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Effect of Zinc–Fortification of Vegetable Pea Zinc and ZSB Solubiliser on Soil Properties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The investigation was carried out in the pot experiment during 2021-2022 at the Department of Soil Science, College of Agriculture, JNKVV, Jabalpur, to study Zinc Fortification of vegetable pea through Zinc and ZSB Solubiliser. There were fourteen treatments viz. T_1-Absolute control, T_2-RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}), T_3-(T_2 + Soil application of 25 kg $ZnSO_4 \cdot 7H_2O$ ha^{-1}), T_4-(T_2 + Seed treatment $ZnSO_4.7H_2O$ @3g kg^{-1} of seed), T_5-(T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_6-(T_3+T_5), T_7-(T_4+ T_5), T_8-(T_3+ T_4+T_5), T_9-(T_2+ Soil application of 2 L^{-1} Acre (liquid ZSB), T_{10}-(T_2+Seed treatment (Liquid ZSB) @10 ml kg^{-1} of seed), T_{11}-(T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB) at flowering and pod formation stage), T_{12}-(T_9+T_{11}), T_{13}-(T_{10}+T_{11}), T_{14}-(T_9+T_{10}+T_{11}). The treatments were replicated three times in a completely randomized design (CRD). The vegetable pea (PSM -3) was grown in the rabi season. Results revealed that the treatment of T_5-(T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), maintained the soil health in terms of pH, EC, organic carbon and available nutrients (N, P and K) and Zn in soil which were better than control.

Keywords: Zinc fortification; vegetable pea; Zinc and ZSB.

1. INTRODUCTION

Vegetable pea (*Pisum sativum* L.), is one of the most nutritious leguminous crops and it fixes nitrogen in the soil legumes are an excellent source of protein, complex carbohydrates, vitamins and minerals in the diets of many millions of people, particularly in developing

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countries. Its cultivation maintains soil fertility through biological nitrogen fixation and thus plays a vital role in fostering sustainable agriculture [1]. India is one of the top five pea-producing countries in the world [2] with an area of 564 million hectares and a production of 5694 million tonnes of grain with a productivity of 1009 kg ha^{-1}. However, in the state of Madhya Pradesh, it is grown in an area of 1.07 lakh ha with a production of 10.37 lakh mt and productivity of 1031 kg ha^{-1}.

Zinc is an essential micronutrient for the plant, as it requires a concentration range of 10^{-6} g/g of plant fresh weight to complete its life cycle, and its absence is not fulfilled by other micronutrients. It is the fourth most important yield-limiting nutrient in crops. Plants absorb most of the zinc from the soil, but unfortunately, Indian soils are poor in zinc (49–63%) [3]. Zinc deficiency is also responsible for 16% of all deep respiratory infections in humans worldwide [4]. The Zn deficiency is strongly related to the severity of the novel COVID-19 infestation. It is estimated that deficiencies of zinc are found in > 50 % of people in the world. The deficiency of zinc has increased from 44% to 48% and it is expected to further increase up to 63% by 2025 [5]. This deficiency can be corrected in a variety of ways, among which bio-fortification is the most common technique.

Agronomic bio-fortification has proved to be an effective and fast solution for increasing Zn concentration in the edible parts of several crops, particularly crops. Thus, agricultural and nutrition science together for reducing malnutrition by increasing levels of zinc in staple foods at no additional cost to consumers. Bio-fortification *via* foliar Zn application is effective in increasing grain Zn concentration in crops grown in either Zn-sufficient or Zn-deficient soils. Secondly, soil Zn application was not effective in increasing grain Zn concentration, but increased grain yield. Bio-fortification aims to produce plants that have an augmented content of bioavailable nutrients in their edible parts. Zn and ZSB, have some optimistic relations leading to increased crop yield and reduced environmental threats. Zinc solubilizing bacteria alone or with organic materials may increase the bioavailability of native and applied zinc to the plant, improving the yield and quality of the crop [6].

