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Consequences of foliar zinc application on soil properties and quality of garden pea (*Pisum sativum* L.) in Assam condition

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Abstract
A field experiment was conducted during the months of November-January 2018-19, at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat to study the effect of foliar application of zinc on the quality of garden pea (*Pisum sativum* L.) and the soil properties, for which five different treatments were applied in four replications. Among the various treatments, the highest available nitrogen (274.09kg/ha), available potassium (125.56kg/ha) and available zinc content (1.39 mg/kg) of the soil as well as the highest zinc content of the leaves (54mg/kg) were recorded with T_5 (1% Zn), followed by T_4 (0.75% Zn). T_3 (0.50% Zn) recorded the highest nitrogen content of the leaves (3.71%) while the highest phosphorous content of the leaves (0.55%) was obtained in T_1 (control). In case of seed quality characters, T_4 (0.75% Zn) recorded the highest nitrogen content (3.86%), crude protein content (24.12%), starch content (46.92g/100g), moisture content (62.31%) as well as ascorbic acid content (9.15mg/100g), followed by T_5 (1% Zn), whereas the highest total sugar (13.47g/100g) and TSS content (15.10°Brix) were recorded in T_5 (1% Zn), followed by T_4 (0.75% Zn). In many instances the trend decreases after a particular point, due to negative effect of excess micronutrient application than the optimum amount needed, which affects the plant in various ways. In a broader view, it can be suggested from the present study, that the one with 0.75% zinc application (T_4) turns out to be the optimum treatment, beneficial towards improving the quality of garden pea and soil characters.

Keywords: Garden pea, zinc sulphate, foliar application, seed quality, soil

Introduction

Garden pea (*Pisum sativum* L.), the third most important pulse crop in the world and the third most important rabi pulse of India, belongs to the Leguminaceae family and is known as Motor in Assamese and Matar in Hindi. A cool season herbaceous annual crop garden pea, though now grown in many parts of the world, is originally from the Mediterranean basin and near east. India is one of the top five pea producing countries of the world (Rawal and Navarro, 2019) [26]. Garden pea is one of the most nutritious leguminous vegetable rich in vitamins, minerals phytonutrients, antioxidants, proteins, fiber and ascorbic acid, having low quantity but high quality fat as well. It has several health benefits, like prevention against stomach cancer, arthritis, Alzheimer's, diabetes, ageing and enhancing immunity. Being a leguminous crop, garden pea fixes nitrogen in the soil and therefore not just for human body, it is beneficial for the agricultural field as well.

Zinc as an essential micronutrient for crop nutrition, is involved in many physiological functions and enzyme activities, which are needed for protein and auxin synthesis, carbohydrate metabolism, pollen formation and maintenance of the cellular membrane. Unfortunately, about 50% of Indian soils are deprived of zinc (Singh and Sampath, 2011) [36], which causes visible abnormalities in plants like chlorosis, stunted growth, smaller leaves, spikelet sterility etc. It can also adversely affect the quality of harvested products, like the plants show lower protein synthesis and protein accumulation rate under zinc deficiency and it also increases the plant susceptibility to high light or temperature injury and fungal infections. Naturally, soil is the only source for zinc availability to plants. But the intensive cropping system and high yielding varieties are depleting the soil zinc, leading to zinc deficiency becoming a major problem all over the country, that has increased from 44% to 48% and by 2025, is expected to further increase up to 63% (Shukla and Tiwari, 2014) [32]. The poor use efficiency of the soil zinc application has compelled the search for alternatives and hence different modes have been widely studied and adopted (Yashona *et al.*, 2018) [40]. One such alternative, suitable for the micronutrients is the method of foliar application.

A very efficient method, which may show the most favourable response with low rate but multiple applications, in a proper time frame of growing period. Considering different reports, application of zinc is necessary for good quality produce and its foliar application has shown some positive effects in various crops. Based on this background, the present investigation was carried out for assessing the effect of foliar application of zinc, in the form of zinc sulphate ($ZnSO_4$) on the quality of garden pea and soil in Assam condition.

