The Pharma Innovation Journal 2021; 10(11): 1668-1671

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(11): 1668-1671

www.thepharmajournal.com
Received: 15-09-2021
Accepted: 27-10-2021

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Physico-chemical properties and nutrient availability of blackgram growing soil influenced by sulphur and bio-inoculants

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Abstract
A field experiment was conducted on effect of sulphur and bio-inoculants on available nutrient status of blackgram growing soil at College of Agriculture, Latur. The experiment was laid out in randomized block design with seven treatments and three replications.
The result showed that chemical properties of soil like pH, EC and calcium carbonate were affected non-significantly but organic carbon showed significant results. The significantly highest organic carbon (7.5 g kg $^{-1}$) was recorded with treatment T_7 (RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) followed by T_6 (RDF+ 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) and the lowest organic carbon (6.1g kg^{-1}) was recorded with treatment T_1 (RDF). Soil pH, EC, calcium carbonate of soil after harvest was decreased as compare to initial value but the organic carbon content was increased in soil samples collected after harvest of blackgram than the initial soil samples.
Available nutrients *viz;* N, P, S, Fe and Zn were affected significantly due to application of different levels of sulphur and bio-fertilizers, however available K, Mn and Cu were affected non significantly. The treatment T_7 (RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) was recorded significantly maximum available N (243.53 kg ha $^{-1}$), P (27.20 kg ha $^{-1}$), S (25.10 kg ha $^{-1}$), Fe (5.76 mg kg $^{-1}$) and Zn (0.68 mg kg $^{-1}$) than the other treatments followed by treatment T_6 (RDF+ 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*). The available N, P, K, S, Fe, Mn, Zn and Cu content in soil after harvest of blackgram was increased than the initial soil sample.

Keywords: Blackgram, organic carbon, available nutrients, bio-inoculants

1. Introduction
Blackgram is consumed in various forms as dal (whole or split, husked and unhusked). The whole plant is used as fodder for cattle and is a good green manure and soil conservation crop. Many delicious food items can be prepared from blackgram e.g. dosa, idli, curry, papad, bari (spiced balls), pudding (halva) and imurti (a delicious sweet). Pulse crops have significant impact on soil biology, increasing soil microbial activities even after the harvest of crop, these are also responsible to enhance greater amount and different types of amino acids than non-legumes. These are N- fixing crops that improve sustainability of annual cropping system.
Thiobacilli play an important role in sulphur oxidation in soil. Sulphur oxidation is the most important step of sulphur cycle, which improves soil fertility. It results in the formation of sulphate ($SO4^-$), which can used by the plants. While, acidity produced by oxidation helps to solubilize plant nutrients and improves alkali soil.
Sulphur deficiency show reduction in growth rate of the plant and generally the growth of shoots were more affected than that of roots.
Biofertilizer are defining as biologically active products or inoculants like bacteria, algae and fungi which help in nitrogen fixation for the benefit of plant. The term biofertilizers denotes all the nutrient input of biological origin for plant growth. The term biological origin refers to the microbiological process by which complex compounds are synthesized and released into the soil in the vicinity of plant root there by facilitating the uptake of these compounds by plants. Bio-fertilizers have emerged as a promising component of integrated nutrient supply system in agriculture. Our whole system of agriculture depends in many important ways, on microbial activities.
Benefits of bio-fertilizers are different like enrich soil with nitrogen by biological nitrogen fixation, increase crop yield by 15-20 per cent, increase germination potential of seeds, develop resistance against disease in crops, suppress soil borne diseases as some of the inoculants produce antibiotics, improves soil properties and sustain soil fertility.

Help in mineralization of plant nutrients, solubilize unavailable phosphate and sulphur in the soil converting them in available form. All the nitrogen fixing bio-fertilizers significantly improved the leg haemoglobin content in nodule and reached to a maximum level at flowering stage (Kapure and Naik, 2004) [4]. Bio-fertilizers release certain hormones, which increase crop growth. Bio-fertilizers can save fertilizer consumption by nearly 15 per cent. Bio-fertilizers are cheap, handy, eco-friendly, pollution free and easy to transport.

Materials and Methods

The experiment was laid out in randomized block design with seven treatments and three replications. The soil of the experimental site was deep, black in colour with good drainage. The topography of experimental plot was fairly levelled. Before sowing, initial soil sample was collected (0-15) from the experimental area randomly.

