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Review article

AN OVERVIEW ON ROLE OF PHOSPHORUS ON GROWTH, YIELD AND QUALITY OF SUNFLOWER (*HELIANTHUS ANNUS* L.)

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Sunflower is an important oilseed crop in India earning lot of revenue. Research on nutritional aspects relating to sunflower cultivation is abundant and is documented comprehensively. However, the role of major nutrients on crop physiology and the effect of these nutrients on growth and yield of oilseed crops in general and sunflower in particular are scanty. Particularly, the role of phosphorus nutrition in alleviating the yield and its attributes, enhancing the quality and quantity of oil production is important. Coupled with the phosphorus uptake in sunflower is also an important aspect for reaping the benefits of phosphorus absorption. It is precisely at this juncture, research on phosphorus nutrition in sunflower and its effect on growth, yield and quality parameters of its oil gains significance. The literature pertaining to these lines of research in sunflower is presented in an elaborative way and is reviewed in this chapter.

1. ROLE OF PHOSPHORUS IN PLANT GROWTH AND DEVELOPMENT

Phosphorus is vital for plant growth and is found in every living plant cell. It is involved in several key plant functions including energy transfer, photosynthesis, transformation of sugars and starches, and nutrient movement within the plant. When P is limiting, the most striking effects are reduction in leaf expansion and leaf surface area, as well as the number of leaves. Shoot growth is more affected than the root growth; nevertheless, root growth is also reduced by inadequate P, leading to less roots mass to reach water and nutrients. Generally, inadequate P slows down the process of carbohydrate utilization, while carbohydrate production through photosynthesis continues.

The amounts of P taken up by different oilseeds to produce 1 tonne of seed were much higher than those for cereals as rice and sorghum, as well as pulses such as chickpea and pigeonpea (Tandon, 1987).

Phosphorus nutrition

Crop growth

Plant Height

Phosphorus application to sunflower has been shown to have positive effect on plant height. Increase in plant height was found to be significant up to 50 kg P2O5 ha^{-1} according to Gaur *et al* (1973). Likewise, significant improvement in plant height in response to P application was also reported by several workers as follows.

Significant Response	Authors
Up to 60 Kg P_2O_5 ha^{-1}	Kene *et al*. (1992); Mishra *et al* (1994); Kumar *et al*. (1995)
Up to 80 kg P2O5 ha^{-1}	Shanthamallaiah *et al*. (1977); Dhaka and Agrawal (1981); Chaniara *et al*. (1989); Tomar *et al* (1997)
Up to 90 kg P2O5 ha^{-1}	Misra and Sen (1986)
Up to 112.5 kg P2O5 ha^{-1}	Prabhuraj *et al* (1993); Shivaprasad and Sheelavantar (1996)
Up to 150 kg P2O5 ha^{-1}	Raju and Verma (1981)

The increased plant height was attributed to increased rate of physiological process and to root penetration and proliferation. On the other hand, Singhi and Pacheria (1981) reported that plant height of sunflower was not significantly influenced by phosphorus application.

Leaf Area

Following seed germination and seedling emergence, sunflower typically initiates and expands maximum number of leaves during a period which may range from 44-60 days (Unger, 1983). Development of adequate leaf area necessary for interception and utilization of incident radiation is important and has been shown to be closely related to final grain yield (Rawson and Tuner, 1982a and 1982b). The total photosynthetic area was significantly increased by application of phosphorus (Gaur *et al*., 1973). Increase in LAI was significant in sunflower at 20 DAS, flowering and at harvest by application of phosphorus up to 30 kg P2O5 ha^{-1}, and further increase in P level resulted in inconsistent increase in LAI (Varghese *et al*., 1976). Similarly, Somasundaram and Iruthayaraj (1979) and Sarmah *et al* (1992) observed significant influence of graded P levels of LAI.

Significant responses in terms of LAI to P application up to 60 kg/ha were also reported by Mishra *et al* (1994) at 60 DAS; Bhowmick *et al*. (1994) up to 40 kg P2O5 ha^{-1}. Kandalkar *et al* (1991); Tomar *et al* (1997) and Singh and Singh (1997) up to 80 kg P2O5 ha^{-1}; Reddy and Mohammed (2000) up to 120 kg P2O5 ha^{-1}. On the other hand, Chaudhari and Paturde (1981) and Chaniara *et al* (1989) reported that LAI was insensitive to phosphorus application.

