REVIEW ARTICLE

Nitrogen Management in Soybean: A Review

Ritu Bhangu*[1], Harpreet Kaur Virk [2]

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Abstract

Soybean (*Glycine max*) is a leguminous crop grown worldwide for its dual qualities viz. high protein and oil content. It contains about 40–42% protein and 20–22% oil and is one of the major cash crop of the rainy season. The plant growth parameters like plant height, leaf area index (LAI), and dry matter accumulation of soybean increased with the application of nitrogen from 30–80 kg N ha^{-1}. Nodule number and nodule dry weight increased with the application of 40 kg N $ha^{-1}$and decreased afterward whereas, yield and yield attributes of soybean increased with the application of nitrogen up to 100 kg ha^{-1}. Application of nitrogen from 40–80 kg N ha^{-1} as basal dose resulted in an increase in protein content. The split application of nitrogen as basal and at reproductive stages also resulted in an increase in protein content. However, oil content decreased with increasing level of nitrogen. The oil content increased with the application of nitrogen up to 40 kg N ha^{-1}. Application of nitrogen also improved soil properties like organic carbon, available NPK, and saturated hydraulic conductivity.

Keywords: Growth, Nitrogen, Productivity, Soybean.

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Introduction

Soybean [*Glycine max* (L.) Merrill] is an important legume crop grown which is grown worldwide for its high protein and oil content and accounts for 60% of the world's supply of vegetable protein. In India, soybean is grown extensively in Maharashtra, Madhya Pradesh, Rajasthan and in some parts of Karnataka and Tamil Nadu as a sole or intercrop. In India, soybean was grown on an area of 11.6 million hectares, with a production of 8.5 million tonnes and productivity of 738 kg ha–1 during 2015–16 (INDIA STAT 2018). India ranks fifth in the soybean production in the world after USA, Brazil, Argentina, and China. The production of the USA, Brazil, and Argentina together contributes about 80% ofto the total soybean production of the world, whereas the USA alone contributes about 40% to the production pool. Presently, India exports 55% of its soya meal.

The cultivation of soybean is spreading fast in India; however, the productivity of the crop is very low (738 kg ha^{-1}). The main constraint for the low productivity of soybean in India is the nutritional imbalance. Hence, proper nutrient management is one of the ways to enhance soybean productivity. Nutrient management practices, available nutrient sources, production practices, and other management practices influence nutrient availability and crop productivity. Among the fertilizers, nitrogen is a major essential plant nutrient. It has been observed that fertilizer application is very important for high yield in all the crops. For higher yields in legume crops, relatively high amount of nitrogen is required due to their high protein content (Sinclair and De Wit, 1976; Giller and Cadisch, 1995). Soybean utilizes nitrogen either through direct root uptake of NO_3^- or NH_4^+ from the soil or the N_2 fixed by the *Rhizobium* in the root nodules. Biological nitrogen fixations (BNF), uptake of residual N from soil and fertilizer nitrogen are the main sources for meeting the nitrogen demands of the crop.

[1]Department of Agronomy, Punjab Agricultural University, Ludhiana, India

[2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India

Corresponding Author: Ritu Bhangu, Department of Agronomy, Punjab Agricultural University, Ludhiana, India, e-mail: bhangu_ritu@yahoo.in

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Soybean is unable to meet the high nitrogen requirement through biological nitrogen fixation (BNF) (Kumawat *et al*. 2000). Hence, there is a need to supply inorganic nitrogen to soybean for increasing the seed yield.

