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REVIEW PAPER

Key Insights on Influences of Different Seed Rate and Phosphorus Levels on Growth and Productivity of Soybean (*Glycine max* L.): A Review

Baljinder Singh[1]* and Vijay Singh[2]

[1]Department of Agronomy, Guru Kashi University, Talwandi Sabo, Punjab, India
[2]Department of Soil Science, Guru Kashi University, Talwandi Sabo, Punjab, India

*Corresponding author: baljindersds@gmail.com (**ORCID ID:** 0000-0001-6740-5879)

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ABSTRACT

The optimal seed rate is important in contributing to high yield because, in the case of dense plant populations, most plants remain sterile and are more susceptible to disease attack than in normal plant populations. Planting geometry allows for the more efficient use of light, water, land, and other inputs. Phosphorus is more important than other nutrients in increasing soybean yield. Phosphorus is a crucial element and shown to be necessary for the development, growth, and productivity of soybean. To boost the production of oil seed crops, the optimal dose of phosphorus is required. This paper focuses on the role of phosphorus in improving oil seed, crop production indirectly and directly role of phosphorus is to improving the soybean productivity.

HIGHLIGHTS

- Optimum planting technique and seed rate influence the growth and productivity of the soybean crop by saving considerable amount of irrigation water and ensuring better resource utilization ability.
- For better production of soybean with a particular reference to nodule formation, it is mandatory to focus on the application of P-ic fertilizers.

Keywords: Grain yield, Phosphorus, Soybean, Seed rate, Legumes

One of the most significant legume crops for human nutrition is soybean (*Glycine max* L.), which has historically been grown in calcareous soils in dry and semi-arid areas. The high protein content of soybean contributes to its agronomic significance. Due to its distinctive chemical makeup, it is a cost-effective and valuable agricultural commodity. It is one of the most significant leguminous plants in the world. It is as a good source of vegetable oil and high-quality plant protein. It is grown practically everywhere in the world for human consumption, industry, and animal feed due to its high concentration of protein (36-48%), oil (18-24%), and carbohydrates (20%) (Kirnak *et al.* 2010).

One of the crops with the quickest growth in India is soybean. India is the fifth-largest producer of soybeans, behind the United States, Brazil, Argentina, and China. In India, soybeans will cover 113.9 lakh ha in 2019–20, producing 13,505 million tonnes annually on an average of 1185 kg/ha. Madhya Pradesh, Maharashtra, and Rajasthan are the three states that produce the most soybeans (Anonymous 2021). The second most important nutrient for crop growth and high-quality output is phosphorus (P). The root system of the plant is

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where P has the most evident impact. Due to P's important involvement in nodule development and atmospheric nitrogen fixation, nodulating legumes have higher P requirements than non-nodulating crops (Brady and Well, 2002). Due to the important role played by P in the physiological processes of plants, application of P to soil deficient in this nutrient leads to increase groundnut yield. Because the available soil phosphorus will be leached, there is concern that excess P moves through tile drainage systems and move into water sources and pollutes fresh water sources. Excessive fertilization increases cost with no promise in yield, on the other hand, can cause environmental pollution and reduce supply of a finite resource. Long-term P management results in a different soil nutrient composition than short-term P management (Ciampitti *et al.* 2011).

The concentration of P in the soil solution will probably rise after using inorganic P fertilizers on the soil (Pierzynski *et al.* 2005). Phosphorus is an essential element and has demonstrated to be essential for the growth, development, and production of soybean (Kakar *et al.* 2002). Additionally, it is crucial to raise the caliber of the various qualities and worth of the various plant-specific products, as lowering either of these factors will stunt plant growth, delay ripening and maturity, and ultimately reduce crop production by 10% to 15%. (Shenoy and Kalagudi, 2005). Additionally, it has a sizable effect on the fixation of nitrogen, photosynthesis, root growth, seed germination, flowering, crop quality, and maturation (Brady, 2002).