Soil pH and EC estimated by 1:2.5 (soil: water) suspension ratio by using pH meter suggested by Jackson (1973) [3]. Organic carbon in soil was determined by modified method of Walkely and Black (1934) [15]. Rapid titration method was used for determination of calcium carbonate as suggested by Piper (1966) [6]. Alkaline potassium permanganate method was used for determination of available nitrogen as described by Subbiah and Asija (1956) [10]. Available phosphorus was estimated from the soil with 0.5 M sodium bicarbonate as extracting agent on spectrophotometer and determined by Olsen‟s method as proposed by Jackson (1973) [3]. Available potassium was determined with neutral normal NH4OAC and K estimated from extract by using flame photometer as suggested by Jackson (1973) [3]. Williams and Steinberg‟s (1959) [6] method was used for determination of available sulphur on spectrophotometer at 340 nm. Atomic adsorption spectrophotometer was used to determine concentration of DTPA micronutrients such as Fe, Cu, Zn and Mn (Lindsay and Norvell, 1978) [5].

Results and Discussion

Effect on physico-chemical properties of soil

The data regarding physico-chemical properties of soil *viz;* pH, EC, organic carbon and calcium carbonate as influenced by sulphur and bio-fertilizers after harvest of blackgram are presented in table 1.

Soil pH

There was no particular trend regarding increase or decrease in soil pH after harvest of crop. It was not reach to the significant level due to various treatments of sulphur and bio-inoculants. The highest pH (8.08) was recorded with treatment T_1 (RDF) and lowest pH (7.68) was recorded with treatment T_7 (RDF + 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*). Further, data revealed that pH of soil after harvest of crop was decreased as compare to initial pH value (8.9) in blackgram growing soil. The decrease in pH might be due to P-solubilizing activity of phosphobacteria associated with the release of organic acids and a drop in the soil pH of the medium. Different kinds of organic acids, namely citric acids, gluconic acid, lactic acid, succinic acid and propionic acid were produced from the cultures of these isolates. These results are in agreement with the results given by Selvakumar *et al.* (2012) [7]. Similarly, Chaudhary and Das (1996) [1] stated that, beneficial effect of S seems to be in lowering soil pH and improving physical condition of soil. On the other hand, Tagore *et al.* (2013) [1] observed that soil pH remain unaffected under different microbial inoculation.

Electrical conductivity

The highest soil EC (0.19 dSm^{-1}) was found with treatment T_7 (RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) and the lowest EC (0.16 dSm^{-1}) was recorded with treatment T_1 (RDF). In soil, EC was found non significant due to application of different levels of sulphur and biofertilizers. Further, data indicated that the EC of initial soil sample (0.20 dSm $^{-1}$) was higher as compare to the samples collected after harvest of crop. Soil properties changed with the application of S and the oxidation of sulphur resulted in direct chemical changes through the increase in EC this result are in conformity with the observations of Soaud *et al.* (2011) [9].

Organic carbon

The organic carbon content of soil was influenced significantly by different levels of sulphur and bio-inoculants. The maximum (6.57 g kg^{-1}) organic carbon was recorded with application of RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus* (T_7) and remained at par with treatment T_6 (RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB+ *Thiobacillus*). The treatment T_7 was significantly superior over rest of the treatments. The minimum organic carbon content (6.10 g kg $^{-1}$) was recorded with application of RDF (T_1) Further, it was observed that the organic carbon content was increased in soil samples collected after harvest of blackgram than the initial soil samples (6.0 g kg^{-1}). This could be attributed to increased activity of microbes and also due to better root penetration. These results are in conformity with the results of Chaudadhay and Das (1996) [1] reported that increasing levels of P and S application increased growth and root development of blackgram which brought about improvement in organic carbon after the harvest of crop. Similarly, Selvakumar *et al.* (2012) [7] observed that organic carbon was significantly increased by the application of bio-fertilizers.

Calcium carbonate

The data was non-significant under different levels of sulphur and biofertilizers.

