

Effect of Different Iron and Zinc Application on Growth, Yield and Quality Parameters of Mungbean (*Vigna radiata* L.)

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ABSTRACT

An investigation was conducted using 12 mungbean varieties in **kharif** 2011-12 to investigate the effect of different levels of iron and zinc (applied through chemical chelates/fertilizers) under uniform levels of NPK on growth, quality traits (protein, iron and zinc content) and yield performance of diverse mungbean cultivars under irrigated conditions at CCS HAU Research Farm, Hisar, and Regional Research Station, Uchani, Karnal. This experiment depicted notable response in growth, quality (protein, Fe and Zn content) and yield. Highest seed yield (17.27 g/plant) was recorded in T₇ (RDF+50 kg/ha FeSO₄+0.5% FeSO₄ foliar spray before flowering). The interactive effect of mungbean varieties and treatments was found significant in seed protein, iron and zinc contents. Maximum contents of protein (27.89%) and iron (9.90 mg/100 g of seed) were observed with application of T₅ (RDF+0.5% FeSO₄ foliar spray before flowering). Due to application of treatment T₄ (RDF+0.5% ZnSO₄ foliar spray before flowering), zinc content was higher (2.30 mg/100 g of seed) in mungbean. It is strongly recommended to farmers to apply @ 0.5% FeSO₄ and ZnSO₄ as foliar spray (before flowering) along with recommended doses of fertilizer in mungbean for enhancement of production, quality and upliftment of their socio-economic status.

Key words : Mungbean, iron, zinc, protein, micronutrients, growth parameters

INTRODUCTION

Mungbean is an important pulse crop having high nutritive value. Its seed contains 24.2% protein, 1.3% fat and 60.4% carbohydrate. It is a short duration crop and can be grown thrice a year i. e. in **rabi**, **kharif** and **zaid** seasons.

The average yield is quite low which requires attention of the crop experts'. Among various factors, judicious use of fertilizer is of prime importance. It is evident from the literature that application of major nutrients i. e. NPK improved mungbean yield (Ali *et al.*, 2010) vis-a-vis micronutrients also play a vital role in plant growth and sustainability of the crop. Among the other micronutrients iron and zinc play important role viz., Zn helps in production of auxin, regulates starch and chlorophyll formation, root development and biosynthesis of cytochrome and synthesis of leaf cuticle, whereas iron regulates the function of chlorophyll development and energy transfer within the plant system formation and activation of several enzymes requires for plant formation, etc.

Nutritional quality is an important characteristic of food crop varieties that determine their value in the human

diet. Protein and micronutrients (trace elements needed for human health) concentration in turn is an important component of nutritional quality especially for staple food crops in developing functional countries (Howieson *et al.*, 2008). Cultivars of mungbean show variability for yield and seed protein with iron and zinc concentrations.

It has been suggested that such plants might include micronutrient-rich, indigenous food crops that acquire mineral elements more effectively from unfertilized soils. The diversification of rotations to include species with greater concentrations of essential mineral elements for human nutrition in their edible tissue also has the potential to increase the delivery of these elements to the human diet independently (Graham *et al.*, 2007).

The present study was, therefore, contemplated to investigate the effect of different levels of iron and zinc (applied through chemical chelates/fertilizers) under uniform levels of NPK on growth, quality traits and yield performance of diverse mungbean cultivars under irrigated conditions. Such study will be useful in order to create awareness among the farming community about the balanced use of fertilizer to get

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maximum production and micronutrient enriched mungbean.

MATERIALS AND METHODS

The experimental material comprised 12 varieties of mungbean : SML 668, MH 560, Sattya, MH 421, Muskan, ML 776, Basanti, MH 565, MH 3-18, Pusa Vishal, MH 124 and Asha developed by different research institutes.

All the varieties were grown at two locations : Hisar (T_1 to T_7) and Karnal (T_8 to T_{14}) in a randomized complete block design during *kharif* 2011 with three replications per treatment at CCS HAU Research Farm, Hisar, and Regional Research Station, Uchani, Karnal. Each plot consisted of two rows of 4 m length with spacing 30 cm between rows and 10 cm between plants. Recommended cultural practices were followed to grow healthy crop. Five randomly selected plants from each genotype were tagged for data collection on seed yield/plant (g), protein content (%), iron content (mg/100 g dry weight of seed) and zinc content (mg/100 g dry weight of seed).

