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Mepiquat chloride, zinc and boron improves the productivity and profitability of *kharif* mungbean (*Vigna radiata*) in north-western India

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Mungbean [*Vigna radiata* (L.) Wilczek] is the 3rd most important pulse crop of India after chickpea (*Cicer arietinum* L.) and pigeonpea [*Cajanus cajan* (L.) Millsp.]. It is considered highly nutritious having 24–25% protein, higher digestibility, flavour and absence of any flatulence effects. Being short duration, mungbean can be grown both in *kharif* as well as in a summer season. However, its cultivation during *kharif* season in Trans-Gangetic Indian Plains is quite difficult than that of summer. The primary constraint of this season includes heavy rainfall which leads to excessive vegetative growth, poor fruit formation and harvest Index (HI). Furthermore, indeterminate growth habit leading to continuous and constant competition between vegetative and fruiting sinks (pods) for photo-assimilates throughout the crop growth period led to poor grain yield (Shyam *et al.* 2018). These physiological constraints can be overcome with the use of various plant growth regulators. Being a growth retardant, mepiquat chloride (MC) plays significant role to modifying growth of indeterminate crops where vigorous vegetative growth during flowering stage is a major constraint. It restricts the synthesis of gibberellic acid (GA) in plants, makes plants shorter and boost translocation of photoassimilates towards fruiting bodies and increased crop yield (Sharma *et al.* 2013). Optimization of plant mineral nutrition is a sustainable approach towards improving crop yield. Zinc deficiency in plants declines enzymatic activities, disturbs ribosomal stabilization and reduced protein synthesis (Ullah *et al.* 2020). Moreover, it induce flower abortion and ovule infertility resulted in low seed setting and reduction in crop yield (Pathak *et al.* 2012). Similarly, boron, being another important micronutrient, is essential for pollen tube germination, cell division and fruit and seed development in plants. Apart from this, it also plays a critical role to retain flowering and fruit setting in pulses (Zhang 2001). Deficiency of Zn and B adversely affect growth and development of various yield-attributing traits leads to huge economic losses to the growers. Thus, the present study was carried out to investigate the impact of MC (as a growth retardant), Zn and B (micronutrients) on the productivity of mungbean under semi-arid subtropics (north-western India).

The present study was carried out during rainy (*kharif*) season of 2020 at Punjab Agricultural University, Ludhiana (L-1, situated at 30°54′ N latitude and 75°48′ E longitudes), Punjab and Krishi Vigyan Kendra (Punjab Agricultural University, Ludhiana, Punjab), Moga (L-2, situated at 30°23′ N latitude and 75°48′ E longitudes), Punjab. The experiment was laid out in a randomized complete block design (RCBD) having 16 treatments, viz. T_1, Control; T_2, Water spray; T_3, MC 200 ppm [30 DAS (days after sowing)]; T_4, MC 300 ppm (30 DAS); T_5, $ZnSO_4$ 0.5% (35 DAS); T_6, $ZnSO_4$ 0.5% (35 and 45 DAS); T_7, Borax 0.2% (35 DAS); T_8, Borax 0.2% (35 and 45 DAS); T_9, MC 200 ppm + $ZnSO_4$ 0.5% (35 DAS); T_{10}, MC 200 ppm + $ZnSO_4$ 0.5% (35 and 45 DAS); T_{11}, MC 200 ppm + Borax 0.2% (35 DAS); T_{12}, MC 200 ppm + Borax 0.2% (35 and 45 DAS); T_{13}, MC 300 ppm + $ZnSO_4$ 0.5% (35 DAS); T_{14}, MC 300 ppm + $ZnSO_4$ 0.5% (35 and 45 DAS); T_{15}, MC 300 ppm + Borax 0.2% (35 DAS); T_{16}, MC 300 ppm + Borax 0.2% (35 and 45 DAS) with three replication of each.