Stem girth

Phosphorus application @ 60 kg P2O5 ha^{-1} significantly increased the stem girth over control (Kumar *et al*., 1995; and Kathuria *et al*., 1996). Likewise Shiva Prasad and Sheelavantar (1996) observed that application of 125 kg P2O5 ha^{-1} caused significant increase in stem girth of sunflower. Contrary to the above Singhi and Pacheria (1981) noticed no positive influence of P fertilization on stem girth of sunflower.

Dry matter production

Dry matter accumulation in sunflower is a result of leaf and stem growth during vegetative phase, and a combination of capitulum and seed development concurred with shifts in leaf mass during reproductive phase (Andhale and Kalbhor, 1978).

Gangawar and Parameshwaran (1976) observed enhancement in total photosynthetic area with increasing levels of phosphorus which ultimately produced higher dry matter. In the experiments of Adiseshaiah *et al* (1978) dry matter production was not significantly influence by phosphorus application in the first year trial, but was significantly influenced in the second year trial with application of 45 kg P2O5 ha^{-1} . Whereas Mishra *et al* (1995) found response to applied P only up to 40 kg P2O5 ha^{-1} . Likewise, others reported that significant increase in shoot dry matter was registered by increasing P levels up to 60 kg P2O5 ha^{-1} (Misra and Sen, 1986; Shelke *et al*., 1988; Reddy and Reddy, 1975; Kumar *et al*., 1995; Mishra *et al*., 1995) and up to 80 kg P2O5 ha^{-1} (Pal, 1979; Reddy *et al*., 1997).

Contrary to the above, dry matter production of sunflower was not influenced significantly due to phosphorus fertilization (Khokani *et al*., 1993).

Phosphorus nutrition in sunflower on yield attributes

Head Diameter

Significant increase in the head diameter was reported by Gaur *et al*. (1973) by application of phosphorus up to 50 kg P_2O_5 ha^{-1} on a sandy loam soil, beyond this dose, the response was not significant. Adiseshaiah *et al* (1978) and Misra and Sen (1986) also found that increase in head diameter was obtained by increase in the phosphorus level.

Capitulum diameter was significantly superior when P was applied at 60 kg P_2O_5 ha^{-1} over 30 kg P2O5 ha^{-1} and control, but on par with 90 kg P_2O_5 ha^{-1} (Somasundaram and Iruthayaraj, 1981). Further, increase in phosphorus up to 80 kg P_2O_5 ha^{-1} (Dhaka and Agrawal, 1981) also up to 100 kg P_2O_5 ha^{-1} (Shiva Prasad *et al*., 1996), up to 112.5 kg P_2O_5 ha^{-1} (Prabhuraj *et al*., 1993), significantly increased the head size.

However, several investigators also noticed that capitulum diameter was not positively influenced by application of phosphorus (Varghese *et al*., 1976a; Singh and Kaushal, 1975; Gupta and Sharma, 1978; Singhi and Pacheria, 1981; and Patil and Shah, 1983).

Total number of seeds $head^{-1}$.

Application of phosphorus had a significant positive influence on the number of seeds per head of sunflower when applied at 13.3 or 26.4 kg P_2O_5 ha^{-1} (Singh *et al*., 1973).

Several workers have reported positive correlation between seed yield and total number of seeds per head and significant influence of phosphorus on them viz., 40 kg P_2O_5 ha^{-1} (Khan and Hussain, 1996), up to 80 kg P2O5 ha^{-1} (Dhaka and Agrawal, 1981; Chaniara *et al*., 1989), up to 90 kg P_2O_5 ha^{-1} (Khokani *et al*., 1993) and up to 120 kg P_2O_5 ha^{-1} (Tripathi and Kalra, 1980; Megur *et al*., 1993). However, Varghese *et al*. (1976a) and Tripathi and Kaira (1981) reported that no significant influence on the seed number per head was exerted by application of phosphorus to sunflower crop.

Number of filled seeds head-1

The number of filled seeds per head obtained with 60 kg P2O5 ha^{-1} was significantly higher than control treatment according to Gaur *et al* (1973). The sterility percentage of sunflower significantly decreased with increase in P levels in the experiments of Singh and Kaushal (1975) and Misra and Sen (1986). Gupta and Sharma (1978) reported that seed hollowness of sunflower was not influenced by phosphorus levels. Conversely, the work of Gangawar and Parameshwaran (1976) revealed that P application @ 60 kg ha^{-1} resulted in more number of filled seeds $head^{-1}$. So also, number of filled seeds per capitulum was found to be significantly higher with increasing levels of phosphorus i.e., 80 kg P_2O_5 ha^{-1} (Ujjanaiah *et al*., 1989) and 120 kg P_2O_5 ha^{-1} (Megur *et al*., 1993; and Dhoble, 1998).