Effect of Nitrogen on Growth Parameters

Nitrogen (N) is an important nutrient essential for plant growth and development. The application of nitrogen to the crop helps in enhancing above-ground vegetative growth. The parameters like plant height, dry matter production, and crop yield are enhanced with the application of nitrogen. Saxena and Chandal, 1992 studied the effect of nitrogen on crop growth and recorded the maximum plant height with the application of 40 kg N ha^{-1} in soybean. Whereas in a field study conducted by Praharaj, (1994), it was reported that with additional application of 30 kg N ha^{-1} at flowering and pod filling stages, there was a significant increase in plant height, leaf area index (LAI) and dry matter accumulation of soybean. An increase in plant height was observed when nitrogen levels were increased from 0 to 80 kg ha^{-1} (Pradhan *et al*. 1995). Dhurandher *et al*. (1995) reported that dry matter yield of soybean increased with the application of 20 kg N ha^{-1}

as basal and 20 kg N ha^{-1} at pod initiation. In an experiment conducted by Naik and Rao (2004), it was reported that plant height and dry matter accumulation increased significantly with the application of 40 kg N ha^{-1} during the reproductive stage. Werner and Newton (2005), reported that nitrogen application resulted in increased LAI, interception of solar radiations, chlorophyll pigments, photosynthesis and accumulation of dry matter. Caliskan *et al*. (2008) recorded higher LAI, dry matter, and leaf photosynthesis when nitrogen was applied as 80 kg N ha^{-1} (40 kg ha^{-1} before sowing + 40 kg N ha^{-1} at the full blooming stage). Mehmet, 2008 reported that maximum plant height was recorded with the application of nitrogen @ 90 kg ha^{-1}.

In an experiment conducted by Mrkovacki *et al*. (2008,) it was reported that the highest plant height and above ground dry matter were recorded at a flowering stage when 60 kg N ha^{-1} was applied. Similarly, Jahangir *et al*. (2009) conducted an experiment to study the effect of different levels of nitrogen and observed that plant height increased by 17.6 % with the application of 40 kg N ha^{-1} in soybean.

The maximum plant height and number of trifoliate leaves at 30, 60 and 90 days after sowing (DAS) with the application of 50% recommended nitrogen through urea + 50 % N applied through FYM + PSB was recorded by Koushal and Singh, (2011). Begum *et al*. (2015); reported that the maximum plant height was obtained with the application of 40 kg N ha^{-1}. Whereas, the number of branches $plant^{-1}$, number of nodes $plant^{-1}$ were recorded maximum with the application of 25 kg N ha^{-1}. Similar results were reported by Niranjan *et al*. (2015). The maximum plant height, number of branches $plant^{-1}$ and root length were recorded with the application of 40 kg N ha^{-1} as basal. In an experiment conducted with three nitrogen levels (0, 30 and 60 kg N ha^{-1}) in soybean, Shafii *et al*. (2011) reported that application of 60 kg N ha^{-1} recorded the maximum dry matter and the plant height was non-significantly affected by varying levels of nitrogen. Application of 45 kg N and 80 kg P_2O_5 ha^{-1} recorded higher leaf area index as compared to 15 kg N and 40 kg P_2O_5 ha^{-1} at 50 DAS (Singh *et al*. 2012).

Yadravi and Angadi, (2016) conducted an experiment in Dharwad to investigate the response of soybean to time and method of nitrogen application. In the experiment three levels of nitrogen (20, 40 and 60 kg ha^{-1}) were applied three times as basal, 40 and 60 DAS as both soil and foliar spray. The results revealed that the maximum plant height (50.6 cm), total dry matter (34.4 g $plant^{-1}$) at harvest and LAI (3.6) at 60 DAS was obtained when nitrogen was applied as 30 kg ha^{-1} (basal) + 30 kg ha^{-1} (40 DAS).

A field experiment was conducted by Anil *et al*. (2017) to know the effect of nitrogen on growth of soybean and reported that the application of 75% recommended dose of nitrogen (RDN) through urea, 25% nitrogen through FYM and sulfur @ 40 kg ha^{-1} recorded the highest plant height, dry matter accumulation, and leaf area. Raghuveer and Hosmath, (2017) reported that plant height, total dry matter accumulation, the number of branches $plant^{-1}$, leaf area and leaf area index were increased significantly with the application of 60 kg N ha^{-1} as compared to 20 and 40 kg N ha^{-1}. Aboutalebian and Malmir (2017) recorded the maximum plant height with the application of *Bradyrhizobium* + 60 kg N ha^{-1}.

