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Effect of foliar application of zinc and manganese on growth and yield of potato (*Solanum tuberosum* L)

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Abstract
An experiment was conducted during *Rabi* season 2018 at the Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab, India. The experiment was laid out in a randomized block design with three replications. The treatments consisted of foliar application of different combinations of zinc, manganese and farm yard manure which increased the growth and yield in potato. The maximum plant height (41.17 cm at 45 DAP) and (47.67 cm at 90 DAP), numbers of leaves (36.50 at 45 DAP) and (50.40 at 90 DAP), number of shoots per hill (6.54), leaf area index (1.29). The maximum number of tuber per plant (9.17), Tuber yield per plant (647.67g), tuber yield per plot (14.58 kg), tuber yield per hectare (364.42q), marketable yield per hectare (362.92q), unmarketable yield per hectare (1.50 q), were recorded with the application of (recommended dose of NPK + Farm Yard Manure 50 % +Zinc @ 4 kg ha^{-1} + Manganese @ 2.4 kg ha^{-1}). These results suggested that the optimum production of potato can be obtained with application of (NPK 100 %+ FYM 50% +Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}).

Keywords: Foliar application, zinc, manganese, growth and yield attributes

Introduction
Potato is one of the main tubers and notorious crops, which also is very important due to nutritive and economic value. This crop with high performance in unit level is containing abundant carbohydrate with highest biological value of protein is high. It is an important crop and can supplement the food needs of the country in a substantial way as it produces more dry-matter, balanced protein and more calories from unit area of land. Besides, it contains essential nutrients such as proteins, minerals like calcium, phosphorus, iron and vitamins like B_1, B_2, B_6 and C (Pandey *et al*., 2009) [6].

It is an herbaceous plant that grows to 0.4-1.4 m tall and may range from erect to fully prostrate. Stems range from nearly hairless to densely hairy and may be green, purple, or mottled green and purple. It is an herbaceous annual plant with spiral phyllotaxy, spreading or erect habit, height varies from 30 cm to 90 cm compact, medium compact or open. The aerial shoot is initially erect but later becomes partially procumbent, it dies back at the end of a single season, but the plants perenniates by means of underground tubers. Primary and secondary, mainly these two types of stem present in potato plant along with this pinnately compound or occasionally bi-compound leaves with several pairs of leaflets. A much branched, fibrous root system is formed either by the seedling tap root, or by adventitious roots in tuber-grown plants. Inflorescence is simple or compound, erect or dropping, flowering profuse, moderate or scanty.

Potato (*Solanum tuberosum* L.) is reported to have originated in Andean region of high hills of South America and brought to India first by the Portuguese in the 17th century. The total world potato production is estimated at 381,682,000 tones (FAO, 2016). India is the 2nd largest producer of potato after china. In India, the area and production of potato during 2016 -17 is estimated around 21.64 lakhs ha and 46545.99 lac Tones respectively with yield productivity of the predominant states that contribute 80 % potato production are Uttar Pradesh (31.01%), West Bengal (25.82 %), Bihar (15 %), Gujarat (5.59 %) and Punjab (5 %) (Anonymous, 2017). Through the application of optimal NPK dose in balanced proportion, high yield can only be sustained. Although micronutrients are required in very less amount but their deficiency may cause reduction in tuber yield. There are lots of factors which influence to achieve growth and yield potential of potato, among them of zinc and manganese nutrient play prominent position to determine crop yield (Heckman, 2000). Zinc and manganese are essential micronutrient which play important role in vegetative and reproductive cycle of plant. Foliar application of zinc and manganese increase number of tubers and means weight of tuber (Mohamadi, 2000) [4].

Foliar application of nutrients has become an efficient way to increase yield and quality of crops (Horvat *et al*., 2014). Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzyme (Grotz and Guerinot, 2006). Manganese (Mn) is one of the main components in structure of enzymes and is effective in photosynthesis and other reaction. Deficiency of Mn cause yield deduction and quality loss. Manganese in turn is regarded as an activator of many different enzymatic reactions and takes part in photosynthesis. Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII-protein, SOD and phosphatase. Deficiency of Mn induces inhibition of growth, chlorosis and necrosis, early leaf fall and low reutilization (Kabata-Pendias and Pendias, 1999).

