Research Article

Growth and Yield Response of Sunflower to Organic Amendments in Aridisol

Hafiz Hammad Ahmad[1], Mukkram Ali Tahir[1*], Noor-us-Sabah[1], Ghulam Sarwar[1], Sher Muhammad[2], Muhammad Aftab[3], Muhammad Zeeshan Manzoor[1] and Aneela Riaz[4]

[1]Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan; [2]Allama Iqbal Open University, Islamabad, Pakistan; [3]Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan; [4]Soil Bacteriology Section, Ayub Agriculture Research Institute, Faisalabad, Pakistan.

Abstract | Phosphorus (P) is a limited natural reserve and a major limiting factor for global crop production. The adverse soil biogeochemical characteristics of alkaline-calcareous soils make P the least available macronutrient. Therefore, alternative P source such as rock phosphate (RP) can offer a promising choice for sustainable P supply under P stress environment. A pot research was executed to explore the response of sunflower (*Helianthus annuus* L.) to sparingly soluble P sources grown under P deficient environment at research area, College of Agriculture, University of Sargodha during 2018. The experiment was laid out in a Completely Randomized Design (CRD) with eight treatments replicated thrice. The treatments consisted of T_1 = NK + P_0 (Control); T_2 = NPK (Recommended dose); T_3 = NK + Rock phosphate at 7 g pot^{-1}; T_4 = NPK + Rock phosphate at 7 g pot^{-1}; T_5 = NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 14 g pot^{-1}; T_6 = NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1}; T_7 = NK + Rock phosphate at 7 g pot^{-1} + Rice straw at 14 g pot^{-1}; T_8 = NK + Rock phosphate at 7 g pot^{-1} + Rice straw at 28 g pot^{-1}. Observations on various growth and yield parameters of crop were recorded using standard procedures and noted data was examined with a statistical software Statistix 8.1 analysis of variance technique and significant of treatments was tested using LSD test at probability level of 5%. The maximum fresh biomass (95.50 g), dry biomass (25.73 g), plant height (110.90 cm), head size (21.36 cm), number of achene haed^{-1} (864) and achene yield plant^{-1} (32.16 g) of sunflower was observed with application of NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) in cultivar Hysun-33. While, lowest value of fresh biomass (72.73 g), dry biomass (15.72 g), head size (16.63 cm), achene head^{-1} (711), achene yield plant^{-1} (18.36 g) was noted under NK + P_0 (T_1) treatment in Agwara-3. Among the tested sunflower cultivars, Hysun-33 showed superiority over Agwara-4.

Received | October 28, 2020; **Accepted** | December 08, 2020; **Published** | March 04, 2021
***Correspondence** | Mukkram Ali Tahir, Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan; **Email:** rai786@gmail.com
Citation | Ahmad, H.M., M.A. Tahir, N. Sabah, G. Sarwar, S. Muhammad, M. Aftab, M.Z. Manzoor and A. Riaz. 2021. Growth and yield response of sunflower to organic amendments in aridisol. *Pakistan Journal of Agricultural Research,* 34(1): 193-200.
DOI | http://dx.doi.org/10.17582/journal.pjar/2021/34.1.193.200
Keywords | Organic amendment, Phosphorus, Growth, Yield, Sunflower

Introduction

Around the globe as population is increasing with the passage of time so dietary habits of individuals is also changing. Demand for food, fuel and feed is increasing associated with urbanization so there is huge pressure on agriculture to combat this type of situations (Jouffret *et al.*, 2011). In Pakistan agriculture is the occupation through with 70 % of the population is involved directly or indirectly but still we are unable to feed our own people. Most of edible oil is exported from many counties and now a day's Pakistan is 3rd biggest exporter of edible oil. According to economic survey of Pakistan oil consumption was 2.905 million tons production during fiscal year 2015-16. Out of this only 27% of this need was fulfilled by our local producers while rest was exported costing 44 billion rupees (Economic Survey of Pakistan, 2018-2019).

