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EFFECT OF IRON AND ZINC AGRONOMIC BIOFORTIFICATION ON GROWTH AND YIELD OF MUNGBEAN (*Vigna radiata* L. Wilczek) VARIETIES IN SEMI-ARID REGION OF RAJASTHAN

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ABSTRACT

A field experiment was carried out at Instructional Farm of S.K.N. College of Agriculture, Jobner, Rajasthan during *kharif* season of 2024 and 2025 to study the response of mungbean [*Vigna radiata* (L.) Wilczek] varieties to agronomic biofortification. The experiment was laid out in a split plot design, comprised with four varieties namely RMG-492, RMG-975, MH-421 and MH-1142 in main plots and seven treatments of fertilizer levels *viz*., RDF (Control), RDF+$FeSO_4.7H_2O$ (0.5%), RDF+$ZnSO_4.7H_2O$ (0.5%), RDF+ Fe-EDTA (0.5), RDF+ Zn-EDTA (0.5 %), RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) and RDF+ $FeSO_{4.}7H_2O$ (0.5%) + $ZnSO_4$ (0.5%) in sub plots. In this way, the experiment had twenty-eight treatment combinations were replicated thrice. Among main plots, taller plant height was recorded under variety MH-421 at 50 DAS (48.1cm) and harvest (59.7cm) respectively, during both the years as well as pooled basis of experimentations. While cultivar MH-421(1206 kg/ha) was better over RMG-492, RMG-975 and MH-1142 in respect of seed yield of mungbean. A significantly higher stover and biological yield of mungbean was obtained with variety MH-421(2881kg/ha) over RMG-492, RMG-975 and MH-1142 during both the year of experimentation and in pooled analysis. However, in sub plots maximum plant height were recorded with RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) foliar spray treatment at 50 DAS (45.9 cm) and harvest (56.8 cm), respectively. but it remained at par with RDF+ $FeSO_{4.}7H_2O$ (0.5%) + $ZnSO_4$ (0.5%) and RDF+ Zn-EDTA (0.5%) during both the years as well as in pooled mean. While treatment RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) had highest seed yield (1197 kg/ha) and stover and biological yield (2853 kg/ha) compared to rest of treatments, but it was statistically at par with RDF+ $FeSO_4.7H_2O$ (0.5%) + $ZnSO_4.7H_2O$ (0.5%) fertilizer level.
Keywords **:** Mungbean, Foliar spray, Agronomic biofortification, Fe-EDTA, Zn-EDTA, Varieties, growth and yield.

Introduction

Mungbean [*Vigna radiata* (L.) Wilczek] also known as green gram, green bean, mash bean or golden gram, is one of the essential leguminous crops grown in arid and semiarid regions of India. It is a short duration crop. It belongs to the family Fabaceae and addition of this crop to the cereal cropping system has the potential to boost farm revenue, enhance soil productivity and human health, conserve irrigation water, and advance long-term agricultural sustainability. After chickpea and pigeon pea, mungbean is the third most important seed legume grown and consumed in India (Samant and Mohanty, 2017). Its seeds are utilized in making dal, curries, soup, sweets and snacks etc. The sprouted seeds contain a good number of vitamins such as Thiamine, Niacin and Ascorbic acid (Dahiya *et al*., 2015). In India, mungbean is grown on 35.5 lakh hectares' area with a production of 42.44 lakh tonnes with a productivity of 750kg/ha (Anonymous, 2024). The important mungbean growing states are Rajasthan, Madhya Pradesh, Uttar Pradesh, Punjab, Haryana, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. In Rajasthan mungbean growing districts are Nagaur, Sikar, Jodhpur, Jaipur, Ajmer, Pali, Jalore, Jhunjhunu, Tonk, Churu, Barmer and Bikaner. Rajasthan held the top position in India, producing 1.32 million tonnes of mungbean on 2.16 million hectares with an average yield of 610 kg/ha (Anonymous, 2021a). Total area under this crop is 25.60 lakh hectares 18 lakh tonnes of production and productivity of 430 kg/ha (Anonymous, 2024). The ideal environment for its growth is warm and humid climate with temperature range between 25-35 °C and evenly distributed rainfall of 400-550 mm throughout the growing season.

