Research Article

Tillage Instruments and Phosphorus Levels Enhance Grain and Oil Yield in Sunflower

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Abstract | Phosphorus (P) if applied in proper quantity in soil with appropriate tillage implement may enhance oil and grain yield of sunflower. In this regard, an experiment was conducted to evaluate the impact of phosphorus (P) levels and tillage instruments on grain and oil yield of sunflower at Agronomy Research Farm of the University of Agriculture Peshawar (Pakistan) during summer 2017. Split plot arrangement of the Randomized Complete Block design was used with four replications. Tillage instruments including mouldboard (MB) plough, cultivator and rotavator were allotted to main plots and P levels (control, 30, 60, 90 and 120 kg ha^{-1}) to subplots. MB plough applied one time was followed by cultivator; while cultivator and rotavator were applied once in separate experimental units. The results revealed that higher number of achenes (grains) capitulum^{-1} (974) and thousand achenes weights (51.4 g) were produced with MB plough which were statistically at par with cultivator, while higher achene yield (2080 kg ha^{-1}) and oil yield (873 kg ha^{-1}) were observed under MB plough tilled experimental units which were statistically at par with rotavator. In case of P levels, higher plant height (157.3 cm), higher number of achenes capitulum^{-1} (1028), thousand achenes weight (53.8 g), higher achene yield (2527 kg ha^{-1}), oil yield (1146 kg ha^{-1}) and maximum oil contents (38.5%) were observed in experimental units supplied with P @ 90 kgha^{-1}. Finally, it was concluded that tillage operation with MB plough followed by cultivator or only rotavator and P @ 90 kg ha^{-1} were better to maximize grain and oil yields in sunflower.

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Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop because of its higher quantity and premium quality oil contents. Seeds of sunflower botanically called achene contain 40-50% oil (Grompone, 2005) and 20-27% proteins (Rosa et al., 2009). Sunflower has a premium quality of edible oil because of fatty acids linoleic acid (Polyunsaturated omega-6, 59%) and oleic acid (Monounsaturated Omega-9, 30%) which help in controlling blood cholesterol level. Due to this quality, it is mostly used in the diet of heart patients (Thimmegowda et al., 2007). Amongst oilseed crops sunflower had 4th position in the world by area (Fagundes et al., 2007). Worldwide sunflower production was 48 m tons grown on an area of 25 m ha (USDA, 2017). In Pakistan, sunflower production was 85900 tons grown on an area of 82600 ha with average seed yield of 1040 kg ha^{-1} while in Khyber Pakhtunkhwa its production was 300 tones grown on area of 200 ha and average seed yield was 1500 kg ha^{-1} during

2015-16 (MNFSR, 2016). Pakistan is facing huge challenge of the acute shortage of edible oil. The demand for edible oil in Pakistan is increasing with the uncontrollable increase in population; however, edible oil production is not increasing at the same rate each year. Pakistan ranked world 3rd largest importer in edible oil. The country's oil requirement was about 2.966 million tons in which 0.83 million tons (28%) were locally produced and the rest edible oil was imported (MNFSR, 2016). In national edible oil production, cottonseed contributes 63%, sunflower 16%, while rapeseed and canola share 13%. The potential crops which satisfy some requirements of edible oil in the country are rapeseed-mustard, canola and sunflower (PARC, 2014).

Improper nutrient application and seedbed preparation with inappropriate tillage implements are among some of the major causes of low productivity of sunflower in Pakistan (Arshad et al., 2009). Sunflower yield and yield parameters are primarily associated with good production technology and the availability of proper nutrient fertilization (Sadras, 2009). Inappropriate fertilizer application had a significant effect on sunflower productivity worldwide (FAO, 2007). Inorganic fertilizer application in appropriate amount and appropriate tillage implement for seedbed preparation plays vital role in increasing crop yield (Cisse and Amar, 2000).

