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Integrated nutrient management practices for sustainable soybean [*Glycine max* (L.) Merr.] production: A case study of Ghazni province of Afghanistan

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ABSTRACT

A field experiment was carried out during spring season of 2020 at Ghazni province, Afghanistan to evaluate the effects of integrated nutrient management on growth and productivity of soybean and to develop a suitable fertilizer package of integration of inorganic fertilizers with biological and organic manures for soybean. The experiment was laid out in Randomized Block Design (RBD) with three replications having seven treatments. T_1= Absolute control, T_2 =100% RDF, T_3 = 75% RDF + FYM (5 t ha^{-1}), T_4 = 75% RDF + BF (Rhizobium + PSB), T_5 = 50% RDF + FYM (10 t ha^{-1}), T_6 = 50% RDF + BF (Rhizobium + PSB), T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB). Perusal of the results revealed that application of 50% RDF + FYM (5 t ha^{-1}) + BF(Rhizobium + PSB) recorded significantly higher plant height, number of branches, number of root nodules, number of pods per plant (82.7), number of seeds per pod (2.6), 100 seeds weight (12.5 g), seed yield (2687.5 kg ha^{-1}) and straw yield (4424.8 kg ha^{-1}) and gross return (196,977 Afn. ha^{-1}) over control and treatment that received 50% RDF + BF(Rhizobium + PSB). Although, the maximum net return (145,801 Afn. ha^{-1}) was obtained with 100% RDF, but it was non-significant with the application of 50% RDF + BF+ 5t FYM ha^{-1}(143,227 Afn. ha^{-1}). Based on the result of experiment it is recommended that for remunerative soybean cultivation and soil health, the farmer should apply 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB).

Key words: Biofertilizer, FYM, integrated nutrient management, soybean

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a species of legume native to East Asia. The plant is classified as an oilseed as well as pulse. It is an annual plant that has been used in China for 5000 years as a food and a component of drugs. Soybeans are important source of vegetable oil and protein worldwide. Together, oil and protein content account for about 60% of dry soybean by weight. Protein at 40% and oil at 20%, remainder consist of 35% carbohydrate and about 5 per cent ash. It is also called as "gold of soil" due to atmospheric N fixation in soil to maintain the soil fertility and beneficial effect on following crop (Kausadikar et al., 2003).

Soybean accounts for about 50% of oilseeds production in the world. The protein form of soybean is equivalent in quality to that of meat, milk products and eggs. The soya meal is an important human food and soya flour is essential in the various preparations viz. bread, cakes, muffins, biscuits and pastry. Worldwide the cultivation area for soybean is accounted 122.30 million hector with average productivity of 2.70 t ha^{-1} and 330.41 million metric tons production (USDA, 2016). In Afghanistan soybean consumption is going rapidly and is used as soy naan, soy dishes, including soybean korma (soup), soymilk and full-fat soy flour. Production of soybean was recorded 4,000

MT with average productivity of 0.6 to 1.2 t ha^{-1} (NEI, 2015; NEI, 2011). In spite of high yield potential, soybean productivity is much less in Afghanistan than the world average. Among the factors responsible for low productivity, inadequate fertilizer use and emergence of multi-nutrient deficiencies due to poor recycling or organic sources and unbalanced use of fertilizers particularly micronutrients (Chaturvedi et al., 2010). One of the major constraints for low productivity of soybean is inadequate supply of nutrients in balanced manner. It has been established that continuous use of high analysis chemical fertilizers leads to deficiency of secondary and micronutrients, soil salinity and environmental pollution. While Afghan farmers are confined to use high chemical fertilizers which supply only the major nutrients while the crop plants remove all the essential nutrients, which are needed for their normal growth. Mention the recommended dose of fertilizer for Afghanistan and farmers' practice. The chemical fertilizers are also responsible for creating heavy metal pollution in soil. The heavy metal considered to be a threat to the environment are Arsenic (As), Cadmium (Cd), Copper (Cu), Mercury (Hg) and Lead (Pb). The soil factors which are affected by heavy metals are pH, clay content, texture, organic matter content, phosphate additions and exchangeable sodium percent (Singh et al., 1979). Continuous use of chemical fertilizer is leading reduction in crop yield and resulted in imbalance of nutrients in soil, which has adverse effects on soil health. Use of organic manure alone or in combination with chemical fertilizers will help to improve physio-chemical properties of the soil, efficient utilization of applied fertilizers for improving seed yield and quality. The appropriate combination of mineral fertilizers with organic manure can be feasible to sustain agriculture as commercial and profitable ensuring high yield of crop without deterioration in quantity and quality of the produce and soil health.