In this context, micronutrients, particularly zinc and iron, play a vital role in enhancing productivity as well as seed quality. The differential response of mungbean varieties to micronutrient application has also been well documented, where certain genotypes exhibit higher efficiency in nutrient uptake, translocation, and accumulation in seeds. This highlights the significance of varietal selection along with agronomic biofortification practices for improving both yield and micronutrient density in mungbean (Nair *et al*., 2013). Micronutrient deficiencies affect over half of the world's population, notably in underdeveloped nations. Especially iron and zinc deficiencies in human nutrition are widespread in india is one of the emerging Asian nations (Alloway 2008). Factually, zinc is one of the eight essential micro-nutrient require for acceleration of growth and reproduction of the plants. Zinc enriched finger proteins are required in signal transduction, regulation and transcription of deoxyribonucleic acid (DNA) ribonucleic acid (RNA) or other proteins in the plant. Zinc involved in the root nodulation of plant and enables to the pulse crops to fix inert nitrogen in the root nodule. Zinc deficiency is not only causing low productivity of the crops, but it also affects the human health. The major six categories of enzymes which play vital role in the human nutrition have contained zinc (Barak and Helmke, 1993). The solubility of zinc in the soil is very less leading to poor uptake resulted into low bioavailability in the plant and has become the major problems across the world (Alloway, 2009). Iron is an essential micronutrient that plants need to complete their life cycle, according to Arnon and Stout (1939). It actively contributes to the production of chlorophyll and serves as a structural component of hemes, haematin, and leghaemoglobin that is involved in the nitrogen fixation process in pulses, which is facilitated by the enzyme "nitrogenase." Despite iron's widespread abundance in the earth's crust, its limited solubility results in reduced availability and, ultimately, inadequate crop absorption. It is crucial to formation of haemoglobin, oxygen transport, and the activation and deactivation of several enzymes that carried out essential body functions.

Biofortification word derived from Greek language “*bios*” means “*life*” and Latin word “*fortificare*” means “*making strong*”. It can be defined as the process of increasing the concentrations of certain micronutrients in edible portions of crop plants naturally by application of mineral fertilizers *i.e.*, agronomic approaches or through conventional breeding approaches (Majeed *et al*., 2020). Zinc and iron can be agronomically biofortified by soil and foliar applications. Foliar fertilization is more practical and effective as mineral nutrients are easily transferred to edible tissues. Foliar-applied nutrients are absorbed by the leaf epidermis after that are transported to other plant parts via phloem and xylem (Singh *et al*., 2015). Therefore, agronomic biofortification is the easiest, feasible and fastest means of integrating pulse seeds with Fe, Zn or any other desirable micronutrients. Among different types of biofortification techniques, foliar application is considered as the best way of increasing the micronutrient level in crops, as nutrients are directed towards the leaves at growth stages (Jalal and Shah., 2020). Thus, the current experiment was carried out to investigate the response of mungbean (*Vigna radiata* (L.) Wilczek) varieties to agronomic biofortification,

Materials and Methods

A field experiment was conducted during *kharif* seasons of 2024 and 2025 at Instructional Farm of S.K.N. College of Agriculture, Jobner, Rajasthan. Geographically, Jobner is situated 45 km west of Jaipur. The physiographic location of the experimental farm is 26° 5' North latitude and 75° 28' East longitude with an altitude of 427 meters above mean sea level. This region falls under agro-climatic zone IIIa (Semi-Arid Eastern Plain Zone) of Rajasthan. The region receives higher rainfall during July and September months from South-West monsoon with an annual range of 400-500 mm. As weather and climatic condition influences the growth, yield and quality of crop as well as biotic phase of soil during the growing season. Soil of experimental site was sandy loam in texture and slightly alkaline in reaction (pH 8.2 and 8.0) and low in available nitrogen (133.25 and 128.0

