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Effect of NPK levels and Rhizobium on soil physico-chemical properties, growth, yield and economics of summer black gram (*Vigna munga* L.) *var.* Shekhar-2

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Abstract
A field experiment was carried out at Department of Soil Science and Agricultural Chemistry research farm SHUATS, Prayagraj during *Kharif* season 2018-2019. The experiment was laid out in 3×3 randomized block design with three replications, consisting of nine treatments to evaluate the effect of different levels of N, P, K and Rhizobium on soil properties, growth and yield of Black Gram (*Vigna munga* L.) *var.* SHEKHAR-2. The basic information, on the physico-chemical properties indicated that the soil of the experimental field belongs to inceptisol having sandy loam texture with light brown colour which was medium in organic carbon, nitrogen, phosphorus and potassium. Based on mean performance Treatment T_8 @ (100% NPK + 100% Rhizobium) was found to be best in data recorded in post harvest soil as pH (6.8), electrical conductivity (0.26 dS m^{-1}), O.C (0.75%), Pore space (57.26%), Bulk density (1.09 Mg m^{-3}), particle density (2.52 Mg m^{-3}), nitrogen (335.23 kg ha^{-1}), phosphorus (34.86 kg ha^{-1}), and potassium (205.54 kg ha^{-1}). Similarly T_8 yielded significant results with plant height (cm) 40.9 (30 DAS), 49.12 (45 DAS), 60.16 (60 DAS) and number of leaves per plant recorded at 30, 45 and 60 DAS 17, 29, 32 respectively. Moreover, number of pods per plant (38.77) at maturity and seed yield (12.1 q ha^{-1}) at harvest also found significant with T_8. Soil properties as available N, P, K, pH, O.C and porosity were found to be significant while EC, bulk density and particle density were non-significant of soil under black gram crop. There was significant improvement recorded in growth, yield, and soil physico-chemical properties. Seed yield was increased by 52.20% in treatment T_8 over control however; combination of rhizobium and NPK levels had proved significant influence on plant height, number of leaves, number of pod and physico-chemical properties of soil under black gram. Furthermore, economics of different treatment, the maximum gross returns (₹ 72600 ha^{-1}), net returns (₹ 40974 ha^{-1}) and B:C ratio (2.29) was recorded under treatment T_8 for urd bean.

Keywords: NPK, Rhizobium, growth, yield, physico-chemical, economics

Introduction
Pulses are an important commodity group of crops that provide high quality protein complementing cereal proteins for pre-dominantly substantial vegetarian population of the country. In comparison to other vegetables, pulses are rich in protein and contribute about 14% of the total protein of average human diet. Apart from this, pulses possess several other qualities such as improve soil fertility and physical structure, fit in mixed/inter-cropping system, crop rotations and dry farming and provide green pods for vegetable and nutritious fodder for cattle as well. Pulses improve soil health by enriching nitrogen status, long-term fertility and sustainability of the cropping systems. The cultivation of pulses builds-up a mechanism to fix atmospheric nitrogen in their root nodules and thus meet their nitrogen requirements to a great extent. It meets up to 80% of its nitrogen requirement from symbiotic nitrogen fixation from air. Although, being the largest pulse crop cultivating country in the World, India's production of pulses is relatively low in comparison to total cereal crops productions. In India, production of pulses is around 22.4 million tonnes with a very low average productivity of 765 kg ha^{-1}.
Black gram (*Vigna Mungo* L.), is one of the important pulses crop, grown throughout the country contributes about 13 per cent of total area and 10 per cent production of pulses in our country.

Among pulses, black gram has increased from 2.83 m ha in 1980-81 to 3.62 m ha during 2016-17 with production level of 1.94 MT (DES, 2016-17). This increase in production is mainly attributed to additional area brought under the crop as well as yield gains of 537 Kg ha^{-1} during 2016-17. This crop is extensively grown in the states of Maharashtra (23.36%), Andhra Pradesh (18.50%), Uttar Pradesh (12.29%), Madhya Pradesh (11.86%), Tamil Nadu (8.64%) and Rajasthan (4.29%). Black grams are widely considered as an excellent source of high quality protein (26%), carbohydrate (60%), fat (1.3%), minerals (3.2%), fibre (0.9%), calcium (154 mg), phosphorus (385 mg), iron (9.1 mg) with good digestibility and also be rich in vitamin A, B_1, B_3 besides nutritionally rich it has some medicinal properties, like curing diabetes, sexual dysfunction, nervous disorder, hair disorders, digestive system disorders and rheumatic afflictions (Anonymous, 2010) [2].

