

## **Review Article**

### **Effect of Phosphorus Application on Growth, Phenology, Yield and Quality, Nutrient Uptake and Economics of Groundnut (*Arachis hypogaea* L.): A Review**

**Abstract:** The phosphorus in legumes plays an essential role as part of the membrane system of the cell, chloroplast and the mitochondria. Plants use it for energy transfer in metabolic processes such as photosynthesis (in the form of ATP and ADP), starch and sugar transformation and nutrient movement. In addition to promoting cell division and the development of good root systems phosphorus plays an important role for ensuring timely and uniform ripening of crops, promoting carbohydrate breakdown for energy release, and hastening maturity, it is an essential component for ensuring the growth and maturity of plants. Phosphorus is one of the principal nutrients, which boosts root growth, thus facilitating water and nutrient uptake from deeper layers of the soil. Phosphorus increases root growth and thus accelerates growth of oilseed plants. The groundnut crop calls for sensible supply of phosphorus for its regular growth. Phosphorus has been found to improve the crop's effective use of soil nutrients and increase biological N fixation by increasing nitrogenase activity.

**Comment [A1]:** These are not covering completely what has been discussed in manuscript.

**Keywords:** Growth, Phenology, Phosphorus, Uptake, Yield, Economics

**Introduction:** Groundnut (*Arachis hypogaea* L.) is one of the best-known oilseed crops which belongs to the family Leguminosae and sub-family Papilionaceae. It is believed that it has been originated in South America. (Hussain *et al.*, 2023). In India, Groundnut is considered the “king of oilseeds”. This oil seed crop is primarily found in tropical and subtropical regions, and is also known as peanut, earthnut, monkey nut and poor men's cashew nut. The global area, production and productivity of groundnut is 29.7 million ha, 50.8 million tonnes and 17.1 quintal ha<sup>-1</sup>, respectively. China is the world's largest producer of groundnut with 4.6 million ha area, 17 million tonnes production and productivity of 37.0 quintal ha<sup>-1</sup> followed by India. (Anonymous, 2020). Groundnut account for 31.7% of India total oilseed production and about 28.3 % of the cultivated area of total oilseeds (Ali *et al.*, 2021). Groundnut covers an area of 4.8 million ha with production of 9.9 million tonnes and productivity of 20.6 quintal ha<sup>-1</sup> in India during 2019-20. (Anonymous 2020). The major groundnut producing states in India are Gujrat, Rajasthan and Tamil Nadu. Phosphorus is considered a crucial mineral fertilizer for the flourishing production of the crop (Hasan *et al.*, 2021). Both organic and inorganic forms of phosphorus are found in soils, and the relative amounts of each form vary substantially amongst soils. Because it is strongly bound to soil colloids, organic P is typically not available for plant uptake unless it is broken down and released during the mineralization process (Filippelli, 2002). Plants can access phosphorus in its inorganic forms (H<sub>2</sub>PO<sub>4</sub><sup>-</sup> and HPO<sub>4</sub><sup>-</sup>), but very little of it is present in soil solution (Weil and Brady, 2017). Moisture and temperature have a major impact on the chemistry of P cycling in soils, which is quite complex. To meet the nutrient requirements of plants at each stage of their growth cycle, Labile P one of many potential forms of phosphorus must be supplemented regularly. By adding inorganic P fertilisers, the concentration of phosphorus in the soil solution is increased (Sikka *et al.*, 2022). For the synthesis of chlorophyll, phosphorus is an essential component. For cell division and the growth of meristematic tissue, phosphorus is considered

**Comment [A2]:** Short introductory discussion on ground nut-phosphorus relationship is highly recommended to justify the title of the topic.