Crop cultivar ML2056 was sown on 15th and 21st July 2020 at both the locations, respectively, using 20 kg seed/ha on raised beds of 67.5 cm with wheat bed planter at a spacing of 20 cm × 10 cm. As per Punjab Agricultural University, Ludhiana, Punjab recommendation, 12.5 kg N/ha and 40 kg P_2O_5/ha were applied at sowing. The crop was harvested on 5th and 7th October, 2020 at Punjab Agricultural University, Ludhiana, Punjab and Krishi Vigyan Kendra (Punjab Agricultural University, Ludhiana, Punjab), Moga, respectively. After harvesting, threshing was done and seed yield was recorded (kg/ha). For growth and yield parameters, five plants/plot were randomly selected and observations were recorded.

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Table 1 Effect of mepiquat chloride, zinc and boron on growth and yield attributes of *kharif* mungbean

Treatment	Plant height (cm)		Leaf area index		Dry matter accumulation (g/plant)		Chlorophyll content index		Branches/ plant		Pods/ plant		Seeds/ pod		100-seed weight (g)	
	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2
T_1	68.4	73.7	2.33	2.40	21.6	20.0	26.0	25.2	6.2	6.3	18.9	17.9	9.7	8.5	3.4	3.2
T_2	67.0	73.6	2.33	2.37	21.6	20.1	26.3	25.6	6.2	6.5	18.0	17.3	9.2	8.4	3.4	3.2
T_3	58.6	63.3	2.00	2.13	22.2	21.5	29.7	29.0	6.7	6.8	21.1	18.6	9.7	9.2	3.5	3.3
T_4	58.1	62.3	1.90	2.00	22.3	22.5	31.9	31.4	6.8	7.0	22.2	20.5	10.0	9.5	3.6	3.3
T_5	69.7	74.2	2.70	2.90	24.7	23.8	29.4	29.0	6.8	6.8	22.7	21.5	9.8	9.2	3.6	3.4
T_6	72.2	75.6	2.87	3.23	28.2	26.0	33.0	33.5	7.4	7.5	26.8	25.5	11.1	10.9	3.7	3.6
T_7	68.2	73.3	2.50	2.71	23.4	22.9	28.9	29.8	6.8	6.8	22.6	21.4	9.8	9.3	3.5	3.4
T_8	68.3	73.4	2.60	2.78	24.3	23.8	30.4	30.8	6.9	7.1	24.0	23.5	10.8	10.2	3.6	3.5
T_9	65.5	68.6	2.50	2.73	25.6	24.7	30.7	30.0	7.0	7.1	23.1	22.8	10.3	9.7	3.6	3.5
T_{10}	67.1	72.3	2.47	2.93	28.8	27.6	33.9	34.0	7.6	7.7	27.5	26.4	11.6	11.4	3.8	3.7
T_{11}	63.6	66.5	2.17	2.40	24.9	23.5	30.0	30.9	7.1	7.5	24.5	23.0	10.0	9.6	3.5	3.5
T_{12}	63.1	67.0	2.23	2.47	26.2	24.4	31.8	31.6	7.5	7.8	26.3	25.1	11.9	10.8	3.7	3.7
T_{13}	64.2	65.1	1.93	2.07	26.2	25.2	31.7	31.4	7.3	7.6	24.5	23.6	10.5	10.1	3.7	3.6
T_{14}	65.0	70.3	2.56	2.86	30.0	28.9	35.5	34.9	7.8	8.1	30.3	28.8	12.3	11.3	4.0	3.9
T_{15}	62.2	65.2	1.94	2.08	26.2	24.2	31.0	30.9	7.4	7.7	23.9	23.0	10.5	10.0	3.7	3.6
T_{16}	62.9	66.5	2.00	2.33	28.1	26.0	32.6	33.4	7.6	7.9	26.3	25.6	12.4	11.8	3.9	3.8
LSD (P=0.05)	6.5	4.1	0.55	0.66	2.0	4.2	3.8	3.7	NS	NS	5.0	4.2	1.7	1.6	0.3	0.3

L-1, Ludhiana; L-2, Moga; NS, Non-significant. Refer to the methodology for Treatment details.

