Journal of Pure and Applied Agriculture (2021) 6(2): 34-42
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/

Evaluating the effect of foliar applied manganese, iron, zinc and boron at different growth stages of Mash bean [*Vigna mungo* (L.) Hepper]

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Abstract

Pulses cultivation in Pakistan has been markedly declined although these are highly nutritious. Micronutrients deficiency is increasing due to their fixation in calcareous soils of Pakistan. To overcome this problem, a field trial was carried during 2019 at University of Agriculture Faisalabad to assess the effectiveness of different micronutrients (Mn, Fe, Zn and B) on black gram. Randomized Complete Block Design (RCBD) with three replications was used. Chakwal mash was used as a test variety. The treatments were [Control, Water spray at 25 DAS (Days after sowing), Water spray at Flowering, Mn (0.5%) at 25 DAS, Mn (0.5%) at Flowering, Fe (0.5%) at 25 DAS, Fe (0.5%) at Flowering, Zn (0.5%) at 25 DAS, Zn (0.5%) at Flowering, B (0.5%) at 25 DAS, B (0.5%) at Flowering]. Growth parameters observed were significantly affected with treatment (T_8) with foliar application of 0.5 % Zn at 25 DAS. Significantly, the maximum plant height (59.26 cm), number of pods per plant (17.00), pod length (4.63 cm), number of seeds per pod (8.66), 1000-grain weight (35.16 g), seed yield (1031.3 kg ha^{-1}), biological yield (3366.7 kg ha^{-1}), HI (30.63%), grain carbohydrate contents (60%), grain protein contents (23.00 %) were observed in mash bean when 0.5% foliar spray of Zn was applied at 25 DAS. The highest grain Mn, Fe, Zn and B concentration (0.20, 7.60, 3.40, 0.09 mg/100 g) were recorded when 0.5% foliar spray of respective micronutrient was applied. Boron spray also affected the parameters in a similar way with providing fruitful results which were at par with zinc. In conclusion, application of Zn at early stages while the application of B at lateral stages is equally important in yield escalation in mash bean.

Keywords: Foliar application, Growth stages, Mash bean, Micronutrients, Spray

To cite this article: Fatima, H., Tahir, M., & Saleem, M. A. (2021). Evaluating the effect of foliar applied manganese, iron, zinc and boron at different growth stages of mash bean [*Vigna mungo* (L.) Hepper]. *Journal of Pure and Applied Agriculture*, *6*(2), 34-42.

Introduction

Legumes are the chief source of food next to cereals. Black gram (mash bean) is a short duration crop with high nutritive value. In Pakistan, mash bean is cultivable in both summer and winter season and are acceptable in any crop rotation. Inclusion of nitrogen fixing crops is most important in the cropping system to enhance soil health (Yakubu et al., 2008). Pulses are of great importance for protein sources in the human diet (Akram et al., 2020). Bell and Dell (2008) reported that more than 3 billion people in the world are suffering from micronutrient malnutrition. Use of micronutrients helps in good seedling growth and enhances crop productivity in many cases (Farooq et al., 2012). Management of crop nutrition by applying macro and micro-nutrients is important to obtain high yield (Arif et al., 2006). Management of crop nutrition is important to achieve higher yields (Saleem et al. 2020). Farmers are still continuously ignoring the usage of micronutrients. Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Asad & Rafique, 2000). Zayed et al. (2011) stated that spray of micro elements is more advantageous than soil addition. Foliar fertilization of micronutrients is a more useful method for improved yield, protein content and nitrogen fixation (Hemati, 2005). The foliar nutrition to decrease deficiency problem is an alternative option for nutrients uptake failure soil (Cakmak, 2008).

Application of foliar nutrients immediately provides necessary nutrients to the plants (Babaeian et al., 2011). Sprayed nutrients may provide efficiency from 10-20 times than soil application (Zaman & Schumann, 2006). Among different micronutrients, manganese (Mn) affects the process of photosynthesis, respiration, structure of chloroplast, and nitrate accumulation in crop plants (Zarabimafi & Pour, 2014). Deficiency of Mn leads to inhibition of growth, chlorosis, necrosis and early leaf drop (Ghasemian et al., 2010). Iron is one of most important micronutrients that helps in transfer of energy to the plant body (Allen et al., 2007). Yashona et al. (2018) documented that the plants showed lower rate of protein synthesis and protein accumulation under zinc deficiency. Zn acts as cofactor in many enzymes such as superoxide dismutase, alcohol dehydrogenase, RNA polymerase and carbonic anhydrase therefore zinc deficiency may limit protein synthesis in plants (Khan et al., 2004). Zn spray meaningfully enhanced yield of legumes (Sarkar et al., 2007). Boron as a micronutrient involved in pollen tube growth, flower retention, seed set, and metabolites translocation mainly occurred owing to seed setting (Tanaka & Fujiwar, 2008). Boron has a chief role in plant cell wall fidelity (Bassil et al., 2004). It is a prerequisite for cell discrepancy at all plant meristems, where cell division is active (El-Hamdaoui et al., 2003).