There seems a wide potential to upgrade efficiency of these nutrients through better agronomic practices. The low practical options to upgrade the efficiency of applied fertilizer nutrients are judicious combinations of organic and inorganic sources and promoting the use of bio-fertilizers. In recent years, a concept of integrated nutrient supply involving use of organic manures and inorganic fertilizers has been developed to obtain sustained agricultural production (Gaikwad et. al, 1996). Integration of organic and inorganic sources of nutrients along with bio-fertilizers is found to give higher productivity and monetary returns in soybean (Singh and Rai, 2004; Bhattacharyya et al., 2008). Integration of chemical fertilizer with organic manures has been found to be quite promising not only in maintaining higher productivity but also providing greater stability in crop production (Nambiar and Abrol, 1992). Further the organic sources unlike inorganic ones have substantial residual effect on succeeding crops (Shivakumar and Ahlawat, 2008). Whereas integrated nutrient management (INM) involves the use of manures, bio-fertilizers and chemical fertilizers to achieve sustained crop production and maintain better soil health. INM is best approach for better utilization of resources and to produce crops with less expenditure.

Hence, integrating the use of organic input, inorganic input and Bio-fertilizers (Rhizobium+ PSB) would improve the productivity of crop on sustainable basis. Therefore, the present study was aimed to evaluate the effects of integrated nutrient management on growth and productivity of soybean and to develop a suitable fertilizer package by integrating inorganic fertilizers with biological and organic manures for soybean.

MATERIALS AND METHODS

The present investigation was conducted in Mohammad Khan village, Ghazni, Afghanistan, during spring season of 2020. The experimental field is located at longitude 68° 20' 11" East and latitude 33°31' 48" North at an elevation of 2204 m above mean sea level. The Ghazni province is located in the southeast region of Afghanistan. It acquires a transitional climate between semi-arid with cold winter and warm dry summer. Total precipitation is 250 – 300 mm and mostly occurs in winter in the form of snow. The soil of experimental field was sandy clay loam in texture, medium in organic matter and available N was low (233 kg ha^{-1}), P was medium (15.9 kg ha^{-1}) and K was high (392 kg ha^{-1}).

Therefore, the recommended doses of fertilizer (RDF) were maintained on the basis of initial status of available nutrients in the experimental soil to carry out the present investigation.

Experimental design and treatments

The experiment was laid out in Randomized Block Design (RBD) with three replications having seven treatments. T_1= Absolute control, T_2 =100% RDF, T_3 = 75% RDF + FYM (5 t ha^{-1}), T_4 = 75% RDF + BF (Rhizobium + PSB) (5g culture each of Rhizobium and PSB per kg Seed), T_5 = 50% RDF + FYM (10 t ha^{-1}), T_6 = 50% RDF + BF (Rhizobium + PSB) (5g culture each of Rhizobium and PSB per kg Seed), T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) (5g culture each of Rhizobium and PSB per kg Seed). Calculated quantity of fertilizers and farm yard manure were applied plot wise as per treatments. Fertilizer doses were calculated on the basis of recommended dose of nutrients 20 kg N + 60 kg P_2O_5 + 20 kg K_2O + 5 kg Zn ha^{-1} through urea, triple superphosphate, sulphate of potash, and zinc through zinc sulphate respectively. All the fertilizers were given as basal dose. Well-decomposed farm yard manure as per treatments was applied before sowing and incorporated in the soil. Recommended package of practices were followed uniformly for all the treatments.

