research farm of Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during winter (*Rabi*) season of the year 2016-17 with the objectives- To study the effect of foliar application of micronutrients on growth and yield of potato and to work out the economics of different treatment combinations. The potato variety used for the investigation was "Kufri Bahar" which was grown with nine treatments. All the treatment combinations were evaluated for plant growth and tuber yield characters with three replications to assess the effect of foliar application of micro nutrients on production of potato. The salient achievements of these experiments are as under:

- The foliar application of the micronutrients like boron, zinc, vegetable special IIHR and potato specific nutrients formulation applied at 30, 45 and 60 days after planting did not result into any significant effect on plant emergence percent recorded at 30 days after planting.
- The foliar application of different micronutrients on potato crop resulted non significant effect on plant height recorded at 45 days after planting. However, zinc sulphate ($ZnSO_4$) 300 mg/litre + boron 100 mg/litre resulted into significantly higher plant height at 60 days after planting over control. It was found at par with treatment zinc sulphate 150 mg/litre + boron 150 mg/litre. Similar trends also have been observed on plant height at 75 and 90 days after planting. Minimum plant height was recorded in control treatment under all the growth stages of crop.
- Foliar application of zinc sulphate 300 mg/litre + boron 100 mg/litre and zinc sulphate 150 mg/litre + boron 50 mg/litre at 30, 45 and 60 days after planting in potato resulted into significantly higher number of stems per hill as compared to control and other treatments. Minimum number of stems per hill was recorded in control treatment.
- Number of leaves per stem was not affected by any of the foliar spray of micro nutrients in potato. The range of number of leaves per stem was 14.9 to 16.1.

- Foliar application of zinc sulphate 300 mg/litre + boron 100 mg/litre when applied three successive intervals, i.e., at 30, 45 and 60 days after planting recorded maximum leaves and stems weight per hill closely followed by zinc sulphate 150 mg/litre + boron 50 mg/litre in potato. Minimum leaves and stems weight was recorded in control treatment where only water was sprayed.
- Foliage weight of potato was significantly affected by foliar spray of different micronutrients applied at 30, 45 and 60 days after planting. The foliar spray of zinc sulphate 300 mg/litre + boron 100 mg/litre on potato resulted maximum foliage weight per meter square as well as quintal per hectare closely followed by application of zinc sulphate 150 mg/litre + boron 50 mg/litre, while, minimum values were recorded in control treatment.
- Foliar spray of ZnSO4 300 mg/litre + Boron 100 mg/litre resulted into higher number of tubers per plot (12.96 m^2 area) in different sizes, i.e., > 75 g (A-grade), > 50-75 g (B-grade) and > 25-50 g (C-grade) closely followed by ZnSO4 150 mg/litre + Boron 500 mg/litre over all other treatments. However, number of tuber per plot of size < 25 cm (D-grade) was found non-significant with foliar spray of different micronutrients.
- Foliar application of micronutrients with a combination of zinc sulphate and boron (300+ 100 mg/litre or 150 + 50 mg/litre) applied at 30, 45 and 60 days after planting in potato resulted into significantly higher total tuber yield per plot and per hectare as compared to control and other treatments.
- Marketable yield was recorded maximum with foliar application of ZnSO4 300 mg/litre in combination with boron 100 mg/litre applied at subsequent intervals at 30, 45 and 60 days after planting in potato, which was closely followed by ZnSO4 150 mg/litre + boron 50 mg/litre. Minimum marketable yield was noticed in control treatment.
- Foliar application of micronutrients with a combination of zinc sulphate and boron (300+ 100 mg/litre and 150 + 50 mg/litre) applied at 30, 45 and 60 days after planting in potato resulted into significantly higher biological yield per hectare as compared to control and other treatments.
- Harvest index of potato was not affected by any of the foliar spray of micronutrients on potato. Harvest index of potato was in range 66.6 to 67.4.
- Percent dry matter of tubers was recorded significant maximum in potato crop sprayed with zinc sulphate 300 mg/litre + boron 100 mg/litre and zinc sulphate 150 mg/litre + boron 50 mg/litre at 30, 45 and 60 days after planting in potato as compared to all other treatments. Minimum dry matter percent of tubers was recorded in control treatment where only water was sprayed on crop.
- Foliar spray of zinc sulphate 300 mg/litre + boron 100 mg/litre resulted into highest cost of cultivation, gross and net returns of per hectare with highest benefit: cost ratio of 1.77

closely followed by treatment zinc sulphate+ boron (150 +50 mg/litre), while the minimum profit was noticed in control.