**Comment [A3]:** Discussion on role of phosphorus in plant in detail is required.

**Comment [A4]:** Add reputed organizational report as reference for these data (eg. National Agricultural data base of India or International report)

**Comment [A5]:** Add reputed organizational report as reference for these data (eg. National Agricultural data base of India)

an essential component of the cell nucleus (Kumar *et al.*, 2016). By fixing atmospheric nitrogen within its root nodules, the groundnut crop improves soil fertility. Application of phosphorus determines plant reproductive efficiency and promotes plant growth, development and yield (Kamalet *et al.*, 2023). Available literature on the effect of phosphorus in groundnut is presented under following sub-heads.

## Effect of Phosphorus on

### Growth parameters

Hinduja *et al.* (2020) avouched that application of 70 kg/ha Phosphorus + 40 kg/ha Sulphur in groundnut significantly increase plant height (60.3 cm), number of nodules (79.88 plant<sup>-1</sup>) and dry matter accumulation (32.02 g plant<sup>-1</sup>) in groundnut which was significantly higher over 40 kg/ha phosphorus + 20 kg/ha sulphur by 3.8, 16.1 and 14.8 per cent, respectively. Tekulu *et al.* (2020) conducted study in Ethiopia and observed that application of 30 kg N and 69 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> was highly correlated and produced highest plant height (56.1 cm), which was significantly higher over other treatment combinations. Lroet *et al.* (2019) conducted a field experiment in Nigeria and revealed that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly improved plant height of groundnut (34.6 cm) over 40 kg P<sub>2</sub>O<sub>5</sub>, 20 kg P<sub>2</sub>O<sub>5</sub> and 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 19.0, 33.3, 62.9 per cent, respectively.

Kalegore *et al.* (2018) averred that application of 30 kg P ha<sup>-1</sup> in sesame produced highest plant height (104.2 cm), number of functional leaves (80 plant<sup>-1</sup>), leaf area (18.8 plant<sup>-1</sup>), number of branches (4.2 plant<sup>-1</sup>), dry matter accumulation (19.6 g plant<sup>-1</sup>), which were significantly higher over 25 kg P and 20 kg P ha<sup>-1</sup> by 9.5, 9.5, 6.8, 10.5, 13.9 and 13.0, 33.3, 16.0, 13.5, 25.6 per cent, respectively. Pagalet *et al.* (2017) conducted research at U.P. in sesamum and reported that application of 20 mg P<sub>2</sub>O<sub>5</sub>/kg in soil produced higher plant height (139.3 cm) and chlorophyll content at 60 DAS (32.4 SPAD value), which were significantly higher over 0 mg P<sub>2</sub>O<sub>5</sub>/kg in soil by 6.5 and 3.8 per cent, respectively.

Khaswanet *et al.* (2016) conducted a field experiment at Rajasthan in soyabean and investigated that application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased leaf area index at 60 DAS (3.4), chlorophyll content at 60 DAS (2.8 %), crop growth rate at 30-60 DAS (18.8 g/m<sup>2</sup>/day) and at 61-90 DAS (11.9 g/m<sup>2</sup>/day), which were significantly higher over 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 15.0, 17.1, 30.7 and 55.5 per cent, respectively. Sibhatu *et al.* (2016) conducted research at Ethiopia and professed that application of phosphorus @ 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced highest plant (23.5 cm), which was statistically at par with application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and significantly higher over 20 kg, 10 kg and 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 19.8, 22.1 and 46.1 per cent, respectively.

Singh and Thenua (2016) conducted a field experiment at U.P. in mustard and avouched that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher plant height (146.7 cm), number of primary branch (6.75 plant<sup>-1</sup>), number of secondary branch (10.9 plant<sup>-1</sup>) and dry matter accumulation (29.3 g plant<sup>-1</sup>), which were significantly higher over control by 6.0, 14.0, 13.2 and 5.4 per cent, respectively. Mahanta *et al.* (2014) conducted an experiment at IARI, New Delhi in soyabean and asserted that application of 34.9 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced highest specific root length at flower initiation stage (6.91 m g<sup>-1</sup>) and root diameter at flower initiation stage (0.52 mm), which was significantly higher over 17.5 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + PSB by 2.8 per cent and 0.57 percent, respectively.

