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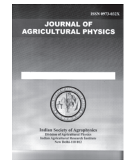

Research Article

Response of Applied Zn by Different Methods on Zn Uptake and Soil Nutrients Availability in Wheat-Moongbean Cropping System under Semi-Arid Region of Punjab

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ABSTRACT

The universal deficiency of nitrogen and phosphorus is followed by Zn and almost 50% of the world soils are Zn deficient. Zinc deficiency is a very important nutrient problem in the Indian soils. In India about 48.5% of soils were deficient in Zn, whereas, in Punjab on an average 12.1% soils were Zn deficient. Efficient Zn management is an important factor to enhance the crop yield potential. Therefore, the present study was conducted to estimate the response of soil and foliar applied zinc on wheat and its residual effect on moongbean. The various Zn applications revealed substantial changes in the amount of zinc uptake and treatment T_5- 2.5 kg Zn ha^{-1} + 0.5% EDTA- Zn+ 1% urea foliar spray showed maximum Zn uptake by grain (153.66 g ha^{-1}) and straw (182.56 g ha^{-1}) followed by T_4 - 2.5 kg Zn ha^{-1} + 0.5% $ZnSO_4.7H_2O$ spray, in which Zn uptake by grain and straw was 148.43 g ha^{-1} and 179.08 g ha^{-1}, respectively. Zinc spray at booting + grain filling stages showed significant higher Zn uptake by grain (133.66 g ha^{-1}) and straw (159.32 g ha^{-1}) as compared to only booting and grain filling stages. The residual effect of different Zn treatments shows significant effect on Zn uptake by later moongbean grain (40.68 g ha^{-1}) and straw (49.58 g ha^{-1}) with maximum value in T_1 where 5 kg Zn ha^{-1} was applied as soil application. However, the result for soil Zn content changed significantly and higher Zn was reported with PBW 725 as compared to PBW 658. The residual effect for different Zn treatments also showed significant differences in soil available Zn with higher soil Zn in treatment T_1 where 5 kg Zn was applied in soil during preceding wheat crop. It was concluded that application of 2.5 kg Zn ha^{-1} in soil along with foliar spray of 0.5% EDTA- Zn +1% urea exhibited superior performance to Zn uptake by wheat, however, for residual effect on succeeding moongbean crops, soil application of 5 kg Zn ha^{-1} showed superior performance for Zn uptake and DTPA–Zn availability in soil.

Key words: Soil applied zinc, Foliar applied zinc, Wheat, Residual effect, Soil macronutrient, Soil micronutrient

Introduction

Soil fertility is an important factor, which decides the growth and yield of crop. It is determined by the presence or absence of nutrients in soil. The reason behind the depletion of soil fertility in India are mainly intensive cropping system, imbalanced use of fertilizer, application of macronutrient alone and ignorance of micro nutrients and organic manures. The universal deficiency of nitrogen and phosphorus is followed by Zn deficiency. Almost 50% of the world soils used for cereal production is Zn deficient (Gibbson, 2006). Zinc deficiency is also a very important nutrient problem in the Indian soils. Total

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Zn concentration is sufficient in many agricultural areas, but available Zn concentration is deficient because of different soil and climatic conditions. Soil pH, lime content, organic matter content, clay type and amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil (Adiloglu and Adiloglu, 2006). According to Dhaliwal *et al.* (2020) about 12.1% of soils in Punjab were zinc deficient, compared to 48.5% of soils in India (Arunachalam *et al.,* 2013). Efficient fertilizer management is an important factor to enhance the yield potential. The application of macro and micronutrients fertilizers in the cultivation zone may not be fulfilling the crop requirement. The alternative approach is to apply these nutrients as foliar sprays. Soil plus foliar applications of micronutrient have been reported to be equally or even more effective as soil application (Firdous *et al*., 2016). Foliar application lead to increase in grain yield components in wheat showed increase in yield components by application of micronutrients (Boorboori *et al.*, 2012). Foliar nutrition is an option when nutrient deficiencies cannot be corrected by application of nutrients to the soil (Cakmak, 2012).On the other hand, soil application of zinc is less effective in increasing grain zinc concentration because of poor zinc mobility and its rapid absorption in alkaline calcareous soils (Alloway, 2008). Therefore, the present investigation was carried out to estimate the response of applied zinc by different methods on crop Zn uptake and soil nutrients availability in wheat-moongbean cropping system under semi arid condition.