Effect of seed rate on growth and yield of soybean

In order to investigate the effects of a variable seed rate 75 on the development and seed yield of soybeans planted using the bed and flat methods, a field experiment was conducted in Ludhiana, Punjab. Revealed that when using the bed planting strategy as opposed to flat sowing, growth characteristics such as emergence count, plant height, dry matter accumulation, leaf area index, and photosynthetic active radiation interception (%) were significantly greater. In bed planted soybeans as opposed to flat-planted soybeans, the pooled seed yield rose by 15.6%. All the growth measures showed substantial results for soybean seeds primed with 100 ppmGA3. When compared to unprimed seeds, primed seeds had a 15.3% higher yield. Seed rate of 62.5 kg ha^{-1} recorded significantly higher emergence count, plant height, dry matter accumulation, leaf area index and photosynthetic active radiation interception (%) which was statistically similar in results with 75 kg ha^{-1} seed rate in both the two years. Pooled seed yield of 62.5 kg ha^{-1} seed rate was 4.61% higher than 75 kg ha^{-1} and 12.6% than 50 kg ha^{-1} seed rate (Jassal and Singh 2020).

Ram *et al.* (2011), conducted a field experiment from 2006 to 2008 to compare the effects of four sowing techniques; raised bed planting (67.5 cm wide, 2 rows per bed); raised broad bed planting (135 cm wide, 4 rows per bed); ridge-furrow sowing (60 cm spacing); and flat sowing (45 cm spacing) as well as three seeding rates 50, 62.5, and 75 kg ha^{-1} of soybean. Raised bed planting had the highest photosynthesis-active radiation interception (PARI) and net returns. In comparison to flat and ridge-furrow sowing techniques, raised bed sowing produced the highest seed yields, which were 6.70 and 5.29% greater, respectively. The highest water productivity was recorded in raised broad bed sowing which was significantly higher than flat sowing and ridge-furrow sowing methods but statistically on par with raised bed sowing. Seed rate of 50 kg ha^{-1}recorded highest crop growth rate (CGR) and pods per plant whereas the highest PARI was observed with 75 kg ha^{-1} seed rate, which was statistically on par with 62.5 kg ha^{-1} seed rate but significantly higher than 50 kg seed ha^{-1}. The soybean productivity was highest with 62.5 kgha^{-1}seed rate.

Higher harvest index (35.5) with 100% RDF application was recorded by Shivakumar and Ahlawat (2008) at Pusa New Delhi whereas higher net returns and B: C ratio (0.89) with 100% recommended dose of fertilizer in soybean were also reported. Nuri (2013) carried out an experiment to investigate the effects of sowing densities on yield and yield components. Seed rates were planted in 40, 50 and 60 cm row spaces and into 5, 10 and 15 cm intra row spaces. Seed rates did not affect the height of plant, number of seeds per pod and 100-seeds weight but affected its branch height, the first pod height and side branches number, number of pods per plant and grain yield. Seed rates increased side branches height and grain yield but decreased side branch number of pods per plant.

Debruin and Pedersen (2008) revealed that soybean yield response to narrow row spacing has been consistently positive in the upper Midwest and new split-row planters have made narrow row soybean production feasible, yet adoption has been slow in Iowa. Wide (76-cm) and narrow (38-cm) row spacing and four seeding rates (185,000; 309,000; 432 000; and 556,000 seeds ha^{-1}) were evaluated at three locations during 2004, 2005, and 2006 to determine seed yield in wide and narrow row spacing and four seeding rates and evaluate economic advantages associated with changes in row spacing. Soybean planted in 38-cm row spacing yielded 248 kg ha^{-1} greater than soybean planted in 76-cm rows after adjustment for differences in final plant populations. Maximum yield at all locations was attained at a final harvest population of 462,200 plants ha^{-1} but >95% of the maximum yield was achieved with final populations as low as 258 600 plants ha^{-1}. Increased production costs associated with greater seeding rates removed the yield benefit from greater harvest plant populations.