The highest calcium carbonate (43.9 g kg^{-1}) was observed in treatment T_1 (RDF) and the lowest (37.7 g kg^{-1}) was with treatment T_7 (RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*). Further, it was observed from the data that calcium carbonate in soil was decreased in soil samples collected after harvest of blackgram as compared to initial soil samples (44.2 g kg^{-1}). It indicates that blackgram crop decreases the calcium carbonate content in soil because of addition of organic matter sufficiently. *Thiobacilli* play an important role in sulphur oxidation in soil. Sulphur oxidation is the most important for improve soil fertility by improving soil properties regarded by Vidyalakshmi *et al.* (2009) [14].

Effect on available N, P, K, S, Fe, Cu, Zn, and Mn content in soil

Available N, P, K and S content of soil

The data (Table 2) showed that available N, P and S in soil affected significantly due to application of different levels of sulphur and bio-fertilizers but available K was not reached to the significant level after harvest of blackgram. It is revealed from the result that the treatment T_7 (RDF+ 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) was recorded significantly maximum available N (243.53 kg ha^{-1}), P (27.20 kg ha^{-1}) and S (25.10 kg ha^{-1}) under sulphur and bio-fertilizer treatments.

However, it was at par with treatments T_3 (RDF + 20 kg S ha^{-1} + *Rhizobium*), T_5 (RDF + 20 kg S ha^{-1} + *Thiobacillus*) and T_6 (RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) in regard to available N and for available P, it was at par with treatments T_4 (RDF + 20 kg S ha^{-1} + PSB) and T_6 (RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) as well as, treatments T_5 and T_6 were in available sulphur. The lowest available N (182.85 kg ha^{-1}), P (20.77 kg ha^{-1}) and S (16.22 kg ha^{-1}) were recorded with treatment T_1 (RDF). Available K was recorded maximum (487.84 kg ha $^{-1}$) and minimum (462.18 kg ha $^{-1}$) with treatments T_7 and T_1, respectively. Further, data revealed that the available N, P, K and S content in soil after harvest of blackgram were increased than the values recorded in initial soil sample. Available N content increased significantly in inoculated soil than un-inoculated control. It might be due to the microbes fixes nitrogen in soil. Higher P content may be due to inoculation and availability of P nutrients in soil by microbes. Available N, P and K content were significantly increased by the application of bio-fertilizers. The soil micro-organisms are responsible for transfer of the immobilized soil phosphorus in to available form through which phosphorus becomes easily available to these legume crops. Similar findings were also observed by Selvakumar *et al*. (2012) [7]. Similarly, Shinde *et al.* (1996) [8] observed that, sulphur availability increased by release of sulphate sulphur in soil by oxidation of insoluble elemental sulphur. All the biofertilizers significantly improved the available P from soil. (Kapure and Naik, 2004) [4] On the other hand, Thenua and Praveen Kumar (2007) [12] found that the seed inoculation with *Rhizobium* and *Rhizobium* + PSB recorded higher N and P status, while the K was unaffected the bio-fertilizers. This is mainly due to the relationship of these bio-fertilizers with N and P only and not with K. The highest values of available N (220.3 kg ha^{-1}), available P (14.1 kg ha^{-1}), available K (556.9 kg ha^{-1}) and available S (13.41 kg ha^{-1}) were recorded under inoculation of both *Rhizobium* and PSB; however, the lowest values of available N, P, K and S were under no inoculation (Tagore *et al.*, 2013) [1].

Available Fe, Mn, Cu and Zn content of so

Available micronutrients (Table 3) *viz;* Fe, Mn, Cu and Zn in soil were influenced significantly due to different levels of sulphur and bio-fertilizers regarding available Fe and Zn and non significant results were observed for available Mn and Cu. It is evident from the data that application of RDF + 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus* (T_7) was recorded significantly higher available Fe (5.76 mg kg $^{-1}$) and available Zn (0.68 mg kg $^{-1}$) than the other treatments and remains at par with treatments T_3 (RDF + 20 kg S ha^{-1} + *Rhizobium)* and T_6 (RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*) in Fe content and at par with treatment T_6 only in Zn content . However, lower content of Fe (3.92 mg kg $^{-1}$) and Zn (0.36 mg kg $^{-1}$) were recorded with treatment T_1 (RDF). Available Mn (4.55 mg kg $^{-1}$) and Cu (0.44 mg kg $^{-1}$) content in soil were also recorded higher with application of treatment T_7 while, lower content were recorded with treatment T_1. Further, data revealed that the available Fe, Mn, Zn and Cu content in soil after harvest of blackgram were increased as compared to the initial soil sample. Sulphur had synergistic relationship with micro-nutrient, acidity produced on oxidation of reduced inorganic sulphur compounds in soil was known to increase the solubility of micro-nutrient due to which increase availability of micro-nutrients. Similar findings were reported by Tiwari (1997) [13]. Similarly, Selvakumar *et al.* (2012) [7] revealed that available Fe, Mn, Zn and Cu content were increased by the application of bio-fertilizer. Heydarnezhad *et al.* (2012) [2] reported that application of elemental sulphur increase available Fe and Zn in soil.