In Pakistan oil seed are classified into three major classes like sunflower, safflower and soybean are in non-conventional group and their share in local production is about 6%. Mustard, sesame, rapeseed, and groundnut are in conventional group. This conventional group of oil seed crop have a share of 18% in overall edible oil production and are most significant winter oil seeds crop. Corn, cotton and bran of rice are classified in non-true oilseeds and add up to 70% towards production of edible oil. Major issue of oil of mustard and rapeseed is that their chemical composition are not suitable and favourable for cooking purposes like manifestation of maximum amount of erucic acid and glucosinolates (Schung and Hanekluas, 1988). Availability of these types of elements affects the palatability and causes nutritional disorders. It had been also reported that these type of acid contains traces of sulfur and majorly occupied by *Brassica* spp. (Vermorel *et al*., 1986).

Sunflower, biologically knows as *Helianthus annuus* L. is of family Compositae (or Asteraceae). Word Helianthus originate from two Greek words i.e. Helios which means Sun while Anthos flower. It is essential oil seed crop originally from North America and around 3000 BC was grown in New Mexico and Arizona by the native Indian Americans. The archaeologist record unveiled that before corn, sunflower was domesticated (Diepenbrock and Pasda, 1995). In 19th century Russians commercialized modern sunflower reported by Shah *et al*. (2005).

Sunflower is 4th significant and largest producible vegetable oil crop in the world. Russia, Ukraine and Argentina producing 82% of total sunflower oil (Prolea, 2012). About 50% of the whole world's sunflower seed production is carried out in European countries. Sunflower crop has its own unique and delicate type of structure. This crop is one of most demanding crop of 20th century due to its unique characteristics, oil, nutritious significant and water use efficiency when contrasted with crops of same group (Diepenbrock and Pasda, 1995).

It was introduced in Pakistan as an oil seed crop about 50 year ago. In Pakistan, the average yield of sunflower seed is about 1.3 tons ha^{-1}. Its oil contents in seed varied between 35% -55%. This crop has wide adaptability and can grown in all types of soil and climate (Barani as well as irrigated). According to FAO (2014), the sunflower total harvested area in Pakistan was 152,675 ha, where total seed produced was 3240 tonnes. The sunflower is an annual and cross-pollinated plant. It is straight type of plant and height may be 12-50 cm. Its stem is firm, non-branched and partially lignified producing large single headed flower having a diameter of 15-30 cm. The characters such as height and head diameter of sunflower depend upon the soil and climate (Merrien, 1986).

For higher yield the role of nutrient is of prime importance. Among essential nutrients role of phosphorus is undeniable (Chen *et al*., 1994). In plant, phosphorus plays vital role in major processes of plant life like reproductive growth of plant is governed by and affected by presence and absence of P (Wojnowska *et al*., 1995). Hussain *et al*. (2006) reported that growth of plants and crops is highly influenced by presence and absence of P. P plays vital role in major processes of plant like photosynthesis, cell division and nucleus formation (Ayub *et al*., 2002). For utilization of starch and sugar P is needed. For reproduction and growth energy is stored in phosphate compounds after photosynthesis. Ali *et al*. (2002) revealed that P can easily transport within plant form tissues of older age to younger through cell of root, stem or leaves.

Use of phosphatic fertilizers had their own pros and cons like can overcome P deficiency but having lot of disadvantages like efficiency of P and fear of depletion of non-renewable rock P reserves mined for production of P fertilizers. Another way is application of rock phosphate which contains P in the form of soluble P and it has been reported that crop plants cannot uptake P in insoluble form (Vance *et al*., 2003). While on the other hand plant nowadays adopted them to P in their rooting medium to P solubilize (Aziz *et al*., 2006). Cultivars show differential P acquisition from sparingly soluble or insoluble P sources.

Considering above mentioned facts this research was planned to investigate the effect of rock phosphate and organic amendments on yield and growth of sunflower under native P deficient soil conditions.