Table 2 Effect of mepiquat chloride, zinc and boron on yield and economic analysis of *kharif* mungbean

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)		Biological yield (kg/ha)		Harvest index (%)		Gross return (₹/ha)		Net return (₹/ha)		Benefit cost ratio	
	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2	L-1	L-2
T_1	787	786	2970	3030	3757	3816	20.9	20.7	56609	56548	28834	23182	1.04	0.83
T_2	786	785	2930	3030	3716	3815	21.1	20.6	56585	56489	28247	23123	1.00	0.82
T_3	860	823	2770	2920	3630	3743	23.8	22.0	61894	59223	33402	25537	1.17	0.90
T_4	886	831	2690	2870	3576	3701	24.8	22.4	63739	59823	35170	26060	1.23	0.91
T_5	914	862	3230	3300	4144	4162	22.1	20.7	65747	61997	37350	28405	1.32	1.00
T_6	1083	1073	3530	3520	4613	4593	23.5	23.3	77957	77213	49500	43562	1.74	1.53
T_7	919	905	3120	3130	4039	4035	22.8	22.5	66155	65100	37098	30848	1.28	1.06
T_8	953	914	3210	3200	4163	4114	23.0	22.2	68564	65757	38787	30785	1.30	1.03
T_9	933	875	3100	3220	4033	4095	23.3	21.4	67163	62941	38611	29195	1.35	1.02
T_{10}	1104	1091	3330	3430	4434	4521	24.9	24.2	79468	78484	50857	44679	1.78	1.56
T_{11}	946	931	3070	3100	4016	4031	23.7	23.2	68067	67007	38855	32600	1.33	1.12
T_{12}	1049	999	3130	3150	4179	4149	25.1	24.2	75510	71918	45578	36792	1.52	1.23
T_{13}	938	910	3050	3190	3988	4100	23.6	22.2	67480	65449	38851	31626	1.36	1.10
T_{14}	1124	1105	3230	3340	4354	4445	26.1	25.0	80907	79516	52219	45633	1.82	1.59
T_{15}	983	947	3000	3050	3983	3997	24.7	23.9	70702	68146	41413	33663	1.41	1.15
T_{16}	1084	1027	3080	3110	4164	4137	26.0	25.0	78029	73879	48020	38675	1.60	1.29
LSD (P=0.05)	184	185	NS	NS	520	430	NS	NS	-	-	-	-	-	-

L-1, Ludhiana; L-2, Moga; NS, Non-significant. Refer to the methodology for Treatment details.

The cost of cultivation consists of variable input costs such as land preparation, seed and seed treatment, irrigation, fertilizers, pesticides, labour, tractor charges, market charges, land interests, growth retardant and micronutrients and fixed costs like land rent. Benefit:Cost (B:C) was calculated as:

$$\text{Benefit: Cost} = \frac{\text{Net returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

The net return was calculated by subtracting the variable cost of cultivation from gross-returns which is the product of mungbean yield and minimum support price.

Statistical analysis: Analysis of variance (ANOVA) was performed using CPCS-1Software, developed by the Punjab Agricultural University, Ludhiana, Punjab (Cheema and Singh 1991). Comparison of difference between means was done at α=0.05.

Plant growth retardant and micronutrients (Zn and B) had significant effect on growth parameters, viz. plant-height, leaf area index (LAI), dry-matter accumulation (DMA) and chlorophyll content index (CCI) (Table 1). Maximum reduction in plant height and LAI was obtained with foliar application MC 200 or 300 ppm and other MC containing treatments with Zn or B. Whereas, 0.5% $ZnSO_4$ applied at 35 and 45 DAS followed by 0.5% $ZnSO_4$ applied at 35 DAS, resulted in significantly higher plant height and LAI. It was also observed that single application of MC (200 or 300 ppm) declined plant height greatly than its application followed by either Zn or B. Maximum DMA and CCI was also recorded with MC 300 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS), which was significant over control, but statistically at par with double application of 0.5% $ZnSO_4$ (35 and 45 DAS). At both locations, lowest DMA and CCI were recorded with control. This increase in DMA with mepiquat chloride application might be due to the attribution of its ability to enhance chlorophyll, which intern inhibit chlorophyllase-enzyme, responsible for degradation of chlorophyll, lead to increased chlorophyll content (Rosolem *et al.* 2013).