Kaisher et al. (2010) reported the effect of boron on pulses and determined that it has an integral part in protein synthesis. Guilfoyle et al. (2001) observed that shortage of boron changes the equilibrium and absorption of three macronutrients; N; P and K. Boron helps in nitrogen fixation, sugar translocation, cell wall composition, sucrose synthesis, protein production, K^+ carrying and membrane rigidity (Singh et al., 2014). Unproductiveness in plants due to falsification of reproductive tissues caused by boron insufficiency that influences pollen germination, as it decreases and enhances flower drop and fruit set respectively (Subasinghe et al., 2003). Boron spray along with N is much more beneficial in comparison to sole application (Farooqi et al., 2019). Boron toxicity also causes adverse effects on crop production (Ahmad et al., 2018). Considering the above facts, the experiment was executed to resolve this problem by foliar feeding of nutrients Mn, Fe, Zn and B. Hence, an experiment was held for scrutinizing the effect of exogenous applied Mn, Fe, Zn and B on black gram.

Materials and Methods

Trial location and soil analysis

During spring season (2019) the trial was executed at University of Agriculture, Faisalabad. Soil sampling was done at the depth of 30 cm by using auger, before sowing. Various soil properties viz. soil pH, organic matter, texture, total nitrogen, EC, available phosphorus, Mn, Fe, Zn and B contents and extractable potassium were observed by using standard methods. Various soil properties were observed before sowing that are shown in Table 1.

Table 1 Analysis of experimental soil

Component	Unit	Value
pH	-	7.8
Electrical conductivity (ECe)	dSm^{-1}	2.2
Organic matter (O.M)	%	0.81
Total nitrogen (T.N)	ppm	0.4
Phosphorous (P)	mg/kg	4.33
Potassium (K)	mg/kg	142
Zinc (Zn)	ppm	0.40
Boron (B)	ppm	0.78
Sand	%	46
Silt	%	36
Clay	%	14
Soil class = Sandy loam	-	-

Seed source and seed bed preparation

Seed of mash cultivar (Chakwal mash) was collected from Ayub Agriculture Research Center for the current experiment. At field capacity, soil pulverization was done with the help of cultivator and planker.

Experimental layout

Crop was sown during March 2019 by hand drill in plots with net size 5.0 m × 1.8 m. Randomized Complete Block Design (RCBD) with three replications was used. Chakwal mash was used as a test variety with seed rate 25 kg ha^{-1}. The treatments were T_1: Control, T_2: Water spray at 25 DAS (Days After Sowing), T_3: Water spray at Flowering, T_4: Mn (0.5%) at 25 DAS, T_5: Mn (0.5%) at Flowering, T_6: Fe (0.5%) at 25 DAS, T_7: Fe (0.5%) at Flowering, T_8: Zn (0.5%) at 25 DAS, T_9: Zn (0.5%) at Flowering, T_{10}: B (0.5%) at 25 DAS, T_{11}: B (0.5%) at Flowering. Percent Mn, Fe, Zn and B spray were made by dissolving the required amount of $MnSO_4$, $FeSO_4$, $ZnSO_4$ and Boric acid in water for each treatment. Volume of water and weight of the micronutrients used were determined according to the plot size.

Plant protection measures

Several protective measures were taken against pathogens. There was weed infestation at an early growth stage which was copped with application of weedicides. Lactofen 250 ml/acre was used to control broad leaf weeds and Quizalofop -p- Ethyl 500ml/acre was used to control narrow leaf weeds.

Fertilizer and irrigation

NPK as recommended (23: 58: 30 kg ha^{-1}, respectively) were used during field preparation. Urea, DAP and MOP were used for N, P and K sources, respectively. All these fertilizers were applied before sowing of crops except urea, which was used in split doses i.e. half before sowing and half with 1st irrigation. Crop during growth season, was irrigated three times with 1st irrigation three weeks after seed germination, 2nd irrigation at flowering stage and 3rd irrigation at pod formation stage.

