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Improved varietal selection and optimum soil application of Zn enhance mungbean (*Vigna radiata* L. Wilczek) productivity and profitability

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Abstract

Mungbean varieties differed in growth, yield attributing characters and yield and responded differently with the addition of zinc. The present investigation was planned and executed in factorial randomized block design where in, four varieties of mungbean ('GM 4', 'GAM 5', 'GM 6' and 'IPM 02-3') and seven levels of zinc (control, 1, 2, 3, 4, 5 and 6 kg ha^{-1}) were undertaken and replicated thrice. Recording of LAI at 25, 50 DAS and at harvest stage were also improved significantly by the variety 'GM 6' over other varieties and the values fetched were 0.67, 3.33 and 3.17, respectively. Among mungbean varieties, 'GM 6' recorded significant improvement in number of nodules $plant^{-1}$ (21.15 and 26.48) and nodule dry weight (47.59 and 73.19 mg $plant^{-1}$) at 25 and 50 DAS of growth stages over rest of the varieties. Significant improvement in yield attributes of mungbean *viz.,* pod length (10.42 cm), number of grains pod^{-1} (11.46) and 1,000 grains weight (50.63 g) were attained by the variety 'GM 6' over rest of the varieties undertaken in the experimentation. Similarly, significantly higher grain (1,313.72 kg ha^{-1}) and stover (3,016.63 kg ha^{-1}) yield were also recorded by the variety 'GM 6' over other varieties. Among varying levels of zinc applied to mungbean, application of zinc at 5 kg ha^{-1} substantially enhanced leaf area index (0.64, 3.45 and 3.28) at 25, 50 DAS and at harvest, respectively. Furthermore, number of nodules $plant^{-1}$ (21.81 and 26.65), nodules dry weight (48.23 and 73.82 mg $plant^{-1}$) at 25 and 50 DAS was also recorded substantially higher over preceding levels of zinc. Moreover, significant improvement in yield attributing characters *viz.,* pod length (9.97 cm), number of grains pod^{-1} (10.49), 1,000 grains weight (51.08 g), grain yield (1,196.81 kg ha^{-1}) and stover yield (2,861.93 kg ha^{-1}) were recorded with the application of zinc at 5 kg ha^{-1} over control and preceded levels of zinc. Optimization of zinc under the study envisage highest yield of mungbean at optimum economic dose (Y_{opt}) by the variety 'GM 6' (1,413.01 kg ha^{-1}) followed by 'GM 4' (1,210.02 kg ha^{-1}). Furthermore, highest response in terms of kg grain kg^{-1} zinc applied was recorded by the variety 'GM 6' (249.67) followed by 'GM 4' (213.91). Therefore, it is recommended to work out the optimization of zinc for the mungbean varieties to realize higher productivity and profitability.

Key words: Economic optimum dose, Mungbean, Nodulation, Yield, Zinc fertilization

Globally, food security is the most vital concern that can only be resolved by improving crop productivity and yield. In India, during the year 2020-21, total pulses covered acreage of 28.78 million hectares with production of 25.46 million tonnes and productivity of 885 kg ha^{-1}. Among pulses, mungbean is cultivated in an area of 5.13 million hectares and contributing 3.09 million tonnes of production with productivity of 601kg ha^{-1} in the country (DES 2021). Pulses are the main source of protein particularly for vegetarians and contribute about 14 per cent of the total protein of average Indian diet. Among micronutrients,

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zinc deficiency is a global problem, affecting both people and plants. Zinc is deficient in ~50 per cent of the world's agricultural soils and is recognized as the world's most critical micronutrient deciency in crops. India has one of the highest rates of zinc deciency in soils and people.

