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Integrated nutrient management and its effect on mungbean (*Vigna radiata* L. Wilczek): A revisit

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Abstract

In developing countries like India where the population is expected to reach 9 billion by the end of 2050, poverty abolition, zero hunger, and food security of the nation are becoming serious considerations. As mungbean (*Vigna radiata* L. Wilczek) is widely popular, crop management approaches are formulated with their major goal of achieving higher yield, overlooking the after-effects as well as the quality of the produce. Plateau in the yields of many major crops irrespective of input, led to the popularization of combinations i.e., integrated nutrient management (INM). Substituting a smaller portion of chemical fertilizers with organic fertilizers in respective balanced doses could result in higher crop productivity. Many researchers reported the triumph of integrated nutrient management for long-term usage of land with higher crop productivity as well as quality. Incorporation of microbes in integrated nutrient management with the chemical and organic doses of the crops results in the availability of organic carbon and nitrogen for the energy of microorganisms, whereas better soil chemical and physical properties, with their significant effects on the succeeding crops. Efforts should be drawn in a way to quantify the optimum concentrations of organic, inorganic, and microbial formulations as per crop requirements for nutrients at different stages, minimizing the nutrient losses to the surrounding environment, maximized productivity with quality produce.

Keywords: Mungbean, Integrated nutrient management, crop productivity, organic, chemical fertilizers

1. Introduction

The consumption of a protein deficit diet among the growing population is a serious threat in developing countries like India. The protein deficiency leads to several disorders such as malnutrition, kwashiorkor that are frequently observed in present days within the populations particularly among children and women. In addition, continuously decreasing soil fertility around the globe raises serious concerns about sustainable food production. According to nutritionists, pulses are an exceptional source of dietary proteins and thus, can play an important role in satisfying the needs of an exponentially increasing population.

Mungbean (*Vigna radiata* L. Wilczek) is one of the widely cultivated, protein-rich crops belonging to the leguminous family. Mungbean is a rich source of protein (21-24 g), carbohydrates (56.72 g), fiber (4.11 g), fat (1.31 g), minerals (3.48 g) such as calcium (124 mg), phosphorous (326 mg), iron (4.42 mg) and supplies a good amount of energy (334 kcal) (Gopalan *et al*., 2002; Dhakal *et al*., 2015) [15, 12]. The crop is massively adopted by farmers due to its short duration nature which makes it suitable for intensive crop rotation. Despite nutritional benefits, it helps in reducing soil erosion; enhance soil fertility status through atmospheric nitrogen fixation (Bansal, 2009) [5]. Thus, it considerably helps in improving the yield of subsequently grown crops (Jat *et al*., 2012) [20]. The green portions of the plant are also used as fodder due to their easy digestibility, palatability, and taste (Kumawat *et al*., 2009a) [27].

Mungbean is cultivated on large scale in South Asian nations such as India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Taiwan South China, and Malaysia. In India, during last year (2019-20) crop was cultivated over an area of 4580.54 million hectares with a production of 2508.87 million tonnes and productivity 547.72 kg/ha (Anonymous, 2019-20). However, the productivity of crops in the USA and Canada (1900Kg/hectare) is far ahead of the country's productivity (GOI, 2015). The crop is ranked third among the pulse crop in terms of production and opted in all three seasons i.e., *kharif*, *rabi*, and *zaid* by farmers. The leading states in mungbean production are Rajasthan (more than 50% production) followed by Madhya Pradesh, Karnataka, Bihar, Gujarat, and Maharashtra.

Micronutrients are highly essential for the proper growth and development of any crop. Both quantitative (seed yield), and qualitative (nutritional quality) characters are highly influenced by soil's micronutrient status (Babaeian *et al*., 2011, Meena *et al*., 2013) [3, 32]. In India, most legume crops including mungbean are cultivated in less fertile, poor, and marginal soils, in addition, low supply of organic and inorganic further contributed to poor yield (Kumawat *et al*., 2010) [25]. Besides this, the cultivation of the crops on problematic soils such as acidic and alkaline soils is estimated to affect more than 50% of the world's yield potential. The excess and improper use of inorganic fertilizers without knowledge of integrated nutrient management further aggravates the lower production and also drastically affects the healthy soil environment (Bradl, 2004) [10].