In an experiment conducted by Virk *et al*. (2018), it was reported that there was no significant effect of the application of different N levels on plant height of soybean. However, the increase in LAI of soybean was reported with the application of nitrogen level from 0 to 100% recommended N level (39 kg ha^{-1}).

Effect of Nitrogen on Symbiotic Parameters

Generally, application of nitrogen is not recommended in legumes under favorable conditions as they can grow well on soil nitrogen, symbiotic nitrogen, and nitrogen stored within the cotyledons. However, in the case of soybean, nitrogen application is recommended to ensure maximum seed yield. Application of nitrogen in soybean helps in the formation of nodules and thus, helps in increasing the symbiotic nitrogen fixation rate.

The increase in number and dry weight of nodules and nodule N % with application of 40 kg N $ha^{-1}$was reported by Pandey *et al*. (1995). In another experiment conducted by Praharaj and Dhingra (2001), it was concluded that nodulation and nitrogenase activity in the nodules were reduced significantly with the application of 90 kg N ha^{-1} over 0, 30 and 60 kg N ha^{-1}. However, the decrease in the number of nodules $plant^{-1}$ with an increase in nitrogen level up to 90 kg ha^{-1} (Singh and Bansal, 2000).

Gan *et al*. (2003) reported that the application of 25 kg N ha^{-1} as starter dose and 50 kg N ha^{-1} at top dressing significantly increased the total N fixed over without N application as a top dressing. However, higher dry weight of nodules $plant^{-1}$ was reported by Kaul and Vyas, (2004) with the application of 40 kg N ha^{-1}. Similary, Niranjan *et al*. (2015) reported that a number of nodule $plant^{-1}$ and nodule dry weight was the maximum with the application of 40 kg N ha^{-1} at sowing. Yoseph and Worku (2014) recorded the maximum number of nodules $plant^{-1}$ and nodule dry weight with the application of 46 kg N ha^{-1}.

Kaschuk *et al*. (2016) conducted an experiment with four treatments of nitrogen viz. control, application of 30 kg N ha^{-1} at sowing, 50 kg N ha^{-1} at full flowering and 30 kg N ha^{-1} as basal and 50 kg N ha^{-1} as basal and top dressing in soybean and found that basal and top dressing treatments of nitrogen had a negative effect on the nodule number, and dry weight with no improvement in the crop yield. In an experiment conducted by Ntambo *et al*. (2017), it was observed that increasing level of nitrogen decreased nodule number and nodule dry weight $plant^{-1}$ and these were significantly higher under inoculation + 50 kg N ha^{-1}as compared to 100 kg N ha^{-1} and 200 kg N ha^{-1}.

Effect on Yield Attributes and Yield

Various researchers have reported that supplementing soybean with nitrogenous fertilizer helps in increasing the seed yield of the crop. Nitrogen along with symbiotic

nitrogen fixation helps in bridging the gap of nitrogen availability and uptake of the crop.

Kang *et al*. (1985) reported that seed yield of soybean increased by 27% when 40 kg N ha^{-1} and 10-20 kg N ha^{-1} was applied as basal and as a top dressing, respectively over control. Similarly, Afja *et al*. (1987) found that total dry matter production and seed yield increased by 11–23% and 37–40%, respectively by application of 20 kg N ha^{-1} as a starter followed by additional application of 40 kg N ha^{-1} during pod filling stage in soybean over control.

In a field experiment conducted by Jayapaul and Ganesraja (1990), it was concluded that the seed yield of soybean was significantly higher with the application of 40 kg N ha^{-1}. Reddy *et al*. (1990) recorded the highest seed yield in soybean with the application of 60 kg N ha^{-1}. Similar results were given by Misra *et al*. (1990) that a significant increase in seed yield was recorded with the application of 60 kg N ha^{-1}. Other researchers revealed that pods $plant^{-1}$, seeds pod^{-1}, and 100-seed weight and seed yield were maximum with the application of 40 kg N ha^{-1} (Singh and Gopalswamy, 1991; Krishanmohan and Rao, 1998).