Soil is dynamic and essential environmental parameter most importantly terrestrial ecosystem. It is a key resource not only for agricultural considered important also towards maintenance of most life processes. Soil is a medium for plant growth. major microbial activity is confined to the 'rhizosphere', *i.e.* aggregates with accumulated organic matter (Lynch, 1990) [15]. Biofertilizer or microbial inoculants generally defined as preparation contains live or latent cells of efficient strains of nitrogen fixing and phosphate solubilizing microorganism have the ability to convert nutritionally important elements from unavailable to available form through biological processes used for treatment of soil (Vessey, 2003) [28]. Biofertilizers may colonizes the rhizosphere and promotes growth by increasing the availability and supply of nutrients and/or growth stimulus to crop. the effects of chemical nitrogen fertilizer and biofertilizer applications on agricultural soil and they concluded that organic matters added to the soil may delay organic nitrogen mineralization. Water and nitrogen availability to plant influence their potential growth and yield (Rajala *et al.,* 2009).

Chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop, continuous use of fertilizers affect the soil health adversely on the physical, chemical and biological properties of soil. So there is need to change the trend of dependency on chemical fertilizer for high yield. Hence integrated nutrient management is applied to get better yield with minimum use of chemical fertilizers. Persistent nutrient depletion is posing a greater threat to the sustainable agriculture. So, there is an urgent need to reduce the usage of chemical fertilizers and in turn increase in the usage of rhizobium which needed to check the yield and quality levels. Use of rhizobium alone does not result in spectacular increase in crop yields, due to their low nutrient status (Subba Rao and Tilak, 1977) [27]. Therefore, the aforesaid consequences have paved way to grow black gram using inorganic fertilizers along with bio fertilizers. Phosphorus is regarded as the pioneer plant nutrient needed by the leguminous crops for rapid and proper root development, which later on becomes helpful for better nodulation by Rhizobium bacteria. Sufficient supply of phosphorus to plant, hastens the maturity and increases the rate of nodulation and pod development. It is also an important constituent of vital substances like phospholipids and phosphor-protein. Since legume is heavy feeder of phosphorus, therefore, application of phosphatic fertilizer to pulses promotes the growth, nodulation and the yield. Phosphorus also imparts hardiness to shoot, improves the quality and regulates the photosynthesis and covers other physico- biochemical process. Most of the phosphorus present in the soil is unavailable to plants which are made available through the activities of efficient micro- organism like bacteria, fungi and even cyanobacteria with production of organic acid and increasing phosphatase enzyme activity. Nitrogen is one of the most essential nutrients required by plant globally. It is an integral component of many compounds such as chlorophyll, nucleotides, alkaloids, enzymes, hormones and vitamins, etc. which are essential for plant growth processes. (Brady 2012). Although N is abundant in atmosphere, yet it is the most limiting nutrient for most crops and soils. Besides being limited, this nutrient has low use efficiency as a large proportion of N applied to the soil through fertilizers get lost by way of leaching, denitrification and volatilization. So, there is a dire need to develop technology that would improve N use efficiency on one hand, and improve soil health on the other hand. Fertilizer nitrogen has contributed tremendously towards increasing food production, yet even with best agronomic practices, the recovery of fertilizer nitrogen hardly exceeds 30-60 per cent, because most of the applied nitrogen gets leached and becomes unavailable for plant use. A number of approaches aimed at increasing N use efficiency have been developed in India and abroad, but none of the strategies is equally effective under different situations. Therefore, there is an urgent need to attempt some alternative approach to tackle the problem of low N use efficiency. Potassium is a major macro element taken up from the soil in large quantity used as a catalyst, chlorophyll formation, respirations, photo-synthesis, water regulation and synergistic effect with nitrogen and phosphorus (Sahai, 2004). However, research on K application has not received on pulses crop