Singh *et al.* (2014) conducted an experiment on groundnut at Morena (MP) and reviewed that application of 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produce higher plant height (66.5 cm), number of primary branch (9.2 plant<sup>-1</sup>), number of secondary branch (21.5 plant<sup>-1</sup>), number of root nodules (174 plant<sup>-1</sup>), dry weight of root nodules (549 mg plant<sup>-1</sup>), tap root length (14.1 cm) and dry weight of root (6.68 g plant<sup>-1</sup>), which were significantly higher over control by 34.1, 33.3, 35.2, 43.8, 44.0, 74.0 and 54.2 per cent, respectively. Akter *et al.* (2013) conducted

**Comment [A6]:** Any experiment with sole phosphorus application should be discussed first and then combination treatments can be discussed for any of these traits.

**Comment [A7]:** Considering the fact that it is a review paper and groundnut-phosphorus relationship is the main theme, it is strongly suggested to remove discussion on effect of phosphorus on any other crops and collect more references on ground nut only.

**Comment [A8]:** During discussion always mention the variety used and location of the experiment for more detailed information as it is a review paper.

a study at Dhaka in soyabean and examined that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced highest plant height (68.5 cm), which was 6.9 per cent higher over control. Hemalatha *et al.* (2013) reviewed that application of 120 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced highest plant height (29.6 cm) in groundnut, which was significantly higher over 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 15.5 per cent.

Kabir *et al.* (2013) stated that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> in groundnut produce higher plant height (59.6 cm), number of branches (7.5 plant<sup>-1</sup>), dry weight (32.0 plant<sup>-1</sup>), crop growth rate (21.0 g/m<sup>2</sup>/day) between 70-100 DAS and leaf area index (1.7), which were significantly higher over control by 26.4, 20.9, 15.6, 15.5 and 17.3 per cent, respectively. Singh *et al.* (2013) opined that application of 20 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O/ha progressively increased root length, shoot length and seedling length of groundnut, which were significantly higher over control by 43.1, 48.7 and 42.7 per cent, respectively. Kamara *et al.* (2011) adduced that in groundnut application of 40 kg P<sub>2</sub>O<sub>5</sub>/ha produced highest plant height (42.3 cm), which was significantly higher over control by 14.0 per cent. Karunakaran *et al.* (2010) conducted a field experiment at Tamil Nadu in groundnut and testified that application of 125 % RDF (17 kg N + 34 kg P<sub>2</sub>O<sub>5</sub> + 54 kg K<sub>2</sub>O/ha) increase height of plant (51.8 cm) as compare to RDF (48.3 cm). Shiyam (2010) concluded that increasing the levels of phosphorus up to 50 kg ha<sup>-1</sup> has significant effected plant height and highest plant height (56 cm) was found with application of 50 kg P ha<sup>-1</sup>.

Kumar and Yadav (2007) conducted an experiment in mustard and examined that application of 39.3 kg P ha<sup>-1</sup> produced higher plant height (172.1 cm), number of primary branch (6.5 plant<sup>-1</sup>), leaf area index (5.0) and dry matter accumulation (61.7 g plant<sup>-1</sup>) which were significantly higher over control by 11.7, 22.6, 6.3 and 49.7 per cent, respectively. Rao and Shaktawat (2001) carried out an experiment at Udaipur, Rajasthan and averred that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher number of branches plant<sup>-1</sup> (4.70), leaf area index (4.41), root dry weight plant<sup>-1</sup> (0.72 g), which were significantly higher over 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 2.2, 2.5, 1.3 and 9.3, 8.6, 9.8 per cent, respectively.

### **Phenology**

Tekulu *et al.* (2020) conducted study in Ethiopia and purported that individual N and P fertilizer rates, as well as combinations of N and P fertilizer rates, had no effect on groundnut phenological parameters such as flowering time and maturity. This could be because biological N fixation provided enough nitrogen for the groundnut plant to begin flowering and maturation. Jahan *et al.* (2019) conducted a study at Bangladesh in sesame and examined that days taken to maturity progressively increase with increasing the levels of phosphorus. Highest days taken to maturity (88.9) noticed with application of 30 kg P ha<sup>-1</sup> while lowest days (86.3) noticed in no application of phosphorus but non-significant increase was noticed among all the levels.