CONCLUSION

Based on the findings of one season study conducted during *Rabi* season 2016-17, it may be concluded that foliar application of zinc sulphate 300 mg/litre + Boron 100 mg/litre applied at 30, 45 and 60 days after planting along with recommended dose of fertilizers (NPK: 150:50:100 kg/ha) gave highest tuber yield (416 q/ha), net return (Rs. 90361 ha-1) and benefit cost ratio (1.77) in potato cv. Kufri Bahar.

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APPENDIX-I
Cost of cultivation of potato per hectare

Sr. No.	Operations/Particulars	No. of units	Rate (Rs.)/unit	Value in Rs.
COMMON COST				
1	Preparatory tillage	4	1000 ha^{-1}	4000
2	Pre-sowing irrigation	1	1000 ha^{-1}	1000
3	Sowing	1	2500 ha^{-1}	2500
4	Seed	30 q	1000 q^{-1}	30000
5	Farmyard manure (FYM)	50 ton	75 ton^{-1}	3750
6	Fertilizer application (Labour)	2	350 $labour^{-1}$	700
7	Urea	325 kg	5.70 kg^{-1}	1853
8	SSP	312 kg	7.00 kg^{-1}	2184
9	MOP	166 kg	11.00 kg-^{1}	1826
10	Irrigation	7	125 ha^{-1}	875
11	Labour for irrigation	7	875 $labour^{-1}$	6125
12	Hoeing and weeding/ herbicide	1	3000	3000
13	Plant protection	1	2000 ha^{-1}	2000
14	Harvesting	35	350 $labour^{-1}$	12250
15	Miscellaneous	-	-	1250
16	Working capital (1 to 15)			**73313**
17	Interest on working capital @ 12% per annum	6 month	-	4400
18	Transportation	-	10000 ha^{-1}	10000
19	Management charge (10% of 16)			7331
20	Risk charges (10%)			7331
21	Rental value of land	6 months	25000/ha/year	12500
			Total	**114815**

Treatment cost per hectare				
Sr. No.	**Operations/Particulars**	**Dose kg ha^{-1}**	**Rate**	**Value in Rs.**
1	Boron 50mg/l	Boric Acid 0.560	1200 kg^{-1}	672.0
2	Boron 100 mg/l	1.120	1200 kg^{-1}	1344.0
3	$ZnSO_4$ 150 mg/l	1.400	600 kg^{-1}	840.0
4	$ZnSO_4$ 300 mg/l	2.800	600 kg^{-1}	1680.0
5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	1.400 + 0.560	600 + 1200 kg^{-1}	840.0 +672.0 = 1512.0
6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	2.800 + 1.120	600 + 1200 kg^{-1}	1680+1344 = 3024
7	Vegetable Special IIHR 5 g/l	9.750	175 kg^{-1}	1706.25
8	Potato Specific Nutrients 4 g/l	7.800	175 kg^{-1}	1365.0
9	Control (water sprayed)	-	-	-

OUTPUTS	
Particulars	**Price Rs./unit**
Tuber yield	600/q

APPENDIX-II

Sr. No.	Treatments	Common cost (Rs./ha)	Treatment cost (Rs./ha)	Total cost (Rs./ha)	Yield (q/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1	Boron 50mg/l	114815	672	115487	366.7	183350	67863	1.59
T_2	Boron 100 mg/l	114815	1344	116159	373.4	186700	70541	1.61
T_3	$ZnSO_4$ 150 mg/l	114815	840	115655	383.3	191650	75995	1.66
T_4	$ZnSO_4$ 300 mg/l	114815	1680	116495	398.3	199150	82655	1.71
T_5	$ZnSO_4$ 150 mg/l + Boron 50 mg/l	114815	1512	116327	408.7	204350	88023	1.76
T_6	$ZnSO_4$ 300 mg/l + Boron 100 mg/l	114815	3024	117839	416.4	208200	90361	1.77
T_7	Vegetable Special IIHR 5 g/l	114815	1706.25	116521.25	387.6	193800	77278.75	1.66
T_8	Potato Specific Nutrients 4 g/l	114815	1365	116180	395.8	197900	81720	1.70
T_{19}	Control (water sprayed)	114815	200	115015	364.4	182200	67185	1.58