Materials and Methods

Experimental soil characteristics

The initial soil characteristic of the experimental site was presented in Table 1. It showed that the site is slightly alkaline in reaction, non-saline and low in organic carbon. The upper (0-15 cm) soil contains higher macro and micro-nutrients as compared to lower (15-30 cm) layers. It was also reported that both soil layers contain low N and high available P and K. The upper (0-15 cm) soil contains higher Fe, Cu, Mn and low Zn, whereas, lower soil (15-30 cm) layer contains high Cu and low Fe, Zn and Mn.

Table 1. Initial characteristic of the experimental soil

Soil characteristics	Value	
	0-15 cm	15-30 cm
$pH_{1:2}$	8.40	8.43
$EC_{1:2}$ (dSm^{-1})	0.32	0.19
Organic carbon (%)	0.32	0.25
Mineralizable N (kg ha^{-1})	193.33	185.58
Available P (kg ha^{-1})	28.75	22.58
Available K (kg ha^{-1})	285.35	235.22
DTPA- Fe (mg kg^{-1})	5.05	4.02
DTPA- Zn (mg kg^{-1})	0.54	0.43
DTPA- Mn(mg kg^{-1})	3.65	3.12
DTPA- Cu (mg kg^{-1})	0.32	0.28

Experimental design and treatments

The experiment was conducted in split-split plot ($3m\times4m=12m^2$) design at Punjab Agricultural University, Regional Research Station, Bathinda during *Rabi* 2020-21 with two wheat variety (V1-PBW 725 and V2-PBW 658) along with recommended doses of N (125 kg ha^{-1}) and P_2O_5 (62 kg ha^{-1}). Five Zn treatments were applied as T_1 = 5 kg Zn ha^{-1}- applied in soil, T_2 = 2.5 kg Zn ha^{-1} -applied in soil + 0.5% $ZnSO_4$. $7H_2O$ - foliar spray, T_3 = 2.5 kg Zn ha^{-1} - applied in soil + 0.5% EDTA- Zn foliar spray, T_4 = 2.5 kg Zn ha^{-1} - applied in soil + 0.5% $ZnSO_4.7H_2O$ + 1% urea -foliar spray and T_5 = 2.5 kg Zn ha^{-1} -applied in soil + 0.5% EDTA- Zn +1% urea - foliar spray. The spray was applied at three different growth stages i.e., booting (S1), grain filling (S2) and booting + grain filling (S3) stages in wheat. After wheat harvest, the residual effect of different treatments was studied on moongbean (ML 2056) crop during *kharif*-2021with recommended doses of N (12.5 kg ha^{-1}) and P_2O_5 (40 kg ha^{-1}).

Zinc uptake by wheat and moongbean

The plant samples were collected at harvest, grounded and the grounded samples (grain and straw) of wheat and moongbean (0.5 g) were digested in a di-acid mixture, i.e., HNO_3 and $HClO_4$ in a ratio of 4:1, respectively (Piper, 2011). The contents of Zn in samples were determined by feeding digested samples to atomic absorption spectrophotometer (Varian Model AAS FS 240), (Page *et al.,* 1982) and observed values were expressed in mg kg^{-1}. The Zn uptake by plants was calculated as follow:

Zn uptake (kg ha^{-1}) = plant dry matter (kg ha^{-1}) × Zn concentration (g kg^{-1})/1000

Soil sampling and nutrients analysis

The samples of soil were collected from all 30 × 3 =90 plots, surface (0-15 cm) and sub-surface (15-30 cm) during the harvesting of wheat and moongbean. The collected soil samples were air dried in shade, ground with the help of wooden pestle mortar. These ground samples were passed through 2 mm sieve and stored in polyethylene bags for further nutrients analysis. Different basic soil chemical properties and available nutrients were analyzed by standard methods as described by Piper (2011). The available micronutrients (Fe, Cu, Zn and Mn) in soil samples were determined by using the atomic absorption spectrophotometer (Varian Model AAS FS 240), Lindsay and Norvell (1978).