Harvesting and threshing

Harvesting of the crop was completed by hand when 90-95% pods were ripened. Pods were threshed manually after sun drying.

Data collection

Leaf area index (LAI) was calculated using the following formula of Watson (1947):

$$\mathrm{LAI} = \frac{\text{Total leaf area}}{\text{Total land area}}$$

Where

Land area = Total area from which sample was taken.

Crop growth rate (CGR) was recorded by means of the formula cited by Hunt (1978):

$$\mathrm{CGR} = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{t2} - \mathrm{t1}}$$

Where

W_1 and W_2 are two consecutive plant dried weights, while t_2 - t_1 is the time interval between readings.

Net assimilation rate (NAR) was calculated by using the following formula suggested by Hunt (1978):

$$\mathrm{NAR} = \frac{\mathrm{TDM}}{\mathrm{LAD}}$$

Where

TDM is total dry matter and LAD is seasonal leaf area duration.

Germination count (m^{-2}) was calculated from individual plots with the aid of quadrat method and at the end, the mean was calculated. Plant height was taken just before harvesting. Whereas, number of pods per plant, pod length (cm), number of seeds per pods, 1000-seed weight (g), seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) were observed after harvesting.

Biochemical parameters

Along with yield parameters, protein and carbohydrate contents of grains were also analyzed for quality determination. Proteins (%) were determined by using Kjeldahl method and the instrument used was Kjeldahl apparatus (UDK 126D). Values obtained after using Kjeldahl apparatus were multiplied with 6.25 which is a factor to find out the protein contents in mash bean. Carbohydrates were noted with gravimetric method.
Following formula was applied for the calculation of Benefit cost ratio (BCR):

$$BCR = \frac{\text{Gross income}}{\text{Total cost}}$$

Statistical analysis

Data from growth, yields and quality characteristics were statistically analyzed through Fisher's variance technique of analysis with the probability level of 5%. The LSD test was used to check significance between treatment's means (Steel et al., 1997).

Results and Discussion

Growth parameters

Data concerning LAI is explained in Fig. 1. Significantly, the highest LAI was observed at 53 DAS with treatment T_8 where 0.5 % Zn was sprayed at 25 DAS. While treatments T_9, T_{10} and T_{11} where Zn sprayed at flowering stage and B sprayed at both stages 25 DAS and at flowering stage respectively were at par with treatment T_8. The LAI was declined at 60 DAS due to senescence and abscission of leaves. Similarly, (Kassab, 2005) also documented that the foliar Zn considerably promoted the growth in mung bean crop. Potarzycki and Grzebisz (2009) concluded various roles of Zn in escalation of chlorophyll contents, green pigment formulation and promoting the photosynthesis rate and efficiency. Renukadevi et al. (2002) stated that foliar used B exploits the light interception ratio and growth parameters in pulses. Boron is an important prerequisite for plant growth (Soomro et al., 2011). Saleem et al. (2020) reported highest LAI values with B spray at reproductive stage. Provided results are witnessed with Sufyan et al, (2012) who observe increase in LAI with micronutrients application. The results concerning mean CGR are illustrated in Fig. 2. Statistically, the maximum CGR (0.4 $gm^{-2}d^{-1}$) was attributed from treatment T_8 where 0.5% Zn was sprayed at 25 DAS.

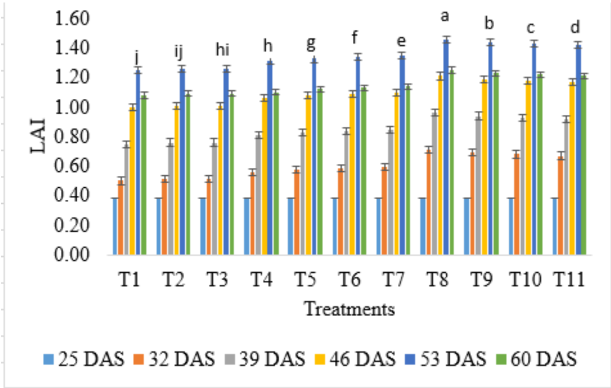

Fig. 1 Effect of foliar applied Mn, Fe, Zn and B on LAI of Mash bean

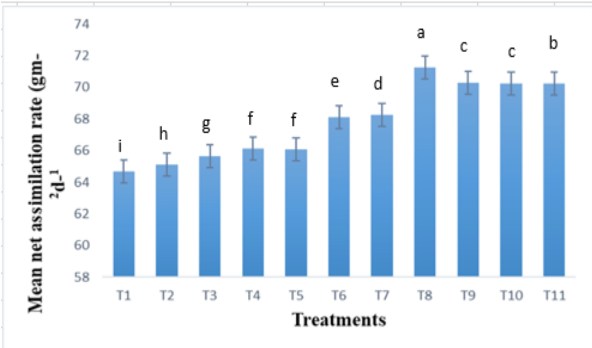

Fig. 2 Effect of foliar applied Mn, Fe, Zn and B on mean CGR (g m^{-2} d^{-1}) of Mash bean