Test Weight

Test weight is shown to have significant and positive relation with seed yield (Shivakumar *et al*., 1973; and Chandrasekhar, 1998).

Rao and Vidyasagar (1981) observed a linear progressive increase in thousand seed weight from 31.1 to 45.5 g with concurrent increase in P from 0 to 20 kg ha^{-1}. Whereas, Adiseshaiah *et al*., (1978) found significant increase in the test weight up to 45 kg P2O5 ha^{-1} . Similar results were obtained by Gangawar and Parameshwaran (1976), Suraj Bhan (1977), Khokani *et al* (1993) and Sarkar *et al* (1995) wherein significant increase in the test weight of sunflower was registered up to 60 kg P2O5 ha^{-1}. Likewise, Mahadevappa *et al*., (1994) and Shivaprasad *et al* (1996) reported significant increase in test weight of sunflower with progressive increase of P levels from 0 to 100 kg P2O5 ha^{-1} , whereas Prabhuraj *et al* (1993) up to 112.5 kg P2O5 ha^{-1} and Ujjanaiah *et al* (1989) and Megur *et al* (1993) up to 120 kg P2O5 ha^{-1} observed significant response to P in respect of test weight.

Seed yield

Blamey *et al* (1987) found that 5.1 kg P (3.9 kg by seed and 1.2 kg by the stover) was taken up by sunflower crop producing 1 tonne seed/ha.

Seed yield was positively influenced by the application of phosphorus at graded levels (Kanwar *et al*., 1983; Ankineedu *et al*., 1983; DOR, 1984; DOR, 1985; Singh and Venkateswarlu, 1985; Kulkarni *et al*., 1986; Tandon, 1987).

Sunflower being oilseed crop found to respond very well to different levels of P. Gangawar and Parameshwaran (1976) attributed 41 to 48 per cent of seed yield increase in sunflower to P application. Vitikov (1976) observed that application of 60 kg P_2O_5 ha^{-1} increased the seed yield (3.13 t ha^{-1}) and further increase of phosphorus beyond 60 kg ha^{-1} was not significant. Similar results were reported by several workers (Tripathi and Kalra, 1980; Misra and Sen, 1986; Mishra *et al*., 1994; Sathiyavelu *et al*., 1994; Mishra *et al*., 1995; Reddy *et al*., 1997; Tamak *et al*., 1997). Such a response to increasing P levels was ascribed to adequate P supply resulting in better root penetration and proliferation contributing to production of photosynthates and their translocation to sink. Positive response to applied P at different P levels viz., up to 40 kg (Sarmah *et al*., 1992; Dhaka and Agrawal, 1981) up to 45 kg (Habeebullah *et al*., 1986; Shelke *et al*., 1988) up to 50 kg (Hiremath *et al*., 1990) up to 75 kg P_2O_5 ha^{-1} (Shivaprasad *et al*., 1996; Chandrasekhara and Patil, 1997), up to 90 kg P2O5 ha^{-1} (Gowda *et al*., 1979; Somasundaram and Iruthayaraj, 1981; Muralidharudu and Reddy, 1992; Naphade and Naphade, 1992; Ateeque *et al*., 1993; Gopal *et al*., 1995), up to 120 kg P_2O_5 ha^{-1} (Megur *et al*., 1993; Prabhuraj *et al*., 1993; Vivek *et al*., 1993; Dhoble, 1998) and up to 150 kg P_2O_5 ha^{-1} (Raju and Verma, 1981) have been reported.

Contrary to the above, several researchers reported that the seed yield of sunflower was not positively influenced by phosphorus application (Singhi and Pacheria, 1981; Chaudhari and Paturde, 1981; Tanimu *et al*., 1991; Satyanarayana *et al*., 1986; Chaniara *et al*., 1989; Khokani *et al*., 1993; and Narayana and Patel, 1998).

Harvest Index (HI)

Application of 60 kg P_2O_5 ha^{-1} resulted in maximum HI (Sarmah *et al*., 1992). Contrary to this, phosphorus application did not influence the harvest index of sunflower (Mishra *et al*., 1994; Kalra and Tripathi, 1980; and Shivaprasad *et al*., 1996).

