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CONTENTS

Black gram (*Vigna mungo L.*) response to plant geometry and biofertilizers in western Himalayan Agroecosystem

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Pulses are the main source of dietary protein for vegetarians and contribute up to 14 % of the total protein of an average Indian diet (Mudryi *et al*., 2014). Pulses improve the soil health by enriching nitrogen status and also maintain long term fertility and sustainability of the cropping systems. India is the largest producer and consumer of pulses in the world. Pulses contain a high percentage of quality protein and fibre besides they supply micronutrients, low fat and complex carbohydrates. Among the pulses, black gram (*Vigna mungo* L. Hepper) is the third-most consumed pulse crop in the world (Swaminathan *et al.,* 2021) cultivated in India and Asian countries including Pakistan, Myanmar and parts of Southern Asia. India occupies an area of 48.07 lakh hectare with production of 27.39 lakh tons and yield of 5.70 quintals per hectare (Calles, 2016). Black gram is beneficial in lowering cholesterol levels (Divyani *et al.,* 2020). It also acts as cover crop and its deep root system protects the soil from erosion. The crop also improves soil fertility by symbiotic fixation of atmospheric nitrogen in root nodules. It is grown well in moisture retentive light soil, but loamy and clay loam soils are suitable for the cultivation of Black gram.

Constraints limiting the productivity of black gram in India are non- availability of quality seeds of improved varieties, cultivation on marginal, less fertile soils with low inputs, lack of pest and disease management, cultivation under moisture stress conditions, imbalanced use of nutrients and unscientific post-harvest practices. Plant density can have a major effect on the final yield of most of the legumes and the general response of yield to increasing population is well documented. Increase in spacing decreases the total population, but with more nutrition to the individual plant grows better and yield more. Row spacing is an important factor which ultimately effect nutrient uptake and growth and yield of plant. To realize the maximum yield potential of black gram during summer and rainy season, maintenance of optimum space made available to individual plant is of prime importance. The spacing requirement depends upon the growth behavior of genotype. So, it is required to maintain spacing for obtaining higher yield (Veeramani, 2019).

The main challenge for the researchers in the field is to reduce the use of intensive chemical fertilizers which negatively affect the environment and food quality, nutritional requirement of increasing population as well as soil health. Continuous use of chemical fertilizers increased crop yield in the early stages but had a negative impact on sustainability (Rana and Verma, 2021; Kumari and Verma, 2023; Juyal *et al*., 2023). The indiscriminate application of major fertilizers resulted in deficiency of nutrients other than those applied and a decrease in soil organic carbon. Furthermore, the imbalance and continuous use of synthetic chemicals harm soil physical, chemical, and biological properties, affecting crop production sustainability and pose health and environmental risks. So, an alternative for chemical fertilizers is the use of bio fertilizers which could potentially play key roles in the productivity and sustainability of soil. Bio-fertilizers are gaining importance as they are eco-friendly, non-hazardous and non-toxic. The use of bio fertilizers improves soil fertility by fixing atmospheric nitrogen, solubilizing insoluble phosphates, producing plant growth-promoting substances in the soil, and promoting nodulation ability. Thus, objective of the present research was to evaluate the influence of plant geometry and biofertilizers on the growth, yield and economics of black gram in western Himalayan regions of Uttarakhand.

