Indian Journal of Agricultural Sciences **93** (4): 382–386, April 2023/Article
https://doi.org/10.56093/ijas.v93i4.133717

Performance of spring-summer blackgram (*Vigna mungo*) with nutrient fortification under eastern Indian plains

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Received: 24 February 2023; Accepted: 9 March 2023

ABSTRACT

Blackgram [*Vigna mungo* (L.) Hepper] is an important grain legume in Indian sub-continent imparting nutritional benefits from ancient times. A field experiment was conducted with blackgram in spring-summer seasons during 2020 and 2021 in Bidhan Chandra Krishi Viswavidyalaya, West Bengal with two sowing dates in March in main plot, two soil applications of Co at 4 kg/ha in sub-plot and five foliar spray levels of 1.25% K and 0.2% B in sub-sub plot in a split-split plot design to explore the effects of Co, K and B in improving growth, physiology, production, quality and production economics of the crop. Pooled analysis indicated that March first week sowing as well as soil application of Co and foliar K+B fortifications separately achieved significantly higher (P=0.05) plant height, dry matter accumulation, root nodulation, branches/plant, pods/plant, seeds/pod, test weight, total chlorophyll and nitrate reductase contents, net photosynthetic rate, physiological efficiency, yield, seed nutrients and protein contents, economic returns and benefit-cost ratio. Seed protein content was a linear function of root nodule numbers explaining about 84.05% variation. Sowing of blackgram during March first week with soil application of Co and foliar K+B spray is a promising agronomic management to improve blackgram production in a cost-effective way under Gangetic plains of Eastern India.

Keywords: Blackgram, Nutrients fortification, Production, Sowing dates, Spring-summer

Among the various pulse crops grown in India, blackgram [*Vigna mungo* (L.) Hepper] holds the third most important position right after chickpea and pigeon pea. It is very much popular for its higher nutritive values with carbohydrate, crude protein and fat with Ca, Fe and P as well as vitamins per 100 g of seeds (Malek *et al.* 2018). Sowing of blackgram during spring-summer in optimum time requires great focus for achieving optimum yield potential for proper harmony between its vegetative and reproductive phases (Banerjee *et al.* 2021a).

Numerous research works have explored the diverse and crucial roles of cobalt (Co), potassium (K) and boron (B) in accelerating the overall growth, physiology, production, quality and economics of different pulse crops (Banerjee *et al.* 2021b). Cobalt is an integral constituent of co-enzyme cobalamine which stimulates the formation of leghaemoglobin required for root nodulation and N fixation (Banerjee and Bhattacharya 2021). Essentiality of K for seed germination and emergence, photosynthesis, nodulation, stomatal regulation, protein synthesis and production have already been established (Abid *et al.* 2016). The role of boron on better vegetative and reproductive growth, effective nodulation and biological nitrogen fixation, photosynthetic activity, yield, nutrient uptake and quality of pulse crops has been reported earlier (Kaisher *et al.* 2010, Bele and Thakur 2019). Additionally, beneficial effect of foliar nutrition at the onset of reproductive stage is effective in mitigating physiological shortcomings including premature shedding of flower and pod and increasing seed yield in legumes (Raj *et al.* 2018).

Balanced nutrition is of utmost importance to magnify the yield potential of blackgram (Banerjee *et al.* 2021b). Fortification with plant nutrients in blackgram cultivation has been established to improve its growth, physiology, productivity, qualitative as well as economic aspects, which may prove as an excellent strategy for the resource poor farming community of the country (Banerjee *et al.* 2023). Against this background, the present experiment was formulated with the objectives to explore the effects of Co, K and B in improving growth, physiology, production, qualitative aspects as well as production economics of blackgram under different sowing dates during spring-summer season.