kg/ha), medium available phosphorus (18.16 and 16.23 kg/ha), available potassium (154.6 and 151.2 kg/ha), available zinc (0.405 and 0.398 ppm) and available iron (4.26 and 3.98 ppm) during both the years *i.e*., 2024 and 2025, respectively. The experiment comprised four mungbean varieties *viz*., RMG-492, RMG-75, MH-421 and MH-1142 and seven fertilizer levels RDF(Control), RDF+$FeSO_4.7H_2O$ (0.5%), RDF+$ZnSO_4.7H_2O$ (0.5%), RDF+ Fe-EDTA (0.5), RDF+ Zn-EDTA (0.5 %), RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) and RDF+ $FeSO_4.7H_2O$ (0.5%) + $ZnSO_4$ (0.5%), thereby making 28 treatment combinations that were laid out in split plot design and replicated three times. The seed were sown in furrow opened at the depth of about 4-5 cm using seed rate of 20 kg/ha with plant geometry of 30 × 10 cm. Before sowing, field was thoroughly ploughed and levelled. Recommended dose of fertilizer for Jobner region is 20 kg N + 40 P_2O_5 kg/ha. Foliar spray of iron (Fe) and zinc (Zn) was applied at 0.5% concentration. The solution was prepared by dissolving 5 g of respective chemical per litre of water. Two foliar sprays were applied at pre-flowering (35 DAS) and pod development stages (45 DAS) after sowing using a spray volume of 500 litres per hectare with a hand sprayer during morning/evening hours to ensure uniform coverage and to avoid leaf scorching. The data recorded for crop growth parameters, yield and other characters were statistically analysed as per the standard procedure outlined by Panse and Sukhatme (1985).

Plant height

Five plants were selected randomly from each plot, tagged permanently and used for measurement of plant height. The height of each tagged plant was measured periodically at 25, 50 DAS and at harvest stage from base of the plant to the tip of the main shoot by metre scale and average of five was computed as mean plant height. The mean plant height (cm) at each growth stage was recorded.

Seed yield

After threshing, winnowing and cleaning the produce of each plot was weighed separately in kg per plot and then converted in terms of seed yield in kg/ha.

Stover yield

Stover yield (kg/ha) was obtained by subtracting the seed yield (kg/ha) from biological yield (kg/ha).

Biological yield

The weight of the thoroughly sun-dried harvested produce of each plot was recorded separately before threshing as biological yield and then converted into kg/ha.

Harvest index

Harvest index was computed by using the formula given by Singh and Stock of (1971) which is expressed as:

Results and Discussion

Effect on plant height and number of branches/plant

Effect of varieties

It is evident from the data presented in Table 1 indicated that on growth attributes significantly influenced plant height at 50 DAS and at harvest stage of mungbean. Mungbean variety MH-421 significantly improved plant height at 50 DAS and at harvest to the tune of 7.12, 15.0, 23.1 and 9.50, 19.6, 30.1 % respectively over varieties MH-1142, RMG-975, RMG-492 on pooled mean basis. While there was no significant variation found at 25 DAS of mungbean during both the years of experimentation as well as pooled mean basis. The significant variations in plant height among the varieties may be due to their genetic variability for this trait. The similar results have also been reported by Choudhary *et al.* (2018) and Goswami *et al.* (2010).

Effect of iron and zinc foliar spray

A perusal of data Table 1 reveals that foliar spray of iron and zinc significantly influenced plant height at 50 DAS and at harvest stage of mungbean, while there was no significant variation found at 25 DAS of mungbean during both the years of experimentation as well as pooled mean basis. On pooled basis, the maximum plant height was recorded with RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) foliar spray treatment compares to rest of treatments. Application of RDF+ Fe-EDTA (0.5%) + Zn-EDTA (0.5%) foliar spray recorded an increase of plant height by 11.4, 8, 7.7 and 6.74 % at 50 DAS and 14.7,13.6,12.7 and 11.6 % at harvest respectively, over RDF(Control), RDF+ $FeSO_4.7H_2O$ (0.5%), RDF+$ZnSO_4.7H_2O$ (0.5%) and RDF+ Fe-EDTA (0.5%) on pooled basis.

