__Original Research Article__

Mode of application of Zn and Mn on growth and yield of Garden pea (*Pisumsativum* var. *hortense*L.)

Abstract

The present investigation entitled **"Mode of application of Zn and Mn on growth and yield of garden pea (*Pisum sativum* var. *hortense*L.)** was carried out at the Research farm of the School of Agriculture, Abhilashi University, Mandi (H.P.) during *Rabi* season 2021. The experiment was laid out in a randomized block design with seven treatments in three replications. The result revealed that the in the term of soil chemical properties *i.e.,* Soil pH (5.98pH) was maximum recorded in T_6 (basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @ 1% and Mn @0.5%.) which showed non-significant effect on soil pH,available Zn and Mn was maximum recorded in T_3 basal application of Zn @ 100% of RDF + Mn @100% of RDF (1.67ppm) and (2.01ppm), maximum organic carbon (0.74%) was maximum observed in T_6basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%.Minimumdays to 50% emergence (25.33), maximum plant height (31.66 cm, 53.33 cm at 30, 45 DAS respectively), number of leaves per plant (23.02 and 41.23 at 30 and 60 DAS respectively), fresh weight (62.06g), dry weight (6.84 g),days to 50% flowering (37.33),number of pods per plant (15.79), shelling percentage (51.40 %), number of seeds/pod (8.46) individual pod weight (6.33g), yield/plant (113.69 g), yield/plot (14.55kg)and yield per hectare (194.00 q/ha) , highest net return (3,26,535) along with maximum benefit: net return per rupee invested (1:4.25) were recorded with the usebasal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%in treatment $T_{6.}$ Thus, application of optimum doses of basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5% was found highly beneficial for plant growth, yield and economics of garden pea.

Keywords: Zinc, Manganese, Growth, Yield and Garden Pea.

Introduction

Garden Pea (*Pisum sativum* var.*hortense*L.) is a commercial legume vegetable crop of Himachal Pradesh as well as India. In Himachal Pradesh, it is grown during both main and offseason. It is a member of the Fabaceae family with a chromosome number 2n=14. Pea is a nativeof Europe and Northern Asia. Ethiopia is the likely the main centre of origin of garden pea. In India, Garden peas are grown over an area of 590 thousand hectares and are produced on an annual basis in the amount of 6182 milliontonnes (Anonymous 2022). Garden Pea (*Pisum sativum* var.*hortense*L.) is a commercial legume vegetable crop of Himachal Pradesh as well as India. In Himachal Pradesh, area under pea cultivation is 26.00 thousand ha. production 328.80 million tonnes/ha.(Anonymous 2022).

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Garden pea major producing states like Madhya Pradesh, Jharkhand, Himachal Pradesh, Punjab, West Bengal, Haryana, Bihar, Uttarakhand, Jammu & Kashmir, Odishaand portions of Rajasthan and Maharashtra the major pea growing states are Uttar Pradesh, Madhya Pradesh, Punjab, Himachal Pradesh, and Bihar. Major producing district in himachal Pradesh are Lahaul and Spiti, Kinnaur, Shimla, Kullu and Mandi districts in Himachal Pradesh are the principal pea-producing regions. The pea is a rich source of nutritional proteins. Being a legume crop it fixes atmospheric nitrogen into soil which helps in soil fertility states.

Comment [CM2]: Replace by Himachal

Himachal Pradesh is fifth and major leading pea producing state during main season, whereas major off season pea producing state of India. Micronutrients like zinc and manganese play an important role in increasing crop yield through their effect of plant itself and help in nitrogen fixing symbiotic process. Garden pea is delicious and healthy for human consumption since they are a good source of protein (7.2%) and other nutrients including slowly absorbed starch (50%) and sugars (12%), amino acids, vitamins A and vitamins C, calcium and phosphorus.

Micronutrients like zinc, manganese play an important role in increasing crop yield through their effect of plant itself and also help in nitrogen fixing symbiotic process. Zinc is an essential component of numerous physiological processes, including the production of chlorophyll, pollen, fertilisation, protein synthesis, cell elongation, and nodule formation. It also controls growth and development. Manganese (Mn) plays an important role in Nitrogen metabolism and forms several compounds needed or plant metabolism. Mn also acts as co-factor for several plant enzymes, where it activates about 35 different enzymes (Mengel and Kirkby, 2001).Keeping this in view, the present experiment is proposed to be undertaken to find out the effect of Zn and Mn on the growth, yield of garden pea.

