Research Article

Phosphorus Utilization Efficiency by Sunflower (*Helianthus annuus* L.) from Sparingly Soluble P Source under P Deficient Environment

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Abstract | In order to scrutinize the phosphorus acquisition efficiency of sunflower from sparingly soluble P source i.e. Rock Phosphate (RP), a pot research was conducted by growing sunflower (*Helianthus annuus* L.) in P deficient environment at research area, College of Agriculture, University of Sargodha in year 2018. The experiment was laid out in a complete randomized design (CRD) with eight treatments which were replicated four times. The treatments plan includes T_1 = NK + P_0 (Control); T_2 = NPK (Recommended rate); T_3 = NK + RP at 7 g pot^{-1}; T_4 = NPK + RP at 7 g pot^{-1}; T_5 = NK + RP at 7 g pot^{-1} + Wheat straw at 14 g pot^{-1}; T_6 = NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1}; T_7 = NK+RP at 7 g pot^{-1} + Rice straw at 14 g pot^{-1}; T_8 = NK + RP at 7 g pot^{-1} + Rice straw at 28 g pot^{-1}. Observations regarding P accumulation, plant P concentration, P uptake efficiency and PE ratio were recorded using standard procedures and obtained data was analyzed statistically 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 P accumulation (178.37 mg P pot^{-1}), P uptake efficiency (1.90) and PE (phosphorus efficiency) ratio (747.15 g DM (g plant^{-1}) of sunflower was observed with application of NK + Rock phosphate at 7 g/pot + Wheat straw at 28 g pot^{-1} (T_6) in cultivar Hysun-33. While, the lowest value of P accumulation (89.13 mg P pot^{-1}), P uptake efficiency (1.18) and PE ratio (605.0 g DM (g plant^{-1}) was noted under NK + P_0 (T_1) treatment in Agwara-3. Among the tested sunflower cultivars, Hysun-33 showed superiority over Agwara-4.

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Introduction

Sunflower ranked 4th with respect to significance 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 types of structure. This crop is one of most demanding crop of 20th century due to its unique characteristics, oil content, nutritious significance 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 grow in all types 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. 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).

Achene (seed of Sunflower) is predominantly grown for its oil contents. Achene oil content was greater than the seed oil content of soybean and rapeseed (Prolea, 2009). It is usually used for cooking purpose such as deep frying, pre-cooked meals and salad dresser. Sunflower has great potential for bio fuel and environmental friendly chemicals. The seed of sunflower is also use to produce seed cakes which can be use as animal feed. It is also used to produce bird feed, bakery products, body painting, for medical purpose such as treatment of spider bites and snake bites, warts, ousting worms and refining eyesight (Borredon *et al*., 2011).

For higher yield role of nutrient is of prime importance. Among essential nutrients role of phosphorus (P) is undeniable (Chen *et al*., 1994). In plant, phosphorus plays vital role in major process of plant life like reproductive growth of plant is governed by and affected by presences and absences of P (Wojnowska *et al*., 1995). Hussain *et al*. (2006) reported that growth of plants and crops is highly influenced by presences and absences of P. Phosphorus plays vital role in major process 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.

Negative balance of P is observed in soils (Ahmad and Rashid, 2003) and 80% Pakistani soils are deficient in P and major reason is high pH and nature of soil either calcareous and salinity (Memon, 2005) and this is chief reason due to which P is present in changed solubility as calcium phosphates. So it is need of time to overcome this issue. There are several ways which can be used to combat this situation like use of mineral fertilizer. It is very simple and effective way to fulfil the requirement of soil and crop but there is very serious issue with this method which is that these types of fertilizer are not good for environmental health and are very expensive which cannot be afforded by ever farmer because of its cost (Gahoonia *et al*., 2000). Another demerit of using these sources is rate of P applied that highly affect to P availability to soil and crop. Some other factors which affect P availability are type, chemical composition, texture of soil, moisture of soil, type of fertilizer applied, time of application and method of application (Mohanty *et al*., 2006).