MATERIALS AND METHODS

The present study was carried out at the A-B block District Seed Farm (22°93' N, 88°53' E at 9.75 m amsl) of

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Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during consequent spring-summer (March–June) seasons of 2020 and 2021 to explore the effects of Co, K and B in improving growth, physiology, production, qualitative aspects as well as production economics of blackgram under different sowing dates. The experimental soil is well-drained Gangetic alluvium (order: Inceptisol) with moderate fertility and nearly neutral in reaction categorised under the class of sandy loam (Banerjee *et al.* 2022). The average daily temperature varied from 22.4–33.6ºC during 2020 and from 22.6–32.8ºC during 2021, with a mean rainfall of 6.1 and 0.1 cm in the respective years. The field experiment on blackgram (Variety: Pant Urd 31) was replicated thrice in a split-split plot design. The main plots were comprised of two sowing dates (D_1, March first week and D_2, March third week), whereas two different levels of soil application of Cobalt (S_1, No cobalt and S_2, Co at 4 kg/ha) in sub plot and five foliar spray levels of K and B at flower initiation stage in sub-sub plots (F_1, no spray; F_2, tap water; F_3, 1.25% K; F_4, 0.2% B and; F_5, 1.25% K + 0.2% B) were allotted randomly (Fig 1). Blackgram seeds were sown at a spacing of 30 cm × 10 cm in individual experimental plots of 4 m × 3 m area. Prior to sowing, recommended dose of fertilizers (20:40:40 kg N:P_2O_5:K_2O/ha) for blackgram was applied at the time of land preparation. One hand weeding was practised at 25–30 days after sowing. One pre-sowing irrigation followed by two occasional irrigations were applied at 7–10 days interval in the initial stage for proper crop stand establishment.

The available nitrogen (N), phosphorous (P) and potassium (K) contents in blackgram seeds were determined respectively by modified Kjeldahl method, Olsen's method and flame photometer method. Seed protein content was computed by multiplying the nitrogen content by a conversion factor of 6.25. The data over two years were pooled and were statistically analyzed by applying the technique of analysis of variance (ANOVA) for split-split plot design (Gomez and Gomez 1984). Significant differences between the treatments were compared by critical difference at 5% level of significance (P=0.05). Tukey's post-hoc test was performed to compare the differences between mean values.

RESULTS AND DISCUSSION

Growth traits: As per the pooled estimation, blackgram sown on March first week (D_1) recorded significantly higher values for growth attributes including plant height (56.1 cm), aerial dry matter (256.4 g/m^2), and nodules/plant (26.0) as compared to March third week sown crop (D_2) (Table 1). Similar increments in growth attributes with early sowing were reported in case of greengram (Kumar and Kumawat 2014) and blackgram (Banerjee *et al.* 2021b). Application of Co (S_2) as well as combined foliar K+B separately (F_5) individually recorded respective higher values for those parameters (55.9 and 61.2 cm 246.6 and 248.8 g/m^2 and 27.5 and 26.7), which were statistically significant over their respective controls. All the nutrients applied left notable impacts on improving plant height, dry matter production and nodule formation in blackgram. This result was in conformity with those of Singh (2017). Initial Co application accounted for height elongation and leaf area expansion along with facilitating nodulation and symbiotic nitrogen fixation (Banerjee *et al.* 2021b). In fact, Co is a structural constituent of co-enzyme cobalamine stimulating the enzyme systems including methionine synthase, ribonucleotide reductase and methyl malonyl co-enzyme A mutase, required for the formation of leghaemoglobin (Banerjee and Bhattacharya 2021). Thus, it is essential for nodulation and nitrogen fixation (Iram *et al.* 2017). Besides, individual importance of foliar K and B in modulation branching, leaf production and nodule formation of grain legumes have also been suggested previously in this regard (Chatterjee and Bandyopadhyay 2017).

Physiology: Superior values were registered with D_1, S_2 and F_5 regarding physiological parameters in terms of total chlorophyll content (1.3, 1.3 and 1.4 mg/g fresh leaf weight), net photosynthetic rate (12.5, 11.5 and 11.8 µmol/m^2/sec) and nitrate reductase content (1.9, 1.8 and 1.9 µmol/g leaf fresh weight/hour) as portrayed in Table 1. Foliar K spray outperformed foliar B spray in this regard. Stress conditions in delayed sown crop might have imposed a negative impact on overall blackgram physiology irrespective of nutrient applications. Soil applied Co and foliar applied K+B turned up to be extremely promising in accelerating the biosynthesis of chlorophyll, which eventually led to greater photosynthetic efficiency (Banerjee *et al.* 2021b). However, improvement in overall photosynthetic activity with foliar nutrition was also reported with special reference to K (Taia *et al.* 2016) and B application (Maqbool *et al.* 2018).

