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Nutrient management in soybean: A review

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Abstract
Soybean (*Glycine max*) contains 40-42% protein and 20-22% oil and it is one of the major rainy season cash crop and its cultivation is fast spreading in India. Still the productivity of the crop is very low in India (1079 kg ha^{-1}). Nutrition imbalance is one of the important constraints for low productivity soybean in India. Proper nutrient management is one of the ways to enhance the soybean productivity. Nutrient management plans document available nutrient sources, production practices, and other management practices that influence nutrient availability, crop productivity and environmental stewardship. Integration of organic manures, inorganic fertilizers and biological sources and their efficient management has shown promise in not only sustaining the productivity and soil health but also in meeting part of crops nutrients requirement.

Keywords: Nutrient, Soybean, *Glycine max* L. Merrill

Introduction
The soybean (*Glycine max* L. Merrill) is a species of legume native to East Asia, widely grown for its edible bean which has numerous uses. Fat-free (defatted) soybean meal is a significant and cheap source of protein for animal feeds and many prepackaged meals. It is outstanding in its nutritive value with enhanced protein (40-42 %) and oil (20 %) content and is also rich in vitamins, minerals, salts and other essential amino acids. In addition to this, soybean protein has five per cent lysine, which is deficient in most of the cereals and enriching the cereal flour with the nutritive quality. Soybean is an important leguminous crop and able to leave residual N effect for succeeding crop equivalent to 35-40 kg N ha^{-1} (Apeji, 1988) [3]. The crop produces enormous amount of biomass thereby enhances the soil organic matter status in soil. It can be grown as a good intercrop or mixed crop with maize, sorghum, pigeon pea and cotton because of its short duration nature. It provides a good protective cover to intercept rain and wind, therefore, minimizes soil erosion. Soybean plant is used as fodder and cake as an excellent concentrate for livestock. Several factors that effect the productivity of soybean. Among several factors responsible for lower productivity improper nutrient management is one of the major factor. Hence, review has been selected for proper nutrient management is required to increase the productivity of soybean.

Macro Nutrients Management in Soybean
Effect on Growth parameters of soybean
Nitrogen
Yadravi and Angadi (2015) [53] visualized that application of nitrogen 60 kg ha^{-1} recorded significantly higher soybean plant height (50.6 cm), number of branches $plant^{-1}$ (6.8), total dry matter production $plant^{-1}$ (34.4 g), leaf area $plant^{-1}$ (10.9 dm^2) and leaf area index $plant^{-1}$ (3.6) compared to other treatments.
Mandic *et al.* (2015) [27] conducted an experiment on two soybean genotypes and concluded that application of 46 kg urea ha^{-1} along with ferticare I (5 kg ha^{-1}) recorded significantly higher plant height (140 and 107 cm, respectively) and higher nodes $plant^{-1}$ (16 and 13, respectively) in the two genotypes (JS-95-60 and JS-97-52).
Shafii *et al.* (2011) [40] opined that application of 60 kg N ha^{-1} recorded significantly higher dry matter (2014 g m^{-2}) compared to other treatments. However, varying nitrogen levels didn't affect the soybean plant height significantly.
Koushal *et al.* (2011) [22] conducted an experiment at Amritsar, observed that application of 50 % recommended N applied through urea + 50 % N applied through FYM + *PSB* recorded maximum plant height of 16.89 cm, 65.78 cm and 73.37 cm at 30, 60 and 90 DAS, respectively and number of trifoliate leaves 6.93, 26.70 and 21.20 at 30, 60 and 90 DAS, respectively, over the other treatments in soybean.

Phosphorus

Geeta and Radder (2015) [15] observed that application of 80 kg P_2O_5 along with cured FYM + *PSB* + VAM recorded significantly higher plant height (66.27 cm), number of branches palnt^{-1} (6.67) and total dry matter production (27.49 g) compared to other treatments in soybean.

Mahmoodi *et al.* (2013) [26] reported that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height (78.66 cm) over the control, 30 and 60 P_2O_5 kg ha^{-1} in soybean.

Bhattacharjee *et al.* (2013) [8] opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher plant height (75.3 cm) and number of leaves (27.4) compared to 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Rana *et al.* (2012) [35] revealed that growth attributes of soybean like plant height (81 cm) and dry matter production (803 g m^{-2}) increased with the application of 60 kg P_2O_5 ha^{-1} in soybean.