Rani (1999) reported that seed yield of soybean increased by 26.6% and 43.1% with application of 20 and 40 kg N ha^{-1}, respectively over control. Singh *et al*. (2001a) observed that a split application of nitrogen as a ½ basal and ½ top dressing in soybean resulted in higher seed yield. A similar trend was shown in stover and biological yield. Gan *et al*. (2002) conducted a field experiment on soybean and concluded that maximum biomass and pod yield was obtained when 50 kg N ha^{-1} was applied as a top dressing at the flowering stage.

Maximum pod yield was obtained with the application of 50 kg N ha^{-1} as a top dressing at the flowering stage (Yinbo *et al*. 2002). Similarly, higher productivity of soybean was reported with the application of 40 kg N ha^{-1} (Padmavathi *et al*. 2003). Ravankar *et al*. (2003) reported that with the application of 15, 30, and 45 kg N ha^{-1}, there was an increase in seed yield of 6.5, 18.4 and 29.9%, respectively over control.

Ralli and Dhingra (2003) recorded higher seed yield (10.7%) over control with application of 30 kg N ha^{-1} as top dressing during pod formation stage in soybean and there was a significant increase in straw yield when N was applied in split doses at reproductive stages, whereas, when nitrogen was applied at later growth stages, harvest index was decreased. Significant increase in the yield attributes and harvest index (HI) was reported when 10 kg N ha^{-1} was applied at 50% flowering stage in green gram (Anbumani *et al*. 2003).

Increase in seed size by 3.6% was reported with the application of 100 kg N ha^{-1} at the R3 growth stage (Gutierrez-Boem *et al*. 2004). Laharia *et al*. (2004) observed that when nitrogen was applied at different growth stages with various application rates (0, 15, 30, 45, 60, 75 kg N ha^{-1}) in soybean, dry matter accumulation, yield and yield components of soybean increased with 75 kg N ha^{-1}. In a study conducted by Nandurkar *et al*. (2000) it was reported that with the application of 45 kg N ha^{-1}, maximum seed yield was obtained, followed by 30 kg N ha^{-1} and 15 kg N ha^{-1}. Gan *et al*. (2003) observed that application of nitrogen @ 50 kg N ha^{-1} at V2 or R1 stages of soybean significantly increased the nitrogen fixation and seed yield.

Barker and Sawyer (2005) reported that when nitrogen was applied at the R6 growth stage of soybean there was an increase in nitrogen concentration in aboveground plant dry matter whereas there was a negative effect on seed yield and seed quality components.

Sabale (2005) recorded higher seed yield (32.87 q ha^{-1}) with the application of nitrogen at 50 kg ha^{-1} half through urea and half through FYM. In another study conducted by Shinde *et al*. (2007), it was reported that there was a significant increase in seed yield, 100-seed weight and number of pods $plant^{-1}$ over control with the application of 45 kg N ha^{-1} (the basal dose). Increase in number and weight of pods, a number of seeds and 1000-seed weight of soybean with the application of increased level of fertilizer from 25–75 kg ha^{-1} was reported by Jadhav *et al*. (2009).

Yadav and Chandel (2010) reported that with the application of 40 kg N ha^{-1} basal + 40 kg N ha^{-1} at 60 DAS + 20 kg N ha^{-1} at 75 DAS along with 34.96 kg P ha^{-1}, provided the highest seed yield of soybean. The seed and straw yield of soybean increased with the application of N up to 75 kg ha^{-1} and decreased with further increase in nitrogen levels as reported by Malhi *et al*. (2011) in a study conducted in Canada. Vaiyapuri *et al*. (2012) reported better growth, yield parameters, and seed yield of soybean with the application of 20 kg N ha^{-1} as basal + 100 ppm foliar spray of salicylic acid. In an experiment conducted by Jyothi *et al*. (2013) to study the effect of foliar application on nitrogen at different growth stages of soybean. It was observed that there was an increment of about 56.9% in seed yield and of about 50% and 27.2% in 100-seed weight and number of pods $plant^{-1}$, respectively with foliar application of 2% urea at flowering and at early pod development stage over control.