Phosphorus is essential for sunflower root development (Inamullah and Khan, 2017; Syed et al., 2006). All crops require phosphorus during all growth stages. Root initiation may use seed reserve and deficiency of P may cause poor root initiation, slow emergence and stunted growth in all crops because the deficiency of P decreases net photosynthesis and thus reducing root to shoot biomass (Jungi et al., 2005). Many researches indicate that about 90 % Pakistani soil is deficient in phosphorus (Shaheen et al., 2011). The overall productivity and growth of sunflower in Pakistan is considerably reduced due to imbalance nutrient fertilization especially phosphorus (FAO, 2007). Therefore, before growing a crop it is necessary to apply P. Fertilization of sunflower field with phosphorus increased yield and also had a prominent effect on oil content of seed (Khan et al., 2014; Muralidharudu et al., 2003). Several researchers have examined that 90% of Pakistani soils are deficient with P (Shaheen et al., 2011). The overall productivity and growth of sunflower in Pakistan is considerably low due to imbalance nutrient fertilization particularly phosphorus (FAO, 2007). Sunflower is a deep-rooted and exhaustive crop. It is usually not fertilized with optimum dose of phosphorus by growers. Awareness about the use of phosphorus is enough but farmers use phosphorus according to their economic resources, although not according to crop demand and soil analysis.

The primary purpose of tillage is to prepare seedbed. Different types of tillage equipment have different tillage depths to modify chemical and physical properties of the soil that affect the crop growth and yield. According to literature, tillage practices play a prominent role in yield and oil contents of sunflower (Barros et al., 2004; Ekin et al., 2005; Kasap and Coskun, 2006; Hussain et al., 2010). For instance, tillage plays an important role in improving soil porosity and soil structure. Reduced tillage operations minimize soil erosion, degradation, improving soil productivity and fertility, crop yield and profitability (Senjobi et al., 2013; Shahzad et al., 2016; Nawaz et al., 2017; Farooq and Nawaz, 2014; Nawaz et al., 2016; Shahzad et al., 2017; Wasaya et al., 2017). Tillage had a prominent influence on soil health (Riley et al., 2008) as well as its infiltration capacity and aeration. Maximum soil moisture content and lesser bulk density were noticed in conventional and deep tillage practices as compared to minimum and shallow tillage operation (Khurshid et al., 2006; Alamouti and Navabzadeh, 2007). Compacted seedbed may result in poor root proliferation and failure of seedling growth which directly affects crop productivity (Amin et al., 2014).

Despite the above facts, deep tillage is usually not carried out in Pakistan because of costly operation. Most of our growers are not well-trained as most of them do not know the required depth of tillage instruments and also not aware of when deep tillage need to be carried out. Out of the total land area, 11% of soil degradation is due to soil compaction (Amin et al., 2014). Deep tillage reduces soil strength and compaction. Moreover, heavy and deep tilling machinery may cause considerable increase in soil loosening (Botta et al., 2006). In light of the above overview, an experiment was carried out to determine the influence of P levels and tillage instruments on grain and oil yield of sunflower in Peshawar region.

Materials and Methods

Location selection and experimental details

Field experiment was carried out at Agronomy Research Farm of the University of Agriculture Peshawar during summer 2017. The research site is located at 34.022° N, 71.471° E and at an altitude of 359 meters above sea level (Inamullah et al., 2011). Weather condition of the experimental duration at the experimental site is given in Figure 1. Sowing was done manually on 11 June using seed rate of 8 kg ha^{-1}. Experiment was conducted in a randomized complete block design with split plot arrangement comprising of four replications. Sunflower hybrid Hysun-33 was sown in the having textural class of silt loam, Piedmont Alluvium Ustochrepth based on USDA classification (Anonymous, 2007). Tillage instruments (mouldboard plough, rotavator and cultivator) were considered as main plot factor and P levels (0, 30, 60, 90 and 120 kg ha^{-1}) as sub plot factor in a plot 4 meters long row and 3.75 m width. Each subplot consisted of 5 rows with 30 cm plant to plant distance and 75 cm row to row. Phosphorus (P) was applied from the source of single super phosphate (SSP) during seed bed preparation using broadcast method (de Wit, 1953). Recommended dose of nitrogen and potash were applied as urea and sulfate of potash at the rate of 150 and 60 kg ha^{-1} respectively. Thinning and earthing-up was carried out at 6 leaf stage of the crop to minimize lodging. Proper irrigation plan was followed; however, changes in irrigation were brought according to weather scenario when needed. Weeds were manually controlled. Standard plant protections measured were adopted including; metalyxialmacnobar @ 2000 ml ha^{-1} spray with the help of hand pump to control fungus attack. Experimental plots were harvested at maturity (about 25-35% moisture content) on 13th November, 2017 when the back sides of more than 90% sunflower capitula turned yellow and outer region of the capitula turned brownish in each treatment.