2. MATERIALS AND METHODS

The investigation was carried out in the Department of Soil Science, College of Agriculture, JNKVV, Jabalpur, during 2021–2022. Jabalpur is situated at 23° 10" N latitude and 79° 57" E longitude at 393 meters above the mean sea level. In the winter season i.e., from November to February the temperature ranges from 4 to 33°C and the relative humidity varies from 70 to 90%. Dry and warm weather usually persists from March to June. The temperature may rise as high as 44°C during these summer months. Monsoon season extends from mid-June to mid-September. The temperature during this period varies between 25°C and 35°C and the relative humidity ranges from 70 to 80%. The total annual rainfall varies from 1200 to 1500 mm.

Jabalpur is located in the “Kymore Plateau and Satpura hills" agro-climatic zone of Madhya Pradesh. The tropic of cancer passes through the middle of the district. It has a sub-tropical climate characterized by hot, dry summers and cool dry winters. The average maximum temperature during May and June varies between 42.5 and 46.4ºC and these are the hottest months of the year, while the average minimum temperature varies between 4.2 and 8.7 ºC during December-January, which are the coldest months of the year. The average annual seasonal rainfall of this region is about 1200 mm which is mostly received between June to September and a little rainfall of 75 to 175 mm is received between October to May. The average humidity of the region is about 73% and the average evaporation is 3.93 mm day^{-1}.

The soil of the experimental field is categorized as Vertisols, and they are from the Kheri series of fine montmorillonite and the Hyperthermic family of Typic Haplusterts, which is known as “black cotton soil." The soil parameters of the experimental site are listed below.

2.1 Experimental Procedures and Details

2.1.1 Collection of materials

Zinc Sulphate Heptahydrate ($ZnSO_4.7H_2O$) Zinc Solubilising Bacterial Strain *Pseudomonas aurigenosa* was taken from MRPC JNKVV Jabalpur. The zinc content in materials was determined by using Atomic Absorption Spectrophotometer. The soil was analyzed for available zinc extracted by 0.005 M DTPA (Di ethylene Tri amine Penta Acetic Acid pH 7.3), 0.01 M $CaCl_2$ and 0.1 M tri ethanol amine (TEA) and determined by Atomic Absorption Spectrophotometer Lindsay and Norvell [7].

2.1.2 Pot experiment

A pot experiment was conducted at the Department of Soil Science, JNKVV, Jabalpur with vegetable Pea (PSM-3). All the necessary cultural practices were carried out when needed. About 5 kg soil was placed in a clean earthen Pot, Zinc and ZSB fourteen combinations were tested according to a 3x3x2 Factorial Complete Randomized Design. Samples were collected from all treatments and analyzed for available zinc. There were *viz.,* zinc and zinc solubilizing bacteria (*Pseudomonas aerugenosa*) on growth, dry matter production, and Zn composition of a vegetable pea.

2.1.3 Treatment details

The treatments were used in the Pot study, with two replications. A pot experiment comprised of fourteen treatments *viz.,* T_1 Absolute control, T_2 RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}) T_3 (T_2 + Soil application of 25 kg $ZnSO_4 \cdot 7H_2O$ ha^{-1}, T_4 (T_2 + Seed treatment $ZnSO_4.7H_2O$ @3g kg^{-1} of seed), T_5 (T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_6 (T_3+T_5), T_7 (T_4+ T_5), T_8 (T_3+ T_4+T_5), T_9 (T_2+ Soil application of 2 L^{-1} Acre (liquid ZSB), T_{10} (T_2+Seed treatment (Liquid ZSB) @10 ml kg^{-1} of seed), T_{11} (T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB) at flowering and pod formation stage), T_{12} (T_9+T_{11}), T_{13} (T_{10}+T_{11}), T_{14} (T_9+T_{10}+T_{11}). The experiment was conducted to study the effect of the Fortification of Zinc and zinc solubilizer with three replications.

The pots were arranged according to the factorial's completely randomized design. The basal dose of 30 N: 60 P_2O_5: 30 K_2O kg ha^{-1} was applied to the vegetable pea crop at the time of sowing. 10 seeds were sown on December 17, 2021, per pot, and 5 plants were maintained for observation and analyzed for yield and attributes of vegetable pea. The vegetable pea crop was harvested on 7 th March 2022. Growth parameters of vegetable pea were also recorded at critical stages of the crop. Plant samples were taken when they were fully mature, and then processed and tested for zinc using an Atomic Absorption Spectrophotometer. At the end of the experiment, soil samples from each pot were taken to examine changes in soil properties.