Since it is the genetic makeup, genetic potential and nutrient use efficiency of the crop which alter the nutrient demand and nutrient use efficiency of the applied nutrients (Singh *et al.,* 2016). Plant species differ in the efficiency with which they acquire and utilize nutrients. The nutrient acquisition by the varieties differs, as complexes at both the developmental stage and physiological levels are under genetic control, being affected by plant species (or cultivar) as well as environment (Randall *et al.,* 2012). Genotypes of plants vary widely in their tolerance of zinc deficient soils, both in zinc uptake and utilization. Efficient genotypes offer more efficient extraction of soil zinc and it is heritable in nature (Graham and Rangel, 1993). Moreover, the extent of variability in Zn efficiency in species of crops and natural plants, the physiological and biochemical nature of the mechanisms of efficiency, what is known of the genetics of inheritance, optimization of zinc requirement of mungbean genotypes would offer efficient and responsive levels in the zinc deficient soils? Fertilizer application is one of the agronomic approaches that can help to enhance the nutrition security through improving the quality of grains in addition to its role in increasing productivity.

Materials and Methods

Field experiments were conducted at the Instructional Farm, College of Agriculture, Jodhpur, Rajasthan, India during *kharif* 2019. Geographically, it is located between 26° 15' N to 26° 45' North latitude and 73° 00' E to 73° 29' East longitude at an altitude of 231 meter above mean sea level. This region falls under Agro-Climatic Zone Ia (Arid Western Plains) of Rajasthan. Climate of the region isarid. The experimental field was well-drained having sandy loam soil texture with pH 7.8, electrical conductivity 0.12 dS m^{-1}, low in available nitrogen (174 kg ha^{-1}), medium in available phosphorus (22.2 kg ha^{-1}), available potassium (325.0 kg ha^{-1}) and available sulphur (14.6 kg ha^{-1}). The soil was also low in DTPA extractable zinc (0.48 mg kg^{-1}) and iron (3.21 mg kg^{-1}). Field experiment was set up in factorial randomized block design with three replications. Treatments consist of four mungbean varieties ('GM 4', 'GAM 5', 'GM 6' and 'IPM 02-3') and seven levels of Zn micronutrient. Before sowing, seeds were treated with *Rhizobium* at 20 g kg^{-1} seed and *Trichoderma* at 5 g kg^{-1} seed. Irrespective of the varieties, recommended fertilizer dose of N (12 kg N ha^{-1}), P (30 kg P ha^{-1}), was supplied to the crop as basal dose through urea and di-ammonium phosphate. Gap filling and thinning operations were carried out wherever necessary to maintain the optimum plant population of mungbean in each plot. Weeds were controlled by manual weeding.

For nodulation studies, the nodules were detached from the roots of the uprooted plants with the help of forceps. These detached nodules were weighed and reported as fresh weight of nodules. Thereafter, the same nodules have been kept in over at 65 ± 1 °C for 48 hours till attaining constant weight and weighed. Additionally, observations onyield attributes viz; pod length (cm), number of grains pod^{-1} were recorded at harvest stage of mungbean crop. For estimation of grain and stover yield, a net plot area of 15.64 m^2 was harvested separately. The harvested produce was sun-dried before recording its biomass and then threshed manually (plot-wise). 1,000 grain weight (test weight) was recorded from the cleaned samples threshed from individual plots using seed counter (Model: S-114C1; Manufacturer: Sun Shine Industries, Haryana, India). Grain and stover yields were also recorded from each net plot after threshing. Stover yield was obtained by subtracting grain yield from total biomass yield (biological yield). Harvest index was computed by dividing the grain yield with biological yield (Grain + stover yield).

Appropriate regression equation (polynomials) was selected based on probability levels significance (P=0.05) and higher values of coefficient of determination (R^2). The quadratic response equation was found to be best fit to define the relationship between X and Y as shown below (Singh *et al.,* 2012):

$$Y = a + bX + cX2$$

Whereas, Y = mungbean grain yield (kg ha^{-1}); X = level of Zn (kg ha^{-1}); a, b and c are constants of quadratic response equation/function.

Data were analyzed using online statistical program OPSTAT (Sheoran *et al.* 1998). Pearson correlation (r) and simple liner regression coefficients (b) of different characters on yield were computed using MS Excel 2007 as per the method given by Snedecor and Cochran (1968).