Schutte and Nleya (2018) A row spacing study was conducted at Aberdeen and Beresford, South Dakota, USA, in 2014 and 2015. The study had two rows spacing (19 and 76 cm), four seeding rates (247,000, 333,500, 420,000, and 506, 500 seeds ha^{-1}), and two soybean varieties at each location. Soybean had greater stand establishment in 19 cm rows (6–10% higher) compared with 76 cm rows. Soybean in 19 cm rows yielded 0.8–10% more than in 76 cm rows depending on the location or year. Seed yield increased with increasing seeding rate with the highest seeding rate of 506,000 seeds ha^{-1} yielding greatest. The increase in seed yield due to the increase in seeding rate ranged from 3 to 7%. At each location, the longer duration soybean variety yielded higher than the shorter duration variety.

Soybean seeding rate describes the number of seeds planted in a given area. Soybean plants display variable amounts of branching depending on the amount of space for growth, which may result in no yield response from increased seeding rates (Carpenter and Board 2007). Planting soybean seeds at variable rates may result in different plant responses. Increasing seeding rates to 516 000 seeds ha^{-1} has been found to increase soybean chlorophyll levels, reduce plant chlorosis, and increase seed yield in iron (Fe) deficient soils (Goos and Johnson 2001). Varying soybean seeding rates have produced similar yield levels with rates as low as 76, 000 seeds ha^{-1} in Kentucky and as high as 388 000 seeds ha^{-1} in Wisconsin (Lee *et al.* 2008).

Effect of phosphorous on growth and yield of soybean

Khanam *et al.* (2017) carried out a field experiment at the Sher-e-Bangla Agricultural University Farm in Dhaka, Bangladesh to assess the impact of potassium (K0: 0 kg, K1: 60 kg MoP ha^{-1}, K2: 120 kg MoP ha^{-1}, K3: 180 kg MoP ha^{-1}), phosphorus (P0: 0 kg, P1: 100 kg TSP ha^{-1}, P2: 175 kg TSP ha^{-1}, and their (Glycine max). Up to 175 kg ha^{-1} TSP, the number of nodules plant^{-1}, full pods plant^{-1}, seeds pod^{-1}, 1000-seed weight, seed yield, biological yield, and harvest index all rose significantly. On the other hand, numbers of nodules plant^{-1}, number of filled pods plant^{-1}, length of pod, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield were enhanced significantly up to 120 kg ha^{-1} MoP. The treatment of combined phosphorus @ 175 kg ha^{-1} and potassium @ 120 kg MoP ha^{-1} depicted the highest number of filled pods plant^{-1} (63.00), length of pod (3.16 cm), number of seeds pod^{-1} (3.11) *vis-a-vis* the highest (3.67 t ha^{-1}) seed yield. Thus, the combined application of 175 kg ha^{-1} TSP and 120 kg ha^{-1} MoP could be the optimum for getting maximum yield of soybean.

Pauline *et al.* (2016) carried out field experiments at the University of Venda experimental farm, Thohoyandou over two seasons. The experiments consisted of a factorial combination of P fertilizer rates (0, 30 and 60 kg P ha^{-1}) and soybean cultivars (Pan 520RR, and LS 555) arranged in a randomized complete block design and replicated three times. Crop biomass (three stages: vegetative phase, 50% flowering and harvest maturity) and grain yield were determined. The (Agricultural Production Systems Simulator) APSIM model (version 5.3) was used to simulate crop biomass and grain yield and to assess the long-term risks associated with yield production of soybean crop. There was a strong positive relationship (R_2 = 0.97) between observed and predicted grain yield data but the predicted yields were generally lower than the observed values. These preliminary findings show firstly, that the addition of P may not affect grain yield of soybean in this area, secondly, that Pan 520 RR may be suitable for cultivation in this area, and lastly, that APSIM model may be a useful tool in predicting soybean productivity in this area

In a field experiment using *Rhizobium japonicum* inoculation and varied phosphorus levels (0, 25, 50, 75, and 100 kg ha^{-1}), Shahid *et al.* (2009) Oil content (%) in soybean seeds was found to be non-significant at all phosphorus levels. While the higher phosphorus levels: 75 and 100 kg ha^{-1} significantly outperformed other phosphorus doses in terms of plant height and the number of pod bearing branches per plant. When compared to all other phosphorus doses, 100 kg P_2O_5 ha^{-1} produced noticeably better results in all other metrics, including the number of pods per plant, the length of the pods, the number of seeds per pod, the biological yield, the harvest index, and the oil output. Inoculation with Rhizobium *japonicum* improved soybean yield and yield components as compared to non-inoculated seed.