In recent years, different approaches have been practiced to sustain agriculture production and among them, integrated use of available nutrient resources is the most promising approach. The balanced use of nutrients along with efficient crop, water, soil, and land management will be crucial for agriculture in the coming days. By keeping in view the changing climate scenario, an integrated approach of nutrient application along with biofertilizers and manures not only ensures improved soil health but also sustains crop productivity (Babulkar, 2000) [4]. However, reports on integrated nutrient management (INM) are lacking in many crops including mungbean. Therefore, through this review chapter, an attempt has been made to present an overview of works carried out to study the effect of integrated nutrient management practices on the growth and yield of mungbean.

2. The theory of INM

Firstly, The INM refers to a broach approach where the benefits from all the conventional (organic, inorganic, and biological originated components) along with modern methods of nutrient management are collectively directed to supports the optimal farming system in a highly integrated, effective, and judicious manner (Janssen, 1993) [18]. The INM enhance the utilization of all features of nutrient cycling (macro and micronutrients) and aims to synchronize nutrient requirement of the growing crop. INM ensures nutrient utilization in a highly efficient manner by minimizing the nutrient losses through leaching, volatilization, surface runoff, immobilization, and emission (Zhang *et al*., 2012) [50]. Furthermore, INM is targeted to minimize land deterioration and improved yield potential by optimizing the soil factors (physical, chemical, and biological) effectively (Janssen, 1993; Esilaba *et al*., 2004) [18, 13]. In a broad sense, INM includes the use of crop residues, natural and inorganic fertilizers, farmyard manure, biological agents, soil amendments, green manures, crop rotations, cover crops, intercropping, conservation tillage, irrigation, and drainage to conserve available water and enhance nutrient availability to crops (Janssen, 1993) [18]. So, the adaptation of these kinds of practices is helping farmers to aim for long-term planning, in place of only focusing on large yield benefits.

3. Components of INM

Integrated nutrient management (INM) implies the utilization of manures, chemical fertilizers, and biological agents to attain sustainable crop production and better soil fertility. Various components (organic and inorganic) are considered as major components of integrated nutrient management and all these components ultimately aims to restore soil fertility and enhance crop production. The components such as (i) use of organic manures of different nature *viz*., vermicompost, compost, FYM, poultry manure, slurry, Phospho-compost, Press mud cakes, biogas, Biological composts, (ii) balanced application of fertilizers according to the crop requirement and targeted yields (iii) use of biological agents (iv) inclusion of green manure and legume crops to restore the soil fertility (v) crop residues recycling (vi) use of highly efficient genotypes.

4. Effect of INM on morpho-physiological characters of Mungbean

Several pieces of literature highlighted the promotive role of different INM components on growth and developmental parameters. The findings of various researchers who have been worked previously on mungbean suggested that the supply of nutrients (macro and micro) through various components significantly enhances the growth and developmental traits. In this regard, Soodi *et al*. (1994) [44] found that the application of 25 kg N/ha alone and/or with 50 kg P_2O_5/ha increases the number of nodules and dry weight of nodules per plant. Similarly, Mathur *et al*. (2007) [31] also suggested that the treatment with N and P alone or in combination significantly enhanced plant height and the number of branches per plant. The reports of Sharma *et al*. (2003) revealed that the physiological parameters *viz*., crop growth rate, relative growth rate, photosynthetic efficiency were enhanced with the increasing supplies of N and P.