Results and Discussion

Growth: Results exhibited that mungbean varieties and application of Zn had significant (p<0.05) influence on leaf area index (LAI) at different growth stages viz; 25, 50 days after sowing (DAS) and at harvest or maturity (Table 1, Figure 1). Leaf area index, an important growth parameter indicating photosynthates assimilation by the plants was estimated. Under the study, mungbean genotype 'GM 6' recorded highest LAI of 0.67, 3.33 and 3.17 at 25, 50 DAS and harvest stage, respectively.

Application of Zn to mungbean significantly improved LAI at all the growth stages of 25, 50 DAS and harvest (Table 1). Soil Zn addition at 5 kg ha^{-1} had consistent effect on LAI of mungbean and noticed higher LAI by 18.5, 18.9 and 15.6 % over control or no Zn. The interaction of varieties and zinc levels was found significant (p < 0.05) for LAI at 25, 50 DAS and harvest (Figure 1). Application of Zn at 5 kg ha^{-1} to 'GM 6' had greatest LAI at 25 DAS (0.73) and at harvest (3.37) which were significantly superior. Albeit, 'GM 6' at 6 kg Zn^{-1} noticed highest value of LAI at 50 DAS (3.55) in mungbean. There are certain differences among the cultivated plant types in terms of their response to zinc deficiency (Graham and Rengel 1993; Thalooth *et al.*, 2006).

***Nodulation*:** Varieties and zinc levels had marked influence on nodulation of mungbean viz; number $plant^{-1}$, nodule fresh weight and nodule dry weight recorded at 25 DAS and 50 DAS growth stages (Table 1). Among varieties, 'GM 6' recorded substantial improvement in number of nodules $plant^{-1}$ at 25 DAS (26.48) and 50 DAS (26.48) over rest of the varieties. Similarly, 'GM 6' also substantially enhanced nodule fresh weight at 25 DAS (248.25 mg $plant^{-1}$), and 50 DAS (482.38 mg $plant^{-1}$). Likewise, nodules dry weight at 25 DAS (47.59 mg $plant^{-1}$) and 50 DAS (73.19 mg $plant^{-1}$) were also recorded markedly higher by the variety 'GM 6' of mungbean.

Application of Zn to mungbean at 5 kg ha^{-1} being on par with 6 kg ha^{-1}, significantly increased

Table 1. Effect of varieties and zinc levels on LAI and nodulation of mungbean.

Treatments	LAI			Number of nodules $plant^{-1}$		Nodules fresh weight (mg $plant^{-1}$)		Nodules dry weight (mg $plant^{-1}$)	
	25 DAS	50 DAS	At harvest	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS
Varieties									
GM 4	0.60	3.23	3.12	19.92	25.75	235.10	442.81	43.98	68.76
GAM 5	0.58	3.13	3.04	18.81	24.58	222.11	437.57	42.45	66.07
GM 6	0.67	3.33	3.17	21.15	26.48	248.25	482.38	47.59	73.19
IPM 02-3	0.50	2.94	2.73	20.12	24.02	238.34	452.67	44.08	70.81
SEm±	0.01	0.05	0.06	0.54	0.56	4.77	10.04	0.99	1.34
CD (P=0.05)	0.03	0.13	0.18	1.53	1.60	13.54	28.48	2.80	3.81
Zinc levels (kg ha^{-1})									
Zn_0	0.54	2.90	2.81	18.35	23.44	217.31	428.08	40.92	65.42
Zn_1	0.55	2.95	2.84	18.65	24.19	220.07	435.42	42.41	66.71
Zn_2	0.57	3.03	2.90	19.12	24.83	225.58	446.33	43.69	67.80
Zn_3	0.58	3.06	2.95	19.96	25.24	232.18	443.42	44.54	69.97
Zn_4	0.60	3.27	3.10	20.73	25.83	244.60	468.17	45.04	72.00
Zn_5	0.64	3.45	3.28	21.81	26.65	259.31	477.92	48.23	73.82
Zn_6	0.63	3.42	3.23	21.41	26.28	252.62	477.67	46.83	72.25
SEm±	0.01	0.06	0.08	0.71	0.74	6.32	13.29	1.31	1.78
CD (P=0.05)	0.04	0.18	0.24	2.02	2.11	17.91	37.67	3.70	5.03
Interaction									
SEm±	0.03	0.12	0.17	1.43	1.49	12.63	26.57	2.611	3.55
CD (P=0.05)	0.07	0.35	NS	NS	NS	NS	NS	NS	NS