R_1		R_2		R_3
$D_1S_1F_3$		$D_1S_2F_5$		$D_1S_1F_2$
$D_1S_1F_5$		$D_1S_2F_1$		$D_1S_1F_4$
$D_1S_1F_1$	C	$D_1S_2F_4$	C	$D_1S_1F_3$
$D_1S_1F_2$	H	$D_1S_2F_3$	H	$D_1S_1F_5$
$D_1S_1F_4$	A	$D_1S_2F_2$	A	$D_1S_1F_1$
	N N E		N N E	
$D_1S_2F_4$	L	$D_1S_1F_1$	L	$D_1S_2F_2$
$D_1S_2F_5$		$D_1S_1F_2$		$D_1S_2F_5$
$D_1S_2F_1$		$D_1S_1F_4$		$D_1S_2F_3$
$D_1S_2F_2$		$D_1S_1F_3$		$D_1S_2F_1$
$D_1S_2F_3$		$D_1S_1F_5$		$D_1S_2F_4$

March 1st week sowing

R_1		R_2		R_3
$D_2S_2F_4$		$D_2S_1F_3$		$D_2S_1F_4$
$D_2S_2F_1$		$D_2S_1F_2$		$D_2S_1F_5$
$D_2S_2F_5$	C	$D_2S_1F_5$	C	$D_2S_1F_1$
$D_2S_2F_3$	H	$D_2S_1F_4$	H	$D_2S_1F_2$
$D_2S_2F_2$	A	$D_2S_1F_1$	A	$D_2S_1F_3$
	N N E		N N E	
$D_2S_1F_3$	L	$D_2S_2F_2$	L	$D_2S_2F_5$
$D_2S_1F_1$		$D_2S_2F_5$		$D_2S_2F_4$
$D_2S_1F_2$		$D_2S_2F_3$		$D_2S_2F_1$
$D_2S_1F_4$		$D_2S_2F_1$		$D_2S_2F_3$
$D_2S_1F_5$		$D_2S_2F_4$		$D_2S_2F_2$

March 3rd week sowing

Fig 1 Layout of experiment.

Table 1 Response of growth, physiology and seed quality of blackgram due to date of sowing, soil and foliar applications of nutrients (pooled)

Treatment	Plant height (cm)	Aerial dry matter (g/m^2)	Nodules/ plant	Total chlorophyll (mg/g fresh leaf weight)	Net photosynthetic rate (µmol/ m^2/sec)	Nitrate reductase (µmol/g leaf fresh weight/ hour)	Seed N content (%)	Seed P content (%)	Seed K content (%)	Seed protein content (%)
D_1	56.1a	256.4a	26.0a	1.3a	12.5a	1.9a	3.73a	0.25a	1.04a	23.2a
D_2	53.3b	229.3b	23.3b	1.2b	8.7b	1.6b	3.59b	0.23b	1.00b	22.4b
SEm±	0.11	0.26	0.08	0.01	0.25	0.01	0.02	0.001	0.002	0.07
LSD (P=0.05)	0.54	2.19	0.50	0.02	0.92	0.02	0.09	0.004	0.01	0.42
S_1	53.3b	239.2b	21.8b	1.2b	9.7b	1.6b	3.56b	0.23b	1.01b	22.1b
S_2	55.9a	246.6a	27.5a	1.3a	11.5a	1.8a	3.77a	0.25a	1.03a	23.4a
SEm±	0.33	0.51	0.09	0.01	0.42	0.01	0.02	0.002	0.002	0.08
LSD (P=0.05)	1.27	2.24	0.37	0.02	1.13	0.02	0.06	0.008	0.006	0.31
F_1	47.9e	225.7e	22.4e	1.0e	7.1e	1.5e	3.27e	0.20e	0.95e	20.2e
F_2	51.3d	232.7d	23.6d	1.1d	7.7d	1.6de	3.38d	0.22d	0.99d	21.4d
F_3	54.7cd	239.4	24.8bc	1.3b	9.9bc	1.8b	3.68bc	0.26cd	1.05c	22.7c
F_4	58.1b	243.1	25.8b	1.2c	8.6c	1.7c	3.85b	0.24bc	1.01b	23.9b
F_5	61.2a	248.8	26.7a	1.4a	11.8a	1.9a	4.11a	0.29a	1.08a	25.5a
SEm±	0.31	0.74	0.14	0.01	0.62	0.01	0.02	0.002	0.002	0.10
LSD (P=0.05)	0.92	2.22	0.39	0.02	1.95	0.02	0.05	0.004	0.006	0.29

Treatment details are given under Materials and Methods.