Materials and Methods

A pot research was conducted to scrutinize the phosphorus acquisition efficiency of sunflower (*Helianthus annuus* L.) grown in P scarce environment at research area of College of Agriculture, University of Sargodha during 2018. Soil analysis was performed before the sowing of the crop. At the depth of 0-10 and 10-20 cm sampling of soil was done by using soil auger. The soil was sandy loam and had a good drainage capacity. Various physio-chemical parameters of soil are shown in Table 1. The experiment was laid out in a Completely Randomized Design (CRD) with eight treatments which were replicated thrice. Treatments include T_1 = NK + P_0 (Control); T_2 = NPK (Recommended dose); T_3 = NK + Rock phosphate at 7 g pot^{-1}; T_4 = NPK + Rock phosphate at 7 g pot^{-1}; T_5 = NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 14 g pot^{-1}; T_6 = NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1}; T_7 = NK + Rock phosphate at 7 g pot^{-1} + Rice straw at 14 g pot^{-1}; T_8 = NK + Rock phosphate at 7 g pot^{-1} + Rice straw at 28 g pot^{-1}. The soil was composed from 30 cm of upper soil layer of a cultivated field and filled in the pots @ 20 kg in each pot. The desired levels of N, P, K, rock phosphate, wheat and rice straw were added and thoroughly mixed in soil before the filling of pots. Three healthy seeds of *Helianthus annuus* L. cultivar Hysun-33 and Agwara-3 were sown separately in each earthen pot. The two healthy seedlings were maintained of each cultivar in each pot after 15 days of sowing. The evacuated plants were assimilated in similar pot. Plants were watered when needed. Pots were kept free of weeds by hoeing after regular duration. The leaf samples were collected after 40 days of sowing for determination of P concentration and accumulation. Afterward one plant from every pot was picked for the determination of plant biomass. Second plant was allowed to grow until maturity and then used for the recording of growth and yield in terms of fresh and dry biomass, head size, number of achene head^{-1} and achene yield plant^{-1}. Different plant parameters were recorded using standard methods. The noted data was examined with a statistical software Statistix 8.1 analysis of variance technique and significant of treatments was tested using HSD test at probability level of 5% (Steel *et al*., 1997).

Table 1: *Soil physio-chemical characteristics before crop sowing.*

Characteristics	Soil sample depth		
	0-10 cm	10-20 cm	Mean
EC	0.40	0.53	0.46
Soil pH	7.8	8	7.9
Organic matter (%)	0.98	1.04	1.01
N (%)	0.38	0.25	0.31
Available P (ppm)	6.4	9.1	7.75
Extractable K (ppm)	134	127	130.5
Texture class	Sandy clay loam	Sandy clay loam	

Results and Discussion

Fresh biomass (g)

Fresh biomass is one of the crucial characters that regulate the yield productivity of sunflower crop. As higher the fresh biomass greater will be the biological yield of crop. It also indicates the crop productivity under different environment. Data showed in Figure 1 revealed that maximum fresh biomass (95.50 g) of sunflower was observed where NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) was applied in sunflower cultivar Hysun-33 which was followed by NK + Rock phosphate at 7 g/pot + Rice straw at 28 g pot^{-1} (T_8) that produced 93.93 g fresh biomass in the same cultivar. While, the lowest value of fresh biomass (72.73 g) was noted under control treatment (NK + P_0) in sunflower cultivar Agwara-3. Results also displayed that among the tested sunflower cultivars, Hysun-33 showed superiority over Agwara-4 in fresh biomass production (Figure 1).

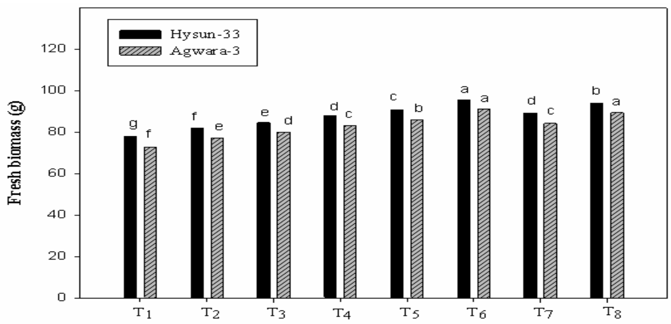

Figure 1: *Effect of different P sources on fresh biomass (g per plant) of sunflower grown under P deficient environment.*

The increase in the fresh biomass of sunflower might be due to rise in the soil P uptake that enhanced the sunflower somatic growth. According to Hafeez *et*

Links Researchers

al. (2010) hereditary varieties among species of crops and their cultivars for expanded phosphorus rate could sustain and may increase the yield of different crops in soils low in accessible P. They also indicated that by application of P, biomass of crop increased significantly. Similarly, Fernandez *et al*. (2009) also informed that various concentration of P expressively influenced the fresh biomass of sunflower.