Integrated nutrient management includes the intelligent use of organic, inorganic, and on-line biological resources so as to sustain optimum yields, improve or maintain the soil physical and chemical properties, and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe. The existing state blanket recommendation for crops does not ensure efficient and economic use of fertilizers, as it does not take into account the fertility variations resulting in imbalanced use of fertilizer nutrients. Among the various methods of fertilizer recommendations, the soil test based fertilizer recommendations is also appropriate practices to improve yield as well as soil nutrient status (Sarwar *et al.,* 2014) [21].

Production of pulses in the county is far below the requirement to meet even the minimum level per capita consumption. The per capita availability of pulses in India has been continuously decreasing which is 32.52g/day against the minimum requirement of 80g/day per capita prescribed by Indian Council of Medical Research (ICMR) (Anonymous, 2009) [1]. The factors attributed for low yields of pulses in India as compared to the world productivity are non availability of quality seeds of improved and short duration varieties, growing of pulses under marginal and less fertile soil with low inputs and without pest and disease management, growing of pulses under moisture stress, unscientific post harvest practices and storage under unfavourable conditions. Hence, there is a scope for improving the production potential of this crop by use of inorganic manures and biofertilizers (Shekhawat *et al.,* 2018) [22]. Therefore, it is necessary for agricultural scientists to evolve strategy to increasing production of pulses to meet the requirements of increasing population of the country. Proper fertilization is essential to improve the productivity of black gram considered maintenance of the soil's integrity over time. Poor management can lead to erosion, loss of fertility, deterioration of soil structure, and poor crop yields. Therefore, an experiment was conducted to study the influence of rhizobium along with NPK on growth, yield and soil associated properties under cultivation of black gram with objective: (1) To study the effect of different levels of NPK and Rhizobium on Physico-chemical properties of soil, (2) To study the interaction effect of different levels of NPK and Rhizobium on growth and yield of black gram and (3) To calculate Cost Benefit ratio (C: B) of different treatment combination of black gram.

Materials and Methods

The experiment was conducted during summer season of 2018-19 at research field of Department of Soil Science and Agricultural Chemistry at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. The experimental site is located in the sub–tropical region with 25^0 24'23"N latitude $81^0$50'38"E longitudes and 98 meter above sea level altitudes with maximum temperature up to 46^0C – 48^0C and seldom falls as low as 4^0C – 5^0C. The relative humidity ranged between 20 to 94 percent with semi- arid climate rains mostly during July- September. The average rainfall in this area is around 1100 mm annually. The experiment was laid out in a 3×3 RBD design with each three levels of NPK and Rhizobium with nine treatments, each consisting of three replicates. The treatment consisted of nine combination of inorganic source of fertilizers T_0 (@ 0% NPK + @ 0% Rhizobium), T_1(@ 0% NPK + @ 50% Rhizobium), T_2(@ 0% NPK + @ 100% Rhizobium), T_3 (@50% NPK + @ 0% Rhizobium), T_4(@ 50% NPK + @ 50% Rhizobium), T_5(@ 50% NPK + @ 100% Rhizobium), T_6(@ 100% NPK + @ 0% Rhizobium), T_7(@ 100% NPK + @ 50% Rhizobium) and T_8(@ 100% NPK + @ 100% Rhizobium). The sources of NPK and Rhizobium were as Urea, SSP, MOP and Rhizobium culture respectively. The total number of plots was 27 Black gram (*Vigna mungo* L.) with each plots size being 2 x 2 m in order of Inceptisol and is alluvial in nature. The soil samples were randomly collected from 0- 15 cm depths and subsequently, subjected to laboratory analysis for soil properties using standard methods to ascertain the influences of different treatments on fertility of the soil. Further, plant characteristics were also noted down to evaluate the treatment effect on growth and yield attributes. From each entry, 10 plants were randomly selected for recording observations on important yield attributing characters, plant height, no. of leaves per plant, no. of pods per plant and seed yield per plant during the plant growth period.