While, treatments T_9, T_{10} and $T_{11}$where Zn applied as foliar spray at flowering stage and B sprayed at both stages 25 DAS and at flowering stage respectively, were at par with treatment T_8. Kassab (2005) documented that the foliar Zn considerably promoted the growth in mung bean crop. These results are also advocated by (Shenkin, 2006) who reported that Zn and B play pivotal part in growth and development as well. Boron spray helped plants in increasing vegetive growth (Pandey & Gupta, 2012). Moreover, Renukadevi et al. (2002) stated that B spray increased net assimilation rate, crop growth rate and seed yield in pulses. Data recorded for NAR depicted in Fig. 3 described that among all the treatments, significantly the maximum NAR (71.23 $gm^{-2}d^{-1}$) was attributed from treatment T_8 where 0.5% Zn application as spray at 25 DAS. While treatments T_9, T_{10} and T_{11} where Zn applied as foliar spray at flowering stage and B sprayed at both stages 25 DAS and at flowering stage respectively, were at par with treatment T_8. The increase in NAR was due to the role of Zn in remobilization of reserves from foliage to grains (Rehman & Farooq, 2016). Boron was helpful in enhancing NAR in wheat (Saleem et al., 2020). Mostafavi, (2012) documented that spray of zinc increased the plant growth and related yield parameters. Renukadevi et al. (2002) advocated the role of B spray in biomass production, LAI enhancement, NAR promotion, CGR escalation and seed yield accumulation in pulses.

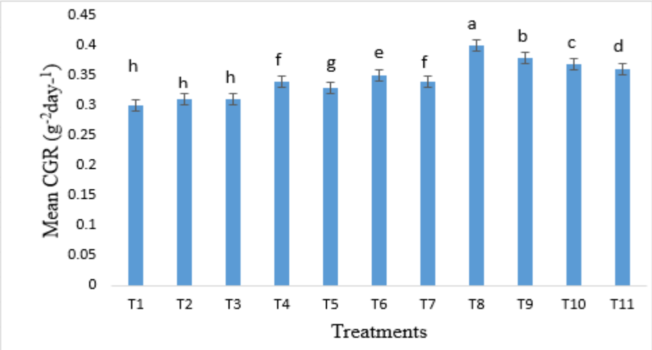

Fig. 3 Effect of foliar applied Mn, Fe, Zn and B on mean NAR (g m^{-2} d^{-1}) of Mash bean

Yield parameters

Plant population (m^{-2})

There was no any spray of micronutrients (Mn, Fe, Zn and B) was applied at any growth stage. Hence, the results were found non-significant as shown in Table 2.

Plant height (cm)

Data noted is provided in Table 2. Although all micronutrients Mn, Fe, Zn and B spray improved the plant height in black gram. However, significantly, the highest plant height (59.26 cm) was recorded with treatment T_8 where 0.5% Zn was sprayed at 25 DAS. While treatment T_9 where 0.5 % Zn was sprayed at flowering stage was non-significant to treatment T_8 and significantly, the lowest plant height (51.06 cm) was observed with treatment T_1 where no spray was done. Plant height was increased 16% with Zn spray. Increase in plant height with Zn application was due to its role in stem elongation (Yavas & Unay, 2016).

Number of pods plant^{-1}

Results are mentioned in Table 2. All micronutrients Mn, Fe, Zn and B spray improved pods plant^{-1} in mash bean. However, significantly, the highest value for pods plant^{-1} (17.00) was found in treatment T_8 where 0.5% Zn was applied at 25 DAS. While, treatment T_{11} where 0.5 % B sprayed at flowering stage was non-significant to treatment T_8 and significantly the lowest pods plant^{-1} (14.66)were noticed with treatment T_1 (Control). Increase of (15.96%) pods were observed with Zn application. El-Habbasha et al. (2013) reported a similar finding. Zn is also involved in upsurge flower setting (Moeinian et al., 2011).