This enhancement in growth parameters could be linked to synergistic effects of Zn and Fe in boosting, chlorophyll formation, enzymes activity and photosynthesis efficiency, which in turn fostered better vegetative growth. Zn has a crucial function in auxin synthesis and protein metabolism, while Fe functions in chlorophyll biosynthesis and electron transport. Hence their combined effect boosted the cellular functions and overall plant vigor. Similar growth enhancing effects of zinc and iron application have been reported by Tiwari *et al*. (2023), Hashim *et al*. (2022) and Krishnaraj *et al*. (2020).

Effect on seed yield, stover yield, biological yield and harvest index

Effect of varieties

Data pertaining to effect of different mungbean varieties on seed and stover yields of mungbean given in Table 2 and fig. 2 clearly showed that variety MH-421 registered significant increase in seed, stover and biological yield as compared to rest of the varieties during individual years as well as in pooled analysis. The pooled analysis of data revealed that mungbean variety MH-421 produced the highest seed yield (1206 kg/ha) and stover yield (2881 kg/ha). It increased the seed yield by in pooled analysis indicated 25.9, 15.2 and 7.1 % higher and stover yield which was 18.7, 13.7 and 7.33 % higher than RMG-492, RMG-975 and MH-1142, respectively on pooled mean basis. Attainments of particularly higher or lower yield attributing character among the different varieties are the genetically controlled phenomenon. Such variations in yield attributes among the mungbean varieties have also been observed by several research workers (Goswami *et al*. 2010, Verma *et al.* 2011, Choudhary *et al*. 2018 and Singh *et al.* 2023). Harvest index remained non-significant under different varieties during both the years as well as in pooled analysis.

Effect of iron and zinc foliar spray

Foliar spray of iron and zinc had marked effect on seed yield, stover yield and biological yield of mungbean during both the years of investigation as well as in pooled analysis. Among fertilizer levels, RDF+ Fe-EDTA (0.5%) +Zn-EDTA (0.5%) obtained significantly higher seed yield (1197 kg/ha) and stover yield (2853 kg/ha) as compared to RDF(Control), RDF+$FeSO_4.7H_2O$ (0.5%), RDF+$ZnSO_4.7H_2O$ (0.5%), RDF+ Fe-EDTA (0.5%) and RDF+ Zn-EDTA (0.5%), respectively during both years as well as in pooled analysis but it was remained statistically at par with RDF+ $FeSO_4.7H_2O$ (0.5%) + $ZnSO_4.7H_2O$ (0.5%) fertilizer level. It was noticed foliar sprayed with RDF+ Fe-EDTA (0.5%) +Zn-EDTA (0.5%) at pre-flowering and pod development stage magnificent increments in seed yield and stover yield by 25.0, 14.7, 12.4, 10.2 and 4.8 and 22.2, 10.5, 9.68, 8.85 and 6.53 % over RDF(Control), RDF+$FeSO_4.7H_2O$ (0.5%), RDF+$ZnSO_4.7H_2O$ (0.5%), RDF+ Fe-EDTA (0.5%) and RDF+ Zn-EDTA respectively, on pooled analysis. Foliar spray of RDF+ Fe-EDTA (0.5%) +Zn-EDTA (0.5%) increase in seed, stover and biological yield may be attributed to the fact that favorable nutritional environment in rhizosphere and absorption of iron by plant leaves led to increased photosynthetic efficiency and production of assimilates as stated above, might have also favored efficient partitioning of photosynthates in different vegetative and reproductive structures particularly the seed which is ultimate sink. Positive effect of zinc application on seed yield may be due to higher carbonic anhydrase activity, which is localized in cytoplasm and chloroplast facilitating the transfer of CO_2 or HCO_3^- during CO_2 assimilation phase of photosynthesis through increasing the rate of equilibrium between CO_2 and HCO_3^- in solution. On the other hand, SOD helps to scavenge free radicles and protects the photosynthetic apparatus from oxidative damage (Potarzycki and Grzebisz 2009). Enhancement in major yield attributes, resulted in higher seed yield. The similar results have also been reported by Pal *et al.* (2019) Phattarakul *et al.* (2012), Rehman *et al.* (2012), Gahlot *et al.* (2020), Singh *et al.* (2023) and Mondal *et al*. (2011). Harvest index remained non-significant under different fertilizer level treatments during both the years as well as in pooled analysis.