Measurement and observations

Data for days to maturity were noted from date of sowing till the back sides of more than 90% sunflower capitula turned yellow and outer region of the capitula turned brownish in each treatment. Plant height (cm) was noticed by randomly selecting five samples in two central rows in experimental plots a week before the crop harvest. Plant height was individually measured and length was taken from base to the top of sunflower disc and then averaged. Capitula m^{-2} were recorded simply by counting all the plants in two middle rows in each subplot randomly and changed to Capitula m^{-2} using the formula:

$$Capitula\ m^{-2} = \frac{\text{Total capitula counted in two central rows}}{\text{row} - \text{row distance (m) x no of rows x row length}}$$

Number of achenes per capitulum were counted manually by selecting five samples from each treatment directly after the achenes were shelled from capitulum. Thousand achenes weight (g) was recorded with the help of seed counter in each experimental unit and then weighed with electronic balance and recorded as 1000-achenes weight. Achene yield of sunflower was recorded from the two central rows harvested for biological yield, their seeds were shelled from capitula, sun dried, weighed and reported as achene yield using the formula:

$$\text{Achene yield (kg ha} - 1) = \frac{\text{Achene yield of two rows}}{\text{Row–Row distance (m)} \times \text{Row length (m)} \times \text{No of Rows}} \times 10000m^2$$

Oil content (%) was recorded with the help of nuclear magnet resonance (NMR) technology available in Nuclear Institute of Food and Agriculture (NIFA) Peshawar. The NMR provides fast and accurate determination of solid fats contents (SFC) in all the seeds. The instrument was calibrated using calibrating equation standardizing with the sample developed for sunflower crop. On successful reading from standard, the experimental samples were run in duplicate machine after each 25 samples. For estimation of sunflower oil yield, the oil content (%) of sunflower seed recorded with help of NMR technology was multiplied with the achene yield of each experimental plots and presented as oil yield (kg ha^{-1}) of that treatment using the given formula:

$$Oil\ yield\ (kg\ ha^{-1}) = \frac{\text{Achene oil content (\%)} \times \text{Achene yield(kg/ha)}}{100}$$

The data were analyzed statistically using appropriate design (Steel et al., 1997) with statistical software Statistix 8.1 (Analytical Software, 2005). The level of significance for means was calculated using least significance differences (LSD) test at 5% level.

Results and Discussion

Phenology and plant height

Data regarding days to maturity of sunflower was considerably influenced by phosphorus (P) levels while tillage implements (TI) and the interactive effect (TI × P) were found non-significant (Table 1). Early maturity (80.6 days) was noticed in experimental plots treated with P at the rate of 120 kg ha^{-1}, followed by experimental units treated with P @ 90 kg ha^{-1}. Delayed maturity (85.7 days) was recorded in experimental units where no P was applied. The earliness in maturity was recorded with increase in P levels as P plays a vital role in accelerating flower initiation and flower formation (Muralidharudu et al., 2003). Sadiq et al. (2000) reported earliness in maturity with increasing in P level compared to control plots. The non-significant results for tillage are at par with the finding of Gul et al. (2014) who investigated that various tillage operations did not affect days to complete maturity of sunflower.

Table 1: *Days to maturity, plant height, capitula m^{-2} and achenes $capitulum^{-1}$ of sunflower planted with different tillage implements and phosphorus levels during summer-2017.*

Tillage Implements (TI)	Days to maturity	Plant height (cm)	Capitula m^{-2}	Achenes $capitulum^{-1}$
Mouldboard Plough	84	148.0 a	4	974 a
Rotavator	83	144.4 b	4	940 b
Cultivator	83	147.4 a	4	957 ab
LSD (0.05)	Ns	2.8	Ns	25.8
P levels (kg ha^{-1})				
0	85.7a	135.4 e	4	871 c
30	85.3a	141.8 d	4	886 c
60	83.8b	146.4 c	4	1018 ab
90	82.8b	152.2 b	3	1028 a
120	80.6c	157.3 a	3	984 b
LSD (0.05)	1.03	4.0	*Ns	39.2
TI × P	Ns	6.9	Ns	Ns