Materials and Methods

A field experiment was conducted in the rabi season of 2018-19, in the Experimental Farm of the Department of Horticulture, Assam Agricultural University. All the plants were subjected to uniform cultural practices, in order to precisely assess the effects of various treatments during the period of investigation. The experiment was laid out with Randomized Block Design in four replications. There were five treatments, consisting of T_1[0% Zn (Control)], T_2[0.25% Zn (11.9g $ZnSO_4$/l water)], T_3[0.50% Zn (23.8g $ZnSO_4$/l water)], T_4[0.75% Zn (35.7g $ZnSO_4$/l water)] and T_5[1.00% Zn (47.6g/$ZnSO_4$/l water)], which were applied in the form of foliar application twice, that is 20 days after sowing and 35 days after sowing respectively. FYM @5t/ha and urea, SSP, MOP and Boron @21.73kg/ha, 75 kg/ha, 62.5 kg/ha and 10 kg/ha respectively were given as basal application during the time of plot preparation. An erect and dwarf mid season pea variety, named DS-10 was used in this experiment, whose seeds were treated with *Rhizobium leguminosarum* @100g/ kg pea seeds, before sowing, for which slurry was prepared by mixing the rhizobium culture with water, in order to soak the seeds, 4 hours prior to sowing. After full pod filling, the green pods were harvested at horticultural maturity of young tender stage. The parameters regarding quality of the produce and soil were carefully analyzed and recorded according to their respective procedures, in proper time. Kjeldahl method (Jackson, 1973) [9] was followed for nitrogen analysis of all the seed, soil as well as leaf samples, and from seed nitrogen content, crude protein was calculated by multiplying it with 6.25. Moisture percentage was obtained by dividing dry weight of the seeds by their fresh weight and further multiplying by 100. Similarly starch content and total sugar content was analysed using Anthrone method (Thimmaiah, 1999) [38] and ascorbic acid content of the seed using 2,6-Dichlorophenol indophenol dye method, as given by Ranganna (1979) [25]. TSS was simply estimated using a digital refractometer. Besides these, the phosphorous, potassium and zinc estimation were carried out using Brays method-I (Jackson, 1973) [9], Flame photometer method (Jackson, 1973) [9] and DTPA Extractable zinc method (Lindsay and Norvell, 1978) [16] respectively. All the recorded data were subjected to statistical analysis as per the standard procedure as described by Panse and Sukhtame (1985) [22].

Results and Discussion

Soil and leaf NPK and Zinc content

Data pertaining to soil NPK and zinc content are presented in Table 1, and that for leaf NPK and zinc content are provided in Table 2. The available nitrogen content in the soil was significantly affected as it increased with the increasing treatment and the highest (274.09kg/ha) was obtained in T_5 (1% Zn) and the lowest in the control (262.65kg/ha). The reason for this can be attributed to the fact that with the application of zinc, the nodule count and root growth increases (Singh and Bhatt, 2013) [34], 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, 2016) [33, 7], leading to the increase in nitrogen content of the leaves, for which T_3(0.75% Zn), has exhibited the highest value (3.71%), closely followed by T_4 (3.63%). Similar results were also shown by Stoyanova and Doncheva (2002) [37], Singh *et al*. (2014) [35], Hamouda *et al*. (2018) [8] and Jamal *et al*. (2018) [10]. On the other hand, the phosphorous content in the leaves of the garden pea plant showed a descending trend, with the increase in zinc dosage, as the control gave the highest value (0.55%). This might be attributed to the fact that the inorganic phosphorous in the soil decreases with zinc application (Menser and Sidle, 1985 and Ghoneim, 2016) [17, 7], and as zinc and phosphorous have antagonistic effect on soil and each other's uptake and distribution in the plant (Mousavi, 2011) [18], therefore it influences the same. Similar results were also reported by Safaya (1976) [29], Stoyanova and Doncheva (2002) [37] and Ladumor *et al*. (2019) [15]. The available potassium content of the soil exhibited ascending trend with the application of zinc, and the highest (125.56kg/ha) was in case of T_5 (1% Zn). The results of Stoyanova and Doncheva (2002) [37], Ghoneim (2016) [7] and Hamouda *et al*. (2018) [8] are in compliance with the findings. The phosphorous content of the soil and the potassium content of the leaves did not show any significant effect with the zinc treatment. The zinc content, whether it is of soil or leaves, exhibited an increasing trend with zinc foliar application obviously, as zinc had been applied as treatment, and the highest in both cases was exhibited by T_5 (1% Zn) with available zinc content of 1.39 mg/kg in the soil, and 54mg/kg of leaf zinc content, closely followed by T_4 (0.75% Zn). It is in compliance with the works of Stoyanova and Doncheva (2002) [37], Rizk (2009) [27], Pathak *et al*. (2012) [23], Rafique *et al*. (2015) [24] and Hamouda *et al*. (2018) [8].