Rathod *et al*. (2012) observed that the maximum seed yield (1968 kg ha^{-1}) was obtained when 60 kg N ha^{-1} as basal + *Rhizobium* was applied. The seed yield was statistically at par with the treatments when nitrogen was applied @ 80 kg ha^{-1} as basal or in two splits as basal and at 50 or 80 DAS. Singh and Singh (2013) observed that there was significant increase in the yield of soybean if nitrogen was applied in two splits i.e. at pre-flowering and pod filling stages as compared to application of single dose of nitrogen at either of these stages and the maximum number of pods $plant^{-1}$, seeds pod^{-1}, seed, and straw yield were obtained with application of 20 kg N ha^{-1} at sowing + 10 kg N ha^{-1} at pod filling + 30 kg K_2O ha^{-1} at sowing.

Sohrabi *et al*. (2012) conducted an experiment to know the effect of nitrogen application during reproductive stages in soybean and reported that 100 kg N ha^{-1} as starter dose gave the maximum number of seeds pod^{-1} and seed yield. Valinejad *et al*. (2013) stated that the application of starter nitrogen @ 32 kg ha^{-1} resulted in higher yield as compared to the control. Begum *et al*. (2015) reported that yield attributes

and seed yield was maximum with the application of 25 kg N ha^{-1} followed by 40 kg N ha^{-1}. The increase in yield attributes and yield was reported by Niranjan *et al.* (2015) with a split application of nitrogen at reproductive stages. The application of 20 kg N ha^{-1} (basal) + 20 kg N ha^{-1} as a top dressing at pod filling stage gave higher yield attributes and seed yield. Similary, Yadravi and Angadi (2016) observed that the maximum number of pods $plant^{-1}$ (62.2), number of seeds pod^{-1} (3.0) and 100-seed weight (13.18 g), seed yield (3287 kg ha^{-1}) and haulm yield (3748 kg ha^{-1}) were obtained when nitrogen was applied as 30 kg ha^{-1} (basal) + 30 kg ha^{-1} (40 DAS).

Gai *et al.* (2017) reported that the highest seed yield was recorded at 50 kg N ha^{-1}. However, Anil *et al.* (2017) recorded the highest seed yield (2290 kg ha^{-1} and stover yield (3270 kg ha^{-1}) with the application of 75% RDN through urea, 25% nitrogen through FYM and 40 kg S ha^{-1}. Raghuveer and Hosmath (2017) recorded significantly higher seed (2444 kg ha^{-1}) and haulm yield (2975 kg ha^{-1}) with application of 60 kg N ha^{-1} as compared to 40 kg N ha^{-1} (2242 and 2735 kg ha^{-1}, respectively) and 20 kg N ha^{-1} (1745 and 2140 kg ha^{-1}, respectively). Increase in yield attributes and yield of soybean by increasing nitrogen level from 0 to 100% recommended N (39 kg N ha^{-1}) was reported by Virk *et al.* (2018).

Effect on Nutrient Uptake

Morshed *et al.* (2008) reported the highest N uptake (490.78 mg $plant^{-1}$) over control with the application of 26.45 kg N ha^{-1}, whereas, P and K uptake in seed was maximum with the application of 10.58 kg N ha^{-1}. Singh *et al.* (2010) reported that application of 20 kg N ha^{-1} at sowing + 10 kg N ha^{-1} at pod filling recorded the highest total uptake of N in straw and seeds of the soybean. In an experiment conducted by Malhi *et al.* (2011), it was reported that with the application of 75 kg N ha^{-1} uptake of N was increased in both seed and straw. Whereas, Rathod *et al.* (2012) reported that NPK uptake increased with the application of 80 kg N ha^{-1}. Maximum nitrogen uptake in seed and straw was recorded with the application of 46 kg N ha^{-1} (Yoseph and Worku, 2014).