Conclusion

Based on pooled analysis of two years' experimental results, it may conclude that growing of mungbean variety MH-421 significantly higher growth attributes and seed yield as compare to rest of varieties *viz*., RMG-492, RMG-975 and MH-1142. Among agronomic biofortification treatments, two times foliar spray of combined application of RDF, Zn-EDTA and Fe-EDTA at 0.5% at pre flowering and pod development stage, greatly improved the growth dynamics and yield performance of mungbean.

Table 1 : Effect of varieties and agronomic biofortification on plant height of mungbean (cm) at different stages.

Treatments	Plant height (cm)								
	25 DAS			50 DAS			At harvest		
	2024	2025	Pooled	2024	2025	Pooled	2024	2025	Pooled
Varieties									
RMG-492	15.0	13.0	14.0	39.2	38.5	38.9	46.6	44.6	45.6
RMG-975	15.4	13.4	14.4	42.2	41.5	41.8	50.9	48.1	49.9
MH-421	15.8	13.9	14.8	48.3	47.9	48.1	60.9	58.5	59.7

MH-1142	15.6	14.1	14.9	45.3	44.6	44.9	55.5	53.6	54.5
SEm ±	0.30	0.24	0.19	0.88	0.85	0.61	1.11	1.17	0.81
CD (P = 0.05)	NS	NS	NS	3.03	2.96	1.88	3.85	4.05	2.49
CV (%)	8.74	8.17	-	9.17	9.08	-	9.53	10.43	-
Fertilizer levels									
RDF (Control)	15.1	13.3	14.2	41.5	40.1	41.2	50.8	48.1	49.5
RDF + 0.5% $FeSO_4.7H_2O$ foliar spray at PF and PD	15.2	13.4	14.3	42.8	42.2	42.5	51.2	49.0	50.0
RDF + 0.5% Fe-EDTA foliar spray at PF and PD	15.3	13.3	14.4	43.4	42.8	43.0	51.9	49.1	50.9
RDF + 0.5% $ZnSO_4.7H_2O$ foliar spray at PF and PD	15.4	13.5	14.5	42.9	42.3	42.6	51.6	49.2	50.4
RDF + 0.5% Zn-EDTA foliar spray at PF and PD	15.9	14.2	15.0	44.7	43.8	44.2	55.1	53.5	54.3
RDF + 0.5% $FeSO_4.7H_2O$ + 0.5 % $ZnSO_4.7H_2O$ foliar spray at PF and PD	15.8	13.9	14.8	44.9	44.1	44.5	56.5	53.9	55.1
RDF + 0.5% Fe-EDTA + 0.5% Zn-EDTA foliar spray at PF and PD	15.4	13.6	14.5	46.2	45.6	45.9	57.3	56.3	56.8
SEm ±	0.27	0.31	0.22	0.77	0.88	0.65	1.12	1.09	0.87
CD (P = 0.05)	NS	NS	NS	2.19	2.49	1.82	3.20	3.10	2.43
CV (%)	6.12	7.76	-	6.10	7.04	-	7.28	7.34	-

PF- Pre-flowering stage

PD- Pod development stage

Table 2 : Effect of varieties and agronomic biofortification on grain, stover, biological yield and harvest index of mungbean