Table 1: Chemical properties of soil as influenced by various treatments at harvest of blackgram crop

Treatments	pH	EC (dsm^{-1})	Organic carbon (g kg^{-1})	$CaCO_3$ (g kg^{-1})
T_1 - RDF	8.08	0.16	6.10	43.9
T_2 - RDF + 20 kg S ha^{-1}	8.07	0.16	6.17	43.7
T_3- RDF+20 kg S ha^{-1} + *Rhizobium*	8.07	0.17	6.25	42.0
T_4- RDF + 20 kg S ha^{-1} + PSB	7.94	0.18	6.39	41.2
T_5- RDF + 20 kg S ha^{-1} + *Thiobacillus*	7.75	0.19	6.43	40.3
T_6- RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	7.98	0.19	6.53	39.7
T_7- RDF + 30kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	7.68	0.19	6.57	37.7
Initial values	8.9	0.20	6.0	44.2
SE +	0.123	0.031	0.010	0.377
CD at 5%	NS	NS	0.031	NS

Table 2: Available nitrogen, phosphorus, potassium and sulphur as influenced by various treatments at harvest of blackgram

Treatments	Available N (kg ha $^{-1}$)	Available P (kg ha $^{-1}$)	Available K (kg ha $^{-1}$)	Available S (kg ha^{-1})
T_1 - RDF	182.85	20.77	462.18	16.22
T_2 - RDF + 20 kg S ha^{-1}	190.99	20.87	466.85	20.53
T_3- RDF+20 kg S ha^{-1} + *Rhizobium*	230.02	23.83	474.87	21.46
T_4- RDF + 20 kg S ha^{-1} + PSB	205.00	25.64	477.10	21.90
T_5- RDF + 20 kg S ha^{-1} + *Thiobacillus*	225.36	24.67	480.32	23.56
T_6- RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	231.29	26.24	482.58	23.94
T_7- RDF + 30kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	243.53	27.20	487.84	25.10
Initial values	180.40	19.04	450.00	15.4
SE +	12.06	0.78	29.36	0.65
CD at 5%	37.15	2.42	NS	2.00

Table 3: Available Fe, Mn, Zn and Cu as influenced by various treatments at harvest of blackgram

Treatments	Available Fe (mg kg $^{-1}$)	Available Mn (mg kg $^{-1}$)	Available Zn (mg kg $^{-1}$)	Available Cu (mg kg $^{-1}$)
T_1 - RDF	3.92	2.24	0.36	0.28
T_2 - RDF + 20 kg S ha^{-1}	4.36	2.70	0.34	0.31
T_3- RDF+20 kg S ha^{-1} + *Rhizobium*	5.50	2.77	0.52	0.32
T_4- RDF + 20 kg S ha^{-1} + PSB	4.46	3.57	0.39	0.34
T_5- RDF + 20 kg S ha^{-1} + *Thiobacillus*	4.84	3.48	0.48	0.39
T_6- RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	5.51	4.46	0.59	0.34
T_7- RDF + 30kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus*	5.76	4.55	0.68	0.44
Initial values	2.84	2.20	0.35	0.25
SE +	0.27	0.55	0.67	0.05
CD at 5%	0.83	NS	0.08	NS

Conclusions

Application of RDF + 30 kg S ha^{-1} + *Rhizobium* + PSB + *Thiobacillus* improved physico-chemical properties, available macro-nutrients (N, P, K and S) and micro-nutrients (Fe, Mn, Zn and Cu) in blakgram growing soil.

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