Results

Table 1: Effect of Rhizobium and NPK-levels on growth and yield attributes of blackgram

Treatments	Plant Height (cm)			Number of Leaves $plant^{-1}$			No. of pod $plant^{-1}$	Seed yield ($q\ ha^{-1}$)
	30 Days	45 Days	60 Days	30 Days	45 Days	60 Days		
T_0	35.33	42.44	51.10	12.00	25.00	28.00	11.50	7.95
T_1	35.57	42.90	53.15	13.00	26.00	29.00	12.89	9.12
T_2	36.10	43.57	53.90	13.00	26.00	29.00	16.33	9.65
T_3	36.18	44.10	55.50	14.00	26.50	29.00	19.22	10.10
T_4	37.23	44.92	55.87	14.00	27.00	30.00	23.77	10.38
T_5	37.57	45.33	57.12	15.00	27.00	30.00	24.78	10.72
T_6	38.84	46.15	57.54	16.00	28.00	31.00	28.22	11.13
T_7	39.42	47.33	58.15	17.00	29.00	32.00	31.56	11.60
T_8	40.90	49.12	60.16	18.00	30.00	33.00	38.77	12.10
F-test	S	S	S	S	S	S	S	S
S. Em+	0.003	0.05	0.000001	0.16	0.16	0.27	0.80	0.04
C.D. (P= 0.05)	0.006	0.11	0.000002	0.33	0.33	0.58	1.69	0.08

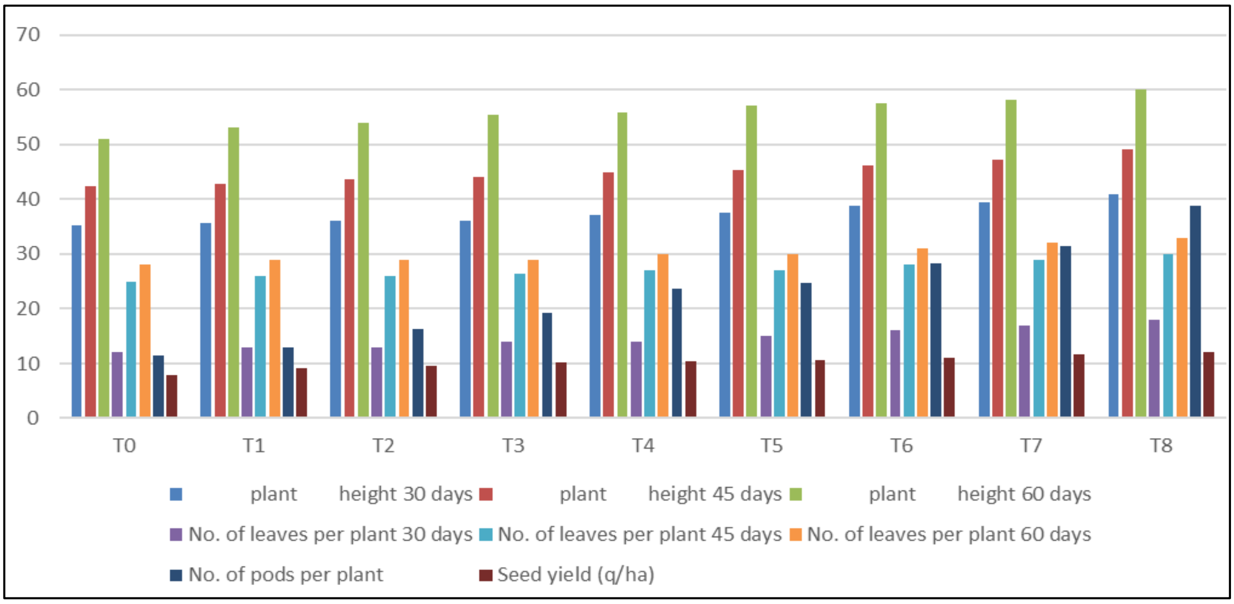

Fig 1: Effect of rhizobium and NPK on the growth and yield attributes

Table 2: Effect of Rhizobium and NPK-levels on physico-chemical properties of soil after harvesting of blackgram

