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Strategies for sustainable and efficient crop production of soybean through integrated nutrient management: A Review

Yuvapratap Reddy[1], Patil S. S.[2], Kumar B.K.[3], Harish V.[4] and Basha S.K.[5]

Department of Agronomy, Lovely Professional University, Phagwara, Punjab

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ABSTRACT

Integrated Nutrient Management (INM) involves the application of a combination of organic and inorganic fertilizers, biological agents, green manures, and other soil amendments to improve soil fertility, nutrient use efficiency, and crop productivity. This presents an overview of the importance of soybean as a source of protein and oil and its significance in sustainable agriculture. It discusses the nutrient requirements of soybean and the factors that affect nutrient availability and uptake. The paper highlights the potential benefits and challenges of using INM for soybean production and presents case studies and numerical examples of the impact of INM on soybean Growth, yield, and nutrient uptake.

Key words: *Growth, Integrated nutrient management, Soybean, Yield.*

Introduction

Glycine max L. Merril, (soybean) is a significant protein and oil seed crop around the world. It's thought to have started in China around 2838 B.C. It is a member of the Papilionaceae subfamily of the Leguminoceae family. Soybean was introduced as new crop in the 1960s as a secondary oil seed crop. It is a significant pulse and oilseed crop used to make various by-products, including soy milk, soy flakes, soy oil, soy biscuits, soy beverages, Tofu and fortified bakery goods. It is a substantial source of protein, unsaturated fatty acids, calcium, phosphorus, and vitamins A, B, and D, providing various nutritional needs (Rahman 1982). Its seed contains about 40–45% protein, 26–26% carbs, and 18–20% edible oil (Gowda and Kaul, 1982). Because of its diverse nutritional properties, the grain legume is known as the soybeans known as the "Golden Bean" or the "miracle crop" of the 20th century (Maruthi *et al.* 2014). soybean is frequently referred to by vegetarians as "poor man's meat" (Singh, 2005). Soybeans are regarded as a way to improve soil because of their capacity to fix atmospheric nitrogen in addition to serving as a source of food for people and animals. It can fix 49–450 kg of atmospheric nitrogen per hectare (Wani *et al.*, 1995).

A wide variety of nutrients have a significant impact on the growth and output of crop plants. both natural and artificial sources to boost production, fertilizers are applied. A balanced supply of nutrients is required since no one source of plant nutrients can match the demand (Shaikh *et al.* 2019). The availability of nutrients also varies depending on the physical, chemical, and microbiological characteristics of the soil, and is frequently tied to the mineralogy of soil. Continuous use of high-analysis chemical fertilizers has been shown to cause environmental pollution, soil salinity, and a lack of secondary and micronutrients. So, it appears that there

is a lot of room for improving the effectiveness of these nutrients through better agronomic practices (Aziz *et al.* 2017). Although having a high potential yield, soybean productivity is substantially lower than that of developed nations, mostly because fertilizers are not applied as effectively as they should be. Nutrition for plants primary factor determining the state of vital nutrient availability in soil is its organic matter content. Crop productivity can be significantly increased by implementing an integrated nutrient management system that makes effective use of organic matter. The usage of FYM is a tool for enhancing the soil's biological, chemical, and physical qualities Farmyard manure, which contains all the necessary nutrients, enhances the humus and organic matter components of the soil. Moreover, FYM is crucial for harboring helpful bacteria, which makes nutrients available to crops. (Bonde and Gawande, 2017)

In order to address these issues, integrated nutrient management (INM) has been suggested as a promising method. INM has the ability to protect the environment and resource quality while simultaneously enhancing plant performance and resource efficiency. It might also contain additional sources of organic manure for sustainable agriculture, such as vermicompost, farmyard manure, and green manure Verma *et al.* (2017). By inoculating soybean with bio-agents like Rhizobium and phosphate-solubilizing microorganisms, the productivity of the plant can be enhanced. With these bio-cultures and co-inoculation, crop productivity has been sustained, and soil fertility has improved (Dubey, 1997). Vermicomposting and FYM are credited with improving the soil's physical, chemical, and biological qualities as well as its ability to utilize nutrients, which increased the availability of several plant nutrients and improved crop development and yields (Sharma *et al.,* 2018)