Matusso and Cabo (2015) revealed a research to inspect the response of soybean under various doses of phosphorous fertilizer. The treatments were covered different doses of phosphorous i.e. 0, 20, 40 and 60 kg P_2O_5 ha^{-1} applied through SSP. The experimental results showed that yield characteristics of soybean enhanced with increase in the rate of phosphorous fertilizer. They also revealed that various parameters of soybean such as biomass yield, 100 seeds weight, pods number, grain return and weight of nodules influenced expressively. The maximum pod number per plant (44.6) of soybean was recorded under 40 kg P_2O_5 ha^{-1}. Therefore, in case of biomass, weight of 100 seeds and grain return were attained higher with 60 kg P_2O_5 ha^{-1}. Overall outcomes of this research directed that to obtain the highest biomass and seed yield the 60 kg P_2O_5 ha^{-1} application must be applied.

Ferreira *et al.* (2018) conducted a field experiment to assess the interaction between seeding rate and levels of phosphorus and potassium fertilization on soybean growth, grain yield and contents of protein and oil in the grains. The experiment was carried out under a randomized complete block design, in a split-plot scheme, with six replicates. Four seeding rates (150, 300, 440 and 560 thousand viable seeds ha^{-1}) were used in the plots, and two levels of phosphorus and potassium fertilizer were applied in the subplots to meet the export of 3 and 6 t ha^{-1} of grains (level 1 = 30 kg ha^{-1} of P_2O_5 + 60 kg ha^{-1} of K_2O and level 2 = 60 kg ha^{-1} of P_2O_5 + 120 kg ha^{-1} of K_2O). There was no interaction between the experimental factors. Increase in fertilizer doses did not alter the evaluated characteristics, regardless of the seeding rate. Seeding rate did not change grain yield or protein and oil contents, but at low densities there was an increase in the number of pods per plant, apparent harvest index and SPAD index.

Lone *et al.* (2019) conducted a field experiment was at Similar Campus during *kharif* seasons of 2004 and 2005 on a silty clay loam soil, medium in available N and K, low in available P to study the production performance of soybean as influenced by seed rate, row spacing and fertility levels under temperate conditions. The experiment comprising 27 treatment combinations viz., 3 levels each of seed rate (40, 60 and 80 kg ha^{-1}), row spacing (30, 45 and 60 cm) and fertility (40:60:40, 60:90:60 and 80:120:80 of N: P_2O_5 : K_2O kg ha^{-1}) was laid out in split plot design replicated thrice. Application of N_{80} P_{120} K_{80} kg ha^{-1} significantly improved the growth parameters viz., plant height, LAI, number of nodules $plant^{-1}$, fresh nodule weight and dry matter accumulation. Uptake of nutrients both N and P were increased with increase in fertility levels. Significantly more protein and oil content were also recorded at highest fertility level of N P_2O_5 K_2O i.e. N_{80} P_{120} K_{80} kg ha^{-1}

CONCLUSION

It is determined that an ideal seed rate is crucial for producing a good yield because, in comparison to a normal plant population, most plants stay sterile and are more susceptible to disease in thick plant populations. A chance for effective use of light, water, land, and other inputs provided by planting geometry. High yield also influenced by the optimal seeding rate because, in cases of dense plant populations, most plants stay sterile and are more susceptible to disease than normal plant populations. In comparison to other minerals, phosphorus is more crucial for boosting soybean output. Phosphorus is a critical element and has demonstrated to be crucial for the growth, development, and productivity of soybean. The optimum dose of phosphorous is required to enhance the production of oil seed crops. The dose depends upon the cultivar used, soil and availability of available phosphorous.

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