Generally, a legume plant tends to curtail the rhizobial activity after flowering initiation just to support the reproductive development by partitioning the photoassimilates to the developing sink organs (Banerjee *et al.* 2019). In fact, the rate of symbiotic nitrogen fixation process tends to nearly zero with the progress in development of pods from the flowers. At that time, the plant cannot fix the atmospheric nitrogen into required ammonium (NH_4^+) form of nitrogen. Thus, it must meet its internal nitrogen demand by reducing the stored nitrate nitrogen (NO_2^+) extracted from the soil reserve and converting into NH_4^+ nitrogen which is indispensable for protein synthesis (Reinprecht *et al.* 2020). In the current experiment, proper balance of nutrition for blackgram with Co, K and B seemed to help in optimum regulations of physiological and biochemical mechanisms, maintaining the level of nitrate reductase concentration (Banerjee *et al.* 2021b).

Seed quality: Pooled over seed protein content was found to have a strong positive relationship with number of root nodules per plant with linear regression (Fig 2). D_1 sown crop performed better regarding qualitative aspects. Delay in sowing for March third week crop (D_2) might have compelled it to be subjected to considerable deficit of moisture during pod development, hampering the translocation of nutrients into developing blackgram seeds, ultimately reducing the seed quality in terms of nutrients and protein contents. These findings were supported by those of Venugopalan *et al.* (2022) with respect to stress induced nutrient deficiency in legume seeds. In contrast, optimum moisture availability in D_1 sown crop facilitated greater nutrients uptake and concentration in seed which eventually realized greater nutrients accumulation and protein biosynthesis (Kumar and Kumawat 2014).

Exogenous applications of Co (S_2) as well as combined K+B (F_5) recorded higher N, P, K and protein contents in blackgram seeds (3.77 and 4.11%, 0.25 and 0.29%, 1.03 and 1.08% and 23.4 and 25.5% respectively) which were statistically significant over control (S_1). Co is involved with nitrogenase activity related to nodulation and nutrients uptake in case of legume crops (Gad *et al.* 2013). K has been reported to positively modulate the enzymatic functions and seed nutrients and protein contents in summer pulse crops under moisture stress situation (Adsure *et al.* 2018). Impact of B on biological nitrogen fixation, photosynthesis and several metabolic pathways has established its key role on improving plant nutrient status of legume seeds (Bele and Thakur 2019). These aforesaid facts clearly justified the enrichment of nutrient contents in blackgram seeds through soil application of S_2 along with F_5 application under the present experiment.

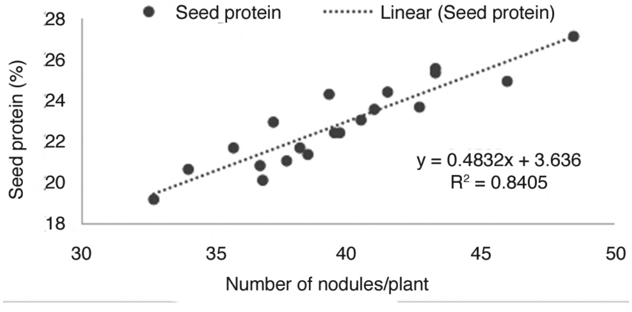

Fig 2 Effect of nodules/plant on seed protein content.

Table 2 Response of yield attributes, yield and economics of blackgram due to date of sowing, soil and foliar applications of nutrients (pooled)