Treatments	Bulk Density (Mg m^{-3})	Particle Density (Mg m^{-3})	Pore space (%)	pH	EC (dS m^{-1})
T_0	1.25	2.24	44.20	7.25	0.15
T_1	1.22	2.32	47.42	7.21	0.16
T_2	1.20	2.28	47.37	7.05	0.19
T_3	1.19	2.52	52.78	7.06	0.20
T_4	1.16	2.34	50.43	7.00	0.21
T_5	1.14	2.50	54.40	6.97	0.22
T_6	1.12	2.38	52.59	6.95	0.23
T_7	1.10	2.62	56.75	6.85	0.24
T_8	1.09	2.52	57.26	6.80	0.26
F-test	NS	NS	S	S	NS
S. Em+	0.05	0.33	1.38	0.06	0.28
C.D. (P= 0.05)	0.11	0.69	2.94	0.12	0.06

Table 3: Effect of Rhizobium and NPK-levels on nutrient content (OC, N, P and K) of post harvest soil samples under blackgram

Treatments	Organic carbon (%)	Available Nitrogen (Kgha^{-1})	Available Phosphorus (Kgha^{-1})	Available Potassium (Kgha^{-1})
T_0	0.54	290.50	24.50	132.90
T_1	0.57	301.83	26.58	145.18
T_2	0.64	303.88	27.19	154.43
T_3	0.61	310.22	28.68	156.27
T_4	0.64	314.31	29.38	167.40
T_5	0.68	320.60	30.68	172.84
T_6	0.66	322.65	31.58	190.90
T_7	0.74	325.93	33.54	198.27
T_8	0.75	335.23	34.86	205.54
F-test	S	S	S	S
S. Em+	0.01	3.24	0.56	7.78
C.D. (P= 0.05)	0.03	6.87	1.18	16.49

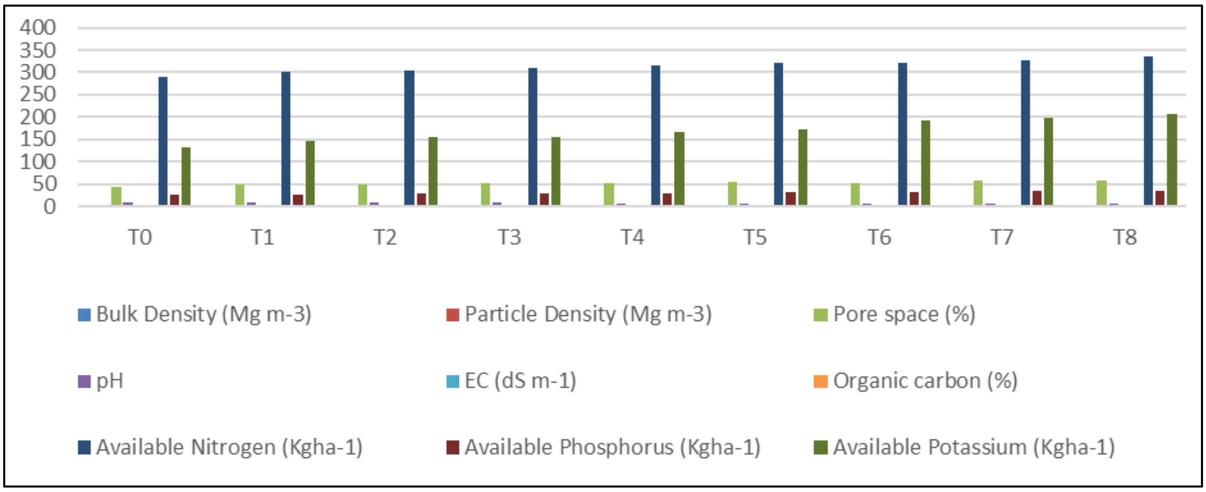

Fig 2: Effect of rhizobium and NPK levels on physico-chemical properties of soil after harvesting of Blackgram

Table 4: Effect on benefit cost ratio (B:C) of Different Treatment Combination with Black gram crop