Dry biomass (g)

Dry biomass is also an important dynamic that boosted or diminish the growth and development of plants. As weight of the dry biomass increases, the accumulation of solids in the shoots increases that enhance the growth of sunflower. Effect of various phosphorus combinations on dry weight of sunflower was found significant. Data displayed in Figure 2 depicted that all combination of phosphorus pointedly boosted the dry biomass of sunflower in both tested cultivars over control treatment. The highest dry biomass (25.73 g plant^{-1}) of sunflower was observed with application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) in cultivar Hysun-33 which was followed Agwara-3 with the same treatment. However, the lowest dry biomass (15.72 g pot^{-1}) was noted under NK + P_0 (Control) treatment. It was also observed from the data exhibited in Figure 2 that the increment in the dry biomass of sunflower was more in cultivar Hysun-33 as compared to Agawara-3.

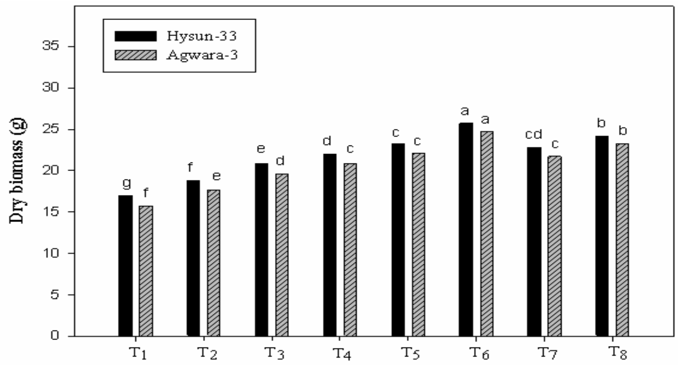

Figure 2: *Effect of different P combinations on dry biomass (g per plant) of sunflower grown under P deficient environment.*

These consequences are buoyed by Soomro *et al*. (2018) who found that by application of P the maximum dry weight of shoot was observed than no P application (control) treatment. The increase in the dry biomass of sunflower under NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) might be due to more addition of nutrients in the soil that will enhanced the growth of sunflower more efficiently than other treatments. The work of the Abbadi and Gerendás (2012) showed that dry weight of sunflower also depends on P application and maximum dry weight of sunflower was observed under P treatment over control (No application of P).

Plant height (cm)

The deterministic agricultural attribute of plant yield is plant height and usually show relative growth and activity in crop plant. Plant height is the main indicator of the green area, high plant height will create a higher green area increases the light activity and contributes to grain productivity. A significant effect of all phosphorus combinations on plant height of sunflower was observed. The highest plant height (110.90 cm) was measured with cultivar Hysun-33 under NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1}(T_6) application. The application of NK + Rock phosphate at 7 g pot^{-1}+ Rice straw at 28 g pot^{-1}(T_8) and NK + Rock phosphate at 7 g/pot + Wheat straw at 28 g pot^{-1}(T_6) produced statistically similar results in Hysun-33 and Agwara-3 respectively. However, the minimum plant height 86.03 cm was recorded under NPK (Recommended dose) in Agwara-4 (Figure 3). The taller plants of sunflower were observed in cultivar Hysun-33 with all applied combinations of phosphorus over Agwara-3.

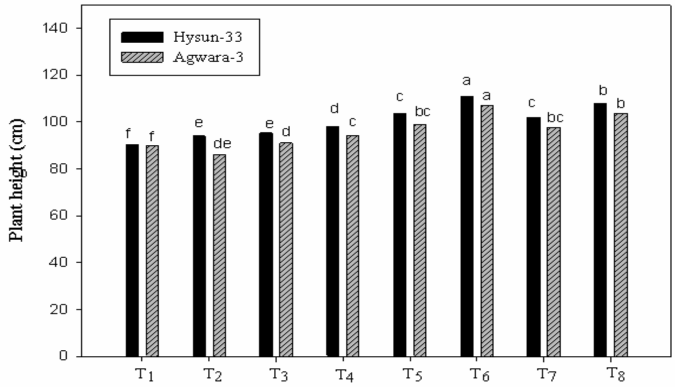

Figure 3: *Effect of different P combinations on plant height (cm per plant) of sunflower grown under P deficient environment.*

The alterations in our results may be due to the different combinations of P application that may change the soil P status and genetic make-up of the species used. Similarly, the outcomes of Shashikumar *et al*. (2013) also stated that a momentous difference was detected by application of P and maximum height of plant and total dry matter was recorded with P treatment. Our outcomes are also braced by Kakar *et al*. (2014) who clarified that application of nitrogen, phosphorus and potassium produced maximum height of plants, higher mean leaf area and yield.