Aziz *et al*. (2006) described that insufficiency of phosphorus is a genuine worry for productivity and efficiency around the world. When P is applied in calcareous soils, P reacts with calcium and produced insoluble compounds after expansion to calcareous soils. To study phosphorus use proficiency of sunflower genotypes, a trail was conducted by Soomro *et al*. (2018). Eight cultivars were used and N and P were applied at 100-50 and 100-90 kg ha^{-1}. Effect of genotypes and treatment and combination of both i.e. impact of expanded P level and cultivars were affected contents of P in seed and leaf. A direct relation between P fertilizer rate and genotypes of sunflower was observed but among genotypes, significant response towards P use efficiency ratio was observed.

Considering above mentioned facts this research was planned to investigate the P sources and plant traits enhancing P acquisition and use efficiency in sunflower grown under P stress environment and to find the effect of rock phosphate and organic sources of P on P acquisition efficiency of sunflower.

Materials and Methods

A pot research was conducted to scrutinize the phosphorus acquisition efficiency of sunflower grown in P deficient environment at research area, 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 possessions of soil are shown in Table 1. The experiment was laid out in a Complete Randomized

Design (CRD) with eight treatments which were replicated thrice. Treatments include T_1 = NK + P_0 (Control without any external P source); T_2 = NPK (Recommended dose); T_3 = NK + RP at 7 g pot^{-1}; T_4 = NPK + RP at 7 g pot^{-1}; T_5 = NK + RP at 7 g pot^{-1} + Wheat straw at 14 g pot^{-1}; T_6 = NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1}; T_7 = NK RP at 7 g pot^{-1} + Rice straw at 14 g pot^{-1}; T_8 = NK + RP 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 the 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 the determination of P concentration and accumulation. Plant P content was determined by using spectrophotometer. Phosphorus uptake efficiency was estimated to the procedure designated by Moll *et al.* (1982) by dividing the amount of total collected P per pot (g pot^{-1}) by exterior phosphorus amount (g pot^{-1}). Phosphorus efficiency ratios (PER) was determined from the procedure reported by Gerloff and Gabelmann (1983) from which PER was estimated as total plant dry mass (g pot^{-1}) divided by total accumulated P (g pot^{-1}).

The 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% (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 (dS m^{-1})	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

P accumulation (mg P pot^{-1})

The accumulation of P in plants is key attribute that meaningfully enhanced the development and yield of crops. More P accumulation resulted in higher growth and yield characteristics of sunflower. Data about the analysis of variance for P accumulation (mg P pot^{-1}) of sunflower clearly showed that impact of different phosphorus combinations on sunflower cultivars was significant. Data showed in Figure 1 exposed that maximum P accumulation (178.37 mg P pot^{-1}) was perceived in pots where NK + RP at 7 g pot^{-1} + Wheat straw at 28 g/pot (T_6) was applied in sunflower cultivar Hysun-33 which was followed by NK + RP at 7 g/pot + Rice straw at 28 g pot^{-1} (T_8) that produced 173.57 mg P pot^{-1} P accumulation fresh in the same cultivar. While, the lowest value of P accumulation (89.13 mg P pot^{-1}) was detected where NK + P_0 (T_1) was applied under sunflower cultivar Agwara-3. It is also showed that among the tested sunflower cultivars, higher values of P accumulation were recorded in Hysun-33 over Agwara-4. Abbadi and Gerendás (2012) also described similar findings to our results who stated that P accumulation in the sunflower plants increased by applying P under P deficit soil. According to Abbadi (2007) a significant enhancement in P accumulation has been observed in sunflower with P application.

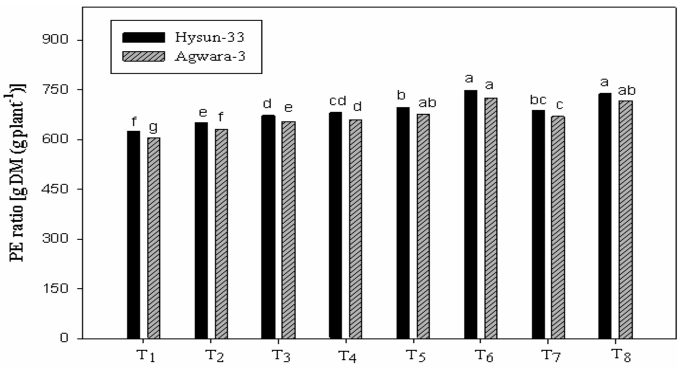

Figure 1: *Effect of different P combinations on P accumulation (mg P pot^{-1}) of sunflower grown under P deficient environment.*