Pod length (cm)

The length of the pod is a crucial yield causative character which defines the total seeds present in it. The data related to pod length is described in Table 2. All micronutrients Mn, Fe, Zn and B applied as foliar spray improved pod length (cm) in mash bean. However, significantly, the highest pod length (4.63 cm) was recorded with treatment T_8 where 0.5% Zn was used as foliar spray at 25 DAS. While, treatment T_{11} where 0.5 % B sprayed at flowering stage was non-significant to treatment T_8. The smallest pod length (2.98 cm) was measured in control (T_1). Foliar spraying resulted in effective absorption of the nutrients during critical stages of growth and in turn contributed to increased pod length (Krishna & Kaleeswari, 2018). This result was in accordance with the earlier findings of Sarkar & Malik (2001).

Number of seeds pod^{-1}

Results shown in Table 2 revealed that significantly, the supreme seeds pod^{-1} (8.66) were perceived with T_8 where0.5% Zn was applied as foliar spray at 25 DAS. While, treatments T_9 where sole dose of 0.5% Zn was used as spray at flowering stage and treatments T_{10} and T_{11} where spray of 0.5% B was applied at both stages 25 DAS and at flowering stage respectively, were non-significant to treatment T_8. Significantly, the lowest number of seeds in pod (7.00) was observed with treatment T_1 (Control). The maximum seeds per pod were owing to Zn application as it helped in effectual translocation of photoassimilates from source to sink. An increase of 23.71% seeds per pod was observed with Zn application. These results are also evidenced by Nadergoli et al. (2011) who reported improved seeds per pod in common bean with Zn. Hussain et al. (2012) stated that B application mends growth, and augments stress tolerance in plants and improves grain production. Pollen tube growth was promoted in the presence of B which might be a reason for increasing the grains number in pods (Verma et al., 2004).

1000-grain weight (g)

It is among the most important yield contributing traits in crop plants. Data illustrated in Table 2 depicted that all micronutrients Mn, Fe, Zn and B applied as foliar spray improved 1000-grain weight in black gram**.** However, significantly, the highest value (35.16 g) of 1000-grain weight was recorded with treatment T_8 where0.5% Zn spray at 25 DAS was applied. While, treatments T_9 where 0.5% Zn used as foliage spray at flowering stage and treatments T_{10} and T_{11} where 0.5 % spray of B was applied at both stages 25 DAS and at flowering stage respectively, were non-significant to treatment $T_{8.}$ The lowest grain weight (32 g) was observed with T_1 (control). Grain weight was increased up to 9.87% with Zn application. Suri et al. (2011) documented that Zn has specific and vital role in plant metabolism, influencing yield and quality. Zn was significant in improving gain weight (Pandey et al., 2006). El-Habbasha et al. (2013) also found Zn spray significantly increased seed weight. Tanaka and Fujiwar (2008) stated that B as a micronutrient involved in pollen tube, flower retention, seed formation, metabolites translocation and seed setting.

Seed yield (kg ha^{-1})

Data given in Table 2 showed that 5.48% seed yield was increased with Zn application. Significantly, the maximum seed yield (1031.3 kg ha^{-1}) was gained with treatment T_8 where 0.5 % Zn was sprayed 25 DAS. While, treatments T_9 and T_{11} where 0.5 % Zn and B applied as foliar spray at flowering stage respectively, were at par with T_8. The lowest seed yield (977.7 kg ha^{-1}) was reported from Control (T_1). Panayotov (2006) also reported that Zn enhanced the yield of treated crops. Zn application promoted root growth which increased the seed yield by increasing water and nutrients uptake from soil (Rengel, 2001). Rehman and Farooq (2016) documented that pollen tube germination promoted seed set in crops which was the key reason influencing the grain yield. Renukadevi et al. (2002) also reported that spray of B significantly increased seed yield in pulses.

Biological yield (kg ha^{-1})

Statistically, the highest biological yield (3366.7 kg ha^{-1}) was attributed from treatment T_8 receiving 0.5 % Zn was sprayed as foliar at 25 DAS. While, treatments T_9 and T_{11} where 0.5 % Zn and B applied as foliar spray at flowering stage respectively, were at par with T_8. The lowest biological yield (3334.0 kg ha^{-1}) was observed from T_1 where no spray was used (Table 2). Fageria et al. (2009) also exposed that the micronutrients spray has a positive influence on the metabolism and yield. Spray of micronutrients has been proved to be a valuable asset in fertilizer management with enhanced yield (Kuepper, 2003). These results are lined with those concluded by El-Habbasha et al. (2013) who reported that use of Zn spray significantly increased the plant yield.

