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Effect of phosphorus on growth, yield and quality of soybean (*Glycine max* L.); A review

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Abstract
Soybean (*Glycine max* L.) is one of the most important source of oil and protein and is commonly used in both human and animal diets. For better production of soybean, it is compulsory to focus on the application of different essential nutrients in the form of fertilizers. Nodule formation of soybean is directly depending on the application of P fertilizer. Even though the application of phosphorus the yield of soybean has been increase, but other hand the application of their surplus quantity will performed adversely effects on yield of soybean. We have to focus towards soybean because soybean is the most important oil seed crop in the world. It is also known as an important grain legume of the world. This paper indirectly focuses on role of phosphorus in improving oil seed crop production and directly focuses on role of phosphorus in improving growth yield and quality of Soybean.

Keywords: Oil; soybean; phosphorous; crop production

Introduction
Soybean (*Glycine max* L.) is a member of Fabaceae family and mainly supplies protein and oil. Its oil considers the world's largest constituent of edible oils (Arif *et al.*, 2010) [4]. Soybean is often referred to be a marvel plant because it holds high protein (39-44%) and oil content (21%) (Hamayun *et al.*, 2010) [22]. So, it's the best protein and oil source and really claims the name of oil or meat on plants. Normally it is castoff for manufacture oil, flour, cakes, sweets, herbal cheese and numerous additional products in food industry (Fatima *et al.*, 2006) [20]. Globally, 30% of the edible oil obtained from soybean. It accounts more than 50% of the high protein meal in the world (Hatam and Abbasi, 1994) [23]. More recently, soybean and their products have been progressively demanded by the individuals who are awake of the health paybacks of its oil and protein, particularly in advanced nations (Mahamood *et al.*, 2009) [34]. Worldwide, it is a favorable pulse crop that is designed to reduce the severe scarcity of oil and protein (Arif *et al.*, 2010) [4]. Edible oil is actually the major imported food in the country. In our country, cotton seed produced more than 50% of indigenous oil production, which is not a genuine oilseed crop and the share of world-renowned oil crops, such as soybean, is much lower (Shahid *et al.*, 2009). Soybean is much cheaper as compared to other protein rich foods like fish, eggs and meat. Despite the great potential of this crop, its production is quite insufficient due to low yields. This creates a huge gap between what is presently produced and what is required (Mahamood *et al.*, 2009) [34]. To improve its production, one of the most important areas to consider is the development of pest and disease resistant varieties, adequate fertilizer management and better cultural practices (Mahamood, 2009) [34]. The sharp increase in soybean crop yields is partly due to the balanced fertilization and good cultural practices (Modali, 2004) [38]. One of the main causes in decline the soybean production is unbalanced fertilization of nutrients (N, P and K). Phosphorus is the main nutrient contributing to the stabilization of biological nitrogen in soybean and eliminates 28 kg of P/ha from the soil (Goswami, 2016) [21]. The discharge of phosphorus from the soil is imperceptible, it must be completely released from the soil to feed the crop. It is the most restrictive nutrient that controls the productivity of soybean (Brennan and Boland, 2004) [11]. It is more important than other nutrients to increase the yield of oilseeds such as soybean. Phosphorus is considered as the crucial component and

has proven to be vital for the development, growth and productivity of soybean (Kakar *et al.*, 2002) [27]. It is also essential to improve the quality of the different attributes and value of various plant-specific products, while their decrease can reduce plant growth, later ripening and maturity, eventually reduced the crop yield about 10-15% (Shenoy and Kalagudi, 2005) [40]. It also has significant impacts on fixation of N, photosynthesis, root expansion, seed establishment, flowering, maturing and quality of crop (Brady, 2002) [10]. Fageria *et al.* (1995) [19] have previously reported that a huge amount of phosphorus fertilizer may need for efficient production of soybean. However, some contradicted findings of the phosphorous fertilizer on soybean were also reported. They showed that the plant components and crop yield in soybeans were not pointedly swayed by solicitation of phosphorous (Erhabor *et al.*, 2001) [18]. Whereas, Chiezey (2001) [15] reported that low level of phosphorous in soil decrease the yield of soybean. The fertilization of an adequate amount of phosphorus promotes root growth, ensures strong formation of plant, rapid physiological maturity, flowering, support seed formation, improve cold tolerance and ultimately enhanced the crop productivity (Malavolta, 1989) [36]. This paper indirectly focuses on role of phosphorus in improving oil seed crop production and directly focuses on role of phosphorus in improving growth yield and quality of Soybean.