Plant P concentration (mg P plant^{-1})

The yield response of sunflower as swayed by P contents in new established blade. By enhancing the supply of P, the nutrient status of the plant also improve that significantly increases the yield of sunflower. Influence of various phosphorus combinations on plant P concentration (mg P plant^{-1}) of sunflower was found significant. Data (Figure 2) indicated that all combination of phosphorus increased the plant P concentration of sunflower in both tested cultivars as compared to control treatment. Application of NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) produced statistically similar results in both tested cultivars (Hysun-33 and Agwara-3). However, the slightly higher value of P concentration (1.78 mg P plant^{-1}) was observed in Hysun-33 under T_6. Whereas, lowest plant P concentration (1.04 mg P plant^{-1}) was recorded under NK + P_0 (T_1) which was followed by the same treatment in Hysun-33. It is clearly observed from the data exhibited in Figure 3 that more plant P concentration was obtained in cultivar Hysun-33 as compared to Agawara-3 under all treatments. The improvement in plant P concentration in sunflower may be due to more availability and uptake of plants under the NK + Rock phosphate at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) treatment. Similar to our outcomes Abbadi (2017) also found that more P has been accumulated in sunflower under P application that enhances the plant P concentration in sunflower.

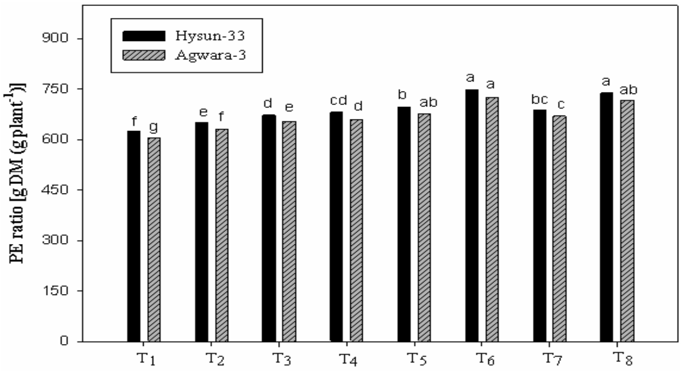

Figure 2: *Effect of different P combinations on plant P concentration (mg P plant^{-1}) of sunflower grown under P deficient environment.*

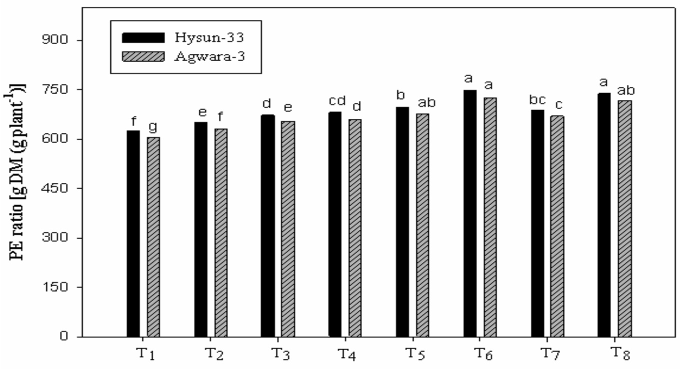

Figure 3: *Effect of different P combinations on P uptake efficiency of sunflower grown under P deficient environment.*

P uptake efficiency

As P is the macro nutrients that plant required in large quantity to perform various functions. If the plants P uptake efficiency improves then plants perform most of the functions normally that increases the growth and yield of crop. A significant effect of all phosphorus combinations on P uptake efficiency of sunflower was detected. The highest P uptake efficiency (1.90) was measured with cultivar Hysun-33 under NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) application. The application of NK + RP at 7 g pot^{-1} + Rice straw at 28 g/pot (T_8) and NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) produced statistically similar results in Hysun-33 and Agwara-3 respectively. However, the minimum P uptake efficiency (1.18) was recorded under NK + P_0 (T_1) in Agwara-4 (Figure 3). The sunflower cultivar Hysun-33 was more efficient in P uptake as compared to Agwara-3 under all applied combinations of phosphorus. The work of the previous researcher Kaffka *et al*. (2001) also reported that by application of P the more availability of P present in the soil from which P uptake efficiency of plants has been increased. Our results are further supported by the findings of Abbadi and Gerendás (2011) who revealed that P uptake efficiency of sunflower enhanced significantly with P application under P deficit soil.