Treatments

- T_1 (Control),
 T_2 [Recommended dose of fertilizer (RDF)+50 kg/ha $ZnSO_4$],
 T_3 (RDF+100 kg/ha $FeSO_4$),
 T_4 (RDF+0.5% $ZnSO_4$ foliar spray before flowering),
 T_5 (RDF+0.5% $FeSO_4$ foliar spray before flowering),
 T_6 (RDF+25 kg/ha $ZnSO_4$ +0.5% $ZnSO_4$ foliar spray before flowering),
 T_7 (RDF+50 kg/ha $FeSO_4$ +0.5% $FeSO_4$ foliar spray before flowering),
 T_8 (Control),
 T_9 (RDF+50 kg/ha $ZnSO_4$),
 T_{10} (RDF+100 kg/ha $FeSO_4$),

- T_{11} (RDF+0.5% $ZnSO_4$ foliar spray before pod initiation),
 T_{12} (RDF+0.5% $FeSO_4$ foliar spray before pod initiation),
 T_{13} (RDF+25 kg/ha $ZnSO_4$ +0.5% $ZnSO_4$ foliar spray before pod initiation) and
 T_{14} (RDF+50 kg/ha $FeSO_4$ +0.5% $FeSO_4$ foliar spray before pod initiation).

The mean values were used for analysis of variance using SAS software. If the F test was significant, means were compared by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Atomic Absorption Spectrophotometer (AAS) analysis was implemented for both iron and zinc concentrations according to the technique of Benton-Jones (1989) and was also based on nitric/perchloric acid digestion with samples read on a 'ZEE nit 700P' make Atomic Absorption Spectrophotometer in the Central Soil Salinity Research Institute, Karnal, analytical services central laboratory. Readings were evaluated against standard curves prepared from iron diluted to a concentration of 100 mg/l and zinc diluted to 50 mg/l. Total nitrogen was determined in the dry seeds by Kjeldhal method using KjelTech (KEL PLUS Classic DX) nutrient analyser according to Association of Official Analytical Chemists. Protein was calculated by multiplying the nitrogen by the factor 6.25

RESULTS AND DISCUSSION

Pooled analysis of variance showed highly significant differences among the genotypes and treatments for yield and quality parameters (protein, iron and zinc content) (Table 1), indicating the presence of genetic variability among the genotypes as well as the treatments under study. The results on various characters are well discussed as under :

Fe and Zn levels affect the days to 50% flowering

Table 1. Pooled analysis of variance for yield contributing characters and iron (Fe) and zinc (Zn) content in mungbean

Source of variation	d. f.	Mean sum of squares							
		Days to 50% flowering	Days to maturity	Plant height	Seed yield/plant	100-Seed weight	Protein content	Iron content	Zinc content
Replication	2	2.27	4.36	349.19**	1164.57**	11.71**	25.06**	110.08**	4.46**
Variety	11	55.02**	29.53**	103.07**	88.57**	3.64**	31.64**	132.94**	3.17**
Treatments	13	3.72	11.98**	32.80	72.74**	0.59**	29.91**	49.39**	0.28**
Variety x Treatments	143	2.77	3.90	39.80	6.71	0.08**	6.92	4.55	0.09
Pooled error	308	3.41	5.24	48.26	12.53	0.02	7.96	10.93	0.09