Lroet *et al.* (2019) did a field experiment in Nigeria and professed that non significant variation in germination percentage was recorded between phosphorus fertilizer application rates. However, the control has a greater germination percentage (68.9 %) than the other treatments (20, 40, and 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) and also concluded that phosphorus rates have a significant effect on days to 50% flowering. The application rate of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> resulted minimum number of days for groundnut to reach 50% flowering (27.7 days), 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> reached 50% flowering at the same time (29.5 days), and the control (0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) reached 50% flowering at 30.5 days.

Melese and Dechassa (2017) purported that applying phosphorus and manure to groundnut genotypes Werer 962 and Oldhale had no influence on flowering and maturity. Sibhatu *et al.* (2016) averred that the highest days to 90% physiological maturity of groundnut (99.0) was obtained with application of 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, while significantly lower days to 90 % physiological maturity (91.3) were obtained in no application of phosphorus So, the crop

fertilized with higher application of phosphorus took long time to mature while less phosphorus fertilizer shortened maturity date.

Bala *et al.* (2011) investigated that days to 50% flowering were increased by the application of 30 kg N + 39 kg P<sub>2</sub>O<sub>5</sub> + 39 K<sub>2</sub>O ha<sup>-1</sup> as compared to 10 kg N + 13 kg P<sub>2</sub>O<sub>5</sub> + 13 K<sub>2</sub>O ha<sup>-1</sup>. Kamara *et al.* (2011) conducted research and inferred that the application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> resulted in the highest percent field emergence (85.33), while the application of 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> resulted in the shortest days to 50% flowering (25) and the shortest days to maturity (89). Khan *et al.* (2009) reviewed that the application of 27 kg N ha<sup>-1</sup> + 69 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased the emergence of plants (11.71 plants m<sup>-2</sup>), days to 50% flowering (33.33) and days to maturity (183.28) in comparison with the control treatment.

#### **Yield and Quality**

Jahan *et al.* (2019) conducted a study at Bangladesh in sesame and purported that application of 20 kg P ha<sup>-1</sup> significantly increased seed yield (1581 kg ha<sup>-1</sup>), stover yield (3034 kg ha<sup>-1</sup>), biological yield (4615 kg ha<sup>-1</sup>), harvest index (34.11 %) and oil content (43.9 %) which were statistically at par with application of 30 kg P ha<sup>-1</sup> and significantly higher over control by 36.5, 17.9, 23.6, 10.1 and 12.9 per cent, respectively. Kalegore *et al.* (2018) propounded that application of 30 kg P ha<sup>-1</sup> in sesame produced highest number of seeds plant<sup>-1</sup> (2099), number of seeds capsule<sup>-1</sup> (43.2), weight of capsules plant<sup>-1</sup> (13.6 g), seed yield plant<sup>-1</sup> (5.7 g), weight of capsules plant<sup>-1</sup> (13.6 g), seed yield (728 kg ha<sup>-1</sup>), straw yield (1785 kg ha<sup>-1</sup>), biological yield (2514 kg ha<sup>-1</sup>), which were significantly higher over 20 kg P ha<sup>-1</sup> by 35.3, 21.3, 27.1, 35.7, 27.1, 34.6, 20.2 and 23.9 per cent, respectively.

Choudhary and Yadav (2017) conducted a field experiment at Anand, Gujarat in groundnut and anticipated that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher pod yield (2657 kg ha<sup>-1</sup>) and haulm yield (4467 kg ha<sup>-1</sup>) which were significantly higher over control by 20.3 and 18.9 per cent, respectively. Ikenganyia *et al.* (2017) purported that application of 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher pod yield of groundnut compared to 50 kg P<sub>2</sub>O<sub>5</sub>, 25 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and control by 15, 32 and 54 per cent, respectively. Sagvekare *et al.* (2017) observed that NP fertilizer ratio 0.40 significantly increased number of pods (30.6 plant<sup>-1</sup>), pod yield (3500 kg ha<sup>-1</sup>) and kernel yield (2630 kg ha<sup>-1</sup>) over rest of NP ratio.