Treatments	**grain yield (kg/ha)**			**Stover yield (kg/ha)**			**Biological yield (kg/ha)**			**Harvest index (%)**		
	2024	**2025**	**Pooled**	**2024**	**2025**	**Pooled**	**2024**	**2025**	**Pooled**	**2024**	**2025**	**Pooled**
Varieties												
RMG-492	1021	895	958	2465	2388	2426	3486	3283	3384	29.2	27.3	28.3
RMG-975	1100	998	1049	2574	2492	2533	3674	3490	3582	29.9	28.6	29.3
MH-421	1238	1173	1206	2945	2817	2881	4184	3990	4087	29.6	29.4	29.5
MH-1142	1164	1087	1126	2767	2600	2684	3932	3687	3809	29.5	29.4	29.4
SEm ±	22	23	16	55	53	38	83	77	57	0.59	0.56	0.41
CD (P = 0.05)	77	78	49.16	190	184	118	288	267	175	NS	NS	NS
CV (%)	9.11	9.99	-	9.37	9.47	-	9.99	9.78	-	9.16	8.94	-
Fertilizer levels												
RDF (Control)	988	925	957	2418	2249	2334	3406	3174	3290	29.00	29.09	29.05
RDF + 0.5% $FeSO_4.7H_2O$ foliar spray at PF and PD	1089	996	1043	2629	2532	2581	3718	3528	3623	29.3	28.2	28.73
RDF + 0.5% Fe-EDTA foliar spray at PF and PD	1135	1036	1086	2660	2581	2621	3795	3617	3706	29.9	28.6	29.3
RDF + 0.5% $ZnSO_4.7H_2O$ foliar spray at PF and PD	1110	1020	1065	2643	2559	2601	3753	3579	3666	29.5	28.4	29.0
RDF + 0.5% Zn-EDTA foliar spray at PF and PD	1152	1058	1105	2743	2612	2678	3895	3670	3783	29.6	28.8	29.2
RDF + 0.5% $FeSO_4.7H_2O$ + 0.5% $ZnSO_4.7H_2O$ foliar spray at PF and PD	1195	1089	1142	2806	2697	2752	4001	3786	3894	29.9	28.7	29.3
RDF + 0.5 % Fe-EDTA + 0.5 % Zn-EDTA foliar spray at PF and PD	1249	1144	1197	2915	2790	2853	4164	3934	4049	29.9	29.0	29.5
SEm ±	26	27	20	52	54	42	78	75	60	0.67	0.67	0.51
CD (P = 0.05)	73	77	56	148	153	116	221	213	168	NS	NS	NS
CV (%)	7.83	9.05	-	6.71	7.25	-	7.05	7.18	-	7.78	8.14	-