2.2 Input Application

2.2.1 Zinc and ZSB *(Pseudomonas aerugenosa)* application

During the pot experiment, the doses of various materials were added according to their per hectare doses which is equivalent to 2.26 x 10^6 kg and then their amount was calculated for 5 kg soil.

2.2.2 Fertilizer application

In all treatments recommended doses of fertilizer 30kg N, 60kg P_2O_5 and 30 kg K_2O ha^{-1} were applied (Table 1) in the forms of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. The amount of fertilizer required for each pot was calculated for 5 kg of soil, considering the weight of soil for 1 ha of land is equivalent to 2.26 x 10^6 kg.

Table 1. Amount of fertilizer applied in a pot

Fertilizer	mg pot^{-1}
Urea	464
Single Super Phosphate	668
Muriate of Potash (Mop)	119

2.2.3 Observations were taken

The pH of the soil sample was determined in 1:2 (soil: water) suspension using a combined electrode (glass and calomel electrodes) and by digital pH meter. The electrical conductivity (EC) was determined in the supernatant liquid of the same extracts with the help of a conductivity bridge and expressed in dS m^{-1} at 25°C. Organic carbon content in soil was determined by the wet oxidation method as outlined by Walkley and Black [8].

The alkaline permanganate method was adopted to measure the amount of available nitrogen in a soil sample, Subbiah and Asija [9]. 5 gm soil sample was taken and mixed with alkaline permanganate and distilled. Organic matter was oxidized by $KMnO_4$ in the presence of NaOH releasing ammonia which was absorbed in 2% boric acid containing methyl red bromocresol green mixed indicator and converted to ammonium borate. This ammonium borate was titrated against standard sulphuric acid. The available P in the soil was extracted using Olsen's reagent (0.5 M $NaHCO_3$ for the neutral soil), Olsen et al. [10]. The intensity of the blue colour developed was determined by a spectrophotometer at 660 nm wavelength. Available potassium was determined by extracting the soil sample with 1 N ammonium acetate (pH 7.0) and K content in the extracts was measured by a Flame Photometer Jackson ML [11].

The soil available Zn was extracted by 0.005 M DTPA (Di ethylene amine Penta Acetic Acid pH 7.3), 0.01 M $CaCl_2$ and 0.1 M tri ethanol amine (TEA) and determined by Atomic Absorption Spectrophotometer, Lindsay and Norvell [7]. Standard statistical procedures were employed for the analysis and interpretation of data by Gomez and Gomez [12].

3. RESULTS AND DISCUSSION

3.1 Effect of Different Treatments on Soil Physico-chemical Properties

Data on soil Physico-chemical properties (pH, electrical conductivity, organic carbon) of vegetable pea as influenced by different treatments are presented in Table 2.

3.2 Soil Reaction (pH)

Data pertaining to the effect of different treatments on pH are presented in Table 1. The pH of the soil ranged from 7.27 to 7.63. The maximum pH of the soil was 7.63 due to the treatment of T_8 (T_3 + T_4 + T5), which was higher than the control (7.27). T_6 (T_3 + T_5), T_{11} (T_2 + Foliar application of 2 L^{-1} Acre (liquid ZSB)at flowering and pod formation stage), T_{14} (T_9 + T_{10} + T_{11}), T_5 (T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_7 (T_4 + T_5), T_4 (T2 + Seed treatment $ZnSO_4.7H_2O$ @ 3 g kg^{-1} of seed), T_9 (T_2 + Soil application of 2 L^{-1} Acre (liquid ZSB), T_{10} (T_2 + Seed treatment (Liquid ZSB) @ 10 ml kg^{-1} of seed), T_2 (RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}) and T_3 (T_2 + Soil application of 25 kg $ZnSO_4{\cdot}7H_2O$ ha^{-1}) had the greatest influence on the soil pH of 7.60, 7.57, 7.52, 7.50, 7.43, 7.40, 7.40, 7.30 and 7.23 respectively. Similar findings given by Batoo et al. [13] who showed a significant reduction in rhizospheric pH with $ZnSB_{24}$ and $ZnSB_{25}$ inoculation by 14% and 12%, respectively. Similar results were reported by David et al. [14] also reported that growth Parameters Pea (*Pisum sativum L.*) and soil properties, increased significantly with the application of a 100% recommended dose of fertilizers EC (dSm^{-1}) increase in fertilizer levels. Singh et al. [15] experimented with four levels of zinc (control,0.02%, 0.04%, 0.08%) applied as a foliar spray at the pre-flowering and past podding stage. The zinc application resulted in a non-significant increase in pH in the soil at harvest.