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Material and methods

The present investigation was conducted during the Rabi season 2021-22 at the Agriculture Research Farm School of Agriculture, Abhilashi University, Mandi (H.P). The experimental is farm situated at 31º33'34" N latitude and 77º00'31" E longitude with an elevation of 1,426 m above mean sea level. The experiment was laid out in Randomized Block Design (RBD) Factorial with three replications comprising of seven treatment combination of Zn and Mn. The treatments were T_1: Control (without Zn and Mn), T_2:Basal application of Zn @50% of RDF + Mn @50% of RDF, T_3:Basal application of Zn @100% of RDF + Mn @100% of RDF, T_4:Basal application of Zn @50% of RDF + foliar application of Zn @1%, T_5:Basal application of Mn @50% of RDF + foliar application of Mn @0.5%, T_6: Basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5% and T_7:Foliar application of Zn @1% and Mn @0.5%. The plot size was 3 × 2.5 $m^2$and a spacing of 30 cm × 15 cm was followed. Seeds of garden pea cv. 'Goldie' were sown in the bed on 12^{st}November, 2021 and harvesting was done on 14^{th} March, 2022.NPK, Zn and Mn were applied before garden pea was sown. Before the commencement of the experiment, soil samples were collected randomly from different plots of the experimental field from depth of 0-15 cm and the composite sample was prepared by mixing all these samples together. The soil sample after drying was passed through 2.0 mm sieve and was analyzed for soil pH, organic carbon and for available Zn and Mn.The results of the analysis and methods used are presented in Table 1. The recommended dose of N, P_2O_5 and K_2O were applied through urea, single super phosphate (SSP), muriate of potash (MOP)or Zinc (Zn) and manganese (Mn) respectively according to the treatment plan. The recommended dose of fertilizers like N, P_2O_5 and K_2O were applied at the time of sowing in each plot as per the distributed to different treatments. Different growth and yield parameters like plant height, number of leaves per plant, number of pods per plant, average individual pod weight, yield per hectare. The statistical analysis was carried out byusing the statistical package OPSTAT.

Comment [CM4]: Indicate that it is RDF

Comment [CM5]: …. and methodsused: They are not indicated.
It seems that table 1 corresponds to results and not to materials and methods.

Result and discussion

Soil Properties of experimental field(post-harvest)

Data pertaining to soil pH, OC (%), available Zn and Mn are present in (Table 1) showed that application of different level of zinc and manganese did not affected pH in the post-harvest soil. The treatments were found significant effect for organic carbon, available zinc and manganese. The result indicates that thecombination of Zn and Mn significantly increase the organic carbon content in soil over control and the application of different level of Zn and Mn successively and significantly increased the available Zn and Mn content in soil.

The minimum pH value was recorded in T_1control (without Zn and Mn) (5.94 pH) and maximum pH was recorded in T_6 (5.98 pH) basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @ 1% and Mn @ 0.5%. Similar result for soil pH was observed by Alam (2020). In case of organic carbon, T_6(basal application of Zn @50% of RDF and Mn @ 50% of RDF + foliar application of Zn @1% and Mn @0.5%)observed the highest organic carbon (0.74%)and T_1[control (without Zn and Mn)] had the lowest organic carbon (0.53). This may be due tothe fall in old leaves of the plant will leads to the amelioration of the crop residue, that will further accumulate the level of organic carbon (Chethanet al. 2018).

Comment [CM6]: Check if the expression "et al." in italics.

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Maximum available zinc (1.67 ppm) was recorded in T_3 (basal application of Zn @ 100% of RDF + Mn @100% of RDF) and minimum available zinc(0.67 ppm) recorded in T_1[control (without Zn and Mn)]. Zinc concentration was significantly increased in soil when applied as soil and foliar application because of considerable exchange of Zn on the clay complexes with other cation on its addition The results are inaccordance with the findings of Kulandaivelet al., (2004). As a result of zinc foliar application, the soil zinc content clearly showed an increasing trend (Stoyanova and Doncheva 2002).Maximum available manganese content(2.01ppm) in soil was found in T_3 (basal application of Zn @100% of RDF + Mn @100% of RDF).Patel (2013) reported that the soil application of manganese sulphate causes significant increase in Mn content of soil after harvest of crop.

Comment [CM8]: Check if the expression "et al." in italics.