Data collection and analysis

Five plants were selected randomly from each plot and tagged for recording plant height, branches per plant, plant dry weight, per pods plant and seeds per pod. For root nodule count, plants were uprooted carefully with the help of khurpa (hoe), the roots were washed carefully and nodules from the tap and lateral roots were counted and the average values were recorded. For yield estimation, the crop was harvested from the net plot area and the pods were threshed manually. The weight of cleaned seeds was recorded as net plot yield. The dried Stover from each plot was harvested and weighed. Both seed and straw yield were expressed as kg ha^{-1}. The harvest index (HI) was computed by dividing grain yield with total biological yield. For computing of benefit:cost ratio, the net return was divided with the cost of cultivation. The value so obtained was considered as cost benefit ratio.

BCR= Net Return/ Total cost of production

Data were analyzed using ANOVA for randomized block design (Rana et al., 2014). Significance of difference among different treatments was tested using F-test. Critical difference (CD) values were calculated for the parameters that exhibited significant differences. The treatment means were compared at 5 per cent level of significance.

RESULTS AND DISCUSSION

Influence on growth

At successive growth stages plant height was significantly influenced by the application of inorganic fertilizers, bio-fertilizer and farm yard manure. At 30, 60 and 90 DAS, significantly higher plant height was recorded with application of 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) over control treatment and application of 75% RDF + BF and 50% RDF + BF (Rhizobium + PSB), but was at par with rest of the treatments (Table 1). It was observed that the integration of bio-fertilizer and organic manure with chemical fertilizers had a significant impact on plant height. This clearly indicated the need for adding organic manures to the soil conjunctive with inorganic fertilizers, which increased the availability of nutrients considerably resulting in a positive effect on growth parameters. These findings are in accordance with the results of Babalad (1999) who had observed increased plant height, number of trifoliate leaves per plant and number of branches per plant in soybean due to the application of organic manure and inorganic fertilizers. Similar findings were reported by Babhulkar et al. (2000), Jayabal et al., 2000, Dikshit and Khatik (2002) in soybean, sunflower and sorghum.

Number of branches per plant differed significantly, as influenced by different nutrient management treatments, at all stages of crop growth (Table 1). At 30, 60 and 90 DAS, application of 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) recorded significantly higher number of branches over control treatment and the treatment which received 50% RDF with only bio-fertilizer, but it was found on par with other treatments. The increase in plant growth attributed to the increase availability of nutrients with the application of inorganic fertilizer, continuous supply of macro and micro nutrients from FYM, which helped in acceleration of various metabolic processes viz. photosynthesis, energy transfer reaction and symbiotic biological N - fixation process. These results are in close agreement with the findings of Bhaskar (2013) who reported that the number of branches per plant was significantly higher with the application of 75% RDF + Zinc (5 kg ha^{-1})+BF (Rhizobium+ PSB)+FYM (2.5 t ha^{-1}) over absolute control but it was at par with 50% RDF+Zinc (5 kg ha^{-1})+BF (Rhizobium +PSB)+FYM 5 t ha^{-1}. The effect of integrated nutrient management at all growth stages on number of root nodules per plant was significant. At 30, 60 and 90 DAS stages application of 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) recorded the highest number of root nodules per plant (12.2, 17.4 and 24.7, respectively), which were significantly superior to the absolute control and the treatment that received only 50% RDF + BF (Rhizobium + PSB), but it was at per with rest of the treatments. The increase in nodules number is the response of inoculation by bio-fertilizer which might have accelerated the nitrogenous activity in plant system and hence such response. Nodules are the niches of microorganisms and fixes atmospheric nitrogen. Also higher number of root nodules per plant might be due to increased nutrients availability, which resulted in the formation of active and more number of root nodules. The results are in close agreement with the findings of Lone et al. (2009), Mohod et al. (2010) and Bhaskar (2013) who reported that the maximum number and dry weight of root nodules per plant were recorded with the application of 75% RDF+Zinc (5 kg ha^{-1})+BF (Rhizobium+ PSB)+FYM (2.5 t ha^{-1}).