Khaswanet *et al.* (2016) conducted intensive research at Rajasthan in soyabean and professed that application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased grain yield (25.9 q ha<sup>-1</sup>), stover yield (37.3 q ha<sup>-1</sup>), biological yield (63.2 q ha<sup>-1</sup>), which were significantly higher over 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 16.4, 11.7, 13.6 and 40.2, 34.3, 36.6 per cent, respectively. Sibhatu *et al.* (2016) conducted research at Ethiopia in groundnut and concluded that increasing the levels of phosphorus up to 20 kg ha<sup>-1</sup> produced higher number of pod (22.6 plant<sup>-1</sup>), seed (3.5 pod<sup>-1</sup>), 100-kernel weight (42.2 g), shelled seed yield (1269 kg ha<sup>-1</sup>) and dry matter yield (3765 kg ha<sup>-1</sup>), which were significantly higher over 10 kg and 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 31.2, 7.53, 1.5, 7.0, 2.0 and 33.9, 24.8, 3.9, 34.0, 16.6 per cent, respectively.

Singh and Thenua (2016) conducted a field experiment at U.P. in mustard and averred that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher number of seeds/siliquae (11.74), test weight (4.4 g), biological yield (38.2 q ha<sup>-1</sup>), grain yield (10.5 q ha<sup>-1</sup>), which were significantly higher over 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 5.8, 6.7, 7.7, 7.0 and 11.0, 13.9, 17.3, 17.8 per cent, respectively. Kumar *et al.* (2015) reviewed that use of N@7 kg/ha by urea at 60 DAS and NP fertilizer ratio will be 0.57 significantly increased total pods per plant (29.53), filled pods per plant (24.27), 100-kernel weight (41.16 g), 100-pod weight (135.33 g) and pod yield (4361 kg ha<sup>-1</sup>) over other NP fertilizer ratio. Yadav *et al.* (2015) asserted that increasing the level of phosphorus up to 27 kg ha<sup>-1</sup> progressively increased number of pods (70.8 plant<sup>-1</sup>), number of kernels (2.0 pod<sup>-1</sup>), pod yield (2.09 t ha<sup>-1</sup>) and haulm yield (3.58 t ha<sup>-1</sup>) which was significantly higher over control by 60.9, 17.6, 38.4 and 39.2 per cent, respectively.

Singh *et al.* (2014) conducted an experiment at Morena (MP) in groundnut and reviewed that application of 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher number of pod (27.7 plant<sup>-1</sup>), pod yield (2535 kg ha<sup>-1</sup>), haulm yield (3103 kg ha<sup>-1</sup>), oil content (43.8 %) and protein content (27.04 %), which were significantly higher over control by 33.8, 48.2, 33.9, 3.9 and 11.8 per cent, respectively. Akter *et al.* (2013) conducted a study at Dhaka in soyabean and asserted that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced highest number of pods (27.73 plant<sup>-1</sup>), number of seeds (80.21 plant<sup>-1</sup>), test weight (93.57 g), grain yield (2.04 t ha<sup>-1</sup>) and biological yield (4.96 t ha<sup>-1</sup>), which were significantly higher over control by 90.3, 47.9, 5.5, 35.0 and 7.1 per cent, respectively.