Table 1: Effect of zinc treatment on the N P K and Zn content of the soil

Treatments	Available Nitrogen (kg/ha)	Available Phosphorous (kg/ha)	Available Potassium (kg/ha)	Available Zinc (mg/kg)
T_1 [0% Zn (Control)]	262.65	44.89	122.08	0.69
T_2 [0.25%Zn]	264.08	44.74	123.30	0.80
T_3 [0.50%Zn]	266.69	44.69	124.13	0.89
T_4 [0.75%Zn]	271.50	44.30	124.61	1.02
T_5 [1.00%Zn]	274.09	43.74	125.56	1.39
S.Ed.	0.90	0.36	0.44	0.04
$CD_{0.05}$	1.98	NS*	0.96	0.09

NS* = Non significant

Table 2: Effect of zinc treatment on the N P K and Zn content of the leaves

Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Zinc (mg/kg)
T_1 [0% Zn(Control)]	3.51	0.55	2.32	34.25
T_2 [0.25%Zn]	3.54	0.51	2.35	37.75
T_3 [0.50%Zn]	3.71	0.44	2.51	42.50
T_4 [0.75%Zn]	3.63	0.41	2.47	49.00
T_5 [1.00%Zn]	3.52	0.42	2.40	54.00
S.Ed.	0.06	0.02	0.06	1.61
$CD_{0.05}$	0.13	0.05	NS*	3.52

NS* = Non significant

Quality parameters

Data pertaining to quality parameters of the garden pea seeds are presented in Table 3. The perusal of results indicated that, the nitrogen content and hence the crude protein content of the garden pea seed shows significant influence and increases with the application of zinc treatment. T_4 (0.75% Zn) with 3.86% nitrogen content and 24.12% crude protein content recorded the highest in both cases, closely followed by T_5 (1% Zn) with 3.76% nitrogen content and 23.53% crude protein content, subsequently followed by T_3 (0.50% Zn), T_2 (0.25% Zn) and T_1 (control). The reason for this can be put forward as the increase in the nitrogen fixation and available nitrogen content of the soil, and also the nitrogen uptake by the plant (Jamal *et al*., 2018) [10]. Moreover, zinc is involved in protein metabolism through several enzyme systems (Roy *et al*., 2013) [28], and the translocation of proteins to grains also improves (Kumar *et al*., 2012) [14]. Similar results were claimed by Kaya *et al*. (2009) [13], Bhamare *et al*. (2018) [4] and Chalak *et al*. (2018) [5].

The starch content of the garden pea seeds were also significantly influenced by zinc application, and showed increase up to T_4 (0.75% Zn) which recorded the highest (46.92g/100g), closely followed by T_5 (1% Zn) and T_3 (0.50% Zn) with 45.48g/100g and 45.45g/100g of starch content respectively. The lowest was recorded in case of T_1. This may be attributed to the fact that, zinc application leads to increased activity of the enzyme starch synthase, which directly improves starch synthesis (Shrotri *et al*., 1980) [31], increasing the production of viable and well developed seeds, and hence seed weight. It is also reported to effect the conversion of sugars to starch (Alloway, 2008 and Mousavi *et al*., 2013) [2, 19]. Similar results were confirmed by several other authors like Pandey *et al*. (2013) [21], Usman *et al*. (2014) [39] and Ladumor *et al*. (2019) [15].