Effect on growth parameters

Singh *et al.* (2007) revealed that Rhizobium + Azotobacter + PSB + FYM along with RDF application produced the highest plant height and dry weight plant-1, followed by Rhizobium + PSB + FYM combination inoculation, which was comparable to but significantly higher than the other treatments. Singh *et al.* (2009) concluded that conjunctive use of RDF along with a combination with rhizobium and azotobacter improved plant height, root and shoot dry weight, and number of branches significantly over control. Devi *et al.* (2013) combined organic manures with inorganic fertilizers and putting them in the soil enhanced the availability of nutrients significantly, leading to a favorable impact on growth parameters. Singh *et al.* (2013) observed that Growth attributes (plant height, branches plant-1, and dry matter plant-1) of soybean are statistically higher under the integrated nutrient management approach over other treatments (15–13.1–16.6 NPK kg ha-1 + 5 t ha-1 poultry manure). Maruthi *et al.* (2014) concluded that With the combined use of 50% of the NPK (15:40:18.75 kg ha-1) recommended dose + Vermicompost (2 t ha-1) + Brady rhizobium (250 g ha-1) + PSB (250 g ha-1) + 50% of the recommended dose of FYM (5 t ha-1) recorded more branches per plant (3.00) and leaves per plant (34.20) and highest plant height (62.90cm) at harvest as opposed to the application of the recommended dose of NPK (30:80:37.5 kg ha-1) alone. Raghuwanshi *et al.* (2018) RDN combined with cow dung manure@ 5 t ha-1 FYM considerably increased plant height (40.37 cm) and dry matter (20.26 g-1plant) accumulation in comparison to RDN. Sharma *et al.* (2018) reported that INM treatments exerted a significant impact upon this growth parameter at every stage of plant growth with treatment (Vermicompost 1.5 t ha-1 Enriched with PSB and Rhizobium + RDF performed the best up to the harvest stage. The plants were found tallest i.e. 59.4 cm at 60 DAS, 63.5 cm at 90 DAS, and 63.4 cm at the harvest stage. Bathula *et al.* (2019) observed that the highest haulm yield resulted from the combined use of recommended fertilizers along with FYM (2852 kg ha-1) 100%RDF + FYM @ 5 t ha-1. Chaudhari *et al.* (2019) observed significant results were obtained from the combined use of inorganic fertilizers, FYM @ 10 t ha-1, inoculation with Rhizobium, and PSB greater outcomes compared to other treatments With respect to the number of nodules per plant, there was a substantial interaction impact between inorganic fertilizers, organic manures, and biofertilizers. Shaikh *et al.* (2019) Concluded that the use of 100% RDF + FYM @ 2.5 t ha-1+ vermicompost @1.25 t ha-1 shows a significant increase in plant height, plant spread, and dry matter production over control.

Effect on nodulation

Due to the beneficial effect of FYM on the physical, chemical, and biological qualities of the soil, and favours nodulation and atmospheric nitrogen fixation Sharma *et al.* (2002). Agronomists and ecologists

are interested in Azospirillum because of its capacity to fix N2 in soil. Interaction with the soybean bacterium Rhizobium japonicum (Melnikova *et al.*, 2002). 75% RDF+ FYM 5t ha^{-1} produced significantly more nodules, both in terms of number and bulk, than any other nutrient. Gosh *et al.* (2004) and Aziz *et al.* (2017) reported that conjunctive application of FYM 10 t ha^{-1}, inoculation with PSB and Rhizobium, and integrated application of inorganic fertilizers greatly enhanced nodules plant^{-1}. Alam *et al.* (2009) observed that the highest quality soybean with the highest nodulation was generated by using integrated nutrient management of biofertilizer with 50% of the recommended dose of chemical fertilizers (NPKS).