Table1: Effect of Zn and Mn on soil properties

Treatments	Soil pH	Organic carbon (%)	Available Zinc(ppm)	Available Mn(ppm)
T_1: Control (without Zn and Mn)	5.94	0.53	0.67	0.78
T_2: basal application of Zn @50% of RDF + Mn @50% of RDF	5.97	0.66	1.27	1.39
T_3: basal application of Zn @100% of RDF + Mn @100% of RDF	5.96	0.70	1.67	2.01
T_4: basal application of Zn @50% of RDF + foliar application of Zn @1%	5.97	0.60	1.13	1.17
T_5: basal application of Mn @50% of RDF + foliar application of Mn @0.5%	5.96	0.64	1.61	1.77
T_6: basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%	5.98	0.74	1.50	1.53
T_7: foliar application of Zn @1% and Mn @0.5%.	6.00	0.68	1.19	1.23
SE(m)±	0.013	0.002	0.004	0.013
CD at 5%	NS	0.003	0.011	0.040

Comment [CM9]: Include: pH; organic carbon (5), available Zinc and Mn.

Plant growth attributes

Improvement in growth characters is pre-requisite to increased yield (Table2). Treatment T_6 (basal application of Zn @50% of RDF andMn @50% of RDF + foliar application of Zn @1% and Mn @0.5%) recorded a minimum days to 50% emergence (25.33), maximum plant height (31.66 cm and 53.33 cm at 30, 45 DAS respectively) and maximum number of leaves per plant 23.02 and 41.23 at 30 and 60 DAS respectively. The increase in plant height may be dueaccumulation of zinc nutrient in plant tissues and altered critical growth processes including photosynthesis and chlorophyll biosynthesisStoyanova and Doncheva (2002).Thereason for the maximum number of leaves can be the plant's cells dividing and lengthening more quickly. Numerous enzymatic processes involve zinc (Zn). It serves as a structural, functional, or regulatory co-factor.

The maximum fresh weight was observed (62.06 g) in T_6 (basal application of Zn @ 50% of RDF andMn @ 50% of RDF + foliar application of Zn @ 1% and Mn @ 0.5%)Zinc stimulates the action of various enzymes and photosynthetic pigments, which promotes plant vegetative development (Sadeghzadeh 2013). Additionally, it affects protein synthesis, energy transfer, and nitrogen metabolism by altering the necessary enzymes (Hafeez et al. 2013) and maximum dry weight (6.84 g) observed in T_6 (basal application of Zn @ 50% of RDF andMn @ 50% of RDF + foliar application of Zn @ 1% and Mn @ 0.5%).

Comment [CM10]: Replace by: ….. (Stoyanova and Doncheva, 2002).

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Table2. Effect of Zn and Mn practices in growth parameters of garden pea

Treatments	**Days to 50% emergence**	**Plant height (cm)**		**Number of leaves**		**Fresh weight of plant after harvesting (g)**	**Dry weight of plant after harvesting (g)**
		30 DAS	**45 DAS**	**30 DAS**	**60DAS**		
T_1: Control (without Zn and Mn)	34.00	18.66	38.66	15.33	24.08	44.55	4.78
T_2: basal application of Zn @50% of RDF + Mn @50% of RDF	30.33	23.67	46.66	19.66	33.18	53.16	5.99
T_3: basal application of Zn @100% of RDF + Mn @100% of RDF	27.33	29.33	51.05	22.33	38.48	58.10	6.54
T_4: basal application of Zn @50% of RDF + foliar application of Zn @1%	32.66	20.00	41.33	18.00	27.12	47.50	4.90
T_5: basal application of Mn @50% of RDF + foliar application of Mn @0.5%	31.00	22.01	43.99	18.66	29.01	50.72	5.32
T_6: basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%	25.33	31.66	53.33	23.01	41.23	62.06	6.84
T_7: foliar application of Zn @1% and Mn @0.5%.	29.33	26.00	49.33	21.03	35.92	56.11	6.29

SE(m)±	1.10	1.46	0.77	1.24	1.21	0.74	0.10
CD at 5%	3.42	4.56	02.41	3.88	3.77	2.32	0.31

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Yield attributes

Minimum days to 50% flowering (37.33)Islam et al. (2018), maximum number of pods/plant (15.79), shelling percentage (51.40) were observed in T_6(basal application of Zn @ 50% of RDF andMn @ 50% of RDF + foliar application of Zn @ 1% and Mn @ 0.5%). The increase in number of pods due to the application of micronutrients especially Zinc sulphate has a positive effect on formation of stamens and pollens and we can attribute the increase of number of pods per plant to this property of micronutrients. The large number of seed (8.46) and individual pod weight were observed in T_6 (basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1%Zinc was applied as a foliar spray, which enhanced seed weight. Seed weight will increase when photosynthesis assimilates is transferred from vegetative organs to the other portions.