Quality characters

Phosphorus is known to play an important role in carbohydrate metabolism and helps in conversion of carbohydrate into oil (Banner and Verner, 1965). Thus, Gangawar and Parameshwaran (1976) reported that the oil content of sunflower seed was significantly increased with the increase in P2O5 levels from 0 to 60 kg P2O5 ha^{-1} . Similar results were also reported by Mishra *et al*. (1995). Similar findings were also reported by Kalra and Tripathi (1980) and Chaudhari and Paturde (1981).

Further, significant increase in oil content was observed at higher levels of P viz., up to 80 kg P2O5 ha^{-1} (Raut and Ghonsikar, 1978; Naphade and Naphade, 1992; Tomar *et al*., 1996a), up to 90 kg P2O5 ha^{-1} (Misra and Sen, 1986; and Maheswarappa *et al*., 1985) and up to 120 kg P2O5 ha^{-1} (Sidhu *et al*., 1991).

However, several investigators reported that the oil content was not at all affected due to P application (DOR, 1987; Lewis *et al*., 1991; Muralidharudu and Reddy, 1992; Khokani *et al*., 1993; Sathiyavelu *et al*., 1994; Sarmah *et al*., 1992).

Phosphorus uptake

Pal (1979) reported that the peak period of P uptake was in between seedling and flowering period. P content in plants increased up to knee high stage and thereafter decreased with crop ontogeny (Kalra and Tripathi, 1980) P uptake increased with increasing level of P application (Rao *et al*., 1984a; Hiremath *et al*., 1990).

Recovery of eleven per cent of applied P was registered in vegetative plant parts (Loubser *et al*., 1990). Graded levels of P significantly increased the N and P uptake both in seed and dry matter yield and the maximum uptake of these nutrients was bracketed at 90 kg P_2O_5 ha^{-1} (Ateeque and Malewar, 1992; Naphade and Naphade, 1992; Ateeque *et al*., 1993; Singh *et al*., 1994a).

According to Kumar *et al*. (1995) phosphorus levels did not show significant effect on P content in both seed and stover, whereas P uptake increased significantly with 60 kg P2O5 ha^{-1} in both seed and stover due to increase in total dry matter yield.

Application of nitrogen @ 60 or 90 kg ha^{-1} without P did not help in increasing the P uptake. Balanced application of 60 kg N and 30 kg P_2O_5 ha^{-1} increased the total P uptake significantly (Bahl *et al*., 1997).

The per cent P utilization showed a decreasing trend with an increase in P dose. It decreased from 14.9 to 10.7 with an increase in total available phosphorus from 40 to 80 kg ha^{-1} At lower level of P application, there was enough competition between the plants to take up P from the limited available P supply leading to higher utilization of the applied P. At higher level, the increased P dose did not lead to proportionate increase in the uptake of applied P leading to lower utilization. Similar observations were also made by other workers (Dravid and Goswami, 1988; Singha *et al*., 1994a; Chandrasekhara and Patil, 1997). On the other hand, Narayana and Patel (1998) observed that phosphorus did not exert any significant difference on P uptake of sunflower.

Priority areas of research at global level on oilseed crops in general and sunflower in particular include the effect of phosphorus on growth, yield and quality. Since, the role of phosphorus in ameliorating these aforementioned parameters is substantial, much more research on these priority areas are to be carried out. The current paper is useful for agricultural researchers in oilseeds in bringing about sizeable positive shift in enhancing the productivity levels of sunflower through phosphorus management.

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REFERENCES

Adiseshaiah, K., Yogeswar Rao, Y. and Sankar Reddi, G. M. 1978. Response of two sunflower varieties to different levels of nitrogen. Oilseeds Journal 8: 11-13.

Andhale, R. K. and Kalbhor, P. N. 1978. Effect of irrigational schedules under varying levels of nitrogen on growth, yield, quality and water use of sunflower (Helianthus annuus L). Journal of Maharastra Agricultural Universities. 3: 200-203.

Ankineedu, G., Rao, J. V. and Reddy, B. N. 1983. Advances in fertilizer management for rainfed oilseeds. Fertilizer News. 28: 76-90.

Ateeque, M. and Malewar, G. V. 1992. Uptake of N, P and B by sunflower as influenced by sources and levels of phosphorus with and without boron. Journal of Soils and Crops 2: 12-14.

Ateeque, M., Malewar, G. V. and More, S. D. 1993. Influence of phosphorus and boron on yield and chemical composition of sunflower. Journal of Indian Society of Soil Science. 41: 100-102.

Bahl, G. S., Pasricha, N. S. and Ahuja, K. L. 1997. Effect of fertilizer nitrogen and phosphorus on the grain yield, nutrient uptake and oil quality of sunflower. Journal of the Indian Society of Soil Science. 45: 293-296.

