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Effect of Bio-nano P and K on Performance of Black Gram Crop

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Abstract

Black gram [*Vigna mungo* (L.) Hepper], is a widely grown grain legume and assumes considerable importance from the point of food and nutritional security in the world. To meet the increasing demand, black gram yield has to be increased. Nanotechnology has the potential to revolutionize the agricultural systems. Nanostructured formulation through mechanisms such as targeted delivery or slow/controlled release mechanisms and conditional release, could release their active ingredients in responding to environmental triggers and biological demands more precisely. The use of nano-fertilizers causes an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries.

A field experiment was carried out in the Instructional Farm of BCKV, West Bengal ($22^0$93'N, $88^0$53'E) during the summer (Pre-*Kharif*) season of 2019 and 2020 on sandy- loam alluvial soil (*Inceptisol*), neutral in soil reaction (pH 7.24) having 0.26% organiccarbon, 351.23 kg / ha available N, 25.07 kg / ha available P_2O_5 and 149.072 kg / haavailable K_2O, to find out the effect of Bio-nano P and K on growth and yield of black gram crop. The crop was raised with 1 light pre-sowing irrigation for better and uniform crop stand and fertilized with a common dose of N-P_2O_5-K_2O @20:60:40kg/ha. The variety **Pant U-31** was used and the experiment was carried out in RBDwith **12** treatments and **3** replications and with 30 cm x 10 cm.

The results revealed that application of Bio-nano P or K had a significant influence on growth and yield of the crop. The growth in terms of LAI and aerial dry mass per unit area were significantly higher in the treatments where the plants got Bio- nano P or K along with 50% of FDF. The maximum grain yield (1027.52 kg/ha) was obtained in the treatment T_{10} where Bio-nano P was applied at 25 and 50 DAS along with 50% of FDF followed by the treatments where Bio-nano P was applied at 25 DAS along with 50% of FDF (T_9) and Bio-nano K was applied at 25 and 50 DAS along with 50% of FDF (T_{12}); however, there were significant differences among the treatments. Application of Bio-nano P or K along with 50% of FDF had significant effect on number of pods/ m^2 (the main yield component). The highest number of pods per unit area (449.76) was recorded in T_{10} where 50% of FDF was applied along with Bio-nano P at 25 and 50 DAS which was statistically at par with T_9 where 50% of FDF was applied along with Bio-Nano P at 25 DAS, T_{11} where 50% FDF was applied along with Bio-nano K at 25 DAS and T_{12} where 50% FDF was applied along with Bio-nano K at 25 and 50 DAS.

Thus, it may be concluded that application of Bio-nano P and K had a distinct effect to increase the yield of summer black gram crop. The experiment may be carried out with different pulses in particular, to study the effect of Bio-nano P and K on their physiology and performance. Further, the residual effect of on post-harvest soil properties along with soil ecology need to be studied in depth. However, the experiment should be repeated for confirmation of result.

Introduction

Pulses are annual leguminous crops yielding between one and 12 grains or seeds of variable size, shape and colour within a pod, used for both food and feed. The term “pulses” is limited to crops harvested solely for dry grain, thereby excluding crops harvested green for food, which are classified as vegetable crops, as well as those crops used mainly for oil extraction and leguminous crops that are used exclusively for sowing purposes.

The global population is expected to increase from 7.2 to 9.6 billion by 2050(UN, 2013), which will increase food demand and fodder requirements for feedstock.We all talk about sustainable development goals now that aim to eradicate hunger andpoverty. Black gram [*Vigna mungo* (L.) Hepper], is a widely grown grain legume and belongs to the family *Fabaceae* and assumes considerable importance from the point of food and nutritional security in the world. The crop is resistant to adverse climatic conditions and improves the soil fertility by fixing atmospheric nitrogen in the soil. Black gram plays an important role in Indian diet, as it contains vegetable protein and supplement to cereal based diet. It contains about 26% protein, which is almost three times that of cereals and other minerals and vitamins. Besides, it is also used as nutritive fodder, especially for milch animals.Black gram is also grown as a cover crop as well as catch crop due to short duration. India is the world’s largest producer as well as consumer of black gram. It produces about 1.5–1.9 million tonnes of black gram annually from about 3.5 million hectares of area, with an average productivity of 600 kg/ha. Black gram output accounts for about 10% of India’s total pulse production (MoA, 2012). Productivity of black gram is low in general due to poor management and low soil fertility of marginal lands where it is cultivated maximum. The sluggish growth pulse production in the country could be due to various physiological, bio-chemical, and inherent factors associated with the crop (Mahala *et al*., 2001). Black gram is basically indeterminate in habit of flowering and fruiting and there is acontinuous competition for available assimilates between vegetative and reproductive sinksthroughout the growth period. Since, the source is highly limited in pulses with lowered translocation of assimilates to the growing reproductive sinks. Apart from the genetic make-up, the physiological factors viz., insufficient partitioning of assimilates, poor pod setting due to flower abscission and lack of nutrients during critical stages of crop growth play a vital role on pulse production (Kalita *et al*., 1994).