Links Researchers

Head size (cm)

Head size of sunflower is the most imperative yield determining trait. The productive capacity of sunflower crop was also determined from the head size. As greater the size of head more will be the yield of sunflower was obtained. Data concerning the analysis of variance for head size of sunflower which evidently indicated that impact of different phosphorus combinations on sunflower cultivars was significant. Data showed in Figure 4 revealed that maximum head size (21.36 cm) of sunflower was observed where NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1}(T_6) was applied in sunflower cultivar Hysun-33 which was followed by NK + Rock phosphate at 7 g pot^{-1}+ Rice straw at 28 g pot^{-1}(T_8) that produced 20.60 cm fresh biomass in the same cultivar. While, the lowest value of head size (16.63 cm) of sunflower was measured under control treatment (NK + P_0) in sunflower cultivar Agwara-3. Results also exhibited that among the tested sunflower cultivars, Hysun-33 showed advantage over Agwara-4 for head size. The maximum head size was obtained with the application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1}(T_6) probably due to the higher nutrients accessibility to sunflower plants under P deficient condition over other treatments. The work of the previous researcher Amanullah and Khan (2010) revealed that by the higher levels of K and P sunflower growth period has been prolonged which greatly improved head size and also ensued in optimal yield. According to the results of Olowe *et al.* (2005) who stated that by the use various rate of nitrogen and phosphorus the head diameter of sunflower was significantly affected and higher head size was observed under application of these (N and P) nutrients.

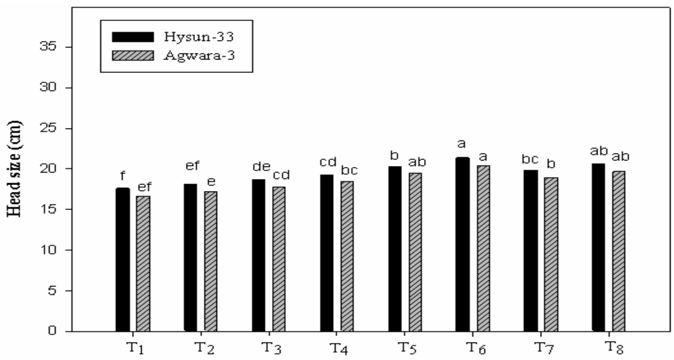

Figure 4: *Effect of different P combinations on head size (cm) of sunflower grown under P deficient environment.*

Number of achene head^{-1}

Number of achene per head considered an essential factor that openly imparts in achieving the impending yield retrieval in sunflower crop. In sunflower number of achene head^{-1} is considered as most significant feature as it directly donates towards seed yield. Effect of various phosphorus combinations on number of achene head^{-1} of sunflower was substantial. Data established in Figure 5 directed that all combination of phosphorus significantly enhanced the number of achene head^{-1} in both tested cultivars of sunflower as compared to control treatment. The highest number of achene head^{-1} (864) of sunflower was observed with application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) in cultivar Hysun-33. The treatments NK + Rock phosphate at 7 g pot^{-1}+ Rice straw at 28 g pot^{-1} (T_8) and NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) statistically similar and produced 852 and 852.3 number of achene head^{-1} in Hysun-33 and Agwara-3 respectively. However, the lowest number of achene head^{-1} (711) was noted under NK + P_0 (Control) treatment. It was also perceived from the data displayed in Figure 5 that the rise in the number of achene head^{-1} was more in cultivar Hysun-33 as compared to Agawara-3.