Harvest index (%)

Foliar application of Zn and B significantly affected H.I of wheat. The data recorded for HI are presented in Table 2. Harvest index was increased (4.46%) with Zn application. Significantly, the maximum HI (30.63%) was observed with treatment T_8 where 0.5 % Zn was sprayed as foliar at 25 DAS. While, treatments T_9 where 0.5% Zn used as spray at flowering stage and treatments T_{10} and T_{11} where 0.5% B was used as spray at both stages 25 DAS and at flowering stage respectively, were non-significant to treatment T_8. Whereas, the lowest H.I. (29.32%) was calculated from treatment T_1 receiving no spray of micronutrients. These outcomes are lined with Nasri and Khalatbari (2011) who revealed that the spray of Zn improved the harvest index of plants.

Benefit cost ratio (BCR)

Ratio between benefits and cost of each treatment (variables) was also calculated. It is the ratio between all expenses and benefits from the field trial. Data (Table 2) revealed that 4.91% more benefits were achieved with Zn spray. Results showed markedly the highest BCR value (4.70) was obtained from the treatment T_8receiving 0.5 % Zn spray at 25 DAS followed by treatment T_{11} (4.69) receiving 0.5 % B spray at flowering stage.

Table 2 Effect of foliar applied Mn, Fe, Zn and B at different growth stages of mash bean

Treatment	Plant population /m^2	Plant height (cm)	Number of pods/plant	Pod length (cm)	Number of seeds/pod
Control	32.00 ± 0.33^a	51.06 ± 0.38^g	14.66 ± 0.33^c	2.98 ± 0.01^d	7.00 ± 0.00^c
Water spray at 25 DAS	32.00 ± 0.67^a	51.56 ± 0.09^g	15.00 ± 0.33^c	2.98 ± 0.01^d	7.00 ± 0.00^c
Water spray at flowering	32.33 ±0.88^a	52.70 ± 0.06^f	15.66 ± 0.67^{bc}	3.03 ± 0.04^d	7.33 ± 0.33^c
Mn (0.5%) at 25 DAS	32.66 ± 0.58^a	55.50 ± 0.35^e	16.33 ± 0.33^{ab}	3.16 ± 0.07^{cd}	8.00 ± 0.00^b
Mn (0.5%) at flowering	32.66 ± 0.58^a	55.30 ± 0.35^e	16.33 ± 0.33^{ab}	3.10 ± 0.06^{cd}	8.00 ± 0.00^b
Fe (0.5%) at 25 DAS	32.00 ±0.58^a	56.43 ± 0.41^{bc}	16.33 ± 0.33^{ab}	3.26 ± 0.03^c	8.00 ± 0.00^b
Fe (0.5%)at flowering	32.33 ± 0.67^a	56.45 ± 0.10^b	16.33 ± 0.33^{ab}	3.20 ± 0.06^{cd}	8.33 ± 0.33^{ab}
Zn (0.5%) at 25 DAS	32.66 ± 0.33^a	59.26 ± 0.31^a	17.00 ± 0.58^a	4.63 ± 0.06^a	8.66 ± 0.33^a
Zn (0.5%) at flowering	32.66 ± 0.33^a	58.83 ± 0.07^a	16.66 ± 0.33^{ab}	4.40 ± 0.06^b	8.66 ± 0.33^a
B (0.5%) at 25 DAS	32.00 ± 0.33^a	56.06 ± 0.30^{cd}	16.66 ± 0.33^{ab}	4.30 ± 0.06^b	8.66 ± 0.33^a
B (0.5%) at flowering	32.66 ± 0.33^a	55.78 ± 0.15^{de}	17.00 ± 0.58^a	4.63 ± 0.12^a	8.66 ± 0.33^a
LSD value	-	0.58	1.14	0.22	0.57

Values with different letters are significant to each other at 5% probability of LSD test

Table 2 continue

Treatment	1000-grain weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	BCR
Control	32.00 ± 0.00^c	977.7 ± 1.23^g	3334.0 ± 0.58^e	29.32 ± 0.04^f	4.48
Water spray at 25 DAS	32.33 ± 0.33^c	978.4 ± 0.98^g	3335.3 ± 0.33^e	29.33 ± 0.03^f	4.42
Water spray at flowering	32.66 ± 0.33^{bc}	984.7 ± 1.45^f	3337.7 ± 1.20^d	29.50 ± 0.05^e	4.45
Mn (0.5%) at 25 DAS	33.33 ± 0.33^b	994.7 ± 2.60^e	3357.1 ± 0.59^c	29.62 ± 0.08^d	4.13
Mn (0.5%) at flowering	33.33 ± 0.33^b	1004.4 ± 0.87^d	3357.6 ± 0.01^c	29.91 ± 0.03^c	4.18