Effect on nutrient and soil organic carbon accumulation

Bhattacharyya *et al.* (2007) reported that the conjunctive use of nitrogen in both organic and inorganic forms results in the Greatest accumulation of SOC (with NPK + FYM treatment). Singh *et al.* (2007) Rhizobium + Azotobacter + PSB + FYM inoculation resulted in the greatest levels of organic C (1.08%) and available K (222.3 kg ha^{-1}). Kundu *et al.* (2007) observed that When compared to the unfertilized control or using only inorganic fertilizers, soil bulk density (BD) was lower with FYM. The unfertilized plant has the highest Bulk density Lowest BD (1.24 Mg m^3) was under NPK + FYM treatment at 0-15 cm depth and treatment at 30-45 cm deep (1.33 Mg m^3). Possible effects of FYM application on soil aggregation and BD reduction. Singh *et al.* (2007) The greatest net gains in N (177.9 kg/ha), P (18.3 kg/ha), and K (69.7 kg/ha) were seen when Rhizobium + Azotobacter + PSB + FYM was inoculated combinedly showing significant results over the control, produced the lowest gains in N (86.4 kg/ha) and K (41.7 kg/ha), respectively. Srinivasa Rao *et al.* (2012) observed that by itself or in conjunction with inorganic fertilizers, the use of FYM considerably boosted the SOC stock. Singh *et al.* (2013) studied that the combined use of organic and inorganic fertilizers showed improved results in the uptake of N and P by seed and stover (15–13.1–16.6 NPK kg ha^{-1} +5 t poultry manure). Devi *et al.* (2013) recorded that the various combinations of organic and inorganic fertilizers had a substantial impact on the number of nodules per plant and its dry weight. The Number of nodules per plant ranges from 11.67 to 43.00 for the plant. The combination of 75% RDF with vermicompost at a rate of 1 t ha^{-1} and PSB produced the most nodules per plant (43.00), which was significantly more than the other treatments. Aziz *et al.* (2015) revealed that the Treatment of chemical fertilizers, FYM together with and without inoculation had the lowest bulk density of all the treatment combinations and concluded that integrated use of organic along with inorganic sources improves soil characteristics and preserves soil health while using less input costs than when using chemicals alone. Satpute *et al.* (2018) observed that 50 % N through Glyricidia (green leaf manure) + 50% N from inorganic sources + biofertilizer + 25 kg K ha^{-1} reported (191.41 g kg^{-1} soil) improvement that is statistically significant compared to all other treatments in soil microbial biomass carbon this is due to the use of organic manure, which led to increased levels of readily mineralizable and hydrolyzable carbon greater microbial biomass carbon as a result of increased microbial activity. Prajapati *et al.* (2018) observed that the combination of nutrient supplies with 50% RDN-FYM sequestered more carbon in the soil profile and maintained positive values of carbon among the available nutrient supply choices flux in the soil compared to 100% RDF and the control. Shaikh *et al*. (2019) concluded that the use of 100% RDF + FYM @ 2.5 t ha^{-1} + vermicompost @1.25 t ha^{-1} shows a significant increase in available nitrogen (195.62 kg ha^{-1}) and phosphorus (22.01 kg ha^{-1}) and potassium (439.41 kg ha^{-1}) over using only recommended dose of fertilizers). Mali *et al.* (2020) concluded that the integrated use of chemical fertilizers along with organic sources increased the soil's organic carbon content and nutrient status (available N, P, K, DTPA-Zn, Fe, Mn, and Cu). Chaudhari *et al.* (2020) reported that Following the harvest of the soybean crop, a considerable increase in the microbial population in the soil was seen with the application of FYM and the recommended amount of fertilizers. The bacteria population's noticeably highest value (23.84) was found in 100% NPKS + Biofertilizer + FYM. Significantly highest values of fungi population (4.18) were noted in 100% NPKS + Biofertilizer + FYM, and Significantly highest values of actinomycetes population (11.11 CFU 10-5) were noted in RDF + 100% NPKS + Biofertilizer + FYM. This treatment provided enough organic matter to act as a substrate and source of food for bacteria.

Effect on yield attributes

Prasad *et al.* (1998) studied that at Nagpur,

(Maharashtra) a field experiment was done during *Kharif*, and it was found that the use of FYM @ 15 t ha-1 + PSB inoculation resulted in a higher soybean seed production. Jain and Trivedi (2005) In terms of growth, yield characteristics, seed yield, and stover, Bradyrhizobium + PSB + 26.20 kg P ha-1 proved to be the most effective. Arora (2009) reported that treatment N50+ Rhizobium showed the greatest average yield increase above control comparing yield, protein content, economic return, and B: C ratio for all the treatments being evaluated. Bathula *et al.* (2019) observed that the highest grain yield was obtained with the application of 100% RDF + FYM @ 5 t ha-1 (T5) (2194kg ha-1). Maruthi *et al.* (2014) concluded that combinations of treatments 50% of the recommended dose of NPK (15:40:18.75 kg ha-1) + 50% of the recommended dose of FYM (5 t ha-1) + Vermicompost (2 t ha-1) + Brady Rhizobium (250g ha-1) + PSB (250 g ha-1) was superior over other treatments in case of seed yield, and yield attributes. Shaikh *et al*. (2019) concluded that at harvest, 100% RDF + FYM at 2.5 t ha-1 and vermicompost at 1.25 t ha-1 recorded the highest mean number of pods per plant (55.23) over RDF Treatment. Shaikh *et al*. (2019) Concluded that a combination of organic and inorganic fertilizers 100% RDF+FYM@2.5 t ha-1+vermicompost@1.25 t ha-1 recorded showed higher seed weight plant-1 (18.65 g) than the remaining treatments. Surve *et al.* (2019) demonstrated that the combined use of organic and inorganic fertilizers significantly increased the yields of soybean over control. When using FYM instead of other organic sources, in case of 50% N substitution resulted in a significantly increased in terms of system productivity (5458 kg ha-1) in of soybean grain. Bonde and Gawande (2017). Greater values of pods per plant (54.1), pod weight per plant (21.7 g), seed yield per plant (14.49 g), and weigh 100 seeds weight (13.13g) were also noted when 75% NP + 4t FYM + 25kg S ha-1 was used in comparison to other treatments due to the continuous and adequate availability of nutrients with the usage of recommended NP along with FYM. Farhad *et al.* (2017) reported that the combined use of 50% recommended dose of fertilizers along with (NPK) Brady Rhizobium (bio-fertilizer) significantly increased seed yield and economic returns of soybean. Kolpe and Bodake (2017) combined use of organic and inorganic sources application of 75 % N through fertilizer + 25 % N through vermicompost with the application of potassium 45 Kg ha-1 showed improved quality and yield (3405 Kg ha-1) of soybean over other treatments. Sharma *et al.* (2018) reported that (Vermicompost 1.5 t ha-1 Enriched with PSB and Rhizobium + RDF) INM treatment significantly increased the factors that are directly important for ultimate grain production, namely the number of pods plants-1, number of grains pod-1, and test weight. Chaudhari *et al.* (2020) reported that the application of 100% NPKS + Biofertilizer + FYM (1815 kg ha-1) due to the collective use of organic and inorganic fertilizers showed a significant increase in yields over control).