Poor and marginal farmers generally produce black gram by using chemical fertilizer. Indiscriminate uses of chemical fertilizers have caused serious degradation of soil fertility, environmental pollution, pest resistivity, loss of biodiversity and economic losses. In case of conventional fertilizers solubility, bioavailability, nutrient use efficiency is low, dispersion of mineral nutrient is low due to larger particle size, excess release of active ingredients leading to toxicity and soil imbalance and lastly lost rate is through leaching but in case of nano fertilizers these points are vice versa. Nanostructured formulation through mechanisms such as targeted delivery or slow/controlled release mechanisms and conditional release, could release their active ingredients in responding to environmental triggers and biological demands more precisely. The use of nano- fertilizers causes an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries. The unexpected properties of nanoparticles are broadly due to the large surface area of the material,which dominates the contributions made by the very small quantities of the material.Nanoparticles, thus, take advantage of their dramatically increased surface area tovolume ratio. The role of nano-biofertilizer in plant and soil systems demonstrated that it acts efficiently for enhancement of agricultural productivity. They act synergistically providing higher retention of soil moisture and essential plant nutrients due to nano material coating as well as microbial revitalization due to the bioorganic component containing plant growth promoters through direct and indirect interactions like biofertilization, rhizore mediation, disease resistance, etc.

Nano-fertilizers balances the release of fertilizer phosphorus and potassium with the absorption by the plant, thereby preventing the nutrient losses and avoiding unwanted nutrients interaction with microorganisms, water and air. Nano- Bio formulation increases plant photosynthesis rate, plant biomass and plant protein; promotes plant growth; reduces stress condition, extends the harvesting period. Requirement of nano-fertilizer is 30-100 times less than chemical fertilizer and 2-4 times less costly.Nano-fertilizers balances the release of fertilizer phosphorus and potassium with the absorption by the plant, thereby preventing the nutrient losses and avoiding unwanted nutrients interaction with microorganisms, water and air. Absorption of nutrients by the plants from soil can be maximized using nano-fertilizer. Nano- fertilizer encapsulated nanosilica can form a binary film on the cell wall of fungi or bacteria after absorption of nutrients and prevent infections, hence improve plant growth under high temperature and humidity. Moreover, nano-coatings provide surfaceprotection for larger particles (Brady and Weil, 1999; Santoso *et al*., 1995). Nanoparticle uptake into the plant body can use different paths. Uptake rates will depend on the size and surface properties of the nanoparticles. Very small sizes nanoparticles can be penetrating through cuticle. Larger nanoparticles can penetrate through cuticle-free areas, such as hydathodes, the stigma of flowers and stomata's.

Most important example: phosphorus (P) particles in nano form may reduce the absorption by Ca, Fe, Al and organic matter as noticed with mega P particles and nullified the competition with Si in soil due to size difference, therefore, enhances P use efficiency from 15% at present to at least more than 50%. The nano P can be coated by oleic acid for preparation of nano P fertilizer which has tremendous impact on crop yield.

Keeping this in view, the present experiment was undertaken to study the effect of application of Bio-nano P and K on growth and yield of black gram under NAZ of West Bengal during summer season with the following objectives:

1. To study the effect of Bio-nano P and K on growth of summer black gram.

2. To find out the effect of Bio-nano P and K on on yield and yield components of summer black gram crop ; and

3. To determine the suitable time of application of Bio-nano P and K and economics of black gram cultivation.

Materials and Methods

Location and Time: Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during 2019 and 2020 during March to May as *pre-kharif* (summer) crop.