3.3 Electrical Conductivity

Data on the electrical conductivity of soil varied due to different treatments. It was also evident from the data that soil EC under the control pot varied from (0.15 dSm^{-1}). When compared to the control, all of the treatments performed much better. The maximum EC was 0.19 dSm^{-1} due to the treatment of T_8 (T_3+ T_4+T_5) which was 0.6 % higher than the control (0.15 dSm^{-1}). T_{12} (T_9 +T_{11}), T_{11} (T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB).at flowering and pod formation stage), T_7 (T_4+T_5), T_5 (T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_{14} (T_9 +T_{10}+T_{11}), T_{13} (T_{10}+T_{11}), T_{10} (T_2+Seed treatment (Liquid ZSB) @ 10 ml kg^{-1} of seed), T_9 (T_2+Soil application of 2 L^{-1} Acre (liquid ZSB), T_6 (T_3 + T_5), T_4 (T_2 + Seed treatment $ZnSO_4.7H_2O$ @ 3 g kg^{-1} of seed), T_3 (T_2+Soil application of 25 kg $ZnSO_4{\cdot}7H_2O$ ha^{-1}) and T_2 (RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}) had the greatest influence on the Electrical conductivity of 0.18, 0. 17, 0.17, 0 .17, 0.17, 0.16, 0.16, 0.16, 0.16, 0.16, 0.16 and 0.16 dSm^{-1} respectively, with responses of 0.5 %**.** Similar results were reported by Borah et al. [16] studied the effect of foliar application of zinc by using five different treatments of zinc in four replications, on the quality of garden pea (*Pisum sativum L.*) and the soil properties, for which It can be suggested that the one with 0.75% zinc application turns out to be the optimum treatment, towards improving the soil characters. David et al. [14] also reported that growth Parameters Pea (*Pisum sativum L.*) and soil properties, increased significantly with the application of a 100% recommended dose of fertilizers EC (dSm^{-1}) increase in fertilizer levels.

3.4 Organic Carbon

The organic carbon content of post-harvest soil as influenced by different treatments Data on organic carbon content under control plot varied from (5.33 g kg^{-1}). When compared to the control, all of the treatments performed much better. The maximum organic carbon was 8.53 g kg^{-1} due to the treatment of T_6 which was 60 % higher than the control (5.33 g kg^{-1}). T_{14} (T_9+T_{10}+T_{11}), T_7 (T_4+T_5), T_{13} (T_{10}+T_{11}), T_5 (T_2+Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_8 (T_3+T_4+T_5), T_{12} (T_9+T_{11}), T_{10} (T_2+Seed treatment (Liquid ZSB) @10 ml kg^{-1} of seed), T_9 (T_2 + Soil application of 2 L^{-1} Acre (liquid ZSB), T_2 (RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}), T_4 (T_2 + Seed treatment $ZnSO_4.7H_2O$ @ 3g kg^{-1} of seed) and T_3 (T_2 + Soil application of 25 kg

$ZnSO_4.7H_2O$ ha^{-1}) had the greatest influence on the organic carbon of 8.47, 8.23, 7.97, 7.80, 7.47, 6.57, 6.67, 6.33, 6.27, and 5.60 g kg^{-1} respectively, with responses of 58.75, 54.38, 49.38,46.25, 45, 40, 23.13, 25, 18.75, 17.50 and 5 %. Kumar et al. [17] application of zinc sulphate @ 40 kg ha^{-1} and FYM @ 350 q ha^{-1} significantly increased organic carbon (OC) content in soil (0.184%). Desai et al. [18] also reported that the acidic pH shown by all the bacterial isolates gives a clue that the solubilization could be due to the production of organic acids and the higher the production of the same, the higher the available zinc in culture both reported that higher availability of Zn directly proportional to acidic pH of the culture broth. However, in some potent strains, other mechanisms may be active and this aspect is being accentuated.

