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Impact of zinc application methods on green gram (*Vigna radiata* L.) productivity and grain zinc fortification

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Abstract

Application of Zn @ 0, 5.5 kg, 22 kg Zn ha^{-1}, 0.1% Zn foliar application, 5.5 kg Zn + 0.1% Zn spray, increased the yield, concentration and its uptake in seed and straw in all the green gram genotypes. However, combined application of 5.5 kg Zn ha^{-1} + 0.1% Zn as foliar increased the straw yield by 56.4% and seed yield by 57%, which was the highest. Maximum Zn concentration in straw and seed (5.48 and 3.5 folds over control) was achieved when combined application of soil + foliar was made. Soil + foliar application of Zn increased the seed crude protein by 26.9% over control. Seed and straw Zn content showed a significant and positive correlation with all yield attributes except branches per plant.

Key words

Green gram, Protein, Yield, Zn fortification

Introduction

There are estimates that more than 30% of agricultural soils globally cause Zn deficiency in crops (Alloway, 2008) and 48 % soils in India are Zn deficient (Singh, 2009). In Haryana, about 28.27 % area fall under low to moderately low Zn status (Narwal *et al.* 2011). Alkaline reaction, low organic matter, high calcium carbonate, low soil moisture and coarse texture nature of soils create such limiting conditions (Malik *et al.* 2008). Under these Zn limiting condition crops show stunted growth along with very low Zn concentrations, particularly in edible parts (Singh, 2009; Graham *et al*., 1992). Low intake of Zn through diet is a major reason for the widespread Zn deficiencies in human populations (Cakmak, 2008). Enrichment of widely applied fertilizers with Zn (Cakmak, 2009) or enrichment of cultivars with Zn (Palmgren *et al.,* 2008) as well as screening of efficient cultivars would be an important strategy for Zn enrichment of food grain as well as to increase crop production. Although major emphasis is on protein energy malnutrition but WHO (2002) data shows that deficiency of micronutrient is far more severe. Zn deficiency affects, on an average, one third of the world's human population, ranging from 4 to 73% in different parts of the world (Hotz and Brown, 2004).

Green gram (*Vigna radiata* L.) when grown under Zn deficient soils suffers yield loss. Soil application of Zn is efficient in combating their deficiencies but may be less efficient to increase its concentration in edible parts, the prime target in combating micronutrient malnutrition (Cakmak, 2008).

Bio-technology and plant breeding currently show efficiency of nutrient enrichment of grains with Zn but these approaches are long term processes, costly and may be affected from very low chemical solubility of Zn in soils due to high pH (Marschner, 1993) and low organic matter content (Catlett *et al.,* 2002). Agriculture can be used as an important tool to alleviate micronutrient mal nutrition or hidden hunger globally to achieve the new paradigm (Welch and Graham, 1999). Fertilization is the key point of nutrient management in agronomic approaches (ferti-fortification) to enhance crop yield and quality. Manuvering fertilization strategy to make food more nutritious was reflected from the work of Yilmaz *et al.* (1997). They recommended combined application of soil and foliar when high concentration of grain Zn is aimed along with high grain yield. Alternatively, sowing Zn enriched seeds together with foliar application of Zn is also an effective way to improve both yield and grain Zn concentration.

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Dhaliwal *et al.* (2009) evaluated wheat variety with foliar application of Zn @ 0.5% $ZnSO_4$ solution at different growth stages of wheat and found that Zn concentration in grain increased from 17.3 to 38.8 % over control. Kutman *et al.* (2010) found increase in grain Zn concentration by soil and/or foliar application of Zn fertilizers in pot experiments under greenhouse conditions in wheat cultivars. In view of the above, an attempt was made to find the impact of Zn application methods on green gram productivity and its enrichment in seed.

Materials and Methods

Bulk soil sample of surface layer (0-15 cm) was collected from Balsamand village in Hisar district Haryana. The soil was air dried, ground and passed through 2 mm sieve. The basal soil sample having textural class- Sand, pH-8.72, E.C.-0.52 dSm^{-1}, Organic carbon-0.12%, $CaCO_3$-Nil , CEC-3.7 C mol (P^+) kg^{-1} and DTPA-extractable Zn-0.52 mg kg^{-1} soil.