Results and Discussion

Zn uptake by wheat and moongbean

The Zn uptake by wheat was presented in Fig. 1, showed that wheat cultivars showed significant differences in Zn uptake by wheat grain and straw. According to the results, wheat grain has less Zn than wheat straw. In contrast to PBW 658; PBW 725 had a greater Zn uptake by its straw compared to grain. Likewise, the various Zn applications revealed substantial changes in the amount of zinc uptake by grain as well as a straw of wheat. Additionally, the Fig1 showed that treatment T_5- 2.5 kg Zn ha^{-1} + 0.5% EDTA- Zn+ 1% urea foliar spray showed maximum Zn uptake by grain (153.66 g ha^{-1}) and straw (182.56 g ha^{-1}) followed by T_4 - 2.5 kg Zn ha^{-1} + 0.5% $ZnSO_4.7H_2O$ spray, in which Zn uptake by grain and straw was 148.43 g ha^{-1} and 179.08 g ha^{-1}, respectively. Similarly, the different spray stages also revealed significant differences in Zn uptake by grain and straw and among the spray stages, booting+ grain filling showed higher Zn uptake by grain (133.66 g ha^{-1}) and straw (159.32 g ha^{-1}) as compared to booting and grain filling stages.

The data compiled in Fig. 2 showed the residual effect of different Zn treatments of preceding wheat crops on Zn uptake by grain and straw of succeeding moongbean crop, resulted that different Zn treatments on earlier wheat crops influenced significant effect on Zn availability in later moongbean grain and straw. It was also observed from the Fig. 2 that Zn uptake was higher in moongbean straw (49.58 g ha^{-1}) as compared to grain (40.68 g ha^{-1}) with maximum value in $T_{1,}$ where 5 kg Zn ha^{-1} was applied as soil application. The increase in the Zn uptake by moongbean grain and straw may be due to the

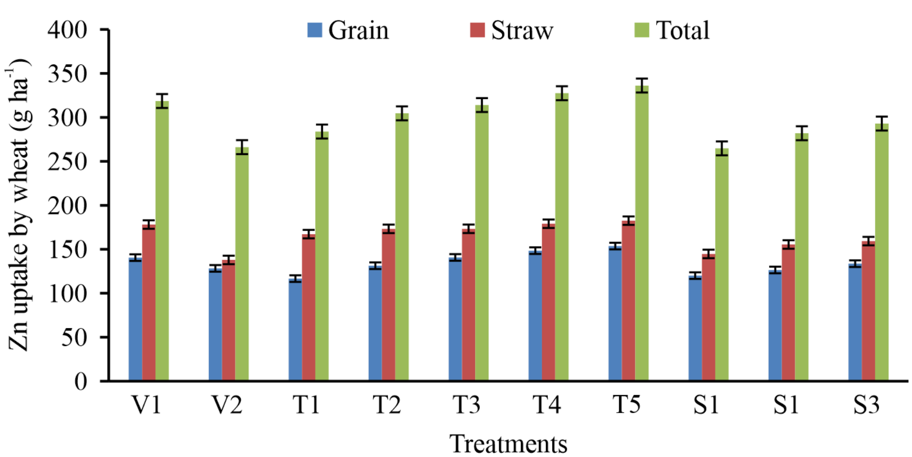

Fig. 1. Effect of different zinc sources and time of application on Zn uptake by wheat. Abbreviation: V1-PBW 725; V2-PBW 658; T_1- 5 kg Zn ha^{-1}(soil application); T_2- 2.5 kg Zn ha^{-1} (soil application) + 0.5% $ZnSO_4$. $7H_2O$ (foliar spray); T_3- 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn (foliar spray); T_4- 2.5 kg Zn ha^{-1}(soil application) + 0.5% $ZnSO_4.7H_2O$ + 1% urea (foliar spray); T_5 - 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA-Zn +1% urea (foliar spray); S1- foliar spray on booting stage; S2- foliar spray on grain filling stage; S3- foliar spray on booting and grain filling stages