Banner, J. and Verner, J. E. 1965. Plant Biochem. Academic Press, New York.

Bhowmik, N. N., Sarkar, R. K. and Raui, N. M. 1994. Response of sunflower to phosphorus and potassium application. Indian Agriculturist. 38: 141-143.

Blamey, F. P. C., Edwards, D. G., and Asher, C. J. 1987. Nutritional disorders of sunflower. Department of Agriculture, University of Queensland, St. Lucia, Queensland, Australia. P. 72.

Chandrasekhar, G. S. 1998. Response of sunflower to varied levels of nitrogen and phosphorus in summer season. M. Sc. (Ag.) thesis submitted to Acharya N G Ranga Agricultural University, Rajendranagar, Hyderabad.

Chandrasekhara, C. P. and Patil, V. C. 1997. Influence of VAM inoculation and phosphorus on dry matter production and seed yield of two sunflower (Helianthus annuus L.) genotypes. Journal of Oilseeds Research. 14: 210-215.

Chaniara, N. J., Patel, J. C., Malavia, D. D. and Baldha, N. M. 1989. Effect of irrigation, nitrogen and phosphorus on the productivity of sunflower. Indian Journal of Agronomy. 34: 399-401.

Chaudhari, C. S. and Paturde, J. T. 1981. Effect of nitrogen and phosphorus on seed and oil yield of sunflower. Indian Journal of Agricultural Research. 15: 141-144.

Dhaka, R. V. S. and Agrawal, J. P. 1981. Effect of plant densities and levels of N and P on the yield of sunflower. Agric. Sci. Digest 1(2): 91-93.

Dhoble, M. V. 1998. Response of sunflower hybrids to nitrogen and phosphorus in rainfed conditions. Indian Journal of Agronomy. 43 (1): 138-141.

Directorate of Oilseeds Research. 1984. Rapeseed and mustard, safflower, linseed-package of practices for increasing production. Ext. Bull. 2. Rajendranagar, Hyderabad, India. P. 86.

Directorate of Oilseeds Research. 1985. Groundnut, sesamum, niger, sunflower, castor-package of practices for increasing production. Ext. Bull. 2. Rajendranagar, Hyderabad, India. P. 86.

Directorate of Oilseeds Research. 1987. Annual Progress Report on Sunflower, Hyderabad.

Dravid, M. S. and Goswami, N. N. 1988. Relative efficiency of mustard (Brassica juncea L.) and sunflower (Helianthus annuus L.) in utilizing soil phosphoru in presence of P, Zn and FYM under normal and saline soil conditions. Journal of Nuclear Agriculture and Biology. 17: 18-22.

Gangawar, M. S. and Parameshwaran, P. M. 1976. Phosphorus and sulphur relationship in sunflower and gut of phosphorus on yield. Oilseed Jounral 6 (3): 28-32.

Gaur, B. L., Tomar, D. S. and Trehan, K. B. 1973. A note on the effect of different levels of nitrogen and phosphorus on yield of sunflower. Indian Journal of Agronomy. 18: 109-110.

Gopal, A. N., Subramaniyam, K. S. and Gopalan, A. 1995. Response of sunflower hybrids to nitrogen and phosphorus under irrigated condition. Madras Agricultural Journal 82 (2): 80-83.

Gowda, K. T. K., Seetharam, A. and Venkataramu, M. N. 1979. Response of sunflower hybrids to spacing and fertilizer levels. Current Research. 8: 43-45.

Gupta, H. K. and Sharma, T. R. 1978. A note on the response of sunflower to nitrogen and phosphorus under rainfed conditions. Oilseeds Journal 8: 58.

Habeebullah, B., Muthuvel, P. and Chamy, A. 1986. Studies on continuous cropping of sunflower. Madras Agricultural Journal. 73: 659-660.

Hiremath, B. R., Patil, V. S., Birdar, D. P. and Hunshal, C. S. 1990. Response of sunflower genotypes to levels of nitrogen and phosphorus fertilization. Karnataka Journal of Agricultural Science. 3: 116-119.

Kandalkar, A. B., Bharad, G. M., Wankhade, S. T. and Khan I A. 1991. Effect of levels of plant density, phosphate and irrigation on growth and yield of sunflower. Annals of Plant Physiology. 5: 81-84.

Kanwar, J. S., Nijhawan, H. L. and Raheja, S. K. 1983. Groundnut nutrition and fertilizer responses in India. ICAR, New Delhi. P. 85.