Role of Phosphorus in Improving Oil Seed Crop Production

Soybean as well as all other nitrogen fixing legumes need phosphorous for proper growth and nitrogen fixation. Beans are particularly sensible to small obtain ability of phosphorous since obsession of nitrogen requires high levels of phosphorous. Its deficiency can reduce the formation of nodules while application of phosphorous overcomes this problem (Carsky *et al.*, 2001) [12]. The soils which fix the phosphorous greatly affect the crop yields and increase fixation of phosphorous in the soil through period of commerce among soluble phosphate and elements of soil (Bationo *et al.*, 2011) [6]. Hussain and Faridullah (2003) [24] indicated that P is vital for healthy plant growth. Optimal level of phosphorus initiate root growth, increased flowering and fruit preparation that finally resulted in enhanced seed productivity. The availability of sufficient phosphorus increases the chances of uniform ripeness and early maturity, legumes increase nitrogen-binding capacity, harvest quality and increase resistance to plant diseases. Solis (2013) [41] directed a research trial to determine the effect of phosphorous on oil contents and seed yield of Camelina (*Camelina sativa*). The outcomes of the trial exhibited that influence of applied nutrient impart positive impact on oil contents and seed yield of camelina crop. While, highest seed yield of camellia was recorded where higher level (100 kg P_2O_5 ha^{-1}) of P was applied. A research study was led by Bharose *et al.* (2011) [8] to investigate the influence of different rates of phosphorus and sulfur on oil content, protein and on availability three major nutrients in oil seed crop (Toria) during rabi season 2008. This investigation includes three levels of phosphorus and sulfur. The increase in the rate of phosphorous and sulfur from 0 to 50 and 0 to 40 respectively, a substantial rise was perceived in protein and oil contents of Toria. The findings of the experiment also indicated that the combination of phosphorous and sulfur (50 kg P_2O_5 ha^{-1} + 40 kg S hai^{-1}) recorded the highest protein, oil contents in Toria and also enhanced the N, P, K availability. Rogerio *et al.* (2013) stated that different level of phosphorus (0, 15, 30, 60 and 90 kg ha^{-1}) on oil seed crop Crambe (*Crambeabssynica* Hoechst). Results directed that oil contents were not significantly increased. However, flowering day to maturity and overall crop growth is influenced by deficiency of phosphorus because its shortage reduces the processes of carbohydrate use although starch biosynthesis continues (Armstrong, 2001) [5]. A research experiment was directed by Ali *et al.* (2002) [2] to deliberate the impact of diverse levels of phosphorus on crop progress and produces of two varieties of linseed (LS-49 and Chandni). The application of phosphorus imparts substantial impact on the capsules number, seed number, seed weight, yield and the contents of oil. The results exhibited that the highest seed yield was achieved in plots where 90 kg P ha^{-1} was applied. Cheema *et al.* (2001) [14] reported that phosphorous at the rate of 60 kg P ha^{-1} produced the highest growth and production of canola (*Brassica napus* L.). Similarly, Nutall *et al*. (1992) [39] also conducted an experiment to assess the response of canola under different application rates of phosphorus. They used five phosphorus ranks i.e 0, 10, 20, 30, and 40 kg P ha^{-1}. They also determined that the yield of canola boosted significantly under all tested applied rates of phosphorous. However, among all the applied levels of phosphorous, the 40 kg P ha^{-1} produced maximum yield of grain and straw.