Moisture percentage too showed an increasing trend, with T_4 (0.75% Zn) and T_5 (1% Zn) almost at par with each other, but still T_4 (0.75% Zn) gave the highest results (62.31%). They were subsequently followed by T_3 (0.50% Zn), T_2 (0.25% Zn) and T_1 (control). The reason which might be attributed to this can be that zinc has the role as an activator of various plant enzymes for different biosynthesis processes, like for auxin. The improved content of which is responsible for the production of more plant cells and increased dry matter, which gets stored in seeds, which acts like a sink. Moreover with increased starch and sugar synthesis, the dry weight of the seed increases, which may lead to the increase of seed moisture percentage, as calculated. Devlin and Withan (1983) [6], Pandey *et al*. (2013) [21] and Aboyeji *et al*. (2019) [1] also reported similar results.

The effect of different treatments towards the ascorbic acid content of the garden pea seeds was found to be significantly responsive. The highest Ascorbic acid content (9.15mg/100g) was recorded in T_4 (0.75% Zn), which was followed in close proximity by T_5 (1% Zn), T_3 (0.50% Zn) and T_2 (0.25% Zn). The lowest ascorbic acid content was recorded in T_1 (7.83mg/100g). Similar results were also reported by Salam *et al*. (2011) [30].

Application of zinc treatment made significant difference in the TSS as well as the total sugar content of the garden pea seeds. The highest TSS was achieved in case of T_5 (15.10 °Brix) and the control treatment gave the lowest results (8.76 °Brix). Similarly, the total sugar content gave positive results with increasing dose of zinc treatment, and the highest (13.47g/100g) was obtained in case of T_5 (1% Zn) and control gave the minimum value (9.92 g/100g). With the application of zinc, the chlorophyll content of the leaves is considerably increased, which enhances the photosynthetic rate of the plants, resulting into improved sugar or carbohydrate synthesis (Pandey *et al*., 2013 and Kanwal *et al*., 2020) [21, 11]. The improvement in total sugar content as well as TSS was also attributed to the improved efficiency in translocation of photosynthates to fruit juice instead of translocating it to any other part of the plant (Baghel and Sarnaik, 1988 and Kavitha *et al*., 2000) [3, 12]. Many other authors like Salam *et al*. (2011) [30] and Kumar *et al*. (2012) [14] have also claimed similar results.

As evident from the data in the tables, in many of the parameters, the values did not increase indefinitely but till a particular treatment, after which it decreased. This may be because zinc being a micronutrient, when applied in even a slightly larger quantity than what the plant needs, shows negative effect in the growth and development of the plant and other related aspects, leading to symptoms of toxicity. Moreover, since the zinc is applied in the foliar form of application, the plants receive it more efficiently, in lesser time, with lesser loss than the soil application, which is another reason for even a little more of the zinc to the plants, to affect it negatively. Similar results were also found in the works of Paivoke (1983) [20] and Stoyanova and Doncheva (2002) [37].

Table 3: Effect of zinc treatment on quality of garden pea seeds

Treatments	Nitrogen content (%)	Crude protein content (%)	Starch content (g/100g)	Moisture %	Ascorbic acid content (mg/100g)	Total soluble solids (TSS) (°Brix)	Total sugar content (g/100g)
T_1 [0% Zn (Control)]	3.50	21.88	42.64	58.51	7.83	8.76	9.92
T_2 [0.25%Zn]	3.61	22.54	44.15	59.81	8.27	12.09	11.76
T_3 [0.50%Zn]	3.67	22.96	45.45	60.23	8.51	12.48	12.08
T_4 [0.75%Zn]	3.86	24.12	46.92	62.31	9.15	14.22	12.89
T_5 [1.00%Zn]	3.76	23.53	45.48	62.08	8.62	15.10	13.47
S.Ed.	0.06	0.42	0.58	1.24	0.33	1.38	0.16
$CD_{0.05}$	0.14	0.93	1.27	2.70	0.72	3.02	0.35

NS* = Non significant

Conclusion

Foliar application of zinc proved to affect the quality of the produce and soil in several ways. It can be concluded from the experiment that, T_4 with 0.75% zinc application is the best treatment when all the parameters are considered and viewed in a broader perspective. Its good performance in the quality attributing characters of the seed is notable.

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