Kathuria, M. K., Habir Singh., Tonk, D. S. and Agarwal, S. K. 1996. Effect of date of sowing and fertility levels on seed and oil yield of sunflower. Haryana Agricultural University. Journal of Research. 126 (1): 39-42.

Kene, H. K., Thosar, V. R., Ulemale, R. B. and Kale, M. R. 1992. Response of sunflower to spacing and nitrogen, phosphorus fertilization. Journal of Maharastra Agricultural Universities. 17: 433-435.

Khan, M. J. and Hussain, H. 1996. Effect of four different moisture stress levels on sunflower in Peshawar, Pakistan. Proceedings of 6th drainage workshop on drainage and the environment, Ljubljaha, Slovenia, April 21-29, pp. 569-576.

Khokani M. G., Ahlawat, I. P. S. and Trivedi, S. J. 1993 Effect of nitrogen and phosphorus on growth and yield of sunflower (Helianthus annuus L). Indian Journal of Agronomy. 38: 507-509.

Kulkarni, J. H., Joshi, P. K. and Sojitra, V. K. 1986. Influence of phosphorus and potassium application on nodulation, nitrogen accumulation and pod yield of groundnut. Legume Research. 9:34-38.

Kumar, S., Singh, A. K. and Vyas, H. K. 1995. Effect of nitrogen and phosphorus application on their uptake and biomass production by sunflower. Annals of Agricultural Research. 16 (4): 513-514.

Lewis, D. C., Potter, T. D. and Wickert, S. C. 1991. The effect of nitrogen, phosphorus and potassium fertilizer on the seed yield of sunflower grown on sandy soils and the production of phosphorus and potassium responses by soil tests. Fetrtilzer Research 28: 185-190.

Loubser, H. L., Grimbeck, C. L. and Bronkhorst, B. 1990. Effect of fertilization on sunflower and N, P and K removal by the crop. South African Journal of Plant Soil. 7: 172-175.

Mahadevappa, K. P., Shambulingappa, K. G. and Basawaraj, G. V. 1994. Role of N and P fertilization on test weight protein and oil per cent and germination of BSFH sunflower. Journal of Seeds and Farms. 11 (1): 23-25.

Maheswarappa, R. P., Shambulingappa, K. G., Basavaraju, G. V. and Ravi Kumar, D. S. 1985. Role of N and P fertilization on test weight, protein, oil and germination of BSH-1 sunflower-seeds and farms. 10: 23-25.

Megur, N. C., Prabhakar, A.S., Hosmani, M. M. and Kalashatagi, S. B. 1993. Effect of nitrogen and phosphorus on growth and grain yield of sunflower. Journal of Oilseeds Research. 10: 127-128.

Mishra, A., Das, P. and Paikaray, R. K. 1994. Performance of sunflower in relation to nitrogen and phosphorus in acid soils of Orissa. Journal of Oilseeds Research. 11: 288-290.

Mishra, A., Dash, P and Paikaray, R. K. 1995. Yield and nutrient uptake by winter sunflower (Helianthus annuus L) as influenced by nitrogen and phosphorus. Indian Journal of Agronomy. 40: 137-138.

Misra, N. M. and Sen, A. 1986. Phosphorus and potash fertilization studies on sunflower. Madras Agricultural Jounral. 73: 163-165.

Muralidharudu, Y. and Reddy, B. N. 1992. Effect of sources and levels of phosphorus on yield and quality of hybrid sunflower under rainfed conditions in udic ustochrept. Annals of Plant Physiology. 6: 9-14.

Naphade, P. S. and Naphade, K. T. 1992. Effects of phosphorus on uptake of nutrients in sunflower. Annals of Plant Physiology. 6: 119-124.

Narayana, E. and Patel, J. C. 1998. Response of sunflower to fertilizers and water. Fertilizer news. 43 (7): 53-55.

Pal, M. 1979. Drymatter production and N, P and potash uptake in sunflower varieties as influenced by soil moisture regimes and fertility levels. Indian Journal of Agricultural Chemistry. 12: 61-67.

Patil, J. R. and Shah, C. B. 1983. Effect of nitrogen and phosphorus on sunflower seed yield under rainfed conditions. Madras Agricultural Journal 70 (4): 242-245.

Prabhuraj, D. K., BAdiger, M. K. and Manure, G. R. 1993. Growth and yield of sunflower (Helianthus annuus L) as influenced by levels of phosphorus, sulphur and zinc. Indian Jounral of Agronomy. 38: 427-430.