According to Lickfett *et al.* (1999) [33] established that maximum contents of oil and low protein attained with the increasing phosphorus level. A research experiment was carried out by Brennan and Polland (2004) [11] to examine the impact of phosphorus fertilizer on canola growth and productivity. Phosphorus fertilizer levels were 0, 5, 10, 15, 20, 40, 86 kg P ha^{-1}. The results exhibited that at 15 kg P ha^{-1} recorded 90% of maximum yield of canola crop. Karamanos *et al*. (2014) [30] led an investigation to measure the impact of different levels of phosphorous on plant growth and yield of various crops. The five different phosphorus rates (0, 15, 30, 45, and 60 kg P ha^{-1}) was applied on canola, spring wheat and barley. Results of the study exhibited that growth and yield was enhanced with phosphorus application in all studied crops. Meanwhile, canola did not illustrate significant reaction to phosphorus levels, but wheat and barley exhibited significant response. Chaubey *et al*. (2000) [13] conducted an experiment to evaluate the impact of phosphorus on green gram and reported that nodules dry weight per plant was improved with the use of phosphorus up to 50 kg ha^{-1} after 30 days of sowing and up to 25 kg ha^{-1} after 50 days of sowing. Another increase in phosphorus up to 100 kg ha^{-1} has not been shown to be useful for nodulation at any phase of the green gram. The application of SSP after 30 days of sowing significantly increased the dry weight of the plant. Substantial alterations were perceived due to the phosphorus source after 50 days of sowing. A linear increase in cereal productivity was recorded as an increase in phosphorus levels. The uppermost yield was attained at 100 kg ha^{-1} however; the grain produce improved expressively up to 50 kg ha^{-1}. Phosphorus sources showed a momentousrise with the SSP application over DAP. When phosphorous was applied as SSP the highest grain yield was observed. The straw yield of green gram improved markedly with increasing phosphorus rates at 75 kg ha^{-1}. Agrawal *et al.* (2000) [1] performed an experiment to examine the impact of phosphorous and sulfur on yield and nutrients uptake of sunflower. The four different levels of phosphorous were used as diammonium phosphate and sulfur as elemental sulfur in this research trial. Results of the research experiment indicated that stover and seed yields were augmented up to the uppermost levels of phosphorous and sulfur, but this enhancement was substantial only up to 40 kg S and 60 kg P/ha.

Effect of phosphorous on growth and yield of soybean

The fertilization of an adequate amount of phosphorus promotes root growth, ensures strong formation of plant, rapid physiological maturity, flowering, support seed formation, improve cold tolerance and ultimately enhanced the crop productivity (Malavolta, 1989) [36]. The solicitation of fertilizers is considered the most imperative feature in improving the produce of crop. Amongst the many factors that can subsidize to the success of soybean, phosphorus has significant implications on growth and yield attributes (Kumaga and Ofori, 2004) [31]. The sharp increase in soybean crop yields is partly due to the balanced fertilization and good cultural practices (Modali, 2004) [38]. Small quantity of phosphorus in the soil is a key obstacle to the growth as well as seed production of soybean. The phosphorus application increased from 60 to 350 kg P_2O_5 per hectare and yield of soybean augmented by almost 18%. Whereas, increasing application of phosphorous to 975 kg P_2O_5/ha has no increase in seed productivity, but has an impact on quality of seed (Antunovic *et al*., 2012) [3]. To expand the progress and enlargement of plants with increase in phosphorus, this is dependent on the supply to the seed, thus ultimately gaining more weight (Devi *et al*., 2012) [16]. A research trial conducted by Kamara *et al.* (2008) [28] to scrutinize the impact of several rates of phosphorous on various attributes of soybean cultivars. The experiment was performed under split plot arrangement. The different rates of phosphorous (0, 20 as well as 40 kg P ha^{-1}) applied in core plot and 04 cultivars of soybean placed in subplot. The application of phosphorous at 20 and 40 kg P ha^{-1} improved the yield of dry matter production of all cultivars of soybean. However, among all the phosphorous level the maximum increase in the yield of all tested cultivars was perceived when 40 kg P ha^{-1} was used. Matusso and Cabo (2015) [37] conducted 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 documented under 40 kg P_2O_5 ha^{-1} was exerted. Meanwhile, in case of biomass, weight of 100 seeds and grain return were attained higher with solicitation of 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.