3.5 Effect of Different Treatments on Available Nutrients and DTPA Extractable Zn

Data on available nutrients and DTPA extractable Zn of vegetable pea as influenced by different treatments are presented in Table 3.

3.6 Available Nitrogen

Data on available nitrogen content in post-harvest soil as affected by treatments. In the control plot, the content of available nitrogen (kg ha^{-1}) varied from 185.76 to 240.78 kg ha^{-1}. All the treatments performed significantly better as compared to the control. Due to the application of T_5 (T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), the maximum content of available nitrogen 240.78 kg ha^{-1} was registered which was 29.62% better over the control (185.76 kg ha^{-1}). This was followed by the influence from T_2 RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}), T_6 (T_3+T_5), T_7 (T_4+T_5), T_8 (T_3+T_4+T_5), T_{13} (T_{10}+T_{11}) and T_{14} (T_9+T_{10}+T_{11}) for the available nitrogen content of 227.19, 224.15, 224.09, 217.36, 216.20 and 216.80 kg ha^{-1} along with response 22.31, 20.67, 20.64, 217.36, 16.39 and 16.71%, respectively. The reason for this can be attributed to the fact that with the application of zinc, the nodule count and root growth increase Singh and Bhatt [19] and also the leghaemoglobin content and rhizobium activity which in turn increases the nitrogen-fixing capacity, and therefore the nitrogen content of the soil Shukla and Yadav, 1982 and Ghoneim [20] Similar results were reported by Singh et al. [15] found that the plots which were fertilized with Zn @ 0.08% nitrogen content in the soil.

3.7 Available Potassium

Data on available phosphorus content in the soil as affected by different treatments. In the control plot, available phosphorus varied from 22.37 to 30.13 kg ha^{-1}. All the treatments performed significantly better as compared to the control. Due to the application of T_{11} (T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB).at flowering and pod formation stage), the maximum content of available P 30.13 kg ha^{-1} was registered which was 25.75 % better over the control (22.37kg ha^{-1}). This was followed by the influence from T_3 (T_2 + Soil application of 25 kg $ZnSO_4·7H_2O$ ha^{-1}), T_6 (T_3+T_5), T_5 (T_4+ T_5), T_{10} (T_2+Seed treatment (Liquid ZSB) @10 ml $kg^{-1}$of seed), T_8 (T_3+ T_4+T_5), T_7 (T_4+T_5), T_{13} (T_{10}+T_{11}) and T_2 RDF (30 N, 60 P_2O_5 and 30 K_2O kg ha^{-1}) for the available nitrogen content of 29.57, 28.98, 27.49, 27.36, 26.95, 25.39, 25.63, 25.00, and 24.05 kg ha^{-1} along with response 24.35, 22.79, 22.79,18.6, 18.24, 16.99,14.74,10.52, 6.98 and 6.98%, respectively. This reason for this can be attributed to the fact that the inorganic phosphorous in the soil decreases with zinc application were reported by Menser and Sidle and Ghoneim [21] and as zinc and phosphorous have an antagonistic effect on soil and each other's uptake and distribution in the plant were suggested by Mousavi [22] therefore it influences the same. Similar results were also reported by Safaya et al. [23], Stoyanova et al. [24], Doncheva Singh et al. [25] and Ladumor et al. [26].

3.8 Available Potassium

Data on available potassium content in the soil as affected by different treatments. Available potassium content varied from 175.56 to 256.03 kg ha^{-1}. All the treatments responded significantly better as compared to the control.