Hemalatha *et al.* (2013) conducted a experiment at ANGRAU, Hyderabad in groundnut and investigated that phosphorus application ranging from 20-150 kg/ha significantly increased pod yields. Kabir *et al.* (2013) averred that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> in groundnut gave higher number of pods (18.9 plant<sup>-1</sup>), 100-pod weight (110.8 g), shelling (64.2 %), pod yield (2.8 t ha<sup>-1</sup>), biological yield (10.8 t ha<sup>-1</sup>), straw yield (8.02 t ha<sup>-1</sup>) which was significantly higher over 25 kg P<sub>2</sub>O<sub>5</sub> and 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 6.4, 0.8, 1.7, 15.3, 6.1, 3.0 and 14.0, 2.4, 10.6, 36.6, 21.5, 17.2 per cent, respectively.

Akbari *et al.* (2011) carried out a field experiment at Gujarat and reckoned that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased haulm yield, pod yield, shelling out percentage and harvest index of groundnut compared to lower doses of phosphorus. Kamara *et al.* (2011) propounded that increasing the levels of phosphorus up to 40 kg ha<sup>-1</sup> significantly increased pod yield in groundnut compared to other lower doses. Nwokwu (2011) observed significant increase in kernel yield when 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> was used which was significantly higher over control by 39.0 per cent.

John (2010) averred that application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased pod yield, haulm yield and kernel yield of groundnut over control. Elayaraja and Singaravel (2009) avouched that application of 150 % RDF significantly improved haulm and pod yield of groundnut by 2930 and 2196 kg/ha respectively. Naabet *et al.* (2009) observed that the application of 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> resulted in a significant increase in pod and kernel yield as compared to 0 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> but it was statistically equivalent to 90 kg P<sub>2</sub>O<sub>5</sub> and 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>. Shahid *et al.* (2009) conducted a field experiment and revealed that increase the levels of phosphorus up to 100 kg ha<sup>-1</sup> in soyabean progressively increased number of pods (4.9 plant<sup>-1</sup>), pod length (4.09 cm), number of seeds (2.74 pod<sup>-1</sup>), seed yield (1963 kg ha<sup>-1</sup>) and oil yield (380 kg ha<sup>-1</sup>), which were significantly higher over control by 14.8, 31.5, 21.2, 60.5 and 61.8 per cent, respectively.

Kumar *et al.* (2008) averred that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased pod yield compared to 0, 20 and 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>. Rajanikant *et al.* (2008) conducted a field experiment at Hyderabad and purported that application of 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased pod yield and shelling out percentage in groundnut as compare to control. Basu *et al.* (2007) conducted a field experiment at Kharagpur and found that RDF (20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O ha<sup>-1</sup>) significantly increased the pod yield (1465 kg/ha) in groundnut over other treatment combinations. Kausale *et al.* (2007) investigated that increasing the level of phosphorus up to 30 kg ha<sup>-1</sup> in groundnut significantly increased pod yield (2754 kg ha<sup>-1</sup>) over other lower doses of phosphorus. Kumar and Yadav (2007) conducted an experiment in mustard and found that application of 39.3 kg P ha<sup>-1</sup> produced higher number of seed (13.9 siliqua<sup>-1</sup>), test weight (4.7 g), seed yield (1.90 t ha<sup>-1</sup>), stover yield (5.32 t ha<sup>-1</sup>) and oil content (38.18 %), which were significantly higher over control by 20.8, 20.8, 47.2, 6.4 and 4.0 per cent, respectively. Ranjit *et al.* (2007) conducted a field experiment and professed that use of 112.5 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> in groundnut significantly produced higher haulm and pod yield of groundnut 4600 kg ha<sup>-1</sup> and 3500 kg ha<sup>-1</sup>, respectively over control.

Gobarahet *et al.* (2006) avouched that increasing the levels of phosphorus from 30 to 60 kg/ha significantly increased number of pods plant<sup>-1</sup>, 100-kernel weight, kernel yield, protein and oil content in groundnut. Karmakaret *et al.* (2005) conducted an experiment at West Bengal in groundnut and asserted that 30 kg N + 60 kg P<sub>2</sub>O<sub>5</sub> + 20 kg K<sub>2</sub>O ha<sup>-1</sup> produced higher haulm yield (4643 kg/ha) and pod yield (2715 kg/ha) compared to other treatment combinations. Panwar and Singh (2003) reviewed that by application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased pod yield (28.40 q ha<sup>-1</sup>) and harvest index (36.5 %) of groundnut as compared to control. Kachotet *et al.* (2001) examined that application of 25 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increase shelling out percentage, oil content and protein content in groundnut over control.