The combined application of organic, inorganic fertilizers with biofertilizers was found synergistic and has an additive effect in enhancing the growth parameters of mungbean (Prajapati *et al*., 2016; Singh *et al*., 2017) [37, 43]. The application of vermicompost at 2.5 t/ha along with Recommended fertilizers dosage (RDF) increased the growth parameters *viz*., plant height, dry matter, and root weight (Rajkhowa *et al*., 2002) [38]. Tarafder *et al*. (2020) [46] found that plant height, branches/plant was highest when treated with 3 t ha^{-1} poultry manure (PM) and 70% soil test-based (STB) inorganic fertilizers. In a similar direction, reports of Singh *et al*. (2017) [43] indicated that the application of RDF and VC at 5.0 t/ha rate increases plant height, number of branches/plant, plant dry weight, number of nodules, and dry weight of nodule when compare to RDF application alone. The identical result was also presented by Prajapati *et al*. (2016) [37]. They suggested that application of 100% RDF with Vermicompost (1.0 t/ha) with Rhizobium improves the morphological traits such as plant height, the number of primary branches/plant, total dry matter accumulation, and maximum leaf area index. The finding from Dhakal *et al*. (2015) [12] suggested that the treatment with 75% RDF with vermicompost (VC) and bio-fertilizers (Rhizobium and phosphorus solubilizing bacteria) caused a significant increase in leaf area index, number of trifoliate, SPAD value of chlorophyll, and enhance the dry matter accumulation. Verma *et al*. (2017) [48] indicated that the application of Rhizobium, phosphorus solubilizing bacteria (PSB), and 20 kg N/ha together gave a significantly higher number of nodules and dry weight of nodules/plant. Furthermore, the findings of Choudhary *et al*. (2011) [11] and Tiwari *et al*. (2011) [41] are also leads to identical conclusions.

The application of biofertilizers (organic manure) with inorganic fertilizers and micronutrients has increased the availability of nutrients over a long period. The collective application of organic and inorganic fertilizers ensures a balanced supply of nutrients to the growing crop and exerts a positive effect on the growth of the plant (Afzal and Bano, 2008) [1]. Alongside, the addition of Mo attributed to better availability and absorption of nutrients; whereas Co application improved the nodulation and maximizes the population of Rhizobia in the rhizosphere (Jena *et al*., 1994) [21].

Not only the soil application but seed inoculations with biofertilizers (Rhizobium and PSB) with micronutrient (Mo and Co) along with maintenance of fertility levels were also proven to be promotive in enhancing the growth and development of mungbean. Singh and Pareek (2003) [42] reported that the seed inoculation with PSB and Rhizobium resulted insuperior plant height, number of branches per plant, total plant dry matter, number of nodules, and dry weight of nodules per plant in mungbean compared to untreated seeds. In addition, the finding of Kumar *et al*. (2003) [24] revealed that vermicompost at the rate of 5 t/ha along with RDF maximizes the plant height and dry matter accumulation.

The combined application of N, P, and biofertilizers played a crucial role in plant processes such as starch cell division, increased sugar utilization, and rate of photosynthesis. Furthermore, at root levels, the growth of the root system is enhanced; thus, a larger root surface area allows severe rhizobium infection and proliferation. Increased colonies of rhizobium with the root leads to the formation of a higher number of nodules that further contribute to increased N fixation and plant growth (Kumawat *et al*., 2009b; Singh *et al*., 2013; Verma *et al*., 2017) [28, 48].

5. Effect of INM on yield attributes and yield of mungbean

Seed yield is a complex trait which determined by several yield components. The genetic make of particular variety/genotype, adopted field agronomic strategies, soil conditions, and growing environment all together have significant effect on final seed yield. The various findings on mungbean suggested that the management of nutrients in an integrated manner improved both yields attributing traits and the final yield of mungbean. In this regard, study carried out by Sheoran *et al*. (2008) [40] under rainfed conditions indicated that the supply of 12.5 kg N and 40 kg P_2O_5/ha to mungbean leads to an increase in seed yield by 4.3 percent over no fertilizer application. Similar to this, Kumar *et al*. (2003) [24] reported that treatment with vermicompost at the rate of 5 t/ha gave almost 16-17% higher seed yield in mungbean when compared to control. In another study, Malik *et al*. (2003) [30] tested different levels of N (0, 25, and 50 kg/ha) and phosphorus (0, 50, 75, and 100 kg/ha) and concluded that the combined application of 25 kg N and 75 kg P_2O_5/ha results in the higher seed yield. The experiment conducted by Sharma *et al*. (2003) revealed that the increasing rates of N and P up to 20 and 60 kg/ha respectively, increased the seed yield in mungbean. Nadeem *et al*. (2004) opined that the application of 30 kg N/ha with the combination of 60 kg P_2O_5/ha significantly recorded higher seed yield. Mathur *et al*. (2007) [31] tested two fertility combinations (10+20 and 20+40 kg N + P_2O_5/ha) and found that with the increasing fertility levels from 10 kg N + 20 P_2O_5 to 20 kg N + 40 kg P_2O_5/ha, the yield contributing traits such as pods per plant, number of seeds per pod, 100-seed weight, and biomass per plant improved by around 25.6%, 21.3%, 7.3%, and 15.5% respectively. Furthermore, Sheoran *et al*. (2008) [40] experimented with rainfed conditions and revealed that the mungbean seed yield increased by almost 4.3% when supplied with 12.5 kg N + 40 kg P_2O_5/ha compared to control.