Pot study : Four kg thoroughly mixed Balsamand sand soil was filled in each plastic pot placed in completely randomized way in the Net house. Basal application of recommended doses of N, P and K were applied. Five rates of Zn [0, 5.5, 22, foliar (0.1% Zn) and foliar (0.1% Zn) + soil (5.5) kg ha^{-1}] through $ZnSO_4.7H_2O$ were applied in respective pots. Ten seeds of each of the seven genotypes of green gram (Asha, Basanti, Satya. MH 421, MH 318, MH 565 and Muskan) were sown during July, 2010. Thinning was done after one week and four uniform plants per pot were allowed to grow up to maturity. In case of foliar application, two sprays of 0.1% Zn, at pre-flowering and pod initiation stage were applied. At maturity (65 days), grain and straw yield was recorded and straw samples and seeds were ground in a stainless steel grinder and digested with di-acid mixture (HNO_3 and $HClO_4$, in 4:1 ratio). Zn concentration in plant digests was determined by atomic absorption spectrophotometer (GBC *Avanta*). Crude protein in seed was calculated by multiplying total seed N with 6.25. The data was statistically analyzed using Microsoft Excel and OPSTAT statistical software.

Results and Discussion

Application of Zn increased yield of green gram significantly over control at all levels of Zn application. It implies that in Zn deficient soil, Zn application effectively increased the yield and an increasing trend in yield was observed when the amount of basal Zn application was also increased (Table 1). The

Table 1: Effect of Zn application on straw yield (g pot^{-1}) and seed yield (g pot^{-1}) of green gram genotypes

Genotype	Straw yield (g pot^{-1})					Seed yield (g pot^{-1})				
	Zn level (kg ha^{-1})			Foliar	5.5 kg Zn ha^{-1} +	Zn level (kg ha^{-1})			Foliar	5.5 kg Zn ha^{-1} +
	Control	5.5	22	(0.1% Zn)	Foliar (0.1% Zn)	Control	5.5	22	(0.1% Zn)	Foliar (0.1% Zn)
Asha	33.7	42.0	51.8	40.5	52.3	4.96	5.99	6.54	6.32	7.58
Basanti	38.0	58.2	61.9	54.5	62.1	5.55	8.22	9.18	7.79	9.29
Satya	45.6	60.5	66.3	54.2	72.1	6.36	9.02	10.26	9.88	10.32
MH 421	29.0	39.0	41.0	36.2	47.9	4.16	5.54	6.15	5.04	6.81
MH 318	36.5	47.2	52.0	42.2	58.1	5.21	6.96	7.85	6.87	8.29
MH 565	39.4	50.2	55.8	45.1	57.2	5.60	7.14	7.97	6.98	8.17
Muskan	46.0	53.1	60.8	51.2	70.1	6.70	7.35	9.23	7.65	10.12
Mean	38.3	50.1	55.6	46.2	59.9	5.51	7.17	8.17	7.22	8.65
CD at 5%	CD at 5%	Treatment = 3.8		CD at 5% Treatment = 0.56						

Table 2 : Effect of Zn application on Zn concentration (mg kg^{-1}) in straw and in seed of green gram genotypes

Genotype	Straw Zn concentration (mg kg^{-1})					Seed Zn concentration (mg kg^{-1})				
	Zn level (kg ha^{-1})			Foliar	5.5 kg Zn ha^{-1} +	Zn level (kg ha^{-1})			Foliar	5.5 kg Zn ha^{-1} +
	Control	5.5	22	(0.1% Zn)	Foliar (0.1% Zn)	Control	5.5	22	(0.1% Zn)	Foliar (0.1% Zn)
Asha	18.1	28.3	38.7	83.2	90.1	17.2	24.6	31.2	45.5	50.2
Basanti	15.6	21.4	34.1	83.6	91.6	12.3	20.3	28.6	36.4	41.3
Satya	13.8	25.0	36.3	78.3	86.1	11.5	22.2	27.5	34.1	41.9
MH 421	15.6	26.4	37.5	82.1	89.2	14.5	24.4	33.6	43.0	49.0
MH 318	17.1	27.7	34.2	73.5	81.4	10.6	19.4	29.1	37.6	44.0
MH 565	14.5	23.9	31.2	78.6	84.1	11.6	22.3	30.8	39.7	47.1
Muskan	16.5	25.0	34.1	79.4	88.1	13.6	23.1	32.1	41.7	46.1
Mean	15.9	25.4	35.2	79.8	87.2	13.0	22.4	30.4	39.7	45.7
CD at 5%	CD at 5% Treatment = 3.5			CD at 5% Treatment = 2.9						

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favourable effect of various methods of Zn application on straw yield of green gram might be due to its direct influence on auxin synthesis, which in turn enhanced elongation processes of plant development as reported by Ranjbar and Bahmaniar (2007). Significant variation was also observed among several genotypes. Highest straw yield (59.7 g pot^{-1}) was recorded in Satya genotype while lowest yield of 38.6 g pot^{-1} was recorded in MH 421 genotype. Variation among genotypes was found due to variation in their efficiency on utilizing Zn to increase crop yield (Qury *et al.,* 2006). Among several application methods of Zn, combined application of soil + foliar increased straw yield to the tune of 56.4% over control (Table 1), which was highest. Sole foliar application of Zn increased straw yield to 20.6% over control which was the lowest as compared to other combined treatment. Foliar application at late growth stage attributed to less vigorous vegetative growth as compared to basal application of the recommended dose indicating that during early growth stage adequate soil available Zn is important to get high yield . Secondly, the amount of nutrient applied through foliar may not be sufficient to meet the requirement of plants. Soil + foliar application of Zn gave the highest seed yield of 8.65 g pot^{-1}. Satya gave the highest seed yield of 9.17 g pot^{-1}, while lowest seed yield of 5.54 g pot^{-1} was recorded in MH 421. Increase in yield with Zn