The highest content of 256.03 kg ha^{-1} was obtained due to T_7 (T_4+ T_5) with a 31.43 % response over that of the control (175.56 kg ha^{-1}). This was followed by the effects from T_8 (T_3+ T_4+T_5), T_{13} (T_{10}+T_{11}), T_4 (T_2 + Seed treatment $ZnSO_4.7H_2O$ @3 g kg^{-1} of seed), T_9 (T_2+ Soil application of 2 L^{-1} Acre liquid ZSB), T_5 (T_2 + Foliar application @ 0.5% ZnSO4.7H2O, at flowering and pod formation stage), T_{11} (T_2 + Foliar application of 2 L^{-1} Acre (liquid ZSB).at flowering and pod formation stage), T_6 (T_3+T_5),

T_2 (RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}) and T_3 (T_2 + Soil application of 25 kg $ZnSO_4.7H_2O$ ha^{-1}) presenting the available content of the nutrient of 255.68, 239.45, 231.75, 228.63, 228.60, 228.22, 223.87, 223.71 and 217.72 and kg ha^{-1} having with percentage response of 31.34, 26.68, 24.24, 23.21, 23.20, 23.07, 21.58, 21.52 and 19.36 respectively. Similar results were reported by Nishith et al. [27] The result of experiments showed that the pea cv.PSM-3 recorded significant Available potassium, in the soil at the harvest stage increased due to the application of this nutrient in the soil.

3.9 Available Zinc

Data on available zinc content in the soil as affected by different treatments. Available Zinc content varied from 0.76 to 1.55 mg kg^{-1}. All the treatments responded significantly better as compared to the control.

The highest content of 1.55 mg kg^{-1} was obtained due to T_{13} (T_{10}+T_{11}) with 104.17% response over that of control (0.76 mg kg^{-1}). This was followed by the effects from T_{14} (T_9+T_{10}+T_{11}), T_7 (T_4+ T_5), T_9 (T_2+ Soil application of 2 L^{-1} Acre liquid ZSB), T_8 (T_3+ T_4+T_5), T_{10} (T_2+Seed treatment (Liquid ZSB) @10 ml kg-1 of seed), T_5 (T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage), T_6 (T_3+T_5), T_{12} (T_9+T_{11}), T_4 (T_2 + Seed treatment $ZnSO_4.7H_2O$ @3 g kg^{-1} of seed), T_{11} (T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB).at flowering and pod formation stage), T_2 (RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1}), presenting the available content of the nutrient of 1.48, 1.43,1.42,1.40, 1.30, 1.25, 1.22, 1.14, 0.89 and 0.87 mg kg^{-1} having with percentage response of 94.96, 88.04, 87.23, 84.30, 71.49, 64.97, 60.76, 50.17, 48.25, 17.07 and 14.91 respectively. Similar results were reported by Kumar et al. [17] application of zinc sulphate @ 40 kg ha^{-1} and FYM @ 350 q ha^{-1} significantly increased zinc content in soil (1.63 ppm) Borah et al. [16] studied the effect of foliar application of zinc by using five different treatments of zinc in four replications, on the quality of garden pea (*Pisum sativum L.*) and the soil properties, for which It can be suggested that the one with 0.75% zinc application turns out to be the optimum treatment, towards improving the quality of garden pea and soil characters. Nishith et al. [27]. The result of experiments showed that the pea cv. PSM-3 recorded significant available zinc in the soil at the harvest stage increased due to the application of this nutrient in the soil.

Table 2. Effect of different treatments on soil Physico-chemical properties

	Treatment	pH	EC (dSm^{-1})	OC (g kg^{-1})
T_1	Absolute control	7.27	0.15	5.33
T_2	RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1})	7.3	0.16	6.33
T_3	T_2 + Soil application of 25 kg $ZnSO_4 \cdot 7H_2O$ ha-1	7.23	0.16	5.6
T_4	T_2 + Seed treatment $ZnSO_4.7H_2O$ @3g kg^1 of seed	7.4	0.16	6.27
T_5	T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage	7.52	0.17	7.8
T_6	T_3+T_5	7.6	0.16	8.53
T_7	T_4+ T_5	7.43	0.17	8.23
T_8	T_3+ T_4+T_5	7.63	0.19	7.73
T_9	T_2+ Soil application of 2 L^{-1} Acre (liquid ZSB).	7.4	0.16	6.67
T_{10}	T_2+Seed treatment (Liquid ZSB) @10 ml kg^{-1} of seed	7.4	0.16	6.57
T_{11}	T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB) at flowering and pod formation stage	7.57	0.17	7.13
T_{12}	T_9+T_{11}	7.37	0.18	7.47
T_{13}	T_{10}+T_{11}	7.27	0.16	7.97
T_{14}	T_9+T_{10}+T_{11}	7.5	0.17	8.47
	S.E(m)±	0.087	0.007	0.526
	C.D (P=0.05%)	NS	Ns	1.576