Raju, M. S. and Verma, S. D. 1981. Effect of fertilizer rates and plant spacing on sunflower yield and yield components. The Andhra Agricultural Journal. 28: 47-49.

Rao, G. V. and Vidyasagar, C. 1981. Effect of nitrogen, phosphorus and potassium along with foliar and soil applied boron on sunflower (Helianthus annuus L.). I. Growth, yield oil content and varietal performance. The Andhra Agricultural Journal. 28: 150-155.

Rao, I. V. S., Danuel Babu, M. and Reddy, P. R. 1984a. Effect of phosphorus and Rhizobium on groundnut. The Andhra Agric J. 31: 253-254.

Raut, R. S. and Ghonsikar, C. P. 1978. Effect of phosphorus and sulphur levels on yield and oil content of sunflower. Oil Seeds Journal. (1-4): 36-38.

Rawson, H. M. and Turner, N. C. 1982a. Recovery from water stress in five sunflower (Helianthus annuus L) cultivars 1. Effect of timing of water application on leaf area and seed production. Australian Journal of Plant Physiology. 9: 437-438.

Rawson, H. M. and Turner, N. C. 1982b. Recovery from water stress in five sunflower (Helianthus annuus L).cultivars. II. The development of leaf area. Australian Journal of Plant Physiology. 9: 449-460.

Reddy, G. V. and Reddy, G. H. S. 1975. Multiple cropping. Journal of Research. Andhra Pradesh Agricultural University. 11 (3&4): 126-132.

Reddy, P. K. and Mohammed, S. 2000. Influence of nitrogen and phosphatic fertilizer on growth, yield components and yield of sunflower. Crop Research 20: 293-296.

Reddy, P. V., Raju, A. S., Rao, A. P. and Sultana, F. 1997 Response and utilization of phosphorus by sunflower. Journal of Nuclear Agricultural Biology 26: 181-184.

Sarkar, R. K., Chakraborty, A. and Bala, B. 1995. Response of sunflower crop to geometry and nitrogen and phosphorus application. Indian Journal of Agronomy. 40 (4): 657-659.

Sarmah, P. C., Katyal, S. K. and Verma, O. P. S. 1992. Growth and yield of sunflower varieties in relation to fertility level of plant population. Indian Journal of Agronomy. 39: 76-78.

Sathiyavelu, A., Pannerselvam, R., Arunachalam, L. and Purushothaman, S. 1994. Effect of nitrogen, phosphoru and potassium on yield of sunflower (Helianthus annuus L.) under rainfed conditions. M. Sc. (Ag.) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Satyanrayana, V., Reddy, E. V. R. and Dutt, K. V. L. N. 1986. Effect of graded levels of nitrogen, phosphoru and plant spacings on sunflower. Journal of Oilseeds Research. 3: 116-119.

Shanthamallaiaah, N. R., Shivaraj, B., Patil, N. M. and Veranna, U. S. 1977. Effect of plant population and fertilizer levels on growth, yield and yield components in sunflower. Mysore Journal of Agricultural Sciences. 11: 477-480.

Shelke, V. B., Shinse, V. S., Dahiphale, V. S. and Chavan, D. A. 1988. Effect of levels of nitrogen, phosphorus and potassium on growth and yield of rabi sunflower. Journal of Oilseeds Research. 5: 140-143.

Shiva Prasad, M. and Sheelavantar, M. N. 1996. Response of rabi irrigated sunflower hybrid (KBSH-1) to sowing dates, nitrogen and phosphorus levels. Journal of Agricultural Sciences 9(4): 581-585.

Shivakumar, A. G., Hosagerappa, K. J., Yadahalli, Y. H. and Kurdikeri, C. B. 1973. Response of sunflower to spacing and fertilizer levels. Mysore Journal of Agricultural Science. 7: 314-315.

Shivaprasad, M., Sheelavantar, M. N., Kulkarni, B. S., Harish Shenoy and Satish Patil. 1996. Effect of sowing dates and phosphoru levels on performance of rabi irrigated sunflower. Farming Systems. 12: 30-36.

Sidhu, M. S., Sahota, T. S., Sharma, B. D. and Sawhney, J. S. 1991. Nitrogen and phosphorus requirements of sunflower as affected by different cropping systems and agronomic practices. Fertilizer News. 26: 35-38.

Singh, K. P. and Singh. J. 1997. Integrated nutrient management in sunflower. Indian Journal of Agronomy. 42 (2): 370-374.