The maximum nitrogen uptake in seed and straw was recorded with the application of 20 kg N ha^{-1} (basal) + 20 kg N ha^{-1} (75 DAS) was reported by Niranjan *et al.* (2015). In another study conducted by Yadravi and Angadi (2016), it was reported that uptake of nitrogen (251 kg ha^{-1}), phosphorus (28 kg ha^{-1}) and potassium (169 kg ha^{-1}) increased with the application of 30 kg N ha^{-1} at basal +30 kg N ha^{-1} at 40 DAS.

Effect on Quality Parameters

Pareek and Shahtawat (1998) reported that there was a significant increase in protein content with the application of 60 kg N ha^{-1}. Jayapaul and Ganesaraja (1990) observed that there was a significant increase in oil and protein content with the application of 40 kg N ha^{-1}. Similar results were given by Vara *et al.* (1994).

Kumawat *et al.* (2000) stated that protein content increased with increase in nitrogen levels from 20-80 kg ha^{-1}, whereas, oil content decreased with increasing level of nitrogen. Singh *et al.* (2001) conducted a field experiment in Ludhiana and reported that oil and protein yield increased with the application of 60 kg N ha^{-1}.

Singh *et al.* (2001a) revealed that application of nitrogen as ½ basal+ ½ top dressing and ½ basal + 1/4 foliar spray resulted in an increase of 11.1% and 13.2% in oil and protein content, respectively as compared to the basal application of nitrogen. Rathod *et al.* (2006) provided the maximum seed protein content (42.9%) by application of 45 kg N ha^{-1} (basal) + 30 kg N ha^{-1}as top dressing at 40 DAS. In another study conducted by Morshed (2008) it was observed that maximum protein content (44.75 %) was obtained with the application of 26.45 kg N ha^{-1} to soybean. In an experiment conducted by Yadav and Chandel (2010) to study the effect of nitrogen at different growth stages of soybean and reported that when nitrogen was applied at the rate of 40 kg ha^{-1} as basal and 40 kg ha^{-1} at 60 DAS, the oil content increased significantly, whereas when additional 20 kg ha^{-1} was applied at 75 DAS then 24.4% protein content of seeds was increased over control.

Jyothi *et al.* (2013) reported that protein and oil content was higher as compared to the control when nitrogen was applied as 2% urea sp.ray during flowering and early pod development stage along with 30 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} as a basal dose. Maryam *et al.* (2013) also reported that soybean protein content increased over control and 16 kg N ha^{-1} with the application of 32 kg N ha^{-1}. Yoseph and Worku (2014) also reported an increase of about 29.8 % and 11.1% in oil and protein content, respectively with the application of 46 kg N ha^{-1}. Niranjan *et al.* (2015) observed that with the application of 20 kg N ha^{-1} as basal dose + 20 kg N ha^{-1} as a top dressing at pod filling stage gave maximum seed protein content of 38 %.

Effect of Nitrogen on Soil Properties

Liebig *et al.* (2002) reported that increased nitrogen rate up to 68 kg ha^{-1} recorded higher organic carbon and total N. However, it lowered soil pH and also reduced microbial biomass by 20%. Kaul and Vyas (2004) reported that application of a higher dose of nitrogen (40 kg N ha^{-1}), recorded the highest gain of available N (170.1 kg ha^{-1}). Similarly, Rathod *et al.* (2012) also reported that available N status of soil increased with increasing level of nitrogen up to 80 kg N ha^{-1}. However, available P and K status of soil decreased with increasing level of nitrogen.

Mere *et al.* (2013) also reported that available NPK in the soil at harvest was highest with the application of 125% RDF (20:80:40) + FYM 5 t ha^{-1}. Sikka *et al.* (2013) reported that organic carbon, available N, P, and K was maximum with the application of 30 kg N, 60 kg P_2O_5, 30 kg K_2O and 10 tonnes FYM ha^{-1}. However, the soil organic carbon, aggregate stability, and saturated hydraulic conductivity were significantly higher with the application of 150% N as

compared to 50% N (Hati *et al*. 2015). A positive increase in N status in soil with the application of nitrogen as 20 kg N ha^{-1} as basal + 10 kg N ha^{-1} as a top dressing at seed initiation stage was reported by Niranjan *et al*. (2015).

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