Table 3. Effect of different treatments on available nutrients and DTPA extractable Zn

Treatment		Available nutrients (kg ha^{-1})			DTPA extractable Zn (mg kg^{-1})
		N	P	K	Zn
T_1	Absolute control	185.76	22.37	175.56	0.76
T_2	RDF (30 N, 60 P_2O_5, and 30 K_2O kg ha^{-1})	227.19	24.72	223.71	0.87
T_3	T_2 + Soil application of 25 kg $ZnSO_4·7H_2O$ ha-1	211.55	29.57	217.72	1.01
T_4	T_2 + Seed treatment $ZnSO_4.7H_2O$ @3g kg^1 of seed	208.50	25.63	231.75	1.13
T_5	T_2 + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage	240.78	27.49	228.60	1.25
T_6	T_3+T_5	224.15	28.98	223.87	1.22
T_7	T_4+ T_5	224.09	22.08	256.03	1.43
T_8	T_3+ T_4+T_5	217.36	22.35	255.68	1.40
T_9	T_2+ Soil application of 2 L^{-1} Acre (liquid ZSB).	187.57	23.38	228.63	1.42
T_{10}	T_2+Seed treatment (Liquid ZSB) @10 ml kg^{-1} of seed	199.23	27.36	202.27	1.30
T_{11}	T_2+Foliar application of 2 L^{-1} Acre (liquid ZSB) at flowering and pod formation stage	204.09	30.13	228.22	0.89
T_{12}	T_9+T_{11}	195.00	26.24	207.55	1.14
T_{13}	T_{10}+T_{11}	216.20	25.00	239.45	1.55
T_{14}	T_9+T_{10}+T_{11}	216.80	22.12	209.82	1.48
	S.E(m)±	6.970	1.336	10.155	0.039
	C.D (P=0.05%)	20.896	4.005	30.444	0.117

4. CONCLUSIONS

- Treatment of T_5 (100% of RDF + Foliar application @ 0.5% $ZnSO_4.7H_2O$, at flowering and pod formation stage) also maintained the soil health in terms of pH EC and organic carbon and availability nutrients and Zn in soil which were better than control.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Negi S, Kumar P, Kumar J, Singh A, Dubey RC. Indigenous nitrogen-fixing microbes engineer rhizosphere and enhance nutrient availability and plant growth. In Rhizosphere Engineering. Academic Press. 2022;19-43.
2. Rawat DK, Verma C, Singh AK, Kumar A, Prasad J. Effect of varieties and micronutrient applications on growth and qualitative characters of chickpea (*Cicer arietinum* L.); 2021.
3. Suganya A, Saravanan A, Manivannan N. Role of zinc nutrition for increasing zinc availability, uptake, yield, and quality of maize (*Zea mays* L.) grains: An overview. Commun. Soil Sci. Plant Anal. 2020; 51(15):2001-2021.
4. Xu Y, Hao Z, Li Y, Li H, Wang L, Zang Z, Liao X, Zhang R. Distribution of selenium and zinc in the soil-crop system and their