Comment [CM13]: Include table 3.

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The highest yield/plant (113.69 g), yield /plot (14.55 kg) and yield /hectare (194.00 q) observed in T_6(basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1%this is might due to the Zinc promotes male and female gametogenesis, which increases the number of flowers per plant, zinc is essentially highly advantageous for the reproductive yield of the crop. The formation of sporogenous tissue is additionally stimulated by zinc treatment, which raises the quantity of pollen grains per anther. These effects result in proper pollen grain germination, normal development and an increase in yield parameters such as the number, size, and weight of pods and seeds (Pandey and Gupta, 2012).

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Table3. Effect of Zn and Mn practices in yield parameters of garden pea

Treatments	Days to 50% flowering	Number of pods per plant	Shelling percentage (%)	Number of seeds per pod	Individual pod weight (g)	Yield/plant (g)	Yield/plot(kg)	Yieldper hectare (q)
T_1: Control (without Zn and Mn)	45.00	11.50	38.35	5.16	4.95	65.27	8.52	113.61
T_2: basal application of Zn @50% of RDF + Mn @50% of RDF	41.33	13.49	44.68	6.60	5.99	100.83	12.46	166.13
T_3: basal application of Zn	39.66	14.24	48.74	7.97	6.23	108.69	13.65	182.00

@100% of RDF + Mn @100% of RDF								
T_4: basal application of Zn @50% of RDF + foliar application of Zn @1%	44.33	12.59	42.34	5.43	5.71	80.91	8.75	116.74
T_5: basal application of Mn @50% of RDF + foliar application of Mn @0.5%	42.33	13.22	43.76	5.63	5.92	88.31	11.96	159.51
T_6: basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%	37.33	15.79	51.40	8.46	6.33	113.69	14.55	194.00
T_7: foliar application of Zn @1% and Mn @0.5%.	40.00	14.06	46.86	6.88	6.13	103.26	13.01	173.47
SE(m)±	1.49	0.37	1.29	0.25	0.10	1.36	0.32	2.04
CD at 5%	4.65	1.17	4.03	0.78	0.31	4.24	1.02	6.36

Economics:

The economics of the various treatment combinations have been presented in Table 4 A perusal of data revealed that highest cost of production ₹ /hectare(₹ 1,00,265),maximum gross income ₹ /hectare amounting to (₹ 426,800), highest net return ₹ /hectare (₹ 326,535), maximum net return/rupee invested (1:4:25) was incurred in treatment T_6 (basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%), whereas lowest cost of cultivation ₹ /hectare (₹ 94,258),minimum gross income ₹ /hectare (₹ 249,942), lowest net return₹ /hectare (₹ 155,684), net return per rupee invested (1:2.65) was observed in treatment T_1 control (without Zn and Mn).

Treatments	Cost of cultivation (₹ /ha)	Gross Return (₹ /ha)	Net Return (₹ /ha)	Net return per rupee invested
T_1:Control (without Zn and Mn)	94,258	249,942	1,55,684	1:2.65
T_2:Basal application of Zn @50% of RDF + Mn @50% of RDF	97,223	365,486	2,67,063	1:3.75
T_3:Basal application of Zn @100% of RDF + Mn @100% of RDF	1,00,189	400,400	2,99,011	1:1.00
T_4:Basal application of Zn @50% of RDF + foliar application of Zn @1%	99,056	268,488	1,69,432	1:2.71
T_5:Basal application of Mn @50% of RDF + foliar application of Mn @0.5%	97,474	350,922	2,53,448	1:3.60

Table4. Effect of Zn and Mn on economics

Comment [CM19]: The title of the table, should go at the top of the table, just like in the other tables

T_6:Basal application of Zn @50% of RDF and Mn @50% of RDF + foliar application of Zn @1% and Mn @0.5%	1,00,265	426,800	3,26,535	1:4.25
T_7:Foliar application of Zn @1% and Mn @0.5%	97,301	381,634	2,84,333	1:3.92

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Comment [CM20]: Include for the final conclusion the phrase that is recorded in the summary:

Thus, application of optimum doses of basal application of Zn @ 50% of RDF and Mn @ 50% of RDF + foliar application of Zn @ 1% and Mn @ 0.5% was found highly beneficial for plant growth, yield and economics of garden pea.

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