**Significant at P=0.01 level.

Table 2. Mean effect of treatment/variety interaction for days to 50% flowering

Treatments	SML	MH	Satya	MH	Muskan	ML	Basanti	MH	MH	3-18	Pusa	MH	Asha	Mean
	668	560	421			776		565			Visal	124		
T ₁ (RDF)	30.67	30.00	33.67	31.33	30.67	33.33	33.67	30.67	30.00	30.00	34.00	30.00	31.33	31.61 a
T ₂ (RDF+50 kg/ha ZnSO ₄)	30.00	30.67	32.00	30.00	34.00	30.00	31.33	31.67	32.00	32.00	32.67	33.33	33.00	31.72 a
T ₃ (RDF+100 kg/ha FeSO ₄)	33.33	32.67	34.67	33.00	31.67	31.67	32.67	33.00	31.67	31.67	33.67	33.33	30.00	32.61 ab
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	31.67	30.00	34.33	30.67	31.67	34.67	32.67	30.67	30.00	30.00	33.00	31.67	33.33	32.02 ab
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	34.33	30.67	32.67	30.00	34.67	33.67	35.00	30.00	33.33	33.33	35.00	35.00	31.00	32.94 b
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	31.67	30.00	33.67	30.00	33.33	33.67	34.00	30.00	31.67	31.67	32.00	32.00	32.33	32.02ab
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	31.67	30.00	32.33	30.00	31.67	32.67	30.67	30.00	31.33	31.33	33.67	33.00	34.00	31.75a
T ₈ (RDF)	30.67	30.00	33.67	31.33	30.67	33.33	33.67	30.67	30.00	30.00	34.00	30.00	31.33	31.61a
T ₉ (RDF+50 kg/ha ZnSO ₄)	31.33	30.00	34.00	30.67	31.33	33.00	34.00	30.00	30.00	30.00	34.00	30.00	32.00	31.69a
T ₁₀ (RDF+100 kg/ha FeSO ₄)	31.33	30.00	33.33	30.67	32.33	33.00	32.33	32.00	30.33	30.33	34.33	30.33	31.67	31.80a
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	33.33	30.00	33.67	30.00	31.67	33.67	32.33	30.00	31.67	31.67	33.67	33.67	32.33	32.16ab
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	32.33	30.00	34.00	30.00	31.67	34.33	32.33	30.00	30.00	30.00	32.00	32.00	34.00	31.88ab
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	32.67	30.67	31.67	30.00	33.00	33.33	31.67	30.00	31.33	31.33	35.00	34.33	34.33	32.33ab
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% ZnSO ₄ foliar spray)	31.00	30.67	33.00	30.67	33.00	34.33	34.67	30.00	30.00	30.00	33.00	31.67	33.33	32.11ab
S. E.	1.07													
C. D. (P≤0.05)	2.97													

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

significantly (Table 2). Earliest flowering (31.61 days) was recorded in the T_1 and T_8 (RDF), whereas delayed flowering (32.94 days) was recorded in T_5 i. e. (RDF+0.5% $FeSO_4$ foliar spray before flowering). These results might be due to varying fertility status of the soil (Khoshgoftarmanesh *et al.*, 2010; Hussain *et al.*, 2011).

Maturity of the different varieties of the mungbean was affected significantly by different treatment combinations. Earliest maturity (61.63 days) was recorded for the T_1 and T_8 (RDF) (Table 3), whereas delayed maturity was recorded for T_5 . These results might be due to varying genetic make-up of varieties and their interaction with treatments (Ali *et al.*, 2010; Khoshgoftarmanesh *et al.*, 2010; Hussain *et al.*, 2011). Different treatment combinations affected the plant height significantly (Table 4). Maximum plant height (70.75 cm) was obtained when treatment combination T_3 (RDF+100 kg/ha $FeSO_4$) was applied, whereas minimum plant height (66.65 cm) was obtained in the plot where only recommended dose i. e. T_8 was applied. These results might be also due to genetic make-up of varieties (Hussain *et al.*, 2011; Sohrabi *et al.*, 2012).

Highest seed yield (17.27 g/plant) was recorded in T_7 (RDF+50 kg/ha $FeSO_4$ +0.5% $FeSO_4$ foliar spray before flowering) against minimum in T_8 (Table 5). These contradictory results can be attributed to differences in genetic make-up or climatic conditions of crop (Thalooth *et al.*, 2006; Safak *et al.*, 2009; Khoshgoftarmanesh *et al.*, 2010; Hussain *et al.*, 2011). Significant differences were also observed as far as different treatments were concerned. The application of T_8 (RDF) resulted in maximum 100-seed weight (3.97 g) followed by T_{12} , T_{11} and T_{10} , whereas minimum 100-seed weight was recorded (2.91 g) when T_7 was applied (RDF+50 kg/ha RDF+0.5% $FeSO_4$ foliar spray before flowering) (Table 6). Results can be attributed to differences in genetic make-up of crop (Khoshgoftarmanesh *et al.*, 2010; Hussain *et al.*, 2011). Protein contents of mungbean seeds were affected significantly by treatment combinations (Table 7). As far as different treatments are concerned, the application of T_5 (RDF+0.5% $FeSO_4$ foliar spray before flowering) resulted in maximum seed protein content (27.89%) and minimum in T_1 (20.14%) and T_8 (21.96%). Such enhancement effect might be attributed to the favourable influence of these nutrients on metabolism and biological activity and their stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage protein

