Introduction

Foliar application of zinc and manganese has become an efficient way to increase yield and quality of crops. Zinc (Zn) is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory co-factor of a large number of enzymes (Grotz and Guerinot, 2006). Manganese (Mn) 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. Several researches indicated a positive influence of micronutrient (Zn, Mn) application in increase of yield and quantitative parameters of crops (Mosavi et al., 2007) on potato.

The aim of this study was to evaluate the effect of foliar application of Zinc and Manganese on growth parameters and yield of Potato (Solanum tuberosum L.) and select out of the best treatment doses in terms of yield and growth parameters.

Materials and Methods

The present investigation was carried out in Rabi season, during 2015-2016 at the Vegetable Research Station Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) India.

Details of the treatments

In order to facilitate their reference the symbol assigned to different treatments are given as under:

T₁: Recommended dose of N:P:K @ 120:80:150 kg ha⁻¹ as basal Control
T₂: R.D.F + ZnSO₄ @ 25 kg ha⁻¹ as basal at the time of planting
T₃: R.D.F + MnSO₄ @ 25 kg ha⁻¹ as basal at the time of planting
T₄: R.D.F as basal + ZnSO₄, 100 ppm as foliar at 50 days after planting
T₅: R.D.F as basal + ZnSO₄, 200 ppm as foliar at 50 days after planting
T₆: R.D.F as basal + ZnSO₄, 300 ppm as foliar at 50 days after planting
T₇: R.D.F as basal + MnSO₄, 100 ppm as foliar at 50 days after planting
T₈: R.D.F as basal + MnSO₄, 200 ppm as foliar at 50 days after planting
T₉: R.D.F as basal + MnSO₄, 300 ppm as foliar at 50 days after planting

The different observations were recorded on Emergence percentage (%), Plant height (cm), Number of haulms per plant, Number of leaves per plant, Fresh weight of plant (g), Dry weight of plant (g), Total number of tubers per plant, Weight of tuber plant per plant (g) and Total yield of tubers per plot (kg q⁻¹). The various statistical techniques were used for calculation of the data as suggested by Fisher and Yates (1949). The experiment was conducted in randomized block design (RBD) for field experiment.

Results and Discussion

The application of foliar and basal doses of zinc sulphate and manganese sulphate, time of application and its combination with recommended dose of fertilizers N, P and K @ 120:80:150 kg ha⁻¹ at the time of planting and foliar application of ZnSO₄ & MnSO₄ as foliar at 50 days after planting i.e. T₁ - (RDF) as basal at the time of planting; T₂ - (RDF and 25 kg ha⁻¹ ZnSO₄ as a basal) at time of planting; T₃ - (RDF and 25 kg ha⁻¹ MnSO₄ as basal) at the time of planting; T₄ - (RDF and 100 ppm ZnSO₄ as foliar); T₅ - (RDF and 200 ppm ZnSO₄ as foliar); T₆ - (RDF and 300 ppm ZnSO₄ as foliar); T₇ - (RDF and 100 ppm MnSO₄ as foliar); T₈ - (RDF and 200 ppm MnSO₄ as foliar) and T₉ - (RDF and 300 ppm MnSO₄ as foliar).

Foliar application of ZnSO₄ and MnSO₄ along with recommended dose of N: P: K @ 120:80:150 kg ha⁻¹ significantly increase the emergence percent of potato plant. Increase in concentration of these chemicals showed linear increase in plant emergence. Maximum emergence percent i.e. 93.65 and 93.35 were obtained at 300 ppm concentration of ZnSO₄ and MnSO₄ applied as foliar at 50 days after planting.
Table 1 Effect of basal and foliar application of Zn and Mn on growth parameters and yield of potato (*Solanum tuberosum L.*)