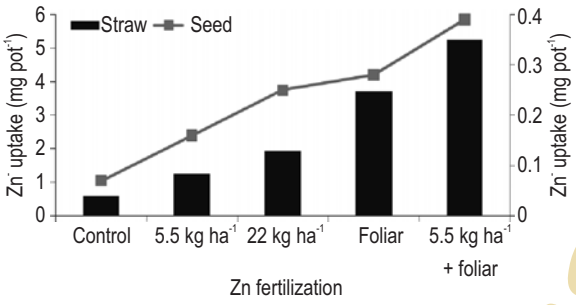

Fig. 1 : Effect of Zn fertilization on uptake (mg pot $^{-1}$) of straw and green gram seed

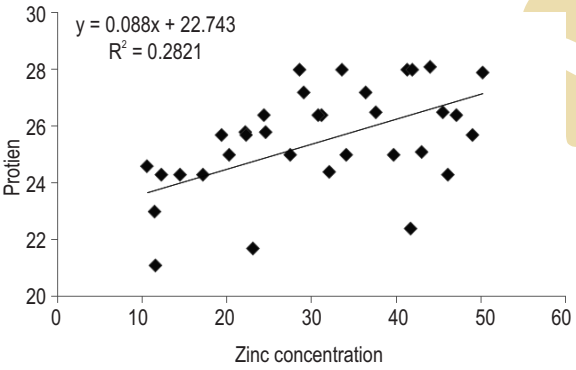

Fig. 2 : Relationship between Zn concentration and crude protein (%) of green gram seed

application was also reported by Ahmadi (2010) in rapeseed. Increase in green gram seed yield might be due to the enhancement of pod formation and subsequent increase in the number of seeds per pod. Moreover, highest seed yield obtained with soil + foliar application, might be due to more availability of Zn to plant at all the growth stages. These results indicate that Zn plays an important role in seed setting as mentioned by Yilmaz *et al.* (1997) and Martens and Westerman (1991).

The result shown in Table 2 revealed that maximum Zn straw concentration (87.2 mg kg^{-1}) was achieved on combined application of Zn as soil + foliar was made. Zinc concentration in straw was found lowest, among all the Zn fertilized when Zn was applied @ 5.5 kg Zn ha^{-1}.Highest Zn concentration in seed (45.7 mg kg^{-1}) was recorded under the treatment of soil + foliar application. On the other hand, basal application of Zn @ 5.5 kg Zn ha^{-1} resulted in lowest increase (22.4 mg kg^{-1}) in Zn content of green gram genotypes. Foliar application was found superior (1.8 fold in seed) over soil application to enhance seed Zn concentration. It may be due to easy penetration of Zn through leaves either by transportation or via stomatal pathway (Haslett *et al*., 2001). When soil + foliar method of Zn application were compared, it was far ahead from the other treatments. Besides, in this study two sprays were done at late growth stages *i.e.,* one at pre-flowering and another at pod initiation stage which helped in more Zn loading into seed. Yilmaz *et al.* (1997), Ekiz *et al*. (1998) and Pearson *et al.*(1998) also found that foliar spray of Zn at late growth stage sequester more Zn in wheat grains.Uptake of Zn both in straw and seed of green gram genotypes increased significantly over control under all the methods of Zn application (Fig 1). The highest uptake of Zn (5.26 mg pot^{-1}) was recorded in treatment receiving combined application of soil + foliar, might be due to higher absorption of Zn through soil + crop foliage leading to increase in dry matter yield as well as Zn concentration in plants. With increase in Zn concentration, the crude protein content in seed of green gram also increased (Fig. 2) as Zn is involved in protein metabolism through several enzyme systems (Zhang *et al.*, 2009). Morgounov *et al.* (2007) and Raboy *et al*. (1984) also found a positive and close relationship between grain concentration of protein and Zn in wheat and soybean, respectively. Seed Zn concentration showed a significant and positive correlation with all the yield attributing characters like seed yield (r =0.43**), straw yield (r =0.42**), pods per plant (r =0.45**), seeds per pod (r =0.72**) and seed weight (r =0.41**) except branches per plant (r =0.27). Combined application of soil + foliar was effective in increasing yield, grain Zn content and protein content of all the green gram genotypes. Seed Zn concentration also showed a significant and positive correlation with all the yield attributes.

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