Dhage *et al.* (2014) [17] directed two years research trial to estimate the impact of S and P on yield, availability of nutrients, plant nutrient uptake and content at harvest stages of soybean. They applied four rates of phosphorus as diammonium phosphate and four rates of sulfur as elemental sulfur. The results showed that the seed and straw yield were improved and absorption of phosphorus and sulfur was also enhanced by increasing the application rates of sulfur and phosphorus applied as individual or in different combination. The yield components of soybean such as straw, seed and total biological yield enhanced pointedly with increased levels of sulfur and phosphorus. Moreover, the interactive impact of the sulfur and phosphorus was highest on biological yield with 60 + 90 kg $ha^{-1}$of S and P respectively over control treatment. Begum *et al.* (2015) [7] studied the role of nitrogen and phosphorous on soybean. They applied phosphorus at 0, 18, 36 and 54 kg P ha^{-1} and nitrogen at 0, 25 and 40 kg N ha^{-1} on soybean. By the application of different rates of phosphorous and nitrogen fertilizer the soybean growth and yield attributes responds significantly. Overall results of the experiment indicated that collective application of N + P at 25and 54 kg ha^{-1} respectively produced highest values of all agronomic attributes as compared to all individual or combination of treatments. To investigate the impact of different doses of phosphorus and nitrogen on growth, yield, its contributing components as well as economics of Soybean, a three years field trial was directed by Lad *et al*. (2014) [32]. The 0, 25, 50 and 75 kg P_2O_5 ha^{-1} of phosphorous levels and 0, 50, 100 and 150 kg ha^{-1} of nitrogen were considered the treatments in the research experiments. The findings of the experiment designated that all levels of N and P found beneficial for the growth and yield of French bean. A great rise in the produce and its components was noted with rise in the level of phosphorous and nitrogen. They reported that uppermost dose of nitrogen 150 kg N ha^{-1} and phosphorous 75 kg P_2O_5 ha^{-1} produced maximum values of straw and grain yield and these doses recorded statistically similar results to 100 kg N and 50 kg P_2O_5 ha^{-1}application. A two years research experiment was performed by Mahamood *et al*. (2009) [34] to determine the growth and grain yield responses of soybean genotypes to different rates of phosphorous fertilizer. The twelve cultivars of soybean were placed in main plots and two rates of phosphorous fertilizer (0 and 30 kg P ha^{-1}) organized in sub-plots. It is clearly showed that during both years of the study several parameters like branches of plants, height as well as rate of growth differed expressively between genotypes and a great enhancement in these attributes were also observed with the application of phosphorous fertilizer. The results also exposed considerable differences in yields of grains among genotypes at 0 kg P ha-1, signifying deviations in phosphorous proficiency of the genotypes at lower glassy of phosphorous. It is assumed that P application impart constructive impact on various attributes of tested crop. Similarly, the number of pods in each plant varied significantly between genotypes and increased with phosphorus application during the both years. The outcomes of study also exhibited significant changes in grain yield of genotypes at 0 kg P ha^{-1}, indicating differences in phosphorus utilization efficiency at low phosphorus rates. Turuko and Mohammed (2014) [42] conducted a study on common beans (*Phaseolus vulgaris* L.) to examine common bean responses to different levels of phosphorus fertilizers and their effects on growth, dry matter yield and yield components of crop. Results of the study revealed that phosphorus had a significant effect dry substance production, yield and development rebukes while it impact was non-significant on height of the plant. In conclusion, it is recommended to apply 20 kg P ha^{-1} to improve the yield of common beans. Ikeogu and Nwofia (2013) [25] conducted a two-year field study to evaluate the impact of phosphorus fertilizers on yield, yield components, and yield stability of five soybean cultivars. Phosphorus levels from 0 to 40 Kg/ha was dispersed as triphosphate (TSP, 20% P) at random on sub-plots and five soybean varieties to main-plots. Results of the study showed that yield and its contributing traits was significantly improved by augmented the rates of phosphorus and tested cultivars of soybean also varied significantly in response to fertilizer application. The highest rate of phosphorous (40 kg/ha) produced the maximum values of seeds/plant, pods/plant as well as seed produce. Overall results of the experiment indicated that under diverse phosphorous rates the two varieties of soybean (TGX 1911-13F and TGX 1420-2E) were performed firmly however, noted highest values with 40 kg/ha of phosphorus application. A research investigation was initiated by Dhage *et al*. (2014) [17] to estimate the impact of S and P on yield, availability of nutrients, plant nutrient uptake and content at harvest stages of soybean. They applied four rates of phosphorus and four rates of sulfur. The results showed that the seed and straw yield were improved and absorption of phosphorus and sulfur was also enhanced by increasing the application rates of sulfur and phosphorus applied as individual or in different combination. The yield components of soybean such as straw, seed and total biological yield enhanced pointedly with increased levels of sulfur and phosphorus. Moreover, the interactive impact of the sulfur and phosphorus was highest on biological yield with 60 + 90 kg ha-1 of S and P respectively over control treatment. Chiezey (2001) [15] reported that low level of phosphorous in soil decrease the yield of soybean. Shahid *et al.* (2009) directed an investigation to evaluate the performance of soybean in response to numerous rates of phosphorous and rhizobium japonicum. The phosphorus rates were 0, 25, 50, 75 and 100 kg ha^{-1} and soybean seed injected with rhizobium japonicum. Outcomes of this particular research indicated that higher rate of phosphorous 100 kg ha^{-1} produced significantly highest pod length, pods/plant, biological and oil yield as well as harvest index as compared to all other treatments. The soybean seed inoculated with rhizobium also gave maximum yield and its components over non-inoculated seed.