Fe (0.5%) at 25 DAS	33.33 ± 0.33^{b}	1006.5 ± 1.04^{cd}	3357.9 ± 0.01^{c}	29.97 ± 0.03^{bc}	4.10
Fe (0.5%)at flowering	33.33 ± 0.33^{b}	1008.3 ± 0.88^{c}	3358.1 ± 0.01^{c}	30.02 ± 0.03^{b}	4.11
Zn (0.5%) at 25 DAS	35.16 ± 0.44^{a}	1031.3 ± 1.20^{a}	3366.7 ± 0.88^{a}	30.63 ± 0.04^{a}	4.70
Zn (0.5%) at flowering	34.49 ± 0.25^{a}	1028.9 ± 1.08^{ab}	3365.7 ± 0.33^{ab}	30.57 ± 0.03^{a}	4.67
B (0.5%) at 25 DAS	34.41 ± 0.29^{a}	1027.3 ± 0.88^{b}	3364.0 ± 0.58^{b}	30.53 ± 0.02^{a}	4.66
B (0.5%) at flowering	34.78 ± 0.21^{a}	1030.3 ± 1.20^{ab}	3365.7 ± 0.33^{ab}	30.61 ± 0.03^{a}	4.69
LSD value	0.76	3.47	1.71	0.10	-

Values with different letters are significant to each other at 5% probability of LSD test

Table 3 Effect of foliar applied Mn, Fe, Zn and B on biochemical responses and grain nutrients of mash bean

Treatment	Grain carbohydrate contents (%)	Grain protein contents (%)	Grain Mn contents (g/100 mg)	Grain Fe contents (g/100 mg)	Grain Zn contents (g/100 mg)	Grain B contents (g/100 mg)
Control	57.80±0.06^{i}	21.00±0.06^{h}	0.02±0.00^{h}	4.20±0.06^{j}	2.01±0.01^{g}	0.01±0.00^{f}
Water spray at 25 DAS	58.10±0.06^{h}	21.50±0.06^{g}	0.05±0.01^{fg}	5.00±0.01^{h}	2.10±0.06^{fg}	0.02±0.01^{ef}
Water spray at flowering	58.00±0.03^{h}	21.40±0.06^{g}	0.04±0.01^{gh}	4.80±0.06^{i}	2.10±0.06^{fg}	0.01±0.00^{f}
Mn (0.5%) at 25 DAS	59.10±0.06^{e}	22.00±0.00^{e}	0.20±0.00^{a}	6.00±0.06^{f}	2.30±0.06^{e}	0.03±0.01^{e}
Mn (0.5%) at flowering	58.50±0.06^{g}	21.70±0.01^{f}	0.18±0.01^{b}	5.80±0.06^{g}	2.20±0.06^{ef}	0.03±0.01^{e}
Fe (0.5%) at 25 DAS	59.30±0.06^{d}	22.20±0.06^{d}	0.06±0.01^{f}	7.60±0.12^{a}	2.70±0.06^{c}	0.05±0.01^{d}
Fe (0.5%) at flowering	58.80±0.06^{f}	21.90±0.00^{e}	0.05±0.01^{fg}	7.40±0.06^{b}	2.50±0.06^{d}	0.05±0.01^{d}
Zn (0.5%) at 25 DAS	60.00±0.01^{a}	23.00±0.06^{a}	0.12±0.01^{c}	7.03±0.04^{c}	3.40±0.06^{a}	0.07±0.01^{c}
Zn (0.5%) at flowering	59.60±0.06^{c}	22.60±0.06^{c}	0.08±0.01^{e}	6.70±0.06^{d}	3.30±0.06^{a}	0.07±0.00^{bc}
B (0.5%) at 25 DAS	59.50±0.06^{c}	22.30±0.06^{d}	0.10±0.00^{d}	6.40±0.06^{e}	2.99±0.01^{b}	0.09±0.01^{a}
B (0.5%) at flowering	59.80±0.06^{b}	22.80±0.06^{b}	0.08±0.00^{e}	5.94±0.03^{f}	2.80±0.06^{c}	0.08±0.00^{ab}
LSD value	0.15	0.12	0.01	0.13	0.12	0.01