Singh, P. P. and Kaushal, P. K. 1975. Effect of nitrogen and phosphorus rates and spacings on the seed yield and yield attributing characters of sunflower. Mysore Journal of Agricultural Sciences. 9: 660-663.

Singh, P. P., Sharma, Y. K., and Kaushal, P. K. 1973. Effect of varying levels of N and P on yield and quality of sunflower. JNKVV Research Journal. 2: 134-136.

Singh, R. P. and Venkateswarlu, J. 1985. Role of All India Coordinated Project for Dryland Agricultural Research Development. Fertilizer News. 30: 43-55.

Singh, S., Dutta, O. and Pal, D. 1994a. Utilization of phosphate from different phosphorus carriers by sunflower (Helianthus annuus L.). Agricultural and Biology. 23: 238-241.

Singhi, S. M. and Pacheria 1981. Effect of varying row spacing nitrogen and phosphorus levels on sunflower. Indian Journal of Agronomy. 26: 20-23.

Somasundaram, S. and Iruthayaraj, M. R. 1979. Effect of irrigation and phosphorus levels on growth analysis parameters in (Helianthus annuus L). Madras Agricultural Journal 66: 783-788.

Somasundaram, S. and Iruthayaraj, M. R. 1981. Effect of irrigation regimes and phosphorus levels on yield attributes in sunflower (Helianthus annuus L). Indian Journal of Agricultural Research. 15: 212-215.

Suraj Bhan, B. 1977. Studies on the optimum scheduling of irrigation, row spacing and fertilizer dose for sunflower in central tract of Uttar Pradesh. Indian Journal of Agronomy. 22: 212-216.

Tamak, J. C., Sharma, H. C. and Singh, K. P. 1997. Effect of phosphorus, sulphur and boron on seed yield and quality of sunflower (Helianthus annuus L.). Indian J. Agron. 42: 173-176.

Tandon, H. L. S. 1987. Phosphorus research and agriculture production in India. Fertilizer development and consultation organization. New Delhi pp. 142-154.

Tanimu, B., Yayock, J. Y. and Ado, S. G. 1991. Effect of nitrogen, phosphorus and potassium on the performance of sunflower (Helianthus annuus L.). Crop Research 4 (1): 1-10.

Tomar, H. P. S., Dadhwal, K. S. and Singh, H. P. 1996a. Oil content, oil and cake yield and protein content of sunflower (Helianthus annuus L.) as influenced by irrigation, nitrogen and phosphorus levels. Indian Journal of Soil Conservation. 24: 215-220.

Tomar, H. P. S., Singh, H. P. and Dadhwal, K. S. 1997. Effect of irrigation, nitrogen and phosphorus on growth and yield of spring sunflower (Helianthus annuus). Indian J. Agron. 42: 169-172.

Tripathi, P. N. and Kalra, G. S. 1980. Effect of NPK on maturity and yield of sunflower. Indian Journal of Agronomy. 26: 66-70.

Tripathi, P. N. and Kalra, G. S. 1981. Effect of NPK on maturity and yield of sunflower. Indian Journal of Agronomy. 26: 66-67.

Ujjanaiah, U. S., Shanthamallaiah, N. R. and Murali, N. M. 1989. Effect of different row spacing and N and P2O5 fertilzer levels on growth, yield, yield components and quality of seeds in sunflower (Helianthus annuus L.). Mysore Journal of Agricultural Sciences. 23: 146-150.

Unger, P. W. 1983. Irrigation effect on sunflower growth, development and water use. Field Crops Research. 7: 181-194.

Varghese, T. P., Sadanandan, N. S. and Vikraman Nair, R. 1976. Effect of different levels of nitrogen and phosphorus at various stages of growth of sunflower variety Peredovik. Agricultural Research Journal of Kerala. 14: 105-108.

Varghese, T. P., Sadanandan, N. S. and Vikraman Nair, R. 1976a. A study on LAI and NAR of sunflower (Helianthus annuus L) variety peredovik as affected by graded doses of nitrogen and phosphorus. Agricultural Research Journal of Kerala. 14: 53-57.

Vitikov, M. 1976. Irrigation regime and consumptive use of water by sunflower on podzolized chernozem soils. Rasteniev “dniNauki” 13 (1): 103-111 (Fld Crop. Abstr. 30: 4894, 1977).

Vivek, Chakor, I. S. and Sharma, S. K. 1993. Effect of irrigation and phosphorus levels on the yield of sunflower under foot hill conditions of Himachal Pradesh. Agricultural Science-Digest-Karnal. 13: 147-148.