content (Thalooth *et al.*, 2006; Akbari *et al.*, 2008; Khoshgoftarmanesh *et al.* 2010; Hussain *et al.*, 2011). The seed Fe content was also affected significantly by different treatment combinations (Table 8). Maximum seed Fe content (9.90 mg/100 g) of dry seed weight was recorded when T_5 (RDF+0.5% $FeSO_4$ spray before flowering) was applied. This variation is associated with increasing plant growth and metabolism, seed morphology, as the tissue distribution of Fe in mungbean seeds is under genetic control (Ariza-Nieto *et al.*, 2007; Fang *et al.*, 2008; Khoshgoftarmanesh *et al.*, 2010; Sohrabi *et al.*, 2012). Lowest seed Fe content (2.54 mg/100 g dry weight of seed) was observed in the plot where only T_8 (RDF) was applied.

Significant difference for seed Zn content in mungbean was also observed (Table 9). As far as different treatments are concerned, the application of T_4 (RDF+0.5% $ZnSO_4$ foliar spray before flowering) followed by T_2 (RDF+50 kg/ha $ZnSO_4$ before flowering) resulted in maximum Zn content (2.30 and 2.11 mg/100 g dry weight of the seed, respectively), whereas minimum Zn content was recorded in plots where only RDF was applied (T_8). Foliar applications of either $ZnSO_4$ or Zn-chelates can increase grain Zn concentrations in plants with adequate Zn mobility in the phloem (Thalooth *et al.*, 2006; Fang *et al.*, 2008; Khoshgoftarmanesh *et al.*, 2010; Nasri *et al.*, 2011).

CONCLUSION

It is concluded that besides the macronutrient (NPK) application, micronutrients (Fe and Zn) have equal importance and must be applied to mungbean crop for enhancement of production of micronutrient enriched mungbean. This experiment depicted notable response in growth, quality (protein, Fe and Zn content) and yield due to application of treatment combinations T_4 , T_5 and T_7 . It is strongly recommended to farmers to apply @ 0.5% $FeSO_4$ and $ZnSO_4$ foliar spray (before flowering) along with recommended doses of fertilizer in mungbean for enhancement of production, quality and upliftment of their socio-economic status.

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Table 3. Mean effect of treatment/variety interaction for days to maturity

Treatments	Varieties												
	SML 668	MH 560	Satya	MH 421	Muskan	ML 776	Basanti	MH 565	MH 3-18	Pusa Visal	MH 124	Asha	Mean
T ₁ (RDF)	60.67	60.00	64.67	60.67	60.33	64.00	64.00	60.67	60.00	63.67	60.00	61.00	61.64bcde
T ₂ (RDF+50 kg/ha ZnSO ₄)	61.67	61.67	64.00	62.33	63.67	60.33	62.67	62.33	61.33	52.67	62.33	63.33	61.53e
T ₃ (RDF+100 kg/ha FeSO ₄)	63.33	62.67	64.00	64.33	63.00	62.00	63.33	63.67	61.67	63.00	63.00	61.33	62.94a
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	61.67	60.67	64.00	62.33	62.00	64.00	62.33	62.33	62.00	63.33	62.33	62.33	62.41bcde
T ₅ (RDF+0.5% ZnSO ₄ foliar spray)	64.33	61.00	62.00	62.33	63.33	63.00	65.00	62.00	63.00	64.00	65.00	61.00	63.00bcde
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	62.33	60.67	63.33	61.67	62.00	62.33	62.33	61.00	61.00	62.00	63.00	61.33	61.92ab
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	62.33	60.00	63.67	61.67	61.67	62.33	60.33	60.00	61.00	62.33	61.67	63.33	61.69abc
T ₈ (RDF)	60.67	60.00	64.67	60.67	60.33	64.00	64.00	60.67	60.00	63.67	60.00	61.00	61.64cd
T ₉ (RDF+50 kg/ha ZnSO ₄)	60.67	60.00	65.00	60.33	60.67	63.67	64.00	60.67	60.00	64.00	60.00	61.00	61.67de
T ₁₀ (RDF+100 kg/ha FeSO ₄)	62.00	60.67	64.33	60.67	62.00	63.67	63.00	61.67	60.00	64.33	60.67	62.33	62.11abcd
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	63.00	60.00	63.33	61.67	62.00	62.67	61.33	60.33	61.67	62.00	62.67	62.00	61.89bcd
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	62.00	60.33	63.67	61.67	61.33	63.00	60.67	61.00	61.00	61.67	62.33	62.33	61.75bcde
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	63.00	60.67	62.67	62.33	62.33	63.33	62.33	61.67	62.33	64.00	63.33	63.33	62.61cd
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	61.33	61.00	63.00	61.67	61.00	63.67	64.00	62.00	61.00	63.00	63.00	61.33	62.17abcd
S. E.	1.32												
C. D. (P=0.05)	3.68												