Field trial was conducted during *kharif* 2022 at Crop Research Centre, School of Agricultural Sciences, SGRR University, Dehradun, located in the north western region of Uttarakhand at an altitude of 450 meter above MSL and 29° 58' and 31° 2' 30° North latitude and 77° 34´45´´ and 78° 18´30´´ east longitudes. Summer temperatures ranged from 36.7 °C to 14.4 °C at their highest and lowest points, respectively, while the winter temperatures ranged from 24.1° C to 5.4° C. The average annual precipitation was 1424 mm. The soil in the experimental field had a sandy loam texture with somewhat neutral pH (7.12), medium in available nitrogen (352.3 kg ha^{-1}) and organic carbon (0.42 %), low in available phosphorous (9.1 kg ha^{-1}), and high in available potassium (236.3 kg ha^{-1}). The experiment was laid out in factorial randomized block design (RBD) with two factors i.e. plant geometry and bio-fertilizers each at 3 different levels making nine treatment combinations. Treatment combinations comprised of 25×10 cm + Rhizobium; 25×10 cm + VAM; 25×10 cm + Rhizobium + VAM; 30×10 cm + Rhizobium; 30×10 cm + VAM; 30×10 cm + Rhizobium + VAM; 35×10 cm + Rhizobium; 35×10 cm + VAM; 35×10 cm + Rhizobium + VAM. The field was thoroughly ploughed twice with a tractor-drawn harrow at an optimum moisture content followed by a single harrowing, and the final land preparation was carried out with a tractor-drawn leveller. The Pant Urd- 31 (PU-31) was sown on 23rd June 2022 using seed rate of 12 kg ha^{-1}. At the time of field preparation, recommended dose of fertilizer 20:40:40 kg NPK ha^{-1} were applied. As per treatment, different bio-fertilizers viz., Rhizobium and VAM were mixed in the soil at the time of field preparation. After germination of the crop, gap filling and thinning were also done between 20 and 25 days after sowing (DAS) in an order to maintain definite plant populations. Being *kharif* crop, water needs were being met by rain, however depending upon the soil moisture status, irrigations were provided. The first weeding was done at 25 DAS and the second-hand weeding was done at 35 DAS. The crop was harvested with the help of sickle on September 20, 2022, i.e., 90 DAS. The entire produce was then sun dried for about 4-5 days. The process of threshing was done manually by bashing the plants with sticks.

Dry matter accumulation of the crop at different stages was done by keeping in the hot air oven at 65^{0}C for 72 hours followed by recording the dry weight.

Number of pods per plants, number of grains per pod, test weight, grain yield, straw yield and biological yields were calculated by adopting standard procedures.

The findings made it abundantly evident that alteration or changes in plant geometry and application of different bio-fertilizers significantly influenced plant growth, yield and net returns of the black gram (Table 1 and 2). Among the various treatment combinations, maximum plant height, number of branches per plant, dry matter production per meter square and leaf area index was recorded in 35×10 cm + Rhizobium + VAM followed by 30×10 cm + Rhizobium + VAM and 25×10 cm + Rhizobium + VAM respectively. However lowest values of these parameters were seen where only VAM was applied with the relatively closer plant stands confining the geometry of 25×10 cm.

In addition, 35×10 cm + Rhizobium + VAM also recorded maximum grain yield, net return and B: C ratio as compared to other treatment combinations. Due to the additive effects of these two bio-fertilizers i.e., Rhizobium and VAM in improving the nutritional environment, the growth in terms of branches and dry matter, leaf area index, and their translocation to reproductive structures were enhanced. This resulted in an increase in the yield attributes and, ultimately, the crop's yield. The significant increase in straw production that resulted

Table 1: Plant height, number of branches per plant, leaf area index and dry matter production of black gram as influenced by plant geometry and bio-fertilizers during *kharif* 2022

Treatments	Plant height(cm)			No. of Branches (plant^{-1})			Leaf Area Index (LAI)			Dry matter production (g m^{-2})		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS
25×10 cm + Rhizobium	18.50	51.34	68.49	2.33	6.50	9.45	0.68	4.75	6.75	3.33	25.16	53.03
25×10 cm + VAM	17.12	46.90	66.90	1.92	5.59	8.22	0.58	3.43	5.54	2.14	24.16	51.07
25×10 cm + Rhizobium + VAM	20.65	53.27	70.65	2.92	6.83	11.50	0.75	5.73	7.76	4.72	27.17	53.34
30×10 cm + Rhizobium	19.30	52.18	69.40	2.67	6.63	9.83	0.66	4.28	6.21	3.75	26.07	53.55
30×10 cm + VAM	17.45	49.72	67.17	2.17	5.66	8.49	0.55	2.63	5.40	2.58	24.67	51.34
30×10 cm + Rhizobium + VAM	20.81	53.57	72.22	3.08	6.18	11.18	0.71	5.34	7.34	5.11	27.75	54.91
35×10 cm + Rhizobium	19.62	52.72	69.31	2.70	6.73	9.86	0.63	3.85	5.84	3.96	26.51	53.41
35×10 cm + VAM	17.65	50.74	67.61	2.25	5.88	8.75	0.44	2.22	5.13	2.90	24.39	51.62
35×10 cm + Rhizobium + VAM	22.39	55.23	73.57	3.17	6.84	12.05	0.70	5.07	6.21	5.73	28.32	55.50
C.D. (5 %)	1.14	2.11	1.12	0.44	0.51	0.50	0.03	0.18	0.23	0.50	1.11	0.60