Values with different letters are significant to each other at 5% probability of LSD test

Biochemical parameters

Carbohydrate contents are important constituents in any crop to determine quality of crop. Foliar spray of Zn significantly increased the carbohydrate contents up to 3.80% in mash bean. Significantly, the highest grain carbohydrate contents (60.00 %) were observed with treatment T_8 where 0.5 % Zn was sprayed as foliar at 25 DAS, while the lowest seed carbohydrate contents (57.80 %) were recorded from control (Table 3). Grotz and Guerinot (2006) also reported that zinc is significant in protein and carbohydrates blend and participates in regulation of saccharides and nucleic acid. Yadavi et al. (2014) documented that it is involved in various physiological processes such as synthesis of protein and carbohydrates. Protein contents are also an important constituent in any crop to determine the quality of that crop. Data recorded for the grain proteins in mash bean is demonstrated in Table 3. Increase in grain protein contents (up to 9.52%) was observed with Zn application. Significantly, the maximum proteins (23%) were noticed from treatment T_8 where 0.5 % Zn was used as spray at 25 DAS. However, significantly, the lowest grain protein contents (21%) were recorded with treatment T_1 (Control). Results are evidenced by Hafeez et al. (2013) who found that Zn is important in protein synthesis and also involves the structural integrity of proteins. Singh et al. (2008) also documented zinc involved in nucleic acid formation and protein synthesis. Ahmad et al. (2018) found higher protein and carbohydrate contents in grains when B was used. Farooqi et al. (2019) reported increased carbohydrates concentration with B application. Similarly, Saleem et al. (2020) reported an increase in protein contents in grains with B spray.

Grain nutrients concentration

Table 3 demonstrates the nutrients concentration in mash bean grains, Significantly, the maximum grain Mn contents (0.20 mg/ 100 g) were recorded with treatment T_4 where 0.5% Mn was used as spray at 25 DAS and significantly, the lowest grain Mn contents (0.02 mg/ 100 g) were observed with treatment T_1 (Control). Results are evidenced by Nickelsen and Rengstl (2013) as they concluded that Mn shows a key role in photosystem II as a catalyst in breaking down the water molecule, it is also involved in the initiation of nitrogen metabolism enzymes and RNA polymerase, photosynthesis and synthesis of fatty acid. Significantly, the highest grain Fe contents (7.60 mg/ 100 g) were recorded with treatment T_6 where 0.5% Fe was used as foliar spray at 25 DAS. The lowest grain Fe contents (4.20 g/ 100 g) were recorded with T_1 (Control) Table 3. Findings are advocated by Ling et al. (2013) as they also observed foliar sprays have proved to be an effective strategy to improve Fe levels in edible portions of food crops. Distelfeld et al. (2007) documented that cereals bio fortification with Fe is considered an auspicious approach for diminishing malnutrition.

Zinc insufficiency is the most boundless of all micronutrient inadequacy issues (Alloway, 2004). The data presented in Table 3 revealed that significantly, the highest grain Zn contents (3.40 mg/ 100g) were recorded in treatment T_8 where 0.5 % Zn was sprayed at 25 DAS. While, treatment T_9 where 0.5 % Zn spray was used at flowering stage was non-significant to treatment T_8 and the lowest grain Zn contents (2.01 mg/ 100g) were recorded with control. Hafeez et al. (2013) advocated that sprays demonstrated progressively gainful among any sole method of use regarding addition in plant development, yield and produce quality and expanded food crop content of zinc prompts in improving the dietary status of the plants, as well as human. Significantly, the highest grain B contents (0.09 mg/ 100g) were recorded with treatment T_{10} where 0.5 % B spray was applied at 25 DAS. While, treatment T_{11} where 0.5 % B spray at flowering stage was at par with T_{10}.The lowest grain B contents (0.01 mg/ 100g) were recorded with treatment T_1 where no spray was done at any stage (Table 3). Hussain et al. (2012) also documented that B application improved growth, and enhanced stress tolerance and grain production in plants.

Conclusion

Results from all treatments indicated that all treatments improved the different parameters of mash bean (Black gram). However, Zn showed significant results on different parameters of the mash bean. It is concluded that spray of Zn is much effective to increase growth, yield and quality of the crop. However, boron spray also affected the parameters in similar way with providing fruitful results which were at par with zinc.

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[Received: 6 February 2021; Accepted: 6 June 2021]