Means with the same letter(s) in each column have not statistically significant difference at P<0.05 by Duncan's Multiple Range Test.

Table 4. Mean effect of treatment/variety interaction for plant height

Treatments	SML	MH	Satya	MH	Muskan	ML	Basanti	MH	MH	3-18	Pusa	MHI	Asha	Mean
	668	560	421	776	565	124	75.00	71.50	70.50	75.00	69.00	67.67	73.33	69.58ef
T ₁ (RDF)	67.17	57.50	71.00	66.00	78.83	77.33	63.50	71.50	70.50	75.00	69.00	67.67	73.33	69.58ef
T ₂ (RDF +50 kg/ha ZnSO ₄)	76.50	81.00	70.83	74.33	72.33	74.83	79.00	68.00	71.67	77.00	72.67	73.33	73.33	74.29ab
T ₃ (RDF +100 kg/ha FeSO ₄)	64.00	71.83	78.50	71.00	76.17	78.00	81.00	74.50	74.00	81.00	72.00	75.00	75.00	74.75a
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	71.33	71.00	77.00	78.83	77.50	72.50	70.50	66.50	71.00	72.00	75.00	75.00	82.50	73.81b
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	60.67	77.00	77.00	74.33	78.00	64.33	65.50	66.33	68.67	69.00	63.00	63.00	62.17	68.83g
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	63.00	69.00	76.00	72.33	69.00	78.83	77.83	77.50	76.50	80.33	81.17	74.83	74.83	74.69a
T ₇ (RDF+ 50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	74.17	65.83	74.83	66.50	66.33	71.33	74.67	66.67	75.83	71.67	74.00	63.50	63.50	70.44d
T ₈ (RDF)	64.00	66.00	56.17	67.67	82.33	58.33	52.33	83.83	78.00	57.33	59.50	74.33	74.33	66.65h
T ₉ (RDF +50 kg/ha ZnSO ₄)	62.67	68.00	65.67	75.00	76.00	67.67	61.33	65.00	61.00	73.00	74.00	70.83	70.83	68.35g
T ₁₀ (RDF +100 kg/ha FeSO ₄)	75.83	71.33	70.33	59.33	59.23	61.50	61.33	73.17	84.00	82.00	59.33	87.00	87.00	70.37d
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	61.33	77.00	77.00	74.50	77.50	66.17	64.00	68.33	68.33	68.50	62.67	62.67	62.33	68.97fg
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	70.00	66.00	71.00	74.33	65.50	72.00	80.00	65.00	66.33	61.17	73.33	73.33	63.50	69.01fg
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	65.67	65.67	63.33	61.33	77.00	64.83	61.33	84.67	78.50	84.67	78.50	78.50	76.00	71.79c
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	81.50	67.50	76.00	61.67	63.67	71.33	74.00	65.67	75.00	72.00	73.00	73.00	61.33	70.22de
S. E.	4.01													
C. D. (P=0.05)	11.16													