ABSTRACT

Title of thesis	**:**	Effect of foliar application of micronutrients on potato production
Name of degree holder	**:**	Ziauddin Hamidi
Admission number	**:**	2015A148M
Title of degree	**:**	Master of Science
Name and address of major advisor	**:**	Dr. V.P.S. Panghal Assistant Scientist (Vegetable Science) CCS Haryana Agricultural University, Hisar
Degree awarding university/ institute	**:**	CCS Haryana Agricultural University, Hisar
Year of award of degree	**:**	2018
Major subject	**:**	Horticulture-Vegetable Science
Total number of pages in the thesis	**:**	43 + v + II
Number of words in abstract	**:**	353

Keywords: Potato, foliar application, micronutrients, zinc sulphate, boron, tuber yield

A field experiment was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during *Rabi* season of 2016-17 to study the effect of foliar application of micronutrients on potato production. The treatment comprising different micronutrients like boron (50 and 100 mg/l), zinc sulpphate (150 and 300 mg/l) alone and their combinations zinc sulphate+ boron (150+50 and 300+100 mg/l), Vegetable Special IIHR (5 g/l), Potato Specific Nutrients (4 g/l) and control (water sprayed). The above micronutrients along with sticker were sprayed at 30, 45 and 60 days after planting. The total nine treatments including control were laid out in randomized block design with three replications. The tubers were planted on ridges at a spacing of 60x20 cm in a plot size of 4.6x4.0 m. The recommended dose of fertilizer (NPK: 150:50:100 kg/ha) was applied as bend placement at the time of planting. The obtained results clearly indicate that applying $ZnSo_4$ in combination with boron significantly increased the plant growth, yield and quality traits in tubers as compared to control. The foliar spay of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre sprayed at three times in 15 days interval (30, 45 and 60 GAP) gave the superior results pertaining to all measured parameters than other treatments, which was closely followed by application of zinc sulphate 150 mg/litre+ boron 500 mg/litre. The maximum plant height at 60, 75 and 90 days after planting (72.7, 76.4, 77.5 cm), number of stems per hill, number of tubers per plot of size >75 g (158.0) >50-75 g (168.0) >25-50 g (269.0), upto 25 g (386.0), total tuber yield (416.4 q/ha) and percent dry weight of tuber (17.38%) was recorded with foliar application of zinc sulphate 300 mg/litre+ boron 100 mg/litre closely followed with lower dose of zinc sulphate 150 mg/litre+ boron 50 mg/litre. The maximum gross and net return (Rs. 208200 and 90361 ha^{-1}, respectively) and benefit to cost ratio (1.77) was recorded in potato crops which received foliar application of zinc sulphate (300 mg/litre) + boron (100 mg/litre) sprayed three successive interval at 30, 45 and 60 days after planting. From the present study it is suggested that besides recommended dose of fertilizer, foliar application of zinc sulphate 300 mg/litre in combination with boron 100 mg/litre gave the highest productivity and profitability in Kufri Bahar cultivar of potato.

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M.Sc.	CCS HAU, Hisar	2018	66%	Vegetable Science
B.Sc.	Balkh University	2009	63%	All Agricultural Subjects
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Co-curricular activities: Reading books, internet browsing and playing volleyball

Work experience:

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Dated:

Place: Hisar **(Ziauddin Hamidi)**

UNDERTAKING OF COPY RIGHT

I, Ziauddin Hamidi, Admission Number 2015A148M, undertake that I give copy right of my thesis entitled, "Effect of foliar application of micronutrients on potato production" to the CCS Haryana Agricultural University, Hisar.

I also undertake the patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of CCS Haryana Agricultural University, Hisar.

Signature of student
(Ziauddin Hamidi)