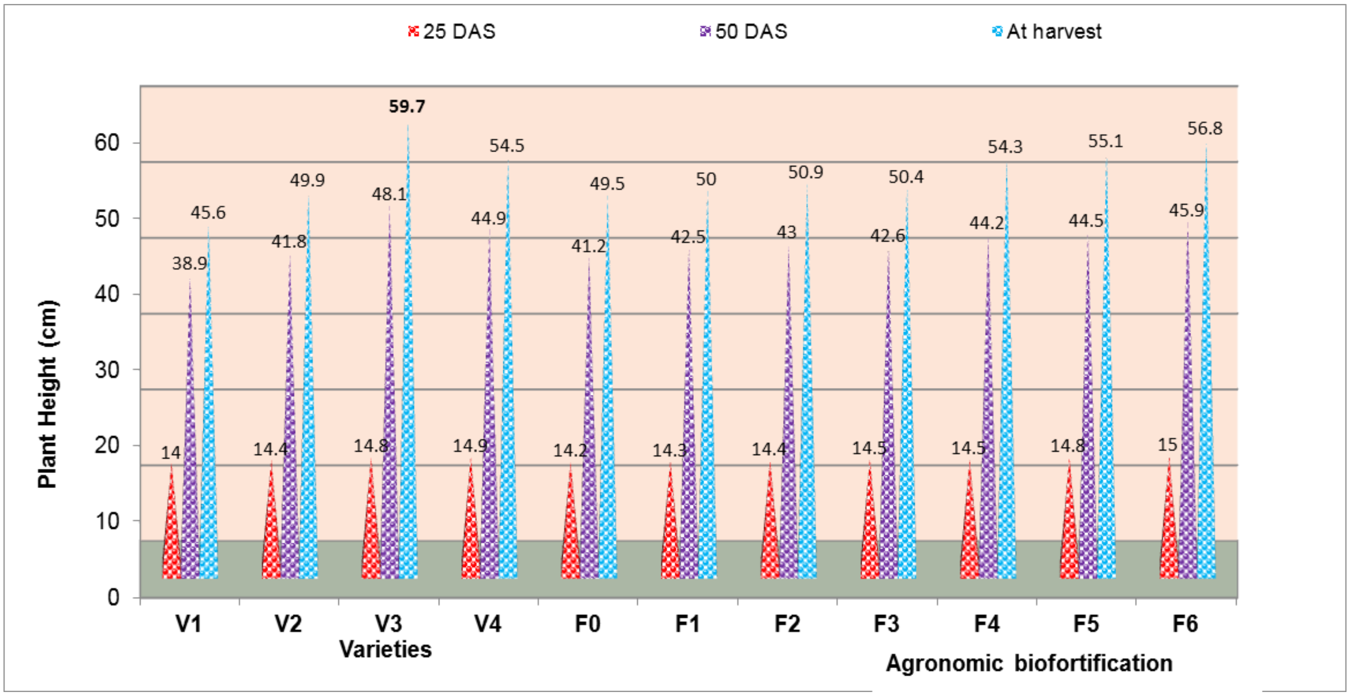

Fig. 1 : Effect of varieties and agronomic biofortification on plant height at different stages of mungbean

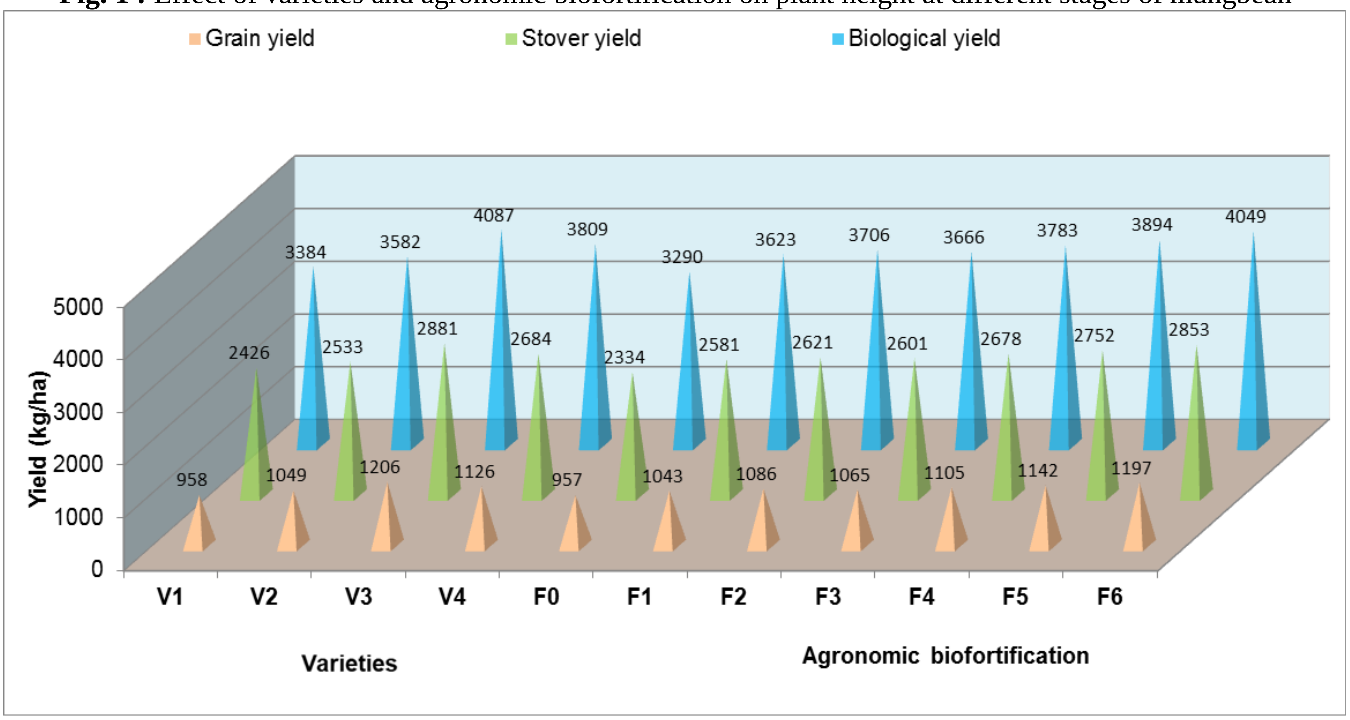

Fig 2 : Effect of varieties and agronomic biofortification on grain, stover and biological yield of mungbean

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