Table 2: Yield attributes, yield and economics of black gram as influenced by plant geometry and bio-fertilizers during *kharif* 2022

Treatments	No. of pods per plant	No. of grains per pod	Test weight(g)	Grain yield (kg/ha)	Straw yield (kg/ha)	H.I. (%)	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C
25×10 cm + Rhizobium	59.00	6.88	40.62	600.6	1791.8	25.10	39583	70804	31220	0.79
S_1B_2: 25×10 cm + VAM	62.60	6.11	39.15	592.6	1581.0	27.26	38585	69715	31129	0.80
S_1B_3: 25×10 cm + Rhizobium + VAM	70.20	7.57	41.74	615.1	1972.3	23.78	41164	82377	40212	1.00
S_2B_1: 30×10 cm + Rhizobium	65.48	7.12	41.03	604.4	1811.6	25.02	39686	71263	31576	0.80
S_2B_2: 30×10 cm + VAM	60.00	6.54	39.67	599.5	1626.7	23.23	38705	69882	31176	0.81
S_2B_3: 30×10 cm + Rhizobium + VAM	68.74	7.21	41.48	616.8	2046.2	23.45	41662	82984	40751	1.00
S_3B_1: 35×10 cm + Rhizobium	66.12	7.14	40.11	612.6	1839.8	24.98	40069	71641	31724	0.79
S_3B_2: 35×10 cm + VAM	60.73	6.64	40.14	606.2	1721.1	25.14	38902	70198	31296	0.80
S_3B_3: 35×10 cm + Rhizobium + VAM	71.37	7.96	42.63	633.1	2092.0	26.93	41774	83863	42088	1.21
C.D. (5 %)	2.89	0.72	1.14	12.4	41.1	1.11	-	841.11	1000.14	0.19

from the bio-fertilizer inoculation may have been caused by the enhanced vegetative growth, which may have been caused by the efficient utilization of nutrients taken through the deep roots and the prolific shoot growth as a result of improved nutrition. These findings were in line with the findings of Tanwar *et al.* (2003) and Rathore *et al.* (2010) who stated that application of rhizobium along with VAM shows additive effects resulting in improvement in growth of the crop while providing nutrients in adequate amount for better partitioning of the photosynthates. Again, the increase in yield could be attributed to the fact that phosphorus from the VAM tends to improve the root growth whereby increased growth and development in terms of plant height, branches, and dry matter by enhancing the nutritional environment of the rhizosphere and plant system, which in turn leads to higher plant metabolism and photosynthetic activity (Singh and Sekhon, 2007; Kumawat *et al.*, 2013).

Wider row spacing (35×10 cm) with lesser plant population might have increased all the growth attributes positively due to lesser competition amongst the plants for nutrients, moisture, sunlight and space while narrower row spacing (25×10 cm) ensured late canopy coverage and minimal light interception owing to lesser growth rate and crop biomass, resulting in decreased growth pattern yielding lesser grain yield and net benefits. Similar results have also been reported by Boydak *et al*., 2004; Malek *et al*.,2012.

CONCLUSION

Plant geometry and application of different biofertilizers has influenced growth parameters, yield & yield attributes and net revenues of black gram. Sowing of black gram at the plant geometry of 35×10 cm along with soil application of Rhizobium + VAM showed 10 % and 25 % yield advantage and monetary benefit, respectively over 25×10 cm and 30×10 cm with soil application of biofertilizers suggested for enhancing grain yield and advantageous under Doon Valley areas of Uttarakhand.

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