The combined effect of N and P in enhancing the yield and yield attributing traits could be due to increased solubilization of mineral nutrients including phosphate (Tanwar, 1997; Kumar *et al*., 2010; Kumar and Kumawat, 2014; Verma *et al*., 2017) [26, 48, 45]. Furthermore, the application of these nutrients improved the number of nodules which provide a suitable nutritional environment that result in higher seed yield. Besides this, the application of phosphorus provokes the many physiological processes that attributed to improved growth and final seed yield. These hypotheses are well supported and in agreement with reports of Moolani *et al*. (2006) [34], Kumawat *et al*. (2009a) [27], Panwar *et al*. (2012) [36], and Bhanwariya *et al*. (2013) [6].

Seed inoculation with biofertilizers and micronutrients are also equally effective as soil application and is known to improve the seed yield in mungbean. In this direction, Singh *et al*. (2017) [43] inoculated mungbean seeds with RDF and VC (5 t/ha) and recorded significant improvements not only in yield attributing traits such as number of pods/plant, pod length, number of grains/pod and but also in final seed yield. Similarly, Singh and Pareek (2003) [42] suggested that seed inoculation with PSB + Rhizobium resulted in a higher number of pods per plant, pod length, test weight, and the number of seeds per pod in mungbean. In another study carried out by Mian *et al*. (2005) [33], it was observed that the increased number of seeds, stover, and biological yield can be obtained when seeds are inoculated with biofertilizers.

The combination of organic and inorganic nutrition provides ideal soil conditions for root growth, nodule formation, nitrogen fixation, increased solubilization of native P, availability, and absorption of nutrients from the soil that collectively attributed to higher seed yields in mungbean (Singh *et al*., 2017) [43]. Tarafder *et al*. (2020) [46] reported that yield contributing traits such as pods/plant, number of seeds/pod, 100-seed weight, final seed yield of mungbean were improved upon application of 3 t ha^{-1} poultry manure (PM) and 70% soil test based (STB) inorganic fertilizers. More conclusive shreds of evidence came from a study conducted by Dhakal *et al*. (2015) [12]. They were applied 75% RDF + 2.5 t/ha VC + biofertilizers (Rhizobium + PSB at the rate of 12.34 q /ha) and reported an improved seed, straw, biological yield, and harvest index. Further, Verma *et al*. (2017) [48] in his study showed that yield attributes such as number of pods/plant, pod length, number of seeds/pod, seed yield/plant, and test weight could be possible to obtain with the application of Rhizobium + PSB + 60 kg P_2O_5/ha. In another study carried out by Prajapati *et al*. (2016) [37] it was observed that the application of 100% RDF + Vermicompost at the rate of 1.0 t/ha + Rhizobium enhances the number of pods/plant, the number of seeds/pod, 1000-seed weight, and final seed yield.

The combined application of NPK along with VC and biofertilizers improved the nutrient absorption from the deeper layer of soils that ultimately contributed towards an increased rate of photosynthesis, translocation, and accumulation of photosynthate in the economic sinks. These enhanced physiological activities finally result in increased grain, straw, and biological yields (Dhakal *et al*., 2015) [12]. Besides this, the synergistic effect of Rhizobium and PSB also contributed to increased growth, yield attributes which might be due to increased nitrogenous activity, in turn, supplied more nitrogen by fixation and more access to available phosphorus of soil (Dhakal *et al*., 2015) [12]. On the other hand, micronutrients also played a crucial role in enhancing the final seed yield of mungbean. For example, molybdenum is an important constituent of the nitrogenase enzyme; hence, the additional supply of Mo results in increased activity of nitrogenase enzyme that subsequently enhances N fixation through bacteria. Higher N fixation is directly correlated with better plant growth and improved seed yield at final growth stages (Biswas *et al*., 2009; Biyan *et al*., 2014) [8, 9]. Similarly, cobalt has been attributed to the enhanced developmental processes likeelongation of stem and coleoptiles, hypocotyls hook opening, leaf expansion, and development of buds (Ibrahim *et al*., 1989) [16]. Some other reports explained that inoculation with dual (Rhizobium + PSB) biofertilizers leads to higher production of growth hormones such as auxins, gibberellins, and cytokinin which is attributed to improve plant growth and stimulate microbial development (Verma *et al*., 2017) [48].