Significant effect of MC and micronutrients had observed on yield parameters of mungbean (Table 1) that ultimately contributed towards its final yield (Table 2). Highest seed yield was recorded with MC 300 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS) followed by MC 200 ppm + $ZnSO_4$ (35 and 45 DAS) and 0.5% $ZnSO_4$ (35 and 45 DAS) as compared to control, which was 42.8, 40.3, 37.6 and 40.6, 39.2, 36.5% higher than control at both the locations, respectively. This could be contributed due to higher pod number/plant, seeds/pod and 100-seed weight in MC 300 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS) over control (Table 1). Mepiquat chloride play important role in source-sink realization that enhances seeds per plant and seed weight of soybean (Jaidka *et al.* 2020). Whereas, Zn had a positive effect in metabolism of carbohydrates and N in legumes and increases photosynthetic activities that encourages production and translocation of photo-assimilates towards sink in plants (Pandey *et al.* 2013, Kumar and Dhaliwal 2021). Although, stover yield was recorded non-significantly among different treatments, but significantly higher biological yield was obtained from 0.5% $ZnSO_4$ (35 and 45 DAS) as compared to control at both the selected locations. The growth retardant and micronutrients displayed failure to impact HI significantly, which ranged from 21–26% and 21–24% at both the locations, respectively.

At both the locations, treatments supplying MC, Zn and B gained highest gross returns, net returns and B:C than control (with and without water spray) (Table 2). Maximum gross returns were recorded with MC 300 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS), followed by MC 200 ppm + 0.5% $ZnSO_4$ at 35 and 45 DAS than 0.5% $ZnSO_4$ at 35 and 45 DAS, which was statistically at par with MC 300 ppm + 0.2% Borax (35 and 45 DAS) and MC 200 ppm + 0.2% Borax (35 and 45 DAS). Similarly, highest net returns and B:C was observed through MC 300 ppm+ 0.5% $ZnSO_4$ (35 and 45 DAS) followed by MC 200 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS) and 0.5% $ZnSO_4$ (35 and 45 DAS) at both locations. This increment was due to higher seed yield obtained by application of these treatments as compared to control and water spray and sole application of MC or Zn or B.

SUMMARY

The experiment was conducted during rainy (*kharif*) season of 2020 at Punjab Agricultural University, Ludhiana, Punjab and Krishi Vigyan Kendra (Punjab Agricultural University, Ludhiana, Punjab), Moga, Punjab to evaluate the effect of mepiquat chloride (MC), zinc and boron on productivity and profitability of *kharif* mungbean. Results revealed that with single application of MC 200 or 300 ppm and in combination with micronutrients (Zn/B) reduced the vegetative growth and plant height over control at both the locations. The highest chlorophyll content index (CCI), dry matter accumulation was recorded with MC 300 ppm + 0.5% $ZnSO_4$ (35 and 45 DAS). This treatment also resulted in maximum grain yield, highest net returns and B:C ratio which was statistically similar with 200 ppm MC + 0.5% $ZnSO_4$ (35 and 45 DAS) and double application of 0.5% $ZnSO_4$ (35 and 45 DAS) but significantly higher than control. Thus, MC 300 ppm (30 DAS) + 0.5% $ZnSO_4$ (35 and 45 DAS) evolved as the most remunerative practice under luxuriant vegetative growth conditions. In addition, where excessive vegetative growth is not a problem, double dose of 0.5% $ZnSO_4$ (35 and 45 DAS) were equally effective in increasing the mungbean productivity and profitability.

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