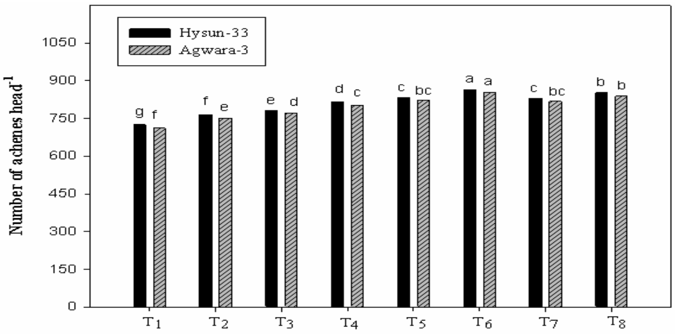

Figure 5: *Effect of different P combinations on number of achene head^{-1} of sunflower grown under P deficient environment.*

Similar to our outcomes Olowe *et al.* (2005) also described that in contrast to control treatment, the application of both N and P significant enhanced the weight of achene per head and seed return of sunflower. Similarly, the findings of Chaves *et al.* (2015) also supported our results that N, P and K at 100, 120 and 120 kg ha^{-1} were found beneficial and expressively boosted the achene head^{-1} as well as weight of achene in sunflower.

Achene yield plant^{-1} (g)

Achene yield is the most vital as it is also recognized as economical yield. As sunflower is a commercial crop and its seeds are used as raw material in industry so more achene yield results in more net benefit from sunflower. A significant effect of all phosphorus combinations on achene yield plant^{-1} of sunflower was observed. The highest achene yield plant^{-1} (32.16 g) was measured with cultivar Hysun-33 under NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) application which was followed by the same treatment in Agwara-3 (Figure 6). The application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 14 g pot^{-1}(T_5) and NK + Rock phosphate at 7 g pot^{-1}+ Rice straw at 28 g pot^{-1}(T_8) produced 28.73 g and 29.66 g achene yield plant^{-1} in Hysun-33. However, the minimum achene yield plant^{-1} (18.36 g) was recorded under NK + P_0 (T_1) in Agwara-4 and statically similar result was observed with NPK (Recommended dose) in Hysun-33 (Figure 6). The data also revealed that greater achene yield plant^{-1} was observed in cultivar Hysun-33 with all applied combinations of phosphorus over Agwara-3.

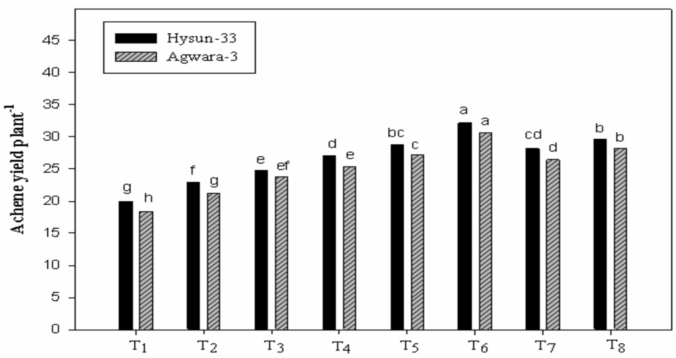

Figure 6: *Effect of different P combinations on achene yield plant^{-1} of sunflower grown under P deficient environment.*

These fallouts are similar to Mollashahi *et al.* (2013) who found that nitrogen and phosphorus application had significant impact on various traits of sunflower. According to Hamayun *et al.* (2011) who showed that due to NPK fertilizer submission a significant enhancement in growth and development parameters was observed and a significant improvement in yield was observed.

Conclusions and Recommendations

It was evident that different phosphorus combinations significantly influenced sunflower cultivars. Among the tested sunflower cultivars, Hysun-33 showed superiority over Agwara-4. However, among all the treatments, the application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1} (T_6) produced highest values of fresh and dry biomass, plant height, head size, number of achene head^{-1}, achene yield plant^{-1}. It is recommended that to obtain optimum growth and yield application of NK + Rock phosphate at 7 g pot^{-1}+ Wheat straw at 28 g pot^{-1}was used with Hysun-33 under P deficit environment.

Novelty Statement

Organic amendments improve biosolubilization of rock phosphate and growth of sunflower in aridisols.

Author's Contributions

Hafiz Hammad Ahmad: Conception and design of the work and conduction of experiment.
Mukkram Ali Tahir: Supervisor of research.
Noor-us-Sabah: Co-supervisor, Drafting and technical assistance.
Ghulam Sarwar: Technical assistance at every step.
Sher Muhammad: Final drafting.
Muhammad Aftab: Technical assistance.
Muhammad Zeeshan Manzoor: Statistical analysis.
Aneela Riaz: Data compilation.