Effect of phosphorus on quality and oil contents of soybean

Several researchers have point out that the use of phosphorus significantly improves the oil content of many oilseed crops (Brennan and Polland, 2004) [11]. Two years field experimentation was executed by Kanojia and Sharrma (2009) [29] to assess the influence of altered rates of phosphorous on yield and quality characteristics of soybean (*Glycine max* L.) under field condition during 2003 and 2004. They used four rates of phosphorous fertilizer (0, 20, 40 and 60 kg P_2O_5 ha^{-1}). A significant increase in the quality parameters of soybean was observed by enhancing the rate of phosphorous from 0 to 60 kg P_2O_5/ha. The offer of 60 kg P_2O_5/ha produced the uppermost protein and oil contents (40.7 and 19.7%) respectively as compared to all other levels of phosphorous. To determine the impact of numerous levels of phosphorous and nitrogen on soybean a field test was laid out by Jahangir *et al*. (2009) [26]. The treatments were entailing of three levels of phosphorous (0, 10, 20 and 30 kg P/ha) and three ranks of nitrogen (0, 20, 30 and 40 kg N/ha). The alone phosphorous application improved the soybean oil contents with 30 kg P/ha than all other treatments. The nutrient contents such as phosphorus, potash and nitrogen in the seed and straw of soybean varied significantly in response to phosphorous and nitrogen treatments. The oil contents % and soybean yield were obtained highest with collective 30 kg P/ha + 40 kg N/ha application over all other levels. Bodkhe *et al*. (2014) [9] directed a trial to determine the response of soybean to diverse levels of fertilizer on growth, yield and its components in 2009 and 2010. Results of the research was exposed that highest improvement in soybean quality was observed with applied fertilizers on the basis of soil test in recommended practice, which ultimately cause improvement in the growth and yield donating attributes that are liable for higher yield to test the consequences of various rates of sulfur and phosphorus on yield and quality of the soybean (*Glycine max* L.) seeds a field trail was directed by Mahmoodi *et al.* (2013) [35]. They used four different rates of phosphorus (0, 30, 60, 90 kg P ha^{-1}) as a first factor and three sulfur ranks (0, 20, 40 kg S ha^{-1}) as a second factor. Results of the experiment clearly indicated that by increasing the doses of phosphorous from 0 to 90 kg P ha^{-1} the oil contents of soybean improved meaningfully. However, the highest values of seed oil contents (17.48%) noted where 90 kg P ha^{-1} was smeared.

Conclusion

It is concluded that phosphorous is more important than other nutrients to increase the yield of soybean. Phosphorus is considered as the crucial component and has proven to be vital for the development, growth and productivity of soybean. The optimum dose of phosphorous is required to improve the production of oil seed crops. The dose depends upon the cultivar used, soil and availability of available phosphorous.

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