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

Table 5. Mean effect of treatment/variety interaction for seed yield/plant

Treatments	Varieties											Mean	
	SML	MH	Satya	MH	Muskan	ML	Basanti	MII	MH	Pusa	MII		Asha
	668	560		421		776		565	3-18	Visal	124		
T ₁ (RDF)	5.44	8.63	7.53	8.65	19.62	7.84	8.30	11.14	12.28	6.36	8.94	12.40	9.76cde
T ₂ (RDF+50 kg/ha ZnSO ₄)	12.43	19.81	15.16	16.93	14.84	23.37	12.81	10.85	24.67	17.76	23.64	15.09	17.28a
T ₃ (RDF+100 kg/ha FeSO ₄)	12.31	17.29	14.91	11.59	19.51	6.62	7.29	20.42	14.30	12.35	24.14	19.49	15.02ab
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	12.94	19.49	12.76	16.32	11.84	9.88	11.99	11.85	11.34	11.91	19.63	13.09	13.59b
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	11.36	7.14	11.53	10.06	7.18	5.92	10.26	9.57	8.12	5.54	12.15	6.82	8.8cdef
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	7.31	13.46	17.23	9.60	12.91	5.06	9.20	13.96	12.16	6.99	16.65	9.50	11.17c
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	8.47	15.03	7.49	7.54	7.48	6.91	9.20	10.44	15.24	13.68	7.97	9.61	9.92cde
T ₈ (RDF)	8.53	10.30	12.15	5.39	11.88	10.49	9.64	16.49	8.28	9.91	10.96	6.68	10.06cd
T ₉ (RDF+50 kg/ha ZnSO ₄)	6.67	8.36	8.14	7.18	7.61	7.01	11.44	7.24	9.14	8.45	10.38	6.72	8.19def
T ₁₀ (RDF+100 kg/ha FeSO ₄)	6.70	8.58	12.39	5.82	8.69	6.54	6.84	7.01	8.78	7.97	10.83	5.82	8def
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	11.40	7.07	10.08	9.94	8.04	6.43	11.77	10.57	7.95	7.28	12.79	7.42	9.23cdef
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	5.55	8.52	11.85	7.14	7.90	6.36	8.23	7.59	8.47	7.55	6.45	6.01	7.63ef
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	4.31	9.73	7.03	9.80	5.15	7.25	6.82	7.34	7.65	5.62	6.58	5.16	6.87f
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	7.88	16.36	6.05	5.83	5.76	6.24	6.52	6.94	12.63	8.57	7.44	8.94	8.26def
S. E.													
C. D. (P=0.05)	2.04												
	5.69												

Means with the same letter(s) in each column have not statistically significant difference at P<0.05 by Duncan's Multiple Range Test.

Table 6. Mean effect of treatment/variety interaction for 100-seed weight

Treatments	Varieties										Mean		
	SML 668	MH 560	Satya	MH 421	Muskan	ML 776	Basanti	MH 565	MH 3-18	Pusa Visal		MH 124	Asha
T ₁ (RDF)	4.33	3.50	3.43	3.17	3.33	2.93	3.40	3.47	3.60	3.50	3.27	2.60	3.38c
T ₂ (RDF+50 kg/ha ZnSO ₄)	3.23	3.87	2.97	4.23	3.33	3.30	3.23	3.40	3.20	4.00	3.17	2.70	3.39c
T ₃ (RDF+100 kg/ha FeSO ₄)	4.03	3.50	2.97	3.37	3.10	2.77	2.80	3.27	4.13	3.50	3.30	2.87	3.3cd
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	3.33	3.37	2.73	3.40	3.20	2.73	3.50	3.13	2.63	3.47	3.37	2.53	3.12de
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	3.40	3.27	3.07	3.17	2.63	2.63	2.70	3.30	3.20	3.27	2.67	2.77	3.01e
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	3.17	3.20	2.80	3.30	3.37	2.40	2.47	3.20	3.23	3.03	2.93	2.67	2.98e
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ Foliar Spray)	3.17	3.17	2.80	3.23	2.73	2.40	3.00	3.20	3.17	3.27	2.40	2.40	2.91e
T ₈ (RDF)	4.37	4.33	4.00	4.33	4.23	3.33	4.00	4.20	3.47	4.30	3.70	3.40	3.97a
T ₉ (RDF+50 kg/ha ZnSO ₄)	4.67	4.37	3.57	4.03	3.33	2.67	3.33	4.23	3.37	4.00	3.67	3.27	3.71b
T ₁₀ (RDF+100 kg/ha FeSO ₄)	4.30	4.40	3.53	4.27	3.33	3.30	3.47	3.80	3.50	4.50	3.53	3.60	3.79ab
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	4.50	4.37	3.37	4.30	3.40	3.37	4.03	3.50	3.53	3.97	3.53	3.50	3.78ab
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	4.27	4.17	3.53	3.93	3.60	3.33	4.20	3.97	3.40	4.50	3.53	3.60	3.84ab
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	4.40	3.53	3.67	4.67	3.43	3.23	3.50	3.57	3.70	4.33	3.43	3.77	3.77ab
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	3.60	3.30	3.33	3.63	3.33	4.27	3.47	3.57	3.43	4.30	4.00	3.53	3.65b
S.E.													
C. D. (P=0.05)													