Conflict of interest

The Authors have declared no conflict of interest.

References

Abbadi, J., 2017. Phosphorus use efficiency of safflower and sunflower grown in different soils. World J. Agric. Res., *5*(4): 212-220. https://doi.org/10.12691/wjar-5-4-3

Abbadi, J. and J. Gerenda. 2011. Effects of phosphorus supply on growth, yield, and yield components of safflower and sunflower. J. Plant Nutr., 34: 1769-1787. https://doi.org/10.1080/01904167.2011.600405

Abbadi, J. and J. Gerendás. 2012. Phosphorus use efficiency of safflower (*Carthamus tinctorius* L.) and sunflower (*Helianthus annuus* L.) studied in nutrient solution. J. Agric. Sci. Technol., 2: 1260-1280.

Ali, J., J. Bakht, M. Shafi, S. Khan and W.A. Shah. 2002. Uptake of nitrogen as affected by various combinations of nitrogen and phosphorus. Asian J. Plant Sci., 1: 367-369. https://doi.org/10.3923/ajps.2002.367.369

Amanullah and M.W. Khan. 2010. Interactive effects of potassium and phosphorus on phenology and grain yield of sunflower in Northwest Pakistan. Pedosphere, 20(5): 674-680. https://doi.org/10.1016/S1002-

0160(10)60057-4

Ayub, M., M.A. Nadeem, M.S. Sharar and N. Mahmood. 2002. Response of maize (*Zea mays* L.) fodder to different levels of nitrogen and phosphorus. Asian J. Plant Sci., 1: 352-354. https://doi.org/10.3923/ajps.2002.352.354

Aziz, T., Rahmatullah, M.A. Maqsood, M.A. Tahir, I. Ahmad and M.A. Cheema. 2006. Phosphorus utilization by six brassica cultivars (*Brassica juncea* L.) from tri-calcium phosphate, a relative insoluble compound. Pak. J. Bot., 38: 1529-1538.

Chaves, L.H.G., D.L. Araujo, H.O.C. Guerra and W.E. Pereira. 2015. Effect of mineral fertilization and irrigation on sunflower yields. Am. J. Plant Sci., 6: 870-879. https://doi.org/10.4236/ajps.2015.67095

Chen, M.L., X.L. Jiang, B.Y. Zoov and Z.Y. Zheri. 1994. Mathematical models and best combination of high yield cultivation technique for rapeseed variety Zhenyouyoum. Acta Agric. Zhejiiangenesis, 6: 22-26.

Diepenbrock, W. and G. Pasda. 1995. Sunflower (*Helianthus annus* L.). In: Advances in plant breeding 17, eds. W. Diepenbrock, and H.C. Becker, Berlin: Blackwell Wissenschafts-Verlag. pp. 91-148.

Economic Survey of Pakistan, 2018-2019. Agricultural statistics of Pakistan. Ministry of Food, Agriculture and Livestock. Government of Pakistan, Islamabad.

Fareed, M.K., 1996. Effect of varying fertilizer rate and plant stand density on growth and yield of spring maize. M.Sc. (Hons) thesis, Dept. Agron. Univ. Agric. Faisalabad, Pakistan.

Fernandez, M.C., H. Belinque, F.H. Gutierrez-Boem and G. Rubio. 2009. Compared phosphorus efficiency in soybean, sunflower and maize. J. Plant Nutr., 32: 2027-2043. https://doi.org/10.1080/01904160903308135

Gerloff, G.C. and W.H. Gabelman. 1983. Genetic Basis of Inorganic Plant Nutrition. In: Encyclopedia of plant physiology, ed., A. Läuchli, and R.L. Bieleski, New York. N.Y. Springer Verlag., pp. 453-480.

Hafeez, F., T. Aziz, M.A. Maqsood, M. Ahmed and M. Farooq. 2010. Differences in rice cultivars for growth and phosphorus acquisition from rock phosphate and mono-ammonium phosphate sources. Int. J. Agric. Biol., 12: 907-910.