Effect on quality parameters

Aziz *et al.* (2011) lysine concentration was highest (61.27 mg/100 g of protein), compared to no inoculation (57.13 mg/100 g of protein) per 100 grams of protein). In comparison to other treatment combinations, FYM @ 10 t ha-1, inoculation with Rhizobium, and PSB were found to be superior when applied at all recommended levels with inorganic fertilizers. Aziz *et al.* (2015) oil content from Rhizobium and PSB inoculation (18.26%) was much better than those from no inoculation (15.89%). Verma *et al.* (2017) maximum oil yield (467.4, 483.2, and 476.2 kg ha-1) and oil content (20.1, 20.2, and 20.1%) were reported with the 75% NPK application plus 25% N from vermicompost, Rhizobium, and PSB. Aziz *et al.* (2017) concluded that the application of organic manure had a considerable impact on grain protein content. The most content was found under FYM (10 t ha-1), then Dalweed (10 t ha-1) rather than no manure (which resulted in less protein content). Pujar *et al.* (2018) observed that Because of INM treatments, the prevalence of *Spodoptera litura* (mrl-1) in soybean varied greatly in (T1 + Gliricidia 2.5 t ha-1 + Pongamia 2.5 t ha-1), (T1 + Vermicompost 1.25 t ha-1 + Gliricidia 2.5 t ha-1), and (T1 + Vermicompost 1.25 t ha-1 + Pongamia 2.5 t ha-1), reduced incidences of Spodoptera larvae were seen. Pujar *et al.* (2018) reported that due to INM treatments, there were substantial differences in the pod borer incidence in soybean and lower pod borers were observed in treatment with (T1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}). Raghuwanshi *et al.* (2018) noted that integrated application of FYM @ 5 t ha^{-1} and RDN significantly increased oil (19.74 %) and protein (36.57 %) content over RDF alone Pod borer incidence in soybean.

Effect on economics

Singh *et al.* (2007) observed that RDF and co-inoculation of Rhizobium + Azotobacter + PSB + FYM were shown to be effective for increasing soybean productivity and they had the highest Benefit: Cost ratio (2.09). Awarsamal *et al.* (2013) revealed that the use of 100% RDF + Rhizobium + PSB + sulphur at 25 kg ha-1 + FYM at 5 t ha-1 (T4) produced higher net financial returns (43293 Rs. ha-1) and which was superior to the other treatments. Kolpe and Bodake (2017) observed that the integrated use of organic and inorganic sources of fertilizers has improved results on the quality and yield of soybean and was found to be profitable over the sole use of RDF. Raghuwanshi *et al.* (2018) observed that economic analysis showed that the integration of graded levels of cow yields boosted net returns gradually in comparison to RDN (16478 ha-1) dung manure combined with RDN gradually increased returns (Rs. 17816-21827 ha-1). Shaikh *et al*. (2019) reported that the application of 100% RDF + FYM at 2.5 t ha-1 and vermicompost at 1.25 t ha-1 produced significantly higher gross monetary returns of Rs. 68358 ha-1 over the recommended dose of fertilizers. Singh and Kushwaha (2020) concluded that Gross return (Rs. 50067 and Rs. 53480 ha-1) and net return (Rs. 40432 and Rs. 42241 ha-1) and B: C ratio (5.20 and 4.76), compared to all other treatments, were substantially increased under treatment (100% NPK+FYM @ 5 t ha-1) which is the integration of organic and inorganic fertilizers.

Conclusion

Integrated nutrient management (INM)is a promising approach to crop production that seeks to optimize plant nutrition by using a combination of organic and inorganic sources of nutrients. While it has many potential benefits, it is not without limitations. Further research is needed to better understand the effectiveness of INM under different cropping systems and soil types. However, given the growing interest in sustainable agriculture and the need to reduce the negative environmental impacts of conventional agricultural practices, INM is likely to play an increasingly important role in the future of agriculture.

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