Black gram variety used: **Pant- U- 31**

Spacing: 30 cm x 10 cm

Plot size: 10 m^2

Experimental Design: RBD with 12 treatments and 3 replications

Treatment details:

T- 1: CONTROL (Absolute Control, no fertilizer, no spray of tap water)

T -2: Full Dose of N-P_2O_5-K_2O (FDF) [20-60-40 kg/ha]

T- 3: 50% of FDF

T- 4: Spray of tap water at 25 and 50 DAS

T- 5: Spray of Bio-nano P at 25 DAS

T- 6:Spray of Bio-nano P at 25 and 50 DAS

T- 7:Spray of Bio-nano K at 25 DAS

T- 8:Spray of Bio-nano K at 25 and 50 DAS

T- 9:T – 3 + Spray of Bio-nano P at 25 DAS

T- 10:T – 3 + Spray of Bio-nano P at 25 and 50 DAS

T – 11:T – 3 + Spray of Bio-nano K at 25 DAS

T – 12:T – 3 + Spray of Bio-nano K at 25 and 50 DAS

Bio-nano P and K product :

The names of the products are Nano P Fertilizer and Nano K Fertilizer. According to IFFCO, these environment-friendly products have been introduced for the first time in India and have potential to reduce usage of conventional chemical fertilizers by 50 per cent besides raising crop output by 15-30 per cent. These nano products were launched at an event held at Kalol unit (Gujarat).

The dose of Bio-nano fertilizer used was **4 ml/ litre** of water.

Crop management: In the experimental fieldone light pre-sowing irrigation was given for uniform and better seed germination and to get optimum plant population. Thereafter the crop was raised as rainfed crop, thus no irrigation was given after seed germination.The land was prepared with two deep ploughings by tractor followed by one ploughing with power tiller in order to make the soil friable and pulverized. Total number of plots were 36 with each plot size of 4 m × 2.5 m.

Full dose of fertilizer (FDF) 20-60-40 kg/ha N-P_2O_5- K_2O and 50% FDF was applied in the above mentioned plots as basal. Seeds were sown manually. Small furrows were opened with the help of a hand tyne and seeds were dropped into the furrows; then the furrows were covered with soil. Spraying of tap water, Bio-nano P and Bio-nano K were done at different schedule which were mentioned above. Inter cultural operation like thinning was done once at 15 DAS and hand weedings were done twice at 20 DAS followed by 35 DAS. Spraying of insecticide (Dimethoate 30% EC @ 2 ml / litre of water was done as a precautionary measure to avoid the attack of white fly and hairy caterpillar. No fungicide was applied; it may be worth mentioned here that the disease attack was below the economic threshold level. Harvesting of the crop was done by hand picking of pods and then cutting of the stalks by sickle. Two rounds of picking of pods were done to avoid losses due to shattering. The pods were then dried on the threshing floor then threshed by beating with sticks. The clean seeds were sun dried for 3-4 days to bring their moisture content at 12%.

Methodology used: In this field experiment each plot (10 m^2) was demarcated into two portions, nearly 5 m^2 area was used for biometrical observations (for destructive samplings) and calculation of growth functions; remaining 5 m^2 area was utilized for estimation of yield. The growth attributes of black gram like plant height, leaf area index (LAI), dry aerial biomass (DAM) production were noted at different crop growth stages, while yield components, grain yield and stover yield were determined at maturity.

For chemical analysis of soil sample composite soil samples were collected twice from 5 randomly selected locations in each experimental plot up to a depth of 45 cm, with the help of soil auger, before sowing and application of basal dose of fertilizer and after harvesting of crop. Collection of soil sample was done from three depths 0-15 cm, 15-30 cm and 30-45 cm. The samples were taken diagonally and they were mixed thoroughly. The composite soil sample was then dried in shade, pulverized and passed through 0.2 mm sieve and kept in polythene packet for determination of different nutrient content, organic carbon, pH, *etc*.

The data obtained were analyzed statistically by the analysis of variance method (Panse and Sukhtame, 1985; Gomez and Gomez, 1984). The significance of different sources of variations was tested by Error Mean Square of Fisher Snedecor's 'F' test, at probability level 0.05. The tables formulated by Fisher and Yates (1963) were consulted for the comparison of 'F' value and for the determination of critical difference (CD) at 5% probability level.

The cost of cultivation of different treatments was calculated. The variable costs included the cost of Bio-nano P and K depending upon the particulars of treatments. The total cost of cultivation, thus, consists of the cost of cultivation plus variable costs. Gross return was calculated by multiplying the yield with the market price of black gram. The benefit-cost ratio was then calculated by dividing gross return by total cost of cultivation.

Results and Discussion

Phenological development of summer black gram was monitored through regular observation and dates of ooccurrence of different phonological stages. Observations were recorded on different growth parameters like plant height, dry matter accumulation, leaf area index and yield components like number of pods per unit area, length of pods, number of seeds per pod, test weight etc. and grain yield, stover yield and harvest index at periodic interval and data were analyzed.