PE ratio [g DM (g plant^{-1})]

As an appropriate mean of conveying consumption productivity with reverence to P, the PE ratio is extensively used that is defined as the biomass production or yield (achene or oil) per unit P accumulated. Effect of various phosphorus combinations on PE ratio of sunflower was found significant. Data demonstrated in Figure 4 directed that all combination of phosphorus significantly boosted the PE ratio of sunflower in both tested cultivars as compared to control treatment. The highest PE ratio (747.15 g DM (g plant^{-1}) of sunflower was observed with application of NK + Rock phosphate at 7 g/pot + Wheat straw at 28 g pot^{-1} (T_6) in cultivar Hysun-33. The treatments containing NK + RP at 7 g pot^{-1} + Rice straw at 28 g pot^{-1} (T_8) and NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) produced 738.25 and 725.67 g DM (g plant^{-1} PE ratio in Hysun-33 and Agwara-3, respectively. However, the lowest PE ratio (605 g DM (g plant^{-1}) was noted under NK + P_0 (T_1) treatment. It was also alleged from the data displayed that the increase in PE ratio was more in cultivar Hysun-33 as compared to Agawara-3 (Figure 4). The increase in the PE ratio with NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) may be due to more availability of nutrients to sunflower that reactive in augmenting their consumption proficiency poor P status soil. These fallouts are reinforced by the conclusions of Abbadi and Gerendás (2012) who informed that PE ratio in sunflower augmented with P supply. Similarly, Abbadi and Gerendás (2011) also reported that PE ratio of sunflower increased by improving in the P concentration in the plants.

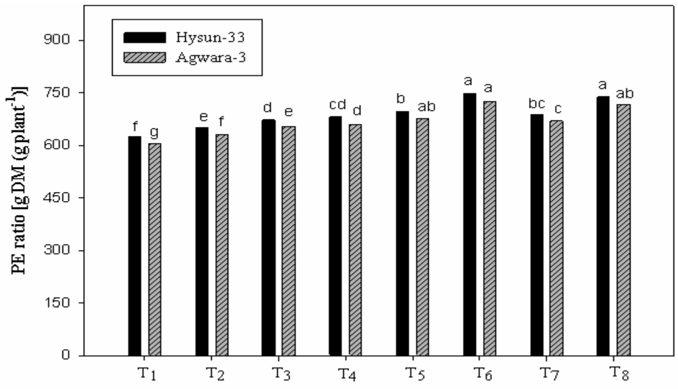

Figure 4: *Effect of different P combinations on PE ratio [g DM (g plant^{-1})] of sunflower grown under P deficient environment.*

Conclusions and Recommendations

It is clearly showed that different phosphorus combinations significantly influenced sunflower cultivars efficiency for P uptake. Among the tested sunflower cultivars, Hysun-33 showed superiority over Agwara-4. However, among all the treatments, the application of NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} (T_6) produced highest values of P accumulation or concentration, P uptake efficiency and PE ratio in cultivar Hysun-33. It is recommended that to obtain optimum growth and yield application of NK + RP at 7 g pot^{-1} + Wheat straw at 28 g pot^{-1} was used with Hysun-33 under P deficit environment.

Novelty Statement

The study is novel as it investigates that organic amendments improve phosphorus utilization efficiency by sunflower from sparingly soluble P source under P deficient environment.

Author's Contribution

Hafiz Hammad: Carried out the study.
Mukkram Ali Tahir: Designed and supervised the study.
Noor-us-Sabah: Co-supervised the research.
Ghulam Sarwar: Assisted technically.
Muhammad Aftab: Drafting of study.
Muhammad Zeeshan Manzoor and Aneela Riaz: statistical analysis of data.
Abid Niaz and Muhammad Arif: Proof reading.

Conflict of interest

The authors have declared no conflict of interest.

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