relationship with environmental factors. Chemosphere. 2020;242:125289.
5. Shukla AK, Behera SK, Pakhre A, Chaudhari SK. Micronutrients in soils, plants, animals and humans. Indian Journal of Fertilisers. 2018 ;14(3):30-54.
6. Ibrahim EA, Ramadan WA. Effect of zinc foliar spray alone and combined with humic acid or/and chitosan on growth, nutrient elements content and yield of dry bean (*Phaseolus vulgaris* L.) plants sown at different dates. Scientia horticulture. 2015; 184:101-5.
7. Lindsay WL and Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal. 1978;42(3): 421-428.
8. Walkley A and Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil science. 1934;37(1):29-38.
9. Subbiah BV, Asija G L. A rapid procedure for the determination of available nitrogen in soils. 1956;25:259-260
10. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture; Washington; 1954.
11. Jackson M L. Prentice hall of India Pvt. Ltd. New Delhi. 1978;498.
12. Gomez KA and Gomez AA. Statistical procedures for agricultural research- Hand Book. John Willy & Sons, New York; 1984.
13. Batool S, Asghar HN, Shehzad MA, Yasin S, Sohaib M, Nawaz F, Uzair M. Zinc-solubilizing bacteria-mediated enzymatic and physiological regulations confer zinc biofortification in chickpeas (*Cicer arietinum* L.). Journal of Soil Science and Plant Nutrition. 2021;21(3):2456-2471.
14. Chethan VK, David AA, Thomas T, Swaroop N, Rao S, Hassan A. Effect of different levels of NPK and Zn on physico-chemical properties of soil growth parameters and yield by pea (*Pisum sativum L.*) Cv. Rachana. Journal of Pharmacognosy and Phytochemistry. 2018;7(3):2212-2215.
15. Singh AK, Bhatt BP. Effect of foliar application of zinc on growth and seed yield of late-sown lentil (*Lens culinaris*). Indian Journal of Agricultural Sciences. 2013;83(6):622-626.
16. Borah L, Saikia J and Basumatary A. Consequences of foliar zinc application on soil properties and quality of garden pea (*Pisum sativum* L.) in Assam condition; 2021.
17. Kumar A, Suri VK, Choudhary AK, Yadav A, Kapoor R, Sandal S, Dass A. Growth behaviour, nutrient harvest index, and soil fertility in okra-pea cropping system as influenced by AM fungi, applied phosphorus, and irrigation regimes in Himalayan acidic Alfisol. Communications in Soil Science and Plant Analysis. 2015; 46(17):2212-2233.
18. Desai S, Kumar P, Sultana U, Pinisetty S and Reddy G. Potential microbial candidate strains for management of nutrient requirements of crops. African Journal of Microbiology Research. 2012;6(17): 3924-3931.
19. Singh AK, Bhatt BP. Effect of foliar application of zinc on growth and seed yield of late-sown lentil (Lens culinaris). Indian Journal of Agricultural Sciences. 2013;83(6):622-626.
20. Ghoneim AM. Effect of different methods of Zn application on rice growth, yield and nutrients dynamics in plant and soil. J. Agric. Ecol. Res. Int. 2016;6(2):1-9.
21. Menser HA, Sidle RC. Effect of zinc levels on phosphorous and zinc content in sand-cultured soybeans. J. Plant Nutr. 1985; 8:89-97.
22. Mousavi SR. Zinc in crop production and interaction with phosphorus. Aust. J. Basic Appl. Sci 2011;5(9):1503-1509.
23. Safaya NM. Phosphorus-zinc interaction in zinc application methods in relation to absorption rates of phosphorus, zinc, copper, manganese, and iron in corn. J. Soil Sci. Soc. Am 1976;40:719-722.
24. Stoyanova Z, Doncheva S. The effect of zinc supply and succinate treatment on plant growth and mineral uptake in pea plant. Brazilian Journal of Plant Physiology. 2002;14:111-6.
25. Dandona L, Dandona R, Kumar GA, Shukla DK, Paul VK, Balakrishnan K, Prabhakaran D, Tandon N, Salvi S, Dash AP, Nandakumar A. Nations within a nation: variations in epidemiological transition across the states of India, 1990–2016 in the Global Burden of Disease Study. The Lancet. 2017;390(10111): 2437-60.
26. Ladumor RG, Gudadhe NN, Onte S, Narwade AV, Karmakar N,

Thanki JD. Evaluation of maize for different methods and levels of zinc application. Maydica. 2019;64(3): 1-14.

27. Gupta N, Sharma RP, Tiwari RJ, Bhargav KS. Response of pea (*Pisum sativum* L.) varieties to different fertility levels. Research on Crops. 2016;17(1):90-4.

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