Kumaran (2001) reviewed that application of RDF (34 kg N + 17 kg P<sub>2</sub>O<sub>5</sub> + 54 kg K<sub>2</sub>O/ha) + FYM as basal @ 12.5 t/ha + 17 kg P<sub>2</sub>O<sub>5</sub>/ha at 30 DAS produced higher number of pods (14.95 plant<sup>-1</sup>) and seed index (30.23 g) which was significantly higher over application of only RDF by 22.8 and 9.5 per cent, respectively. Majumdar *et al.* (2001) conducted a field experiment and stated that application of 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased haulm (4670 kg ha<sup>-1</sup>) and pod yield (3000 kg ha<sup>-1</sup>) of groundnut whereas, oil and protein content was significantly higher over control by 8.3 and 9.7 per cent, respectively. Rao and Shaktawat (2001) carried out an experiment at Udaipur, Rajasthan in groundnut and opined that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> produced higher pod yield (18.54 q ha<sup>-1</sup>), biological yield (50.93 q ha<sup>-1</sup>), oil content (49.2 %), protein content (24.3 %), which were significantly higher over 40 kg and 20 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> by 3.6, 3.9, 2.5, 3.0 and 13.6, 9.3, 5.3, 5.1 per cent, respectively.

#### **Nutrient content and uptake**

Kamal *et al.* (2023) conducted a field experiment at Hisar in groundnut and reported that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> progressively increased N, P, K and S uptake in kernel and haulm, which were significantly higher over 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and control but statistically at par with 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>.

Musa *et al.* (2017) conducted a field experiment at Nigeria in groundnut and reproduced that increasing the levels of phosphorus up to 24 kg ha<sup>-1</sup> progressively increased nitrogen (12.5 kg ha<sup>-1</sup>) and phosphorus (4.6 kg ha<sup>-1</sup>) uptake in haulm, which were significantly higher over control by 50.4 and 38.4 per cent, respectively.

Choudhary and Yadav (2017) conducted a field experiment at Anand, Gujarat in groundnut and averred that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> progressively increased phosphorus content in kernel (0.48 %) and phosphorus uptake by kernel (13.25 kg ha<sup>-1</sup>), which were significantly higher over control by 14.3 and 16.1 per cent, respectively. Chirwa *et al.* (2017) conducted a field experiment at Tanzania and concluded that application of 20 kg N + 30 kg P ha<sup>-1</sup> significantly increased uptake of N, P and Ca compared to other treatment combination and control.

Singh and Thenua (2016) conducted a field experiment at U.P. and inferred that application of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> progressively increased total N uptake (40.0 kg ha<sup>-1</sup>), total P<sub>2</sub>O<sub>5</sub> uptake (10.8 kg ha<sup>-1</sup>) and total S uptake (18.1 kg ha<sup>-1</sup>) in mustard, which were significantly higher over control by 17.5, 17.1 and 17.5 per cent, respectively. Yadav *et al.* (2015) averred that increasing the level of phosphorus up to 27 kg ha<sup>-1</sup> progressively increased uptake of N (120.5 kg ha<sup>-1</sup>), P<sub>2</sub>O<sub>5</sub> (17.7 kg ha<sup>-1</sup>) and K (71.5 kg ha<sup>-1</sup>), which were significantly higher over control by 43.1, 48.6 and 42.7 per cent, respectively.

Singh *et al.* (2014) conducted an experiment at Morena (MP) and avouched that application of 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> progressively increased phosphorus uptake in kernel (9.23 kg ha<sup>-1</sup>) and stover (8.62 kg ha<sup>-1</sup>), which were significantly higher over control by 100.2 and 119.3 per cent, respectively.