Table 1. Effect of integrated nutrient management on growth parameters of soybean

Treatment	Plant height (cm)			Number of branch per plant			Number of root nodules per plant		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T_1= Absolute control	12.1	41.7	63.2	2.0	2.7	3.9	7.1	11.3	14.9
T_2 =100% RDF	16.2	51.3	79.9	2.7	4.0	5.1	11.6	16.2	23.3
T_3 = 75% RDF + FYM (5 t ha^{-1})	14.8	49.7	75.1	2.6	3.8	4.9	10.8	15.5	22.5
T_4 = 75% RDF + BF (Rhizobium + PSB)	14.8	46.7	73.0	2.4	3.7	4.8	10.5	14.8	21.7
T_5 = 50% RDF + FYM (10 t ha^{-1})	15.3	54.7	83.8	2.7	4.1	5.3	11.9	16.8	24.1
T_6 = 50% RDF + BF (Rhizobium + PSB)	14.2	43.2	68.7	2.2	3.1	4.6	9.5	13.0	19.2
T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB)	16.8	54.9	84.0	2.9	4.2	5.4	12.2	17.4	24.7
SEm (±)	0.87	2.51	2.96	0.17	0.22	0.24	0.55	0.90	1.14
CD (P=0.05)	2.67	7.732	9.119	0.513	0.67	0.75	1.71	2.76	3.50

Influence on yield and yield attributes

The yield characteristics viz., numbers of pod per plant, seeds per pod and 100-grains weight were found to vary significantly among the different treatments as influenced by integrated nutrient management practices. Maximum number of Pods per plant (82.7) were recorded by treatment which received 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) than absolute control and the treatment which received only 75% RDF + BF (Rhizobium + PSB), but it was statistically on per with other treatments. Also application of BF (Rhizobium + PSB) recorded significantly higher number of seeds per pod (2.6) and 100-grain weight (12.5 g) as compare to control treatment (Table 2). Improvement in yield components might have resulted from favorable influence of integrated nutrient management practices on the growth characteristic viz., plant height, branches per plant and root nodule account and efficient and greater partitioning of metabolites and adequate translocation of nutrients to developing reproductive structures. Similar findings were also recorded by Singh and Rai (2004), they reported that the highest pods per plant, seeds per pods and 100-grain weight of soybean were recorded through the combination of recommended dose of NPK + FYM @ 5 t ha^{-1} + bio-fertilizers. The results of the investigation showed that different treatments significantly influenced the grain yield of soybean. Application of 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) recorded maximum grain yield (2687.5 kg ha^{-1}), which was significantly higher than absolute control and T6 = 50% RDF + BF (Rhizobium + PSB), but it was at par with other treatments (Table 2).

Table 2. Effect of integrated nutrient management on yield attribute and yield of soybean

Treatment	Pod per plant	Seed per pod	100-grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1= Absolute control	62.3	2.0	10.6	1545.6	2555.8	37.7
T_2 =100% RDF	80.7	2.5	12.3	2577.9	4042.8	39.0
T_3 = 75% RDF + FYM (5 t ha^{-1})	78.9	2.4	11.6	2530.3	4019.3	38.7
T_4 = 75% RDF + BF (Rhizobium + PSB)	74.7	2.4	11.6	2503.1	3919.1	39.0
T_5 = 50% RDF + FYM (10 t ha^{-1})	81.7	2.5	12.4	2598.6	4077.1	39.0
T_6 = 50% RDF + BF (Rhizobium + PSB)	69.9	2.3	11.6	2311.7	3547.5	39.5
T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB)	82.7	2.6	12.5	2687.5	4424.8	38.0
SEm (±)	3.15	0.12	0.38	97.10	202.63	0.44
CD (P=0.05)	9.72	0.36	1.17	299.20	624.368	ns