Nitrogen, phosphorus and potassium

Begum *et al.* (2015) [7] conducted an experiment at Bangladesh, reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher plant height (36.88 cm), number of branches (3.71), dry matter production (20.81 g) compared to other treatments in soybean.

Shinde *et al.* (2015) [43, 44] indicated that application of 100 % RDF (30:60:30 N:P_2O_5:K_2O kg ha^{-1}) recorded higher Plant height (57.09 cm), number of branches plant^{-1} (5.83), leaf area plant^{-1} (12.11 dm^2) and dry matter plant^{-1} (33.32 g) in soybean.

Yan *et al.* (2015) [54] conducted an experiment at China, on two soybean genotypes and concluded that for Liaodou 14, application of NPK and NPK + manure increased plant height by 14.5 % and 16.6 %, respectively over control. For Liaodou 21, application of NPK decreased plant height by 2.2 % but NPK + manure increased it by 7.1 % compared to control.

Basavaraja *et al.* (2014) [6] opined that application 100 % NPK + *Bradyrhizobium* + *Aspergillusniger* + VAM recorded highest growth parameter like branches at 30, 60 DAS and at harvest (4.84, 7.79 and 9.76 cm respectively), leaf area at 30, 60 DAS and at harvest (537.41, 999.57 and 1211.94 cm^2 respectively) and total dry matter at 30, 60 DAS and at harvest (3.36, 27.23 and 32.73 g plant^{-1} respectively) compare to other treatments in soybean.

Effect on Yield parameters of soybean

Nitrogen

Mandic *et al.* (2015) [27] indicated that application of Urea (46 kg N ha^{-1}) + Ferticare I (5 kg ha^{-1}) recorded higher number of pods plant^{-1} (58.1), number of grain plant^{-1} (124.8), 1000 grain weight (185.84 g) and grain yield (3961 kg ha^{-1}) compared to other treatments in soybean.

Ahmed (2013) [2] concluded that *Rhizobium* + 80 kg N ha^{-1}, increased the seed yield (2.54 t ha^{-1}), number of pods plant^{-1} (90.3) and number of seeds pod^{-1} (3.8) compared to other treatments, but the 100 seed weight was non-significant among the treatments in soybean.

Janagard *et al.* (2013) [19] revealed that application of urea 16.5 kg ha^{-1} + 49.5 kg ha^{-1} + *B. japonicum* + *PSB* recorded significantly higher pod weight plant^{-1} (12.2 g) and grain yield per unit area (321.8 g) compared to other treatments in soybean.

Singh and Singh (2013) [8] reported that 20 kg N ha^{-1} as basal and 10 kg N at pod filling stage recorded higher grain yield (25.1 q ha^{-1}), straw yield (43.5 q ha^{-1}), biological yield (68.6 q ha^{-1}) and harvest index (36 %) as compared to control in soybean.

Phosphorus

Kamble and Kathmale (2014) [20] reported that application of 100 % RDP (75 kg P_2O_5 ha^{-1}) + inoculation of *Pencilium bilaji* 10^4 recorded significantly higher seed yield (2919 kg ha^{-1}), straw yield (3874 kg ha^{-1}) and 100 seed weight (12.20 g) compared to 50 % RDP in soybean.

Dhage *et al.* (2014) [12] opined that application of 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (2339.2 kg ha^{-1}), straw yield (4909.8 kg ha^{-1}) and biological yield (7251.7 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Mahmoodi *et al.* (2013) [26] revealed that application of 90 kg P_2O_5 ha^{-1} recorded higher number of pods plant^{-1} (66.30), number of seeds plant^{-1} (129.97), 1000 seed weight (167.20 g) and seed yield (5158.27 kg ha^{-1}) over control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.

Shivran *et al.* (2012) [45] opined that application of 60 kg P_2O_5 ha^{-1} + *PSB* recorded higher pods plant^{-1} (67.47), seeds pod^{-1} (2.7), seed index (10.08 g), seed yield (24.67 q ha^{-1}), straw yield (38.10 q ha^{-1}) and harvest index (39.29 %) compared to other treatments in soybean.

Nitrogen, phosphorus and potassium

Aziz *et al.* (2016) [4] observed that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded higher number of pods plant^{-1} (75), 100 seed weight (12.36 g) and grain yield (1864 kg ha^{-1}) over the control in soybean.