Treatment	Yield (q ha^{-1})	Yield (₹ q^{-1})	Gross return (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Net profit (₹ ha^{-1})	Benefit Cost ratio (B:C)
T_0	8.68	6000.00	52080.00	29313.00	22767.00	1: 1.77
T_1	9.15	6000.00	54900.00	29463.00	25437.00	1: 1.86
T_2	9.62	6000.00	57720.00	29613.00	28107.00	1: 1.94
T_3	9.95	6000.00	59700.00	30319.00	29381.00	1: 1.96
T_4	10.38	6000.00	62280.00	30469.00	31811.00	1: 2.04
T_5	10.72	6000.00	64320.00	30619.00	33701.00	1: 2.10
T_6	11.13	6000.00	66780.00	31326.00	35454.00	1: 2.13
T_7	11.60	6000.00	69600.00	31476.00	38124.00	1: 2.21
T_8	12.10	6000.00	72600.00	31626.00	40974.00	1: 2.29

Discussion

Growth attributes

Plant height (cm), number of leaves $plant^{-1}$ and number of pods $plant^{-1}$

Yield attributes such as Plant height (cm), number of leaves $plant^{-1}$, number of pods $plant^{-1}$ and seed yield (q ha^{-1}) increased significantly with increasing levels of N, P, and K upto 20, 40 and 40 kg ha^{-1} respectively along with rise in Rhizobium up to 20 g kg^{-1}. Rhizobium resulted in higher rate of dry matter accumulation, efficient uptake of nutrients from inorganic fertilizers as well as its translocation from sources to sink in the plants which ultimately reflected for higher values of yield attributing characters. Zodape, (2001) [31] also concluded that, the increase in yield productivity with biofertilizer application is due to micro-nutrient and plant growth regulator contained in the fertilizer. This might be due to the increase in vegetative development and reproductive attributes under proper supplement of nutrients and better physical condition of soil. Application of treatments the increase in yield attributes was mainly due to increase photosynthetic activity of leaves. Translocation of photosynthates from source to sink and nutrient uptake by the application of bio-fertilizer and fertilizer dose. The soil micro organisms are responsible for transfer of the immobilized soil phosphorus into available form through which phosphorus becomes easily available to these legume crops (Singh *et al.*, 2008) [25]. The minimum values of all the attributes were observed under control plot because plants were unable to receive more nutrients with 0% NPK + 0% Rhizobium. The results are in agreement with those of Prakash *et al.*, (2002) [18]. Inoculation of Urd bean with Rhizobium increased all the yield attributing characters of Urd bean.

Yield attributes

Seed yield (q ha^{-1})

Combined application of NPK significantly up to 20, 40 and 40 kg ha^{-1} respectively along with Rhizobium up to 20 g kg^{-1} recorded maximum yields obtained with treatment T_8(@ 100% NPK + @ 100% Rhizobium). Application of T_8 (@ 100% NPK + @ 100% Rhizobium) increased the seed yield by 12.1 q ha^{-1} over control. The increase in seed yield with T_8 was due to (i) increase in source capacity *viz*., plant height and leaves $plant^{-1}$ as well as sink capacity *viz*., pods $plant^{-1}$ and seed number per plant (ii) better utilization of photosynthate towards sink. Increase in translocation might have happened due to increase in nitrogen, potassium and phosphorus uptake which are responsible for quick and easy translocation of the photosynthates from source to sink (Wu *et al.*, 2005) [30]. Inoculation caused to increasing yield through synergistic effects by improving growth prompting hormones, controlling pathogenesis and growth reducing agents via producing fungicide antibiotics and compounds (antagonistic effect), nitrogen fixing and also producing growth prompting hormones such as auxin, cytokinin and gibberellin and solving mineral compound (Buragohain, 2000) [5]. Steady and higher availability of major, secondary and micronutrients during the crop growth period which have enhanced the growth and yield attributes and finally augmented to better seed yield (Stamford *et al.*, 2013) [26].