number of nodules plant^{-1} at 25 DAS (21.81) and 50 DAS (26.65) over control and preceded levels. Correspondingly, application of Zn to mungbean at 5 kg ha^{-1} fetched 19.3% and 11.6% higher nodule fresh weight at 25 and 50 DAS of growth stage, respectively. In the same way, nodule dry weight was also improved substantially due to soil application of Zn at 5 kg ha^{-1} to the extent of higher by 14.9 and 12.8 % respectively, at 25 and 50 DAS of crop growth stage.

The wide significant differences among the growth traits indicated the availability of a wide degree of genetic variation among the mungbean genotypes (Gerrano *et al.,* 2019). The favourable influence of zinc on photosynthetic and enzymatic activities would in turn increase vegetative growth of plants (Thalooth *et al.,* 2006).

***Yield attributes, yield and harvest index*:** Mungbean varieties and varying levels of zinc substantially influenced yield attributing characters viz; pod length, number of grains plant^{-1}, 1,000 grain weight and grain and stover yield (Table 2). However, application of zinc to mungbean failed to affect harvest index significantly. Although, mungbean variety 'GM 6' had markedly higher harvest index (30.36) over rest of the varieties. Among mungbean varieties, significantly greater pod length (10.42 cm), number of grains pod^{-1} (11.46) and 1,000 grain weight (50.63 g) yield attributes were recorded by 'GM 6' variety. Similarly, noticeably higher grain (1313.72 kg ha^{-1}) and stover (3016.63 kg ha^{-1}) yield was attained by 'GM 6' followed by 'GM 4'.

Soil application of zinc to mungbean at 5 kg ha^{-1} being on par with 6 kg ha^{-1}, considerably improved pod length (9.97 cm), number of grains pod^{-1} (10.49) and 1,000 grain weight (51.08 g) yield attributes over preceded levels. Likewise, application of Zn at 5 kg ha^{-1} being on par with 6 kg ha^{-1} statistically enhanced grain and stover yield by 20.2 % and 8.9 %, respectively, over control or no zinc.

Growth pattern of a crop in its vegetative phase mainly determines the formation of number and size of sink, which ultimately serves as the base for developing yield attributes. Thus, the yield attributing characters of a plant are closely correlated with growth characters emerged in vegetative phase (Dubey *et al.,* 2018). The improvement in yield was due to substantial improvement in pods and grain weight, as an adequate zinc supply helps in better seed setting owing to bet-

Table 2. Effect of varieties and zinc levels on yield attributes and yield of mungbean.

Treatments	PL	NGP	TGW	GY	SY	HI (%)
Varieties						
GM 4	9.95	10.18	46.54	1114.41	2763.63	28.73
GAM 5	9.43	9.18	47.39	1018.49	2616.18	28.01
GM 6	10.42	11.46	50.63	1313.72	3016.63	30.36
IPM 02-3	8.01	8.10	44.08	944.64	2623.19	26.48
SEm±	0.21	0.25	0.86	19.59	39.67	0.49
CD (P=0.05)	0.59	0.72	2.44	55.53	112.48	1.39
Zinc levels (kg ha^{-1})						
Zn_0	8.72	9.10	43.50	995.88	2629.13	27.35
Zn_1	9.21	9.30	44.80	1035.79	2665.66	27.94
Zn_2	9.35	9.43	45.92	1093.07	2725.56	28.56
Zn_3	9.46	9.64	46.83	1113.25	2762.96	28.65
Zn_4	9.64	9.91	48.40	1122.44	2807.70	28.46
Zn_5	9.97	10.49	51.08	1196.81	2861.93	29.40
Zn_6	9.81	10.25	49.60	1127.45	2831.39	28.39
SEm±	0.27	0.33	1.14	25.91	52.48	0.65
CD (P=0.05)	0.78	0.95	3.22	73.46	148.80	NS
Interaction						
SEm±	0.55	0.67	2.273	51.82	104.96	1.30
CD (P=0.05)	NS	NS	6.445	NS	NS	NS