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

Table 7. Mean effect of treatment/variety interaction for protein content

Treatments	Varieties	SML 668	MH 560	Satya	MH 421	Muskan	ML 776	Basanti	MH 565	MH 3-18	Pusa Visal	MH 124	Asha	Mean
T ₁ (RDF)		23.17	18.69	23.60	24.24	21.07	24.61	23.73	21.49	21.52	23.81	19.21	20.63	22.15fg
T ₂ (RDF+50 kg/ha ZnSO ₄)		24.02	21.22	26.36	24.50	23.56	24.04	23.71	23.09	20.29	23.25	23.55	21.55	23.26cdef
T ₃ (RDF+100 kg/ha FeSO ₄)		26.23	24.49	23.42	25.58	16.68	21.83	17.62	23.08	20.92	23.56	23.56	24.64	22.63efg
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)		24.00	21.36	22.79	29.47	25.57	31.22	29.48	29.17	27.31	26.98	24.34	24.04	26.31b
T ₅ (RDF+0.5% FeSO ₄ foliar spray)		29.26	27.91	28.95	37.30	26.37	28.23	28.23	29.56	23.72	30.10	25.91	19.22	27.9a
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)		22.62	23.79	23.42	24.26	23.41	22.51	23.42	21.96	24.15	21.55	23.23	23.71	23.17defg
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)		25.10	24.57	23.82	23.85	24.59	23.75	24.16	24.28	23.73	24.50	23.13	21.79	23.94cd
T ₈ (RDF)		22.93	18.91	19.22	20.08	21.56	25.60	23.27	18.62	23.05	23.77	21.94	24.61	21.96g
T ₉ (RDF+50 kg/ha ZnSO ₄)		27.76	23.73	19.04	25.75	22.79	24.03	20.60	24.34	25.44	29.03	25.44	21.07	24.09cd
T ₁₀ (RDF+100 kg/ha FeSO ₄)		22.03	22.77	23.29	26.83	24.25	24.28	24.20	23.23	20.04	21.95	24.65	23.35	23.41cde
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)		22.62	26.03	25.96	23.04	25.74	26.39	21.85	24.66	15.78	19.52	25.25	22.93	23.31cdef
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)		27.42	25.92	24.80	25.57	25.02	23.61	23.11	23.48	23.37	24.61	23.16	23.18	24.44c
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)		23.00	22.52	22.33	21.42	21.18	23.98	24.78	20.90	25.60	24.88	24.10	24.19	23.24cdef
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)		23.98	23.61	25.33	24.64	24.67	24.64	24.83	24.75	21.19	24.76	22.26	23.89	24.05cd
S. E.		1.63												
C. D. (P=0.05)		4.53												

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

Table 8. Mean effect of treatment/variety interaction for iron content

Treatments	Varieties												Mean
	SML 668	MH 560	Satya 421	MH 421	Muskan 776	ML 776	Basanti 565	MH 3-18	Pusa Visal	MH 124	Asha		
T ₁ (RDF)	3.44	5.27	4.39	5.17	1.98	6.82	2.89	2.07	3.51	3.68	4.09	3.75i	
T ₂ (RDF+50 kg/ha ZnSO ₄)	3.03	1.08	4.61	2.04	5.88	11.41	4.90	2.57	2.36	1.21	4.31	4.04gh	
T ₃ (RDF+100 kg/ha FeSO ₄)	3.32	2.14	2.51	2.84	3.10	4.95	1.16	2.03	1.01	3.48	3.50	2.64k	
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	1.61	1.76	7.67	1.51	13.20	11.93	11.30	11.18	2.97	3.82	11.79	7.29c	
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	4.46	6.91	6.56	12.22	7.33	14.90	12.28	12.24	11.79	11.36	6.18	9.9a	
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	3.97	4.22	4.06	7.81	5.57	13.88	1.67	9.48	5.58	4.77	6.62	6.28d	
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	3.60	4.22	4.89	5.20	2.69	6.80	3.74	5.92	3.15	2.83	1.68	4.22g	
T ₈ (RDF)	1.25	2.91	2.89	2.15	2.75	4.57	5.04	0.91	1.90	1.03	4.02	2.55k	
T ₉ (RDF+50 kg/ha ZnSO ₄)	2.33	4.99	4.32	1.77	1.36	10.91	2.33	1.51	2.79	1.03	4.73	3.42j	
T ₁₀ (RDF+100 kg/ha FeSO ₄)	1.56	3.18	4.34	3.74	1.19	11.15	2.42	2.23	1.05	6.45	1.11	3.81hi	
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	8.87	1.08	1.65	1.82	4.74	11.03	9.91	1.41	0.83	5.14	10.20	4.8f	
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	4.67	6.28	1.26	1.90	8.25	11.66	8.75	5.81	1.62	7.07	9.96	6.01c	
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	3.16	9.28	1.95	8.49	1.16	13.26	3.78	11.89	8.66	9.75	3.58	6.46d	
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	5.32	11.50	5.24	8.61	9.60	13.06	8.45	10.03	5.93	6.78	7.43	8.73b	
S.E.													
C. D. (P=0.05)													