Kumar and Yadav (2007) conducted an experiment in mustard and examined that application of 39.3 kg P ha<sup>-1</sup> produced highest uptake of phosphorus (12.9 kg ha<sup>-1</sup>), which was statistically at par with application of 26.2 kg P ha<sup>-1</sup> and significantly higher over 13.1 kg P ha<sup>-1</sup> and control by 24.0 and 46.6 per cent, respectively. Ranjit *et al.* (2007) found that applying 112.5 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased uptake of N, P, K, and Ca compared to lesser phosphorus doses. Mirvatet *et al.* (2006) averred that increasing the phosphorus dose from 30 to 60 kg P<sub>2</sub>O<sub>5</sub> faddan<sup>-1</sup> significantly increase protein and NPK content in kernel of groundnut considerably over control. Deka *et al.* (2001) adduced that applying 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> significantly increased N, P and K uptake in groundnut over control, while 75 and 100 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> had similar results.

### **Economics**

Hinduja *et al.* (2020) adduced that maximum net return (₹ 1,38,787/ha) and benefit cost ratio (1.82) in groundnut were obtained with phosphorus dose 70 kg/ha + sulphur dose 40 kg/ha, which were significantly higher than rest of the treatments. Vali *et al.* (2020) found that application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + 30 kg Zn ha<sup>-1</sup> fetched highest net returns (₹ 1,39,103/ha) and benefit cost ratio (1.8) in groundnut, which were significantly higher over 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + 0 kg Zn ha<sup>-1</sup> by 37.1 and 29.5 per cent, respectively.

Sagvekaret *et al.* (2017) testified that using 30 kg N ha<sup>-1</sup> + 75 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> resulted in a greater net return of (₹ 58,826 ha<sup>-1</sup>) and a benefit cost ratio of (1.78), which was significantly higher over other treatment combinations. Yadav *et al.* (2015) reported that increasing the level of phosphorus up to 27 kg ha<sup>-1</sup> progressively increased net returns (₹ 65,450/ha) and benefit cost ratio (2.54) in groundnut, which were significantly higher over control by 14.1 and 11.9 per cent, respectively.

Singh *et al.* (2014) examined that application of 20 kg N + 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> fetched highest net returns (₹ 30,123/ha) and benefit cost ratio (2.29) in groundnut, which were significantly higher over control by 73.9 and 20.0 per cent, respectively. Vishwakarma *et al.* (2012) reported that highest gross return (₹ 29,000 ha<sup>-1</sup>) and benefit cost ratio (2.23) obtained with application of 30 kg N ha<sup>-1</sup> + 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> + 40 kg K<sub>2</sub>O ha<sup>-1</sup>, while lowest gross return (₹ 12,060 ha<sup>-1</sup>) and benefit cost ratio (1.21) obtained with control.

Patra and Bandyopadhyay (2010) found that 150 percent phosphorus through phosphocompost grade-I had the highest net return (₹ 28590.47), while 100 percent phosphorus through phosphocompost grade-I had the highest B:C ratio (1.68) and they were far more cost-effective than sole application of chemical fertilizer and also combined sources of P application. Kumar and Yadav (2007) averred that maximum net returns (₹ 12,729/ha) and benefit cost ratio (1.10) in mustard obtained with the application of 39.3 kg P ha<sup>-1</sup> and 26.2 kg P ha<sup>-1</sup> respectively, which were significantly higher over 13.1 kg P ha<sup>-1</sup> and control. Rana *et al.* (2005) investigated that maximum net return (₹ 19,214/ha) and benefit cost ratio (3.29) in mustard obtained with application of 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> which was higher over 25 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and control.

### **Conclusion**

It is concluded that phosphorus plays an important role to increase the yield of groundnut. The optimum dose of phosphorus significantly enhanced oil content, protein content, pod yield, haulm yield and prolonged crop maturity besides significant improvement in the performance of various growth parameters and dry matter production in groundnut.

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