Hamayun, M., S.A. Khan, A.L. Khan, Z.K. Shinwari, N. Ahmad, Y.H. Kim and I.J. Lee. 2011. Effect of foliar and soil application of nitrogen, phosphorus and potassium on yield components of lentil. Pak. J. Bot., 43: 391-396.

Hussain, N., A.Z. Khan, H. Akbar and S. Akhtar. 2006. Growth factors and yield of maize as influenced by phosphorus and potash fertilization. Sarhad J. Agric., 22(4): 579-583.

Jouffret, P., F. Labalette, J. Thibierge and V. George. 2011. Atouts et besoins en innovations du tournesol pour une agriculture durable. Innov. Agron., 14: 1-17.

Kaffka, S.R., T.E. Kearny, P.D. Knowles and M.D. Miller. 2001. Safflower production in California. http://agric.ucdavis.edu/crop/oilseed/saff”oil.htm.

Kakar, K.M., A. Khan, I. Khan, Z. Shah and Z. Hussain. 2014. Growth and yield response of maize (*Zea mays* L.) to foliar NPK-fertilizers under moisture stress condition. Soil Environ., 33: 116-123.

Merrien, A., 1986. Physiologie du tournesol. Cahier Technique Tournesol, Ed. Cetiom, pp. 47.

Mollashahi, M., H. Ganjali and H. Fanaei. 2013. Effect of different levels of nitrogen and potassium on yield, yield components and oil content of sunflower. Int. J. Farm. Allied Sci., (2-S): 1237-1240.

Olowe, V.I., O.A. Adebimpe and T.E. Obadiahi. 2005. Response of sunflower (*Helianthus annuus* L.) to nitrogen and phosphorus application in the forest-savanna transition zone of south west, Nigeria. Niger. J. Hortic. Sci., 10: 23-29. https://doi.org/10.4314/njhs.v10i1.3405

Prolea, 2012. De la production à la consommation. Statistiques des Oléagineux et Protéagineux. Prolea Documentation, Paris, pp. 48.

Schung, E. and S. Hanekluas. 1988. Theoretical principles for the indirect determination of the total glucosinolates content in the rapeseed meal quantifying the sulfur concentration via X-ray florescence (XRF method). J. Sci. Food Agric., 45: 243-254. https://doi.org/10.1002/jsfa.2740450307

Shah, N.A., H. Shah and N. Akmal. 2005. Sunflower area and production variability in Pakistan: opportunities and constraints. Helia, 28(43): 165-178. https://doi.org/10.2298/HEL0543165A

Shashikumar, R. Basavarajappa, S.R. Salakinkop, H. Manjunatha, M.P. Basavarajappa and

H.Y. Patil. 2013. Influence of foliar nutrition on performance of blackgram (*Vigna mungo* L.), nutrient uptake and economics under dry land ecosystems. Legume Res., 36(5): 422-428.

Soomro, F., N.A. Talpur, M.K. Soothar, S.B. Jamro, A.A. Panhwar, N.A. Memon, J.K. Soothar, U. Ali and M.H. Soomro. 2018. Identification of phosphorus use efficiency of different sunflower genotypes at Tandojam-Pakistan. Pure Appl. Biol., 7(3): 1026-1037. https://doi.org/10.19045/bspab.2018.700122

Steel, R.G.D., J.H. Torrie and D.A. Dichey. 1997. Principles and procedures of statistics: A biometrical approach, 3rd Ed. McGraw Hill Book Co., New York, USA.

Vance, C.P., C. Uhde-Stone D.L. Allan. 2003. Phosphorus acquisition and use: Critical adaptations by plants for recurring a non-renewable resources. Tansely review. New Phytol., 157: 423-447. https://doi.org/10.1046/j.1469-8137.2003.00695.x

Vermorel, M., R.K. Heaney and G.R. Fenwick. 1986. Nutritive value of rapeseed: Effects of individual glucosinolates. J. Sci. Food Agric., 37: 1197-1202. https://doi.org/10.1002/jsfa.2740371208

Wojnowska, T., H. Panak and S. Seikiewiez. 1995. Reaction of winter oilseed rape to increasing levels of nitrogen fertilizer application under condition of Ketizyn Chernozem. Rosling Oleiste, 16: 173-180.