Similar finding was recorded by Koushal and Singh (2011) who observed the highest seed yield in the treatment that received 50% recommended N applied through urea + 50% N applied through FYM + PSB and the lowest seed yield in control. Kumpawat (2010) also reported that integrated nutrient management of inorganic chemical fertilizers along with application of FYM and inoculation with biofertilizers (rhizobium and PSB) produced higher yield. Straw yield also showed significant differences due to different treatments. Higher straw yield (4424.8 kg ha^{-1}) was recorded with the T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) as compared to absolute control and treatment that received 75% RDF+ BF (Rhizobium + PSB) (Table 2). Increasing in straw yield in this treatment occurred mainly due to maximum plant height and higher number of branches per plant. Such finding was supported with the work of Koushal and Singh (2011) thy reported that the highest straw yield was recorded in the treatment 50 % recommended N applied through urea+50% N applied through FYM+PSB. Menaria et al. (2003) reported that application of 75% recommended N through RDF+25% N through weed biomass + PSB + Rhizobium increased growth and yield contributing parameters. Harvest index is the ratio of grain yield to biological yield. The result of this study showed that there were non-significant differences among different treatments for harvest index (Table 2). Data are mentioned in table and hence only significant major finding should be highlighted in the text not big paragraphs on individual characters. Characters having similar trends should be combined and mentioned in short.

Economics

Economics of production is very important aspect to a judge the efficiency of different production system based on physical feasibility and its commercial viability, economics determination, cost of cultivation, gross returns, net returns and B: C ratio were considered. The compatibility of different treatments was workout with a view to understanding its feasibility and economic viability in a given system. In the current study significantly higher gross return (196,977 Afn. ha^{-1}) of soybean was recorded with Application of 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) compared to control treatment and the treatment that received 50% RDF + BF (Rhizobium + PSB) and it was on par with the rest of the treatments (Table 3). The higher gross return was mainly due to higher grain and straw yields of soybean in the respective treatments. These results are in close agreement with the findings of Farhad et al. (2017) who reported that the maximum gross return and gross margin were recorded from the treatment T6 which was 50% recommended dose (N-P-K) + 1.2 kg ha^{-1} biofertilizer. The lowest gross return and gross margin were obtained from the control treatment. Net return is actual profit gained under a particular treatment by subtracting the cost of cultivation from the gross return under the same treatment. The maximum net return (145,801 Afn. ha^{-1}), was obtained with 100% RDF, it was followed by the 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB), 75% RDF + BF (Rhizobium + PSB), 75% RDF + FYM (5 t ha^{-1}), 50% RDF + BF (Rhizobium + PSB) and 50% RDF + FYM (10 t ha^{-1}). That they were all significantly higher than absolute control, but they was at par to each other (Table 3). Production of higher net return by application of 100 RDF and other treatments could be attributed to higher grain yield of soybean and reduction in cost of cultivation. Significantly higher B:C ratio (3.41) was recorded with the application of 100 % RDF over absolute control, 75% RDF + FYM (5 t ha^{-1}), 50% RDF + FYM (10 t ha^{-1}) and 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB), but it was at par with the application of 75% RDF + BF (Rhizobium + PSB) and 50% RDF + BF (Rhizobium + PSB). Application of 50% RDF + FYM (10 t ha^{-1}) recorded significantly lower B:C ratio (1.87) over all other treatments (Table 3). Production of lower B:C ratio by application 50% RDF + FYM (10 t ha^{-1}) attributed to higher cost of cultivation, which consequently helped in recording significantly lower B:C ratio.

Table 3. Effect of integrated nutrient management on gross returns, net returns and B:C ratio of soybean

Treatment	Gross return (Afn. ha^{-1})	Net return (Afn. ha^{-1})	B:C ratio
T_1= Absolute control	113,306	83,543	2.81
T_2 =100% RDF	188,539	145,801	3.41
T_3 = 75% RDF + FYM (5 t ha^{-1})	185,162	130,668	2.40
T_4 = 75% RDF + BF (Rhizobium + PSB)	183,055	141,061	3.36
T_5 = 50% RDF + FYM (10 t ha^{-1})	190,058	123,808	1.87
T_6 = 50% RDF + BF (Rhizobium + PSB)	168,912	130,161	3.36
T_7 = 50% RDF + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB)	196,977	143,227	2.66
SEm (±)	7,167.3	7,167.3	0.147
CD (P=0.05)	22,084.5	22,084.5	0.454

*One USD is equal to with 77 Afn.

CONCLUSION

After going through the finding of the present study, it can be concluded that integrated nutrient management of 50% recommended dose of chemical fertilizers + FYM (5 t ha^{-1}) + BF (Rhizobium + PSB) was more effective compared to other treatment combinations in recording higher growth parameters, seed yield and net return of soybean.

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