| Treatments | Emergence Percentage | Plant Height (cm) | Total no. of tuber per plant (g) | Weight of tuber per plant (g) | Yield of tuber per plot (kg.) |
|------------|----------------------|-------------------|---------------------------------|-------------------------------|-------------------------------|
|            | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
| **T1**     | 74.53  | 24.80  | 29.64  | 31.39  | 36.41  | 4.33   | 336.79 | 17.46  |
| **T2**     | 75.91  | 25.23  | 31.36  | 33.06  | 38.52  | 5.67   | 352.02 | 21.39  |
| **T3**     | 77.06  | 24.94  | 30.98  | 32.89  | 37.27  | 5.33   | 341.87 | 19.37  |
| **T4**     | 85.65  | 25.22  | 33.75  | 36.42  | 38.59  | 6.33   | 380.22 | 22.57  |
| **T5**     | 93.20  | 26.47  | 34.39  | 36.61  | 40.55  | 7.00   | 391.77 | 25.25  |
| **T6**     | 93.65  | 29.53  | 35.05  | 42.07  | 43.14  | 8.00   | 435.12 | 26.98  |
| **T7**     | 78.85  | 25.80  | 31.85  | 34.73  | 40.28  | 6.00   | 360.01 | 23.54  |
| **T8**     | 88.35  | 25.88  | 33.62  | 38.97  | 40.33  | 6.57   | 384.90 | 24.37  |
| **T9**     | 93.35  | 26.49  | 34.60  | 40.27  | 41.09  | 7.33   | 418.64 | 26.32  |
| C.D.(p=0.05) | 2.82  | 2.653  | 2.201  | 3.425  | 3.674  | 1.466  | 39.353 | 2.652  |

**Fig. 1** Effect of basal and foliar application of Zn and Mn on number of haulms per plant of Potato (*Solanum tuberosum L.*)

**Fig. 2** Effect on fresh weight of plant (g) at various stages as influenced by basal and foliar application of ZnSO₄ and MnSO₄
Fig.3 Effect on dry weight of plant (g) at various stages as influenced by basal and foliar application of ZnSO$_4$ and MnSO$_4$

Basal application of ZnSO$_4$ and MnSO$_4$ did not showed significant effect on emergence.

Maximum plant height were increases (18.48%) in T$_6$ (RDF and 300 ppm ZnSO$_4$ as foliar) at 50 days after planting as compared with T$_1$ (control) similarly number of haulms were increases (88.23%) in T$_6$ as compared with T$_1$ (control) and maximum number of leaves per plant were increase (27.93%) in T$_6$ at par with T$_9$ as compared with T$_1$ (control). Plant height, number of haulms and number of leaves are morphological phenomenon which mainly control by hormonal balance towards a substantial increase in the cytokinine content and cytokinine/ABA ratio which lead to the cell division and cell elongation at and growing region of the plant, Barben et al., (2007) also investigated the plant height, number of hauls and number of leaves. The above result is similar to finding of Sayed Rohella et al., (2007). Different parameters are given in table 1 and Figure 1, 2 & 3.

The zinc and manganese basal and foliar application markedly increased the number of tubers per plant. Maximum percent increase (84.75) number of tubers per plant was observed in T$_6$ followed by in T$_9$ over control (T$_1$). Similarly, weight of tuber per plant was increases (29.19%) in T$_6$ followed by T$_9$ as compared with T$_1$ (control). Maximum yield of potato tuber per plot increases (54.52%) in T$_6$ followed by T$_9$ as compared with T$_1$ (control). Moreover, foliar application of zinc and manganese sulphate increases all plant characteristics relating to yield and quality of potato crop. Similar findings were also reported Alloway et al., (2004) and Hashemy et al., (1998).

On the present investigation we concluded that these micronutrients (Zn & Mn) are very necessary to improve the yield and quality of potato tuber crop. Further, linear increase an all parameters traits were observed with increase of concentration of these elements, thus its need further validation to include more concentration.

Maximum plant emergence percentage, plant height, number of haulms per hill and number of green leaves per plant was obtained in T$_6$; RDF and ZnSO$_4$ 300 ppm as foliar), followed by T$_9$; (RDF and MnSO$_4$ applied as foliar) at after 50 days after planting respectively. Fresh and dry weight of plant was significantly increased in the T$_6$; RDF and ZnSO$_4$ 300 ppm as foliar, followed by T$_9$; RDF and MnSO$_4$ 300 ppm as foliar) at 50 days after planting respectively. The above results similar to findings of (Mosavi et al., 2007) and Parmar et al., (2016).
Fresh and dry weight of plant was significantly increased in the T6; RDF and ZnSO4 300 ppm as foliar, followed by T9; RDF and MnSO4 300 ppm as foliar) at 50 days after planting respectively Rest the treatment did not showed significant effect on chlorophyll content at all crop growth stages. Foliar application of ZnSO4 and MnSO4 @ 300 ppm along with RDF applied as basal significantly increased T6; RDF and ZnSO4 300 ppm as foliar) at 50 days after planting.

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