Physico-Chemical properties

Among these treatments, treatment T_8 (100% NPK + 100% Rhizobium) was found significantly best treatment with Pore space (57.26%), OC (0.75%), EC (0.26 ds m^{-1} at 25^0C), Nitrogen (335.23 kg ha^{-1}), Phosphorus (34.86 kg ha^{-1})and Potassium (205.54 kg ha^{-1}). Addition of Rhizobium with NPK can improve the soil physical properties is a well-documented and scientifically proven that significant changes in the soil physical properties can be recorded when Rhizobium treatment compared with chemical fertilizer treatment (Berger *et al.*, 2013) [4]. Application of biofertilizer has favorable effect on physical, chemical and biological properties of soil and hence provided congenial environment for root growth and proliferation thereby creating maximum absorptive power by crop (Saravanan and Kumar, 2013) [20]. Organic carbon content in soil improved slightly due to integration of nutrient sources (Khandelwal *et al.*, 2012) [12]. As the production of total biomass was higher in these treatments, more amount of residue might have added in the soil in form of leave fall and roots which will build up the organic matter level in soil that might be the reason in lower pH and low bulk density with T_8. While, maximum pH (7.25) and maximum bulk density (1.25 Mg m^{-3}) was obtained with control (T_0 @ 0% NPK + @ 0% Rhizobium) with no particular trend found in soil under different treatments, However, particle density (2.62 Mg m^{-3}) recorded maximum with treatment T_7 (@ 100% NPK + @ 50% Rhizobium) having non significant effect with all treatment combinations. Reduction in pH might be due to production of organic acid by manure on decomposition (Silva *et al.*, 2012). Significantly higher O.C attributed to bulk posting of organic matter rich in nitrogen which enhanced microbial activity in the soil and thereby greater conversion of organically bound nitrogen to inorganic form by the activities of microbes (Menon *et al.*, 2010) [16]. The higher available N attributed to higher activity of N- fixing bacteria, thereby making N greatly available in the soil by (Singh and Mukherjee 2009) [24]. Significantly higher available phosphorus might be due to the lower loss of nutrients due to slow available nutrients in soil (Wagadre *et al.*, 2010) [29]. Similar results were obtained by Kumar *et al.*, (2003) [14] and Jamir *et al.*, (2013) [10] have also noted the improvement in available phosphorus status due to balanced use of chemical fertilizers.

Economics

The cost of cultivation, gross return and net return increased with increase in each level of NPK and Rhizobium. Application of 100% NPK + 100% Rhizobium recorded highest gross income of Rs. 72600 and net return of Rs. 40974. The net return Re^{-1} investment (B:C) increased upto 100% NPK + 100% Rhizobium recoding highest values of Rs. 2.29. This was attributed to greater increase in seed yield as compared to cost of cultivation with increasing levels NPK along with Rhizobium. These results are in conformity with those observed by Mitra *et al.*, (2006) [17] who reported increased benefit cost ration and net income with increasing levels of phosphorus.

Conclusion

The best treatment was T_8 (@ 100% NPK+ @ 100% Rhizobium) which showed the highest yield regarding, and gave the best results with respect to plant height 60.16 cm, number of leaves $plant^{-1}$ 33, it gave highest yield, 12.10 q ha^{-1}, In post soil the important parameter on chemical properties on black gram crop different treatment of NPK and Rhizobium, Percentage Pore Space, pH, organic carbon (%), Available nitrogen (kg ha^{-1}), Available phosphorus (kg ha^{-1}), Available potassium (kg ha^{-1}) was found significant and EC was found non-significant. pH, organic carbon (%), available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}), and potassium (kg ha^{-1}) was recorded as 6.8, 0.75, 335.23, 34.86, and 205.54 respectively in the treatment that was significantly higher as compared to other treatment combination. EC was recorded as 0.26 (dS m^{-1}) that was non significantly higher as compared to other treatment combination. The economy of different treatment concerned, the treatment T_8 provides highest net profit of Rs. 40974.00 with cost benefit ratio is 1: 2.29. It was concluded from trail that the highest stimulatory effect of root associative beneficial bacteria, especially strains of Rhizobium have potential to be used as biofertilizer increase the productivity of blackgram with controlled fertilization from inorganic sources. Overall utilization of biofertilizers with single and combined treatments found beneficial to increase the availability of major and micro nutrients, reduce the use of fertilizers and subsequent build up significant improvement in residual soil fertility in addition to increased yield could be a strategy to achieve sustainable agriculture.

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