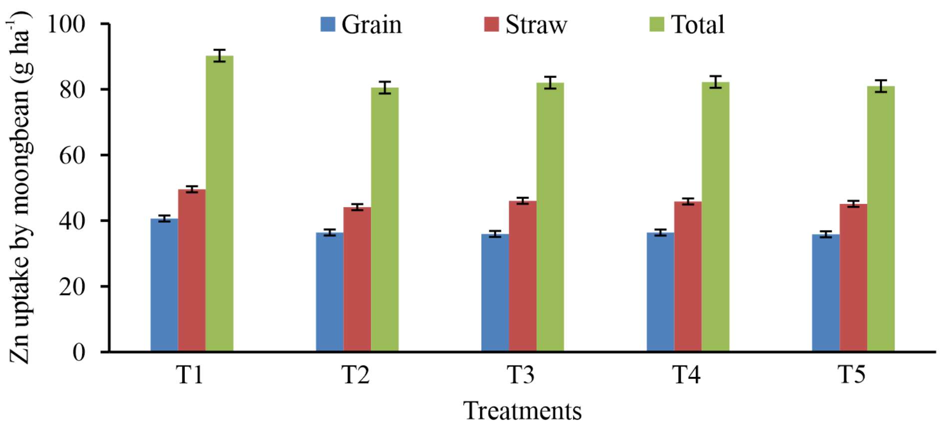

Fig. 2. Residual effect on Zn uptake by succeeding moongbean crop after different zinc sources and application time of Zn on preceding wheat crop*. Abbreviation*: T_1- 5 kg Zn ha^{-1}(soil application); T2- 2.5 kg Zn ha^{-1} (soil application) + 0.5% $ZnSO_4$. $7H_2O$ (foliar spray); T_3- 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn (foliar spray); T_4- 2.5 kg Zn ha^{-1}(soil application) + 0.5% $ZnSO_4.7H_2O$ + 1% urea (foliar spray); T_5 - 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn +1% urea (foliar spray).

application of Zn, which allowed for improved uptake and resulted in the presence of additional Zn in the soil solution.

Significant variation in different varieties regarding to Zn uptake might be due to differential capability of varieties to acquire and utilized nutrient from the soil. Significant differences in micronutrient concentrations in different varieties were also reported by Narwal *et al.* (2012); Shekhari *et al.* (2015) and Nawaz *et al.* (2015). In the current study, the major source of Zn in grain and straw depended on the concentration of available soil Zn (DTPA-Zn). Application of Zn fertilizer to soil could increase the concentration of DTPA-Zn (i.e., available Zn) in soil and then have an effect on root growth. Rose *et al.* (2013) suggested that root surface area and root length density should be increased and helps to increase the capture of immobile Zn and supply to grain and straw. Under Zn sufficient conditions, however, shoot uptake of Zn during grain-filling is the main source of Zn in grain (Impa *et al.,* 2013). The increase in the Zn content in grain and straw might be due to the presence of increased amount of Zn in soil solution by the application of Zn that facilitated greater absorption. Prior studies have demonstrated that zinc fertilization increases the Zn content of both straw and grain (Mollah *et al.,* 2009; Fageria *et al.,* 2011). Spray of Zn at booting + grain filling stage showed higher Zn uptake by grain and straw compared to only booting and grain filling stages may be due to higher Zn accumulation in grains and straw due to twice Zn spray as compared to single spray at only booting or grain filling stage. Under Zn-sufficient conditions, shoot uptake of Zn during grain filling stage is the main source of Zn in grain (Impa *et al.,* 2013).

Soil chemical properties and nutrients availability

The soil chemical properties (pH, EC and OC) and macronutrients (N, P_2O_5 and K_2O) revealed that with all the treatments, after wheat harvest non-significant differences between two cultivars, different Zn treatments and the time of Zn spray were reported. Similarly, the residual effect on these parameters after succeeding moongbean crop for different Zn treatments on preceding wheat crop was also non-significant (data not presented). The wheat cultivars showed non-significant differences in the soil available micronutrients (Fe, Cu and Mn) and were higher in cultivar PBW 658 as compared to PBW 725. However, the result for soil Zn content changed significantly and higher Zn was reported with PBW 725 as compared to PBW 658 (Fig. 3).

Similarly, different Zn treatments showed significant effect on soil Zn availability, however, the effect was non-significant for soil Mn, Cu and