Shinde *et al.* (2015) [43, 44] indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.

Gharpinde *et al.* (2014) [14, 16] revealed that application of 30:75:25 NPK kg ha^{-1} + biofertilizers recorded higher grain yield (14.26 q ha^{-1}) and straw yield (30.68 q ha^{-1}) over rest of the treatments in soybean.

Sikka *et al.* (2013) [46] reported that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along with 5 t FYM ha^{-1} to soybean recorded significantly higher number of pods plant^{-1} (150.3), test weight (10.4 g) and seed yield (32.6 q ha^{-1}) compared to control.

Effect on nodule number, nutrient uptake and quality parameters of soybean

Nitrogen

Yadravi and Angadi (2015) [53] indicated that application of 60 kg N ha^{-1} recorded higher nutrient uptake N (249.5 kg ha^{-1}), P (27.9 kg ha^{-1}) and K (169.2 kg ha^{-1}) compared to other treatments in soybean.

Maryam *et al.* (2013) [28] revealed that application of 32 kg N ha^{-1} increased soybean protein content to 21.1 g kg^{-1} over control and 16 kg N ha^{-1}. However, nitrogen levels did not show any significant effect on oil content. Ahmed (2013) [2] did not find any significant effect on soybean oil and protein contents with increasing levels of nitrogen in Sudan.

Rathod *et al.* (2012) [38] observed that application of 60 kg N ha^{-1} + *Rhizobium* recorded significantly higher total nutrient uptake N (174.6 kg ha^{-1}), P (28.8 kg ha^{-1}) and K (159.9 kg ha^{-1}) compared to other treatments in soybean.

Sohrabi *et al.* (2012) [51] reported that application of 100 kg N ha^{-1} recorded higher protein yield (97 g m^{-2}) over the control but it was on par with 50 kg N ha^{-1} in soybean.

Saini and Chogtham (2010) [39] observed that application of 125 kg N ha^{-1} increased protein content upto 39.2 % over 75 and 100 kg N ha^{-1} (36.0 % and 38.8 %, respectively) in soybean. However higher level of nitrogen didn't show significant effect on oil content.

Morshed *et al.* (2008) [30] revealed that application of 26.45 N

kg ha^{-1} recorded higher nutrient uptake N (490.78 mg plant^{-1}), P (35.50 mg plant^{-1}) and K (32.13 mg plant^{-1}) compared to other treatments in soybean.
Nastasija *et al.* (2008) [312] concluded that application of 30 kg N ha^{-1} recorded significantly higher nodule count (80.87) and dry weight of nodules (398.5 mg) over the control, 60 and 90 kg N ha^{-1}.
Son *et al.* (2006) [52] revealed that application of 40 kg N ha^{-1} + *Bradyrhizobium* (10 kg ha^{-1}) + *PSB* (100 kg ha^{-1}) + 30 kg K_2O recorded higher nodule number plant^{-1} (40.8) and nodule dry weight plant^{-1} (0.361 g) over the control in soybean.

Phosphorus
Geeta and Radder (2015) [15] reported that application of 80 kg P_2O_5 along with cured FYM (6 t ha^{-1}) + *PSB* (6 g kg^{-1} seed) + VAM (20 kg ha^{-1}) recorded significantly higher nodule number (32.0) and nodule dry weight (0.32 g) compared to other treatments in soybean.
Dhage *et al.* (2014) [12] observed that application of 90 kg P_2O_5 ha^{-1} recorded higher phosphorus uptake in grain (13.69 kg ha^{-1}), straw (11.39 kg ha^{-1}) and total P uptake (25.09 kg ha^{-1}) over the control, 30 and 60 kg P_2O_5 ha^{-1} in soybean.
Lamptey *et al.* (2014) [24] visualized that application of phosphorus 30 kg ha^{-1} as source of yara legume recorded higher nodule number (220) and nodule dry weight (1.45 g) compared to control and 15 kg P ha^{-1} in soybean.
Application of 90 kg P_2O_5 ha^{-1} recorded significantly higher protein content (40.03 %) compared to 60 and 30 kg P_2O_5 ha^{-1} in soybean (Bhattacharjee *et al.*, 2013) [8].
Devi *et al.* (2012) [10] showed that application of 80 kg P_2O_5 kg ha^{-1} recorded significantly higher oil content (17.63 %), oil yield (294 kg ha^{-1}), protein content (36.42 %) and protein yield (607 kg ha^{-1}) over the 20, 40 and 60 kg P_2O_5 ha^{-1} in soybean.
Shahid *et al.* (2009) [41] indicated that application of phosphorus @ 100 kg ha^{-1} recorded higher oil content (19.35 %) and oil yield (380.1 kg ha^{-1}) over the control in soybean.
Abbasi *et al.* (2008) [1] opined that application of 50 kg P_2O_5 ha^{-1} + combination of S77 + S79 *B. japonicum* recorded higher nodule number plant^{-1} (86.5) and dry weight of nodules (0.92 g plant^{-1}) compared to other treatments in soybean.
Singh *et al.* (2008) [50] indicated that application of 60 kg P_2O_5 + *Rhizobium* + *PSB* recorded significantly higher phosphorus uptake (21.4 kg ha^{-1}) compared to other treatments.
Application of 112.5 kg P_2O_5 kg ha^{-1} recorded significantly higher oil content (47.85 %) and oil yield (917.03 kg ha^{-1}) compared to other phosphorus levels (Ranjit *et al.*, 2007) [37].