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

Table 9. Mean effect of treatment/variety interaction for zinc content

Treatments	Varieties										Mean		
	SML	MH	Satya	MH	Muskan	ML	Basanti	MH	MH	Pusa		MII	Asha
	668	560	421	776	565	3-18	Visal	124					
T ₁ (RDF)	1.93	1.99	1.74	1.76	1.82	2.78	1.75	1.58	1.67	1.54	1.93	1.67	1.84c
T ₂ (RDF+50 kg/ha ZnSO ₄)	2.19	1.74	1.17	2.42	2.77	2.93	2.51	2.42	1.74	1.74	1.99	2.01	2.11b
T ₃ (RDF +100 kg/ha FeSO ₄)	2.07	1.61	1.85	1.77	1.62	2.63	2.42	1.67	1.65	2.06	2.06	2.06	1.96c
T ₄ (RDF+0.5% ZnSO ₄ foliar spray)	1.74	2.65	2.37	2.73	2.34	3.36	2.02	2.21	1.80	2.55	2.15	1.79	2.31a
T ₅ (RDF+0.5% FeSO ₄ foliar spray)	1.87	1.98	1.51	1.47	1.81	2.77	1.89	1.73	1.82	1.69	1.47	1.25	1.77g
T ₆ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	2.79	1.46	1.06	1.35	1.89	2.89	1.72	1.60	1.47	1.36	1.29	1.62	1.71i
T ₇ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	1.41	1.46	1.07	1.86	1.71	1.94	1.68	1.58	1.54	1.50	1.72	1.71	1.6j
T ₈ (RDF)	1.30	1.81	1.37	1.25	1.56	2.35	1.48	1.31	1.36	1.16	1.34	1.39	1.47k
T ₉ (RDF+50 kg/ha ZnSO ₄)	1.80	1.84	1.69	2.06	1.85	2.87	1.93	1.99	1.83	1.74	1.93	1.98	1.96c
T ₁₀ (RDF +100 kg/ha FeSO ₄)	1.57	1.99	1.26	1.64	1.58	2.48	1.45	1.63	1.63	1.55	2.56	2.19	1.79f
T ₁₁ (RDF+0.5% ZnSO ₄ foliar spray)	2.28	2.21	1.09	2.07	2.18	2.81	2.13	1.57	1.63	1.98	1.42	1.84	1.93d
T ₁₂ (RDF+0.5% FeSO ₄ foliar spray)	1.92	1.75	1.94	1.79	1.88	2.23	1.74	1.42	1.79	1.43	1.55	1.56	1.75h
T ₁₃ (RDF+25 kg/ha ZnSO ₄ +0.5% ZnSO ₄ foliar spray)	2.28	1.73	1.86	1.33	1.63	2.54	1.60	1.62	1.41	1.93	1.38	1.79	1.76gh
T ₁₄ (RDF+50 kg/ha FeSO ₄ +0.5% FeSO ₄ foliar spray)	1.23	1.53	1.29	1.26	1.53	2.47	1.30	1.86	1.99	1.85	2.03	2.13	1.7i
S.E.	0.18												
C. D. (P=0.05)	0.49												

Means with the same letter(s) in each column have not statistically significant difference at P≤0.05 by Duncan's Multiple Range Test.

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