Treatment	Branches/ plant	Pods/ plant	Seeds/ pod	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Gross return (₹/kg)	Net return (₹/kg)	Benefit-cost ratio
D_1	2.9a	33.8a	4.8a	37.3a	1251.9a	2570.5a	44.5a	105633a	50916a	2.1a
D_2	2.6b	30.9b	4.4a	36.2b	1120.7b	2400.2b	44.0b	87226b	40509b	1.9b
SEm±	0.02	0.29	0.14	0.06	6.15	1.53	0.08	475.30	475.35	0.01
LSD (P=0.05)	0.14	1.71	NS	0.40	17.94	9.47	NS	2932.29	2932.58	0.06
S_1	2.6b	27.7b	4.4b	36.0a	1095.4b	2434.7b	43.2b	85447b	40890b	1.9b
S_2	2.9a	34.0a	5.1a	37.5a	1277.2a	2535.9a	45.5a	109312a	50535a	2.0a
SEm±	0.05	0.33	0.09	0.07	4.25	6.34	0.12	333.82	333.83	0.01
LSD (P=0.05)	0.18	1.30	0.36	NS	16.59	24.76	0.46	1303.37	1303.39	0.03
F_1	1.6e	19.7e	3.6e	34.5e	858.6e	2150.5e	42.9e	77112e	25522e	1.6e
F_2	2.2d	25.4d	4.3d	35.7d	1048.4d	2332.6d	43.7cd	81752d	34043d	1.7d
F_3	2.7c	31.1c	4.7cd	36.8c	1200.2c	2507.9c	44.4bc	103523bc	45654c	1.9bc
F_4	3.2b	36.4b	5.4b	37.9b	1342.8b	2651.6b	44.9b	114518b	56759b	2.0b
F_5	3.5a	41.2a	5.8a	38.8a	1481.4a	2784.1a	45.6a	125244a	66584a	2.2a
SEm±	0.13	0.41	0.15	0.16	9.07	8.65	0.19	697.19	697.19	0.01
LSD (P=0.05)	0.36	1.18	0.44	NS	26.13	24.93	0.55	2008.95	2008.93	0.04

Treatment details are given under Materials and Methods.

Yield attributes and yield characters: Variation in production depicted the effectiveness of individual levels of all three factors of the experiment. Pooled estimation vividly validated the strong positive influence of sowing dates, soil and foliar applied nutrients on yield attributes encompassing branches/plant, pods/plant, seeds/pod and test weight as well as yield characters including seed yield, stover yield and harvest index of spring-summer blackgram as a whole (Table 2). Maximum values for all the yield attributes were observed under D_1, S_2 and F_5, which eventually led to 11.7, 16.6 and 72.5% increase in seed yield with corresponding significant improvement in stover yield and harvest index in the concerned treatments. However, variation in date of sowing could not impose any significant impact on number of seeds/pod. Also, nutrients application whether through soil or by foliar did not influenced the test weight of the crop.

The delayed sown crop might have left with lesser soil moisture at the time of seed filling, which probably resulted in poor source to sink partitioning and seed filling and eventually yield reduction (Banerjee *et al.* 2021b). Besides, the plant nutrients promote the state of intra-cellular metabolism of plants, invariably escalating nutrients absorption, retention and subsequent utilization (Malek *et al.* 2018). Co-application in soil and combined foliar K+B might have increased the production of leaves, pods and seeds through better photosynthesizing capacity and source to sink partitioning, which in turn acquired greater photosynthetic area and substantial yield (Iram *et al.* 2017). Nevertheless, nutrients application exerted no such impact on the test weight of spring-summer sown blackgram. Co, K and B have been found to be associated with various enzymatic activities which evidently contributed to development of qualitative and quantitative aspects of various yield attributes, resulting into significant increase in seed yield, stover yield and harvest index (Sritharan *et al.* 2015, Maqbool *et al.* 2018).

Production economics: Pooled data presented in Table 2 regarding production economics revealed that, significant improvement in gross and net returns were obtained with the treatments for D_1, S_2 and F_5, which in turn attributed to highest benefit-cost ratio in the respective treatments (2.1, 2.0 and 2.2) compared to control (1.9, 1.9 and 1.6). Combinations of these nutrients attained higher seed and stover yields irrespective of the sowing dates which in turn attracted higher gross and net returns with greater benefit-cost ratio (BCR). Results were in line with those of Kumar *et al.* (2009). In this connection, Meena *et al.* (2017) and Chaudhary *et al.* (2019) recorded a similar improvement in production economics of blackgram in terms of biological yield, net return and BCR with scheduling nutrient management strategies.

Based on the findings, it may be concluded that sowing in March first week (D_1) along with nutrient fortification by soil application of Co at 4 kg/ha (S_2) and exogenous foliar nutrition of 1.25% K and 0.2% B (F_5) at flowering initiation stage is a potent agronomic management to intensify blackgram production in a cost-effective manner. Thus, this combined nutrient schedule may be recommended as an economically profitable option for the resource poor farmers to harvest higher production in spring-summer grown blackgram in eastern India.

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