Material and methods

The present investigation entitled "Effect of foliar application of zinc and manganese on growth and yield of potato (*Solanum tuberosum* L.)" was carried out at Experimental farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib during Rabi season 2017-18. The objectives of the present investigation were to study the effect of integrated nutrient management in potato on growth, yield and quality of potato tuber. Geographically Fatehgarh Sahib is located situated at an elevation of 246 meter above mean sea level latitude 30° 27´, 30° 46´ N and 76°- 04', 76°- 38' E longitude and elevation of 246 m (807 ft) above the mean sea level. The experimental field had an even topography and good drainage. Composite soil samples were drawn from 0-30 cm soil depth from the experimental plot before planting the crop. Chemical analysis of the composite soil sample was carried out soil pH 7.5, Electrical conductivity (dsm^{-1}) 0.30, Available nitrogen (kg ha^{-1}) 290, Available phosphorus (kg ha^{-1}). Kufri Pukhraj variety of potato transplanted at spacing of 65 cm X 25 cm. The recommended dose of fertilizers for potato are 75, 25, 25 kg of N, P_2O_5 and K_2O ha^{-1}, respectively. Experiment plot was kept free from weeds and irrigation given whenever its need. All the plant protection measures and other culture practices were given same to all plots. Growth attributes were taken from each plot on marked/tag plants such as height, number of leaves, number of plants per hill, leaf area index. Yield attributes such as number of tuber per plant, tuber yield per plant, tuber yield per plot, tuber yield per hectare, marketable yield, and unmarketable yield were taken after harvesting from the tag plants of particular plots. Statistical data was analyzed by standard procedure.

Result and Discussion

The result of the present study (Table 1) represent the growth attributes such as plant height, number of leaves, number of shoots per hill and leaf area index. Measurement of plant height after 45 and 90 DAP from the five different plants tagged for data collection. Same procedure was held for numbers of leaves after 45 and 90 DAP. Numbers of shoots were getting counted on the hill of each and every plot. Among the all treatments, T_{10} is better in plant height (41.17cm at 45 DAP and 47.67cm at 90 DAP) and number of leaves (36.50 at 45 DAP and 50.40 at 90 DAP). According to (Mousavi *et al.*, 2007) [5] increased in plant height due to use of zinc and manganese the synthesis of protein, enzyme activating, oxidation and revival reaction and metabolism of carbohydrates. (Kelling and Speth 2001) [3] reported that utilization of Zn and Mn from resource sulphate together increased the efficiency of potato crop. Number of shoots per hill also get maximum were the addition zinc, manganese and farm yard manure which is in T_{10} (NPK 100% + FYM 50% + Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}) with 6.54 at par with T_7 NPK 100% + Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1} 6.46. (Ghamry *et al.* 2009) [2] effect of farm yard manure and micronutrient increased vegetative growth of plant. Leaf is major portion of vegetative growth so measuring leaf area index T_{10} (1.29) have maximum value than other treatments. Several researches indicated a positive influence of micronutrients (Zn and Mn) application on yield and quantitative parameters of crops (Mousavi *et al.* 2007) [5] on potato. Numerous studies have reported that utilization of micronutrients increases performance and quality of potato tubers (Mohamadi 2000, Mousavi *et al.* 2007) [4, 5].

Yield attributes with considering (Table 2) on basis of result, that relevant to vegetative development of plant. A perusal of data revealed that maximum numbers of tubers per plant (9.17), yield of tuber per plant (647.67 g), total yield per plot (14.58 kg), Tuber yield per hectare (364.42q), Marketable yield per hectare (362.92 q), Unmarketable yield per hectare (1.50 q). Due to metabolic role of Zn in synthesis of proteins, enzyme activation and metabolism of carbohydrate, utilization of fertilizers containing this element increases qualitative and quantitative performance of potato tubers. Due to shortage of Zn, performance and quality of potato decreases (Alloway, 2004) [1]. Application of FYM in combination with foliar application of micronutrients had the highest effect on all quantitative yield characteristics (Ghamry *et al.* 2009) [2]. The integrated use of organic and inorganic fertilizers though influenced the marketable tuber yield to a variable extent. (Sanchez and Jam, 2000) [7] reported that integration of organic (FYM) and inorganic (NPK, Zn, Mn) inputs sustained crop production due to positive interaction and complementarities effects.