Nitrogen, phosphorus and potassium
Aziz *et al.* (2016) [4] indicated that application of 45 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} recorded significantly higher nodule number plant^{-1} (34.13) and nodule dry weight plant^{-1} (3196 mg) over the control and 22.5 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} in soybean.
Begum *et al.* (2015) [7] reported that application of 25 kg N + 54 kg P_2O_5 ha^{-1} recorded significantly higher number of nodules plant^{-1} (11.07) compared to other treatments in soybean.
Gharpinde *et al.* (2014) [14, 16] opined that application of 30:75:25 NPK kg ha^{-1} + biofertilisers recorded higher nutrient uptake of N (132.24 Kg ha^{-1}), P (23.17 Kg ha^{-1}) and K (47.5 Kg ha^{-1}) compared to other treatments in soybean.
From the study conducted at Mohanpuran (Imphal), Devi *et al.* (2013) [11] revealed that application of 75 % RDF along with 5 t FYM ha^{-1} and *PSB* recorded significantly higher protein (36.7 %) and oil (18.6 %) content over control in soybean.
Sikka *et al.* (2013) [46] reported that application of 30 kg N, 60 kg P_2O_5, 30 kg K_2O ha^{-1} along with 5 t FYM to soybean recorded significantly higher amount of NPK uptake (267, 53, 150 N, P_2O_5 and K_2O kg ha^{-1} respectively) over control in soybean.
Patel *et al.* (2012) [33] reported that application of 30:60:40:10 N:P:S:Zn kg ha^{-1} recorded higher protein (42.32 %) and oil content (22.08 %) compared to other treatments in soybean.
Application of 25:60:25 kg N: P: K ha^{-1}, *PSB* (1250 g ha^{-1}) and *Rhizobium* (1250 g ha^{-1}) to soybean recorded higher uptake of nitrogen (195.0 kg ha^{-1}), phosphorous (21.6 kg ha^{-1}) and potassium (82.8 kg ha ^{1}), over control (Nagaraju *et al.*, 2009) [31].

Micronutrient Management in Soybean
Singh *et al.* (2014) opined that application of zinc @ 30 kg ha^{-1} in 2009 and 2010, recorded significantly higher seed yield (1958 kg ha^{-1} and 1839 kg ha^{-1}), biological yield (5776 kg ha^{-1} and 5025 kg ha^{-1}), where as harvest was non significance among the treatments.
Rajendran *et al.* (2012) [34] revealed that application of boron @ 1 kg ha^{-1} recorded significantly higher growth and yield parameters in soybean.
Barik and chandel (2006) [5] reported that application cupper @ 2.5 kg ha^{-1}, recorded significantly higher Leghemoglobin content at 45 and 60 DAS (mg g^{-1} of fresh nodule) and protein content in soybean.
Application of molybdenum @ 3g kg^{-1} seed as treatment seed treatment recorded higher plant height, number of seeds per pod, 100 seed weight and seed yield (Hugar and Kurdikeri, 2000) [18].