***Growth attributes*:** The result of the experiment indicated that at 30 DAS, 60 DAS and at harvesting plant height was significantly influenced by the different levels (Table 1). At 30 DAS, the highest plant height (12.35 cm) was recorded in the treatment T_2 where full Dose of N-P_2O_5- K_2O (FDF) [20-60-40 kg/ha] was applied. At 60 DAS, the maximum plant height (36.94 cm) was recorded in the treatment T_{10} where 50% of FDF + Bio-nano P at 25 and 50 DAS was applied. At harvest, the tallest plant (44.15 cm) was recorded in the treatment T_{10} where 50% of FDF + Bio-nano P at 25 and 50 DAS was applied.

The leaf area index of the black gram increased steadily up to the 60 DAS and then declined due to senescence of older leaves as the crop progressed towards its maturity (Table 1). At 30 DAS, the highest LAI (0.56) was observed in the treatment T_2 where full Dose of N-P_2O_5-K_2O (FDF) [20-60-40 kg/ha] was applied. At 60 DAS, the highest leaf area index (3.52) was noticed in T_9 where 50% of FDF + Spray of Bio-nano P were applied at 25 DAS. At harvest, the highest leaf area index (2.29) was observed in T_9 where 50% of FDF + Spray of Bio-Nano P were applied at 25 DAS.

The real picture of crop growth can be obtained from the data of dry aerial biomass. Study on dry aerial biomass of black gram crop showed progressive increase with the advancement of crop growth (Table 1). At 30 DAS, the highest DAM (17.45 g/m^2) was observed in T_2 where full Dose of N-P_2O_5-K_2O (FDF) [20-60-40 kg/ha] was applied. At 60 DAS, the highest dry aerial biomass production (141.35 g/ m^2) was recorded in T_{10} where 50% of FDF + Bio-nano P at 25 and 50 DAS was applied. At harvest, the highest dry aerial biomass production (248.13 g/ m^2) was recorded in T_{10} where 50% of FDF + Bio-nano P at 25 and 50 DAS was applied.

TABLE 1. Effect of Bio-nano P and K on growth attributes of black gram crop at different crop growth stages in *pre-kharif* season

Treatment	Plant height (cm) Crop Growth Stage			Leaf Area Index (LAI) Crop Growth Stage			Dry Aerial Biomass Crop Growth Stage		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T – 1	9.45	27.33	38.05	0.32	2.26	1.40	12.25	69.98	101.42
T – 2	12.35	35.44	42.75	0.56	2.35	1.44	17.45	135.67	212.82
T – 3	11.28	34.57	41.91	0.48	2.40	1.58	16.52	118.45	176.07
T – 4	9.63	28.39	39.12	0.35	2.43	1.49	12.67	71.21	105.36
T – 5	9.87	34.06	42.12	0.36	2.52	1.55	12.81	104.88	158.33
T – 6	9.73	34.17	42.30	0.41	2.67	1.78	13.18	112.56	181.24
T – 7	9.68	34.28	42.81	0.39	2.95	1.71	13.04	100.95	140.21
T – 8	10.03	34.50	42.06	0.43	3.33	1.90	12.54	109.34	163.25
T – 9	11.91	35.87	43.60	0.50	3.52	2.29	16.06	128.48	198.27
T – 10	12.18	36.94	44.15	0.55	2.59	1.60	16.35	141.35	248.13
T – 11	11.85	35.03	42.94	0.48	2.68	1.68	16.18	117.97	185.54
T - 12	11.92	35.79	43.08	0.52	2.93	1.70	16.03	130.32	226.18
SEm (±)	**0.51**	**1.76**	**0.84**	**0.03**	**0.06**	**0.04**	**1.26**	**15.41**	**17.69**
CD at 5%	**1.49**	**5.14**	**2.45**	**0.09**	**0.18**	**0.12**	**3.69**	**45.03**	**51.72**

Yield components and yield: Some yield components were significantly influenced by Bio-nano P and K at different levels.

The number of pods per unit area varied from 449.76 to 216.43. The highest number of pods per unit area (449.76) was recorded in T_{10}. The lowest pods per m^2 (216.43) were obtained in T_1 treatment. Data recorded on number of pods per m^2 at harvest was statistically analyzed and placed in Table 2.

In true sense, pod length is not a yield component of black gram crop; however, it gives an idea of seed size and number of seeds/pod and helps in photosynthesis to some extent. The highest pod length was recorded in T_3 (4.73 cm) where 50% of FDF was applied and the lowest pod length was recorded in T_1 treatment (4.37 cm) which was absolute Control and no fertilizer, no spray of tap water. Data recorded on pod length at harvest was statistically analyzed and placed in Table 2.

From the results of the experiment conducted during summer season it was revealed that there was no significant difference in seeds per pod and test weight within the treatments. None of the treatments had any significant effect on seeds per pod and test weight of black gram.