Conclusion

The results showed that integrated use of zinc, manganese and farm yard manure fertilizer had significant effect on the potato growth and yield parameters. On the premise of the forgoing discussion it can be concluded that the foliar application of micronutrient zinc and manganese is help in growing the growth and yield in potato. The increase, yield and great potential of potato can be improved with micronutrient of zinc @ 4 kg ha^{-1} and manganese @ 2.4 kg ha^{-1}. The mixture of zinc and manganese executed better with recognize to growth characters (plant height (cm), number of leaves, leaf area index, number of shoots $hill^{-1}$) and yield contributing characters (Number of tuber $plant^{-1}$, tuber yield $plant^{-1}$ (kg), tuber yield $plot^{-1}$ (kg), yield $hectare^{-1}$ (q), marketable yield $hectare0^{-1}$ (q), unmarketable yield $heactare^{-1}$ (q). Therefore, application of aggregate zinc, manganese and farm yard manure with NPK may be counseled after on-farm trying out in trail for industrial cultivation of potato for getting better tuber yield with most net returns consistent with per unit area in potato.

Table 1: Effect of foliar application of Zn and Mn on growth attributes

Treatment details	Plant height (cm)		Number of leaves		Number of shoots per hill	Leaf area index
	45 DAP	90 DAP	45 DAP	90 DAP		
T_1 - Control	22.33	29.03	22.26	37.65	2.91	0.50
T_2- NPK 100 %	30.92	35.66	31.63	41.86	4.63	0.82
T_3- NPK 100 % + FYM 50%	33.31	39.98	31.17	42.45	5.07	0.96
T_4- NPK 100% + FYM 100%	34.03	41.91	32.05	45.24	5.20	1.04
T_5 - NPK 100% + Zn @ 4 kg ha^{-1}	37.42	42.57	32.25	46.60	5.34	1.06
T_6 - NPK 100% + Mn @ 2.4 kg ha^{-1}	36.35	41.18	33.25	45.49	5.24	1.07
T_7 - NPK 100% + Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}	38.99	44.22	35.17	48.04	6.46	1.23
T_8- NPK 100% + FYM 50% +Zn @ 4 kg ha^{-1}	38.63	45.05	33.89	46.94	6.31	1.13
T_9 - NPK 100% + FYM 50% + Mn @ 2.4 kg ha^{-1}	38.32	43.83	33.87	46.25	5.93	1.16
T_{10}- NPK 100% + FYM 50% + Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}	41.17	47.67	36.50	50.40	6.54	1.29
SE(m)±	0.93	1.03	0.97	0.83	0.16	0.02
CD $_{(0.05)}$	2.77	3.05	2.65	2.48	0.47	0.07

Table 2: Effect of foliar application of Zn and Mn on yield attributes

Treatment details	Number of tubers per plant	Tuber yield per plant	Tuber yield per plot	Tuber yield per hectare	Marketable yield per hectare	Unmarketable yield per hectare
T_1- Control	5.00	249.67	8.43	260.83	200.00	10.83
T_2- NPK 100%	5.10	384.00	12.10	302.50	295.00	7.50
T_3- NPK 100% + FYM 50%	5.27	395.00	12.21	305.25	300.00	5.25
T_4- NPK 100% + FYM 100%	5.60	397.67	12.27	306.67	302.18	4.49
T_5 - NPK 100% + Zn @ 4 kg ha^{-1}	6.45	498.33	12.45	311.17	305.04	3.50
T_6 - NPK 100% + Mn @ 2.4 kg ha^{-1}	6.18	468.00	12.34	308.58	305.00	3.55
T_7 - NPK 100% + Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}	8.15	601.00	13.82	345.50	343.50	2.00
T_8- NPK 100%+ FYM 50% +Zn @ 4 kg ha^{-1}	7.67	542.00	13.08	327.08	324.83	2.25
T_9- NPK 100%+ FYM 50% + Mn 2.4 kg ha^{-1}	7.55	529.00	12.36	309.08	306.82	2.26
T_{10}- NPK 100%+ FYM 50% +Zn @ 4 kg ha^{-1} + Mn @ 2.4 kg ha^{-1}	9.17	647.67	14.58	364.42	362.92	1.50
SE(m)±	0.48	16.22	0.26	6.52	8.10	0.14
CD $_{(0.05)}$	1.42	48.18	0.77	19.36	24.06	0.42

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