6. Effect of INM on nutrient content, uptake and quality of mungbean

The nutritional aspects like protein content increased uptake of nutrients can also be improved with the optimal management of nutrients. In this regard, the findings of Singh *et al*. (2017) [43] revealed that different fertility levels along with biofertilizers positively influence the protein content, protein yield, and uptake of nutrients. The application of RDF, along with VC (5 t/ha) gave the highest protein content (25.2%) and protein yield (107.6 kg/ha). In addition, Malik *et al*., (2003) [30] studied the different dosages of nitrogen (0, 25, and 50 kg/ha) and phosphorus (0, 50, 75, and 100 kg/ha) and found that the highest protein content (25.6%) was obtained when crop supplied with 50 kg N + 75 kg P_2O_5/ha.

The N, P and K uptake by mungbean was also significantly higher when supplied with micronutrients such as Mo, and Co. The study carried out by Rajkhowa *et al*. (2003) [38] on mungbean suggested that the application of vermicompost at 2.5 t/ha + 100% RDF has significantly improved the organic carbon, available N, P, and K status of the soil. The application of micronutrients such as Mo and Co were also found promotive in increasing the protein content and protein yield (Khan *et al*., 2002; Jain *et al*., 2007; Singh *et al*., 2017) [43, 22, 17]. Alongside, Tarafder *et al*. (2020) [46] found that the soil total N, available P, exchangeable K, Ca, Mg, and available S, Zn, Fe, Cu, and B were increased with the increased levels of organic manures. The highest values of these parameters were obtained with the application of 3 t ha^{-1} poultry manure + 70% soil test base (STB) inorganic fertilizer, and 3 t ha^{-1} vermicompost + 70% STB. Singh and Pareek (2003) [42] inoculated mungbean seeds and reported that application with PSB and Rhizobium not only increased the N and P content in seed but also enhance the protein content in comparison to sole inoculation.

The enhanced uptake of nutrients could be due to the application of Rhizobium (Bhattacharyya and Pal, 2001) [7]; whereas phosphor-bacteria (Bacillus) attributed to higher P-solubilization in the presence of organic matter and contributed to enhanced P uptake. The improved P uptake through organic fertilizers allows higher cation exchange capacity via acidification that further imparts in holding the cations such as K+ cations and its availability to crops (Kumar *et al*., 2009 and Jat *et al*., 2011) [27, 19]. Besides this, the addition of different organic manures imparts in decreasing the soil acidity Organic residues (either plant or animal-based) especially poultry manure and vermicompost when applied to soil release organic anions which in turn neutralizes the hydrogen ion of acid soil (Wang *et al*., 2013; Tarafder *et al*., 2020) [46, 49].

7. Conclusion

The adaptation of the INM approach encourages the utilization of all possible nutrient sources to meet the soil demand and crop requirements. A balanced application of nutrients (macro and micro) not only increases crop productivity but also considerably reduces nitrogen losses and greenhouse gas emissions. The precise implication of agricultural inputs and judicious application of minerals with high resource-use efficiency ensures a healthy soil-plant-microbes-environmental ecosystem. Based on the findings reviewed in this article, it was observed that different treatments with either organic or inorganic fertilizers significantly influenced the morpho-physiological traits, quality traits, nutrient uptake, yield contributing traits, and final seed yield in mungbean to a greater extent. Alongside, it can also be noticed that bioinorganic combinations have also played a crucial role in improving the growth, quality, and yield traits in mungbean even better in many cases than sole supply all the nutrients. Therefore, integrated use of organic, inorganic, and biological sources of nutrients together is suggested to ensure not only superior yields in mungbean but also improved the soil health and ecology.

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