PL = Pod length (cm); NGP = Number of grains pod^{-1}; TGW = Thousand grain weight (g); GY = Grain yield (kg ha^{-1}); SY = Stover yield (kg ha^{-1}); HI = Harvest index (%)

ter pollen germination and fertilization (Pandey *et al.* 2006). In an earlier study, Jamal *et al.* (2018) reported that mungbean responded upto application of zinc at 10 kg ha^{-1}. The similar results of increased pod length, and number of grains pod^{-1} of mungbean with soil application of zinc was reported by Quddus *et al.* (2011) and Haider *et al.* (2018).

Response function: The response of mungbean to zinc was found to be quadratic with varying levels of zinc among the mungbean varieties (Table 3). The second degree (polynomial) regression equation describing the yield response of mungbean to the zinc rates applied within the range of 0 to 6 kg Zn ha^{-1}. The computed R^2 value of 0.996 indicates that 99.6 per cent of the total variation in mean yields was explained by the quadratic regression equation estimated. The computations of data revealed that maximum yield dose (X_{max}) of zinc was recorded by the variety 'GM 4' (5.91 kg Zn ha^{-1}) followed by 'GM 6' (5.90 kg Zn ha^{-1}), 'IPM 02-3' (5.83 kg Znha^{-1}) and 'GAM 5' (5.69 kg Zn ha^{-1}). Likewise, optimum economic dosein terms of kg Zn ha^{-1}(X_{opt}) for the experimental varieties ranged from 5.66 (GM 6), 5.66 (GM 4), 5.60 (IPM 02-3) and 5.46 (GAM 5). Furthermore, yield at maximum yield dose (Y_{max}) was differed due to varieties and the values recorded in order of hugeness were as 1413.36, 1210.39, 1112.22 and 1045.67 kg ha^{-1} by the varieties 'GM 6', 'GM 4', 'GAM 5' and 'IPM 02-3', respectively. Similarly, highest yield at optimum economic dose

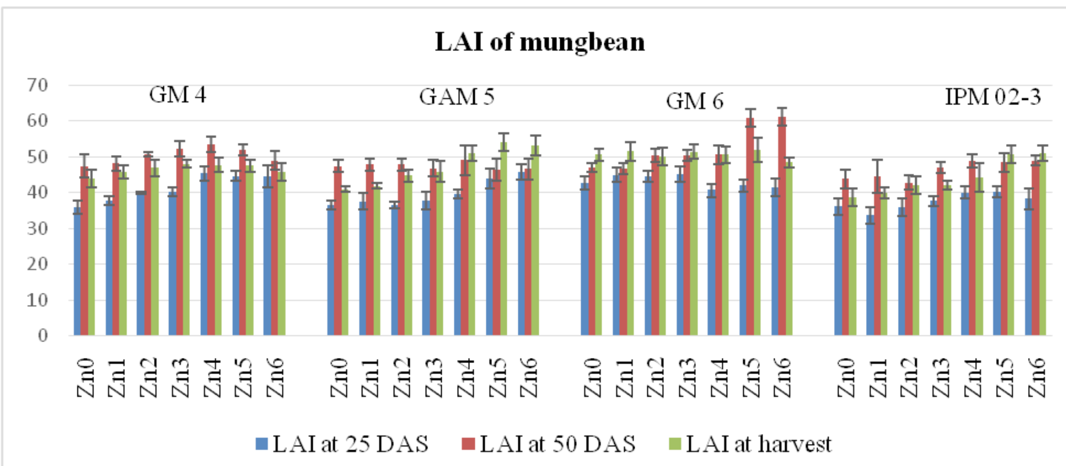

Fig. 1. Interaction effects of varieties and zinc level on LAI at 25 DAS and 50 DAS and at harvest in Mungbean.
Bar show standard error of mean with LSD value 0.07 (LAI at 25 DAS), 0.35 (LAI at 25 DAS) and 0.47 (LAI at harvest) at P=0.05 to determine the significance differences among the treatment mean