Grain yield, an end product of interaction between yield components, differed significantly among twelve treatments tested in the investigation. The highest grain yield (1027.52 kg/ ha) was recorded in T_{10} which was statistically at par with T_9 and T_{12}. The lowest grain yield (475.23 kg/ ha) was recorded in T_1 treatment which was statistically at par with T_4. Data pertaining to grain yield as influenced by different treatments was tabulated in Table 2.

The highest stover yield (2185.92 kg/ ha) was recorded in T_{11}. The lowest stover yield (1607.16 kg/ ha) was recorded in $T_{10.}$ Data pertaining to stover yield as influenced by different treatments was tabulated in Table 2.

The harvest Index of the twelve treatments varied differentially due to variation between the economical and biological yield. The highest harvest index (39.03 %) was recorded in T_{10} where 50% of FDF + Bio-nano P at 25 and 50 DAS. The lowest harvest index (19.96 %) was recorded in T_4 where spraying of tap water was done at 25 and 50 DAS. The harvest Index values are given in Table 2.

TABLE 2. Effect of Bio-nano P and K on yield components of Black gram crop

Treatment	No. of pods / m^2	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)
T – 1	216.43	475.23	1787.81	20.99
T – 2	375.26	848.30	2076.92	28.94
T – 3	311.02	696.44	2089.34	24.97
T – 4	219.44	488.17	1952.70	19.96
T – 5	272.98	587.46	1860.29	24.03
T – 6	274.61	632.39	1800.07	25.98
T – 7	258.47	575.10	2039.05	21.99
T – 8	273.08	615.24	2059.73	23.02
T – 9	419.98	964.37	1957.99	33.01
T – 10	449.76	1027.52	1607.16	39.03
T – 11	418.95	936.82	2185.92	29.95
T - 12	430.18	992.04	1842.39	35.04
SEm (±)	**15.32**	**26.56**	**94.40**	**1.03**
CD at 5%	**44.77**	**77.63**	**271.03**	**3.01**

***Economics*:**

Any management practice is considered to be effective only when it becomes economically viable. Therefore, the cost involved in Bio-nano P and K application was analyzed with respect to return obtained from that particular management practice. Although common cost of cultivation for black gram production was same (Rs 29800.00/ ha) for all treatments but variable costs are different for every treatment so, total cost of cultivation is also different. Among all the treatment combinations highest benefit-cost ratio was obtained in T_9 followed by T_{11}, T_{10}, T_{12}, T_2, T_3, T_6, T_8, T_5, T_7, T_1 and T_4 respectively during *pre-kharif* season. The economics of this experiment was worked out and presented in the Table 3.

TABLE 3. Economics of cultivation of Black gram crop

Treatment	Cost of Cultivation (Rs.)	Treatment Cost (Rs.)	Total cost of Cultivation (Rs.)	Gross return (Rs.)	B:C ratio
T – 1	29800.00	0.00	29800.00	41594.02	1.39
T – 2	29800.00	2947.00	32747.00	72017.84	2.19
T – 3	29800.00	1473.50	31273.50	59893.88	1.91
T – 4	29800.00	1200.00	31000.00	42959.00	1.38
T – 5	29800.00	1160.00	30960.00	50717.38	1.63
T – 6	29800.00	2320.00	32120.00	54191.34	1.68
T – 7	29800.00	1160.00	30960.00	50086.10	1.61
T – 8	29800.00	2320.00	32120.00	53338.66	1.66
T – 9	29800.00	2633.50	32433.50	81065.58	2.49
T – 10	29800.00	5267.00	35067.00	85415.92	2.43
T – 11	29800.00	2633.50	32433.50	79317.44	2.44
T - 12	29800.00	5267.00	35067.00	83047.98	2.36

Conclusion :

In general, the climatic conditions were congenial during crop growth period and incidence of pest and disease attack was very less to a greater extent. The results described above led to the following conclusions: Application of Bio-nano P @ 4 ml/ litre of water along with 50% of full dose of fertilizers (FDF) produced taller plants than other treatments. The other growth parameters *viz., leaf area index, dry aerial biomass* were also significantly higher with this treatment. The application of Bio-nano P or K probably reduced flower drops in black gram compared to control, as a result, number of pods per unit area (the most important yield component) was increased significantly over the control treatment (received no Bio-nano P and K). Application of Bio-nano fertilizer increase the crop yield over the treatments receiving no Bio-nano fertilizer due to better crop growth and better absorption of nutrients.

Overall, application of Bio-nano P @ 4 ml/ litre of water in conjunction with 50% of full dose of fertilizers (FDF) at 25 and 50 DAS was found best and performed better over all the treatments.

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