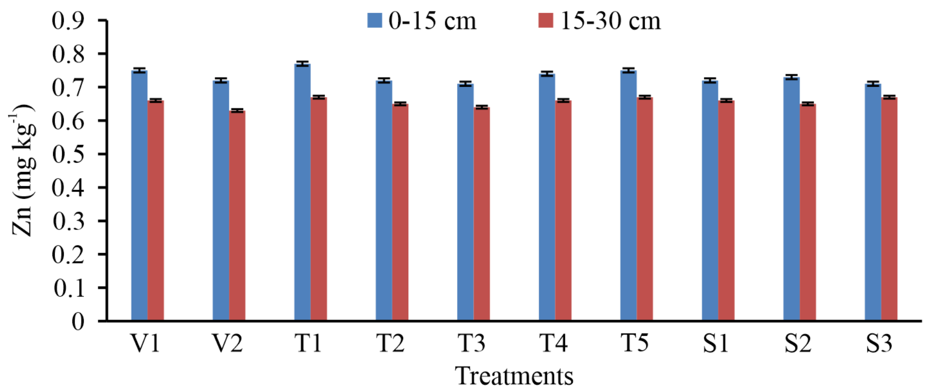

Fig 3. Effect of different zinc sources and time of application on DTPA-Zn availability after wheat harvest. Abbreviation: V1-PBW 725; V2-PBW 658; T_1- 5 kg Zn ha^{-1}(soil application); T_2- 2.5 kg Zn ha^{-1} (soil application) + 0.5% $ZnSO_4$. $7H_2O$ (foliar spray); T_3- 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn (foliar spray); T_4- 2.5 kg Zn ha^{-1}(soil application) + 0.5% $ZnSO_4.7H_2O$ + 1% urea (foliar spray); T_5 - 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn +1% urea (foliar spray); S1- foliar spray on booting stage; S2- foliar spray on grain filling stage; S3- foliar spray on booting and grain filling stages.

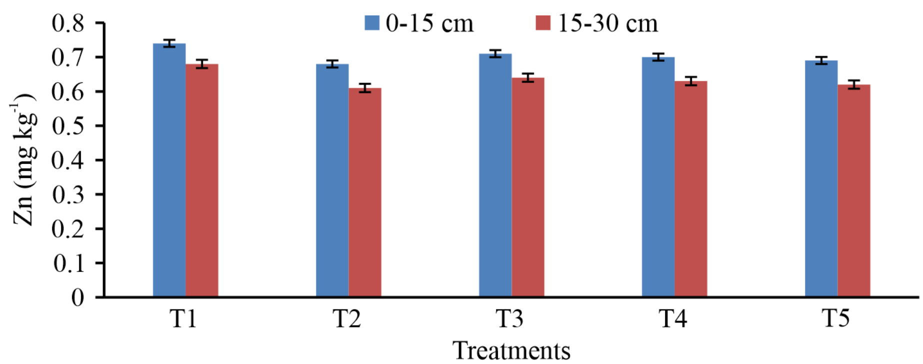

Fig. 4. Residual effect of different zinc sources and application time of Zn on preceding wheat* crop on DTPA-Zn availability in soil after succeeding moongbean crop. Abbreviation *: T_1- 5 kg Zn ha^{-1} (soil application); T2- 2.5 kg Zn ha^{-1} (soil application) + 0.5% $ZnSO_4$. $7H_2O$ (foliar spray); T_3- 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn (foliar spray); T_4- 2.5 kg Zn ha^{-1}(soil application) + 0.5% $ZnSO_4.7H_2O$ + 1% urea (foliar spray); T_5 - 2.5 kg Zn ha^{-1} (soil application) + 0.5% EDTA- Zn +1% urea (foliar spray).

Mn availability. The time of Zn spray showed non-significant differences in soil available micronutrients (Fe, Mn, Zn and Cu).The higher concentrations of Fe, Zn, Mn and Cu were found in the solution of soil with the lower pH value as compared to initial. The Zn treatments showed non-significant differences in soil available Fe, Mn and Cu, however, it showed significant differences in soil available Zn after succeeding moongbean crop as residual effect (Fig. 4).

The soil Zn was higher in treatment T_1 where 5 kg Zn was applied in soil with preceding wheat crop, was decreased with soil depth. Together with increased in soil acidification, an increased in content of available Cu, Fe, Mn and Zn was reported both in soil and the soil solution (Li *et al.,* 2007; Rutkowska *et al.,* 2009; Sienkiewicz *et al.,* 2009). Similar to macro-nutrients, the surface soils showed higher content of Fe, Cu, zn and Mn than sub-surface soils, which exhibited a decreasing trend with increase in soil depth, which might be due to higher organic carbon at surface soils, as organic carbon is a major contributor of available micro-nutrients (Fe, Cu, Zn and Mn) in soils. The results are in conformity with those of Shah *et al.* (2012), Yadav *et al.* (2016) and Bhat *et al.* (2017).

Conclusions

The results of the present study concluded that wheat variety PBW 725 resulted significantly higher Zn uptake by straw and grain due to spraying of Zn fertilizer irrespective of the source. Among all Zn treatments, treatment T_5-2.5 Kg Zn ha^{-1} (soil application + 0.5% EDTA- Zn +1% urea (foliar spray) exhibited superior performance with both wheat verities. Whereas, treatment T_1 (5 kg Zn ha^{-1} (soil application) has the most beneficial residual effect on succeeding moongbean crops in terms of Zn uptake and DTPA –Zn availability in soil under rice- wheat cropping system.

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