Organic Nutrient Management in Soybean
Rana and Badiyala (2014) [36] studied that among the organics treatments application of FYM (2.5 t ha^{-1}) + VC (1.25 t ha^{-1}) recorded higher plant height (76 cm), dry matter (509 g m^{-2}), No. of pods plant^{-1} (63.1), 1000 seed weight (133.2 g), seed yield (1.82 t ha^{-1}) and straw yield (3.25 t ha^{-1}).
Laharia *et al.* (2013) [23] conducted experiment at PDKV, Akola on clay soil and revealed that applicationof 100% RDN through Vermicompost + Jeevamrut (30 and 45 DAS) recorded higher seed yield, straw yield and nutrient uptake compared to other treatment but in was on par with 100% RDN through Vermicompost, 100% RDN through FYM +Jeevamrut(30 and 45 DAS).
Gallani (2013) [13] conducted field experiment in farmer field indore (MP), reported that in soybean organic farming practice (>3 year) recorded significantly higher seed yield, net returns and B:C ratio.

Integrated Nutrient Management in Soybean
Shinde *et al.* (2015) [43, 44] indicated that application of 100 % RDF recorded higher number of pods plant^{-1} (34.69), seed yield (2972 kg ha^{-1}) and straw yield (4529 kg ha^{-1}) in soybean.
Mere *et al.* (2013) [29] reported that application of 125 % RDF + FYM 5 t ha^{-1} to soybean produced maximum dry weight plant^{-1} at all the growth stages, higher number of pods plant^{-1} (62.5), 100 seed weight (15.09 g), seed yield (2.43 t ha^{-1}) and stover yield (3.18 t ha^{-1}) over 75 % and 100 % RDF with or without FYM.
Chaturvedi *et al.* (2012) [9] revealed that application of 100 % RDF along with FYM 10 t ha^{-1} recorded significantly higher number of nodules number, nodule dry weight, growth and

yield parameters in soybean.

Application of 75% Recommended dose of inorganic fertilizer + 1 t ha^{-1} poultry manure recorded higher protein and oil content in soybean (Khaim *et al.*, 2013) [21].

Hosmath *et al*. (2012) opined that application of 125% RDF + FYM 5 t ha^{-1} recorded significantly higher soybean seed yield and yield parameters. However, it was on par with application of 100% RDF + FYM 5 t ha^{-1}.

Maheshbabu *et al*. (2008) [25] concluded that application RDF (40:80:25 N:P:K kg ha^{-1}) + FYM 5 t ha^{-1} recorded higher growth and yield parameters. However, it was at par with Vermicompost (4 t ha^{-1}) + Rock Phosphate (176 kg ha^{-1}).

Nutrient Management of Soybean on Economics

Yadravi and Angadi (2015) [53] observed that application of 60 kg N ha^{-1} recorded higher net returns (₹ 84785 ha^{-1}) and B:C ratio (4.2) compared to other treatments in soybean.

Gharpinde *et al.* (2014) [14, 16] indicated that application of 30:75:25 NPK kg ha^{-1} + biofertilisers recorded higher gross monetary returns (₹ 32953 ha^{-1}), net monetary returns (₹ 16944 ha^{-1}) and B:C ratio (2.06) compared to other treatments in soybean.

Ganvir *et al*. (2014) [14, 16] reported that application of 100% RDF + biofertilizer recorded significantly higher net monitoring retuens and B:C ratio in soybean.

Patel *et al.* (2012) [33] opined that application of 30:60:40:10 N:P:S:Zn kg ha^{-1} recorded higher net returns (₹ 15572 ha^{-1}) and B:C ratio (1.86) compared to other treatments but it was on par with 30:60:40:5 N:P:S:Zn kg ha^{-1} in soybean.

Singh and Kumar (2012) [45, 49] reported that application of 50 % RDF along with biozyme (400 ml ha^{-1}) spray to soybean recorded significantly higher gross returns (₹ 55650 ha^{-1}), net returns (₹ 33885 ha^{-1}) and B:C ratio (1.6) compared to other treatments in soybean.

Saini and Chogtham (2010) [39] concluded that application of 100 kg N ha^{-1} recorded significantly higher gross returns (₹ 24298 ha^{-1}), net returns (₹ 15149 ha^{-1}) and B: C ratio (1.7) over 75 and 125 kg N ha^{-1} in soybean.

Sharma and Kanojia (2008) [42] revealed that application of phosphorus @ 60 kg ha^{-1} recorded higher net returns (₹ 14439 ha^{-1}) and B:C ratio (1.39) over 40 and 80 kg P_2O_5 ha^{-1} in soybean.

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