Table 3. Quadratic response function in mungbean.

Parameters	GM 4	GAM 5	GM 6	IPM 02-3
a	1005.30	908.05	1197.80	824.35
b (Coefficient of 'X')	69.46	71.74	73.13	75.95
c (Coefficient of 'X^2')	-5.88	-6.30	-6.20	-6.20
Maximum yield dose (X_{max}, kg Zn ha^{-1})	5.91	5.69	5.90	5.83
Optimum economic dose (X_{opt}, kg Zn ha^{-1})	5.66	5.46	5.66	5.60
Yield at maximum yield dose (Y_{max}, kg ha^{-1})	1210.39	1112.22	1413.36	1045.67
Yield at optimum economic dose (Y_{opt}, kg ha^{-1})	1210.02	1111.88	1413.01	1045.35
Response at optimum economic dose (kg ha^{-1})	204.72	203.83	215.21	220.99
Response at 5 kg Zn (kg ha^{-1})	200.27	201.15	210.59	216.85
Response in kg grain kg^{-1} Zn	213.91	203.64	249.67	186.54
Profit (ha^{-1})	84139.91	77261.39	98450.11	72541.06
Return (re^{-1} invested on Zn)	72.12	68.61	84.34	62.76

(Y_{opt}) was recorded by the variety 'GM 6' (1413.01 kg ha^{-1}) followed by 'GM 4' (1210.02 kg ha^{-1}), 'GAM 5' (1111.88 kg ha^{-1}) and 'IPM 02-3' (1045.35 kg ha^{-1}). The response at optimum economic dose was recorded highest by the variety 'IPM 02-3' (220.99 kg ha^{-1}) followed by 'GM 6' (215.21 kg ha^{-1}) 'GM 4' (204.72 kg ha^{-1}) and 'GAM 5' (203.83 kg ha^{-1}). On the other hand, the trend of response at 5 kg Zn ha^{-1} was in the order: 'IPM 02-3' (216.85 kg ha^{-1}) 'GM 6' (210.58 kg ha^{-1}) 'GAM 5' (201.15 kg ha^{-1}) and 'GM 4' (200.27 kg ha^{-1}). Furthermore, highest response in terms of kggrain kg^{-1} zinc applied was recorded by the variety 'GM 6' (249.67) 'GM 4' (213.91), 'GAM 5' (203.64) and 'IPM 02-3' (186.54).

To evaluate the profitability of zinc applied to the different varieties, data under experimentation were also analyzed for profit and return using quadratic response function. The results reveal that highest profit was fetched by the variety 'GM 6' (₹98,450.11 ha^{-1}) followed by 'GM 4' (₹84,139.91 ha^{-1}), 'GAM 5' (₹77,261.39 ha^{-1}) and 'IPM 02-3' (₹72,541.06 ha^{-1}). Similarly, highest return in terms of rupees $rupee^{-1}$ invested on zinc was fetched by the variety 'GM 6' (84.34) followed by 'GM 4' (72.12), 'GAM 5' (68.61) and 'IPM 02-3' (62.76).

Conclusions

Thus, it is concluded that the mungbean variety 'GM 6' responded well and fetched higher grain yield at optimum economic dose, profit and return to the tune of 1,413.01 kg/ha, ₹98,450/ha and ₹84.34 re^{-1} invested on Zn, respectively.

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Conflict of interest

The authors have declared that no conflict of interest exists.

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