**Ns= Non-significant; Means followed by different letters within a category of columns and rows considerably vary from each other ($p \leq 0.05$) by using Least Significant Difference (LSD) test.*

Plant height was enhanced with the application of P when tillage instruments were changed from rotavator to mouldboard (MB) plough (Table 1). The interactive effect (TI × P) for plant height was also found significant. Taller plants (148 cm) were obtained from experimental plots where MB plough was practiced followed by plots where cultivator was used. Plant height is the reflection of better soil tilth and amount of optimum moisture available to the developing crop that could be used as a measure of vegetative growth (Iqbal et al., 2014). The reason for significant results with the tillage instruments might be due to better seedbed condition and soil loosening. According to Dikgwatlhe et al. (2014), MB plough helped in preparing an ideal seedbed which influenced growth and development of crops and resulted in tallest plants. Deeper tillage had profound effects on soil structure and health (Riley et al., 2008) as well as its infiltration capacity and aeration. Since deep tillage had positive effects on the soil physical properties, therefore it increased crop growth and yield (Alamouti and Navabzadeh, 2007). Our results showed higher plant height probably due to improved tillage practices. In case of shallow tillage, smaller plants were noticed. In case of P levels, taller plant height (157.3 cm) was observed from experimental units fertilized with P @ 120 kg ha^{-1}, compared to control. It might be due to increase in the vigorous root development which penetrated in the soil to a deeper layer. Guar et al. (2003) reported that increased P level considerably increased plant height of sunflower.

Yield traits

Number of capitula (m^{-2}) of sunflower was non-significantly affected by P levels and tillage implements and similarly the interactive effect of TI × P was also found non-significant on number of capitula (m^{-2}) of sunflower (Table 1). The main reason behind this might be the sowing method which was manual and the good seed germination which maintained optimum plant population. Moreover, thinning was also done manually in plots equally for appropriate crop stand. Our finding was strongly supported by Tiritan et al. (2016) and Cai et al. (2014) who indicated non-considerable effects of both tillage and P fertilization on number of capitula m^{-2} of sunflower.

Number of achenes per capitulum was significantly improved with P levels and tillage implements while the interaction of TI x P was found non-significant for achenes $capitulum^{-1}$ (Table 1). Plots tilled with deeper tillage implements resulted in higher achenes $capitulum^{-1}$ (974 achenes) followed by at par value with cultivator (954 achenes) as compared to the plots ploughed with rotavator (940 achenes) where fewer number of achenes $capitulum^{-1}$ were noticed. The main reason for higher number of seeds $capitulum^{-1}$ might be due to the feasible condition for nutrients uptake (Iqbal et al., 2014). Our findings are in line with Memon et al. (2013) who reported more number of seeds capitulum^{-1} where tillage was practiced. Generally deep tillage causes an increase in soil aeration which is helpful for crop growth (Inamullah and Khan, 2017). Amongst P levels plots fertilized with P @ 60 and 90 kg ha^{-1} showed more achenes capitulum^{-1} (1018 and 1028 respectively), compared with the plots where no P was used (871 achenes). Several scientists reported significant effect of P levels on number of seeds capitulum^{-1}. Our finding is supported by Mohamed et al. (2003) who observed that with the increase in P levels seeds capitulum^{-1} was positively increased. Malik et al. (2004) revealed maximum seeds capitulum^{-1} with the application of phosphorus. Jahangir et al. (2006) reported maximum number of seeds capitulum^{-1} and yield with the application of P to sunflower crop. Thousand achenes weight (g) of sunflower was prominently influenced by tilling instruments and levels of P, however their interaction (TI × P) was found non-significant (Table 2). Heavier achene weight (51.4 g) was noticed in experimental units ploughed with MB plough at par with 1000 achene weight (50.5 g) in cultivator tilled plots and minimum value was recorded for plots ploughed with rotavator (47.1 g). The most prominent cause for heavier achene weight could be the MB plough which played vital role in loosening the soil crust, considerably increasing root length, dry weight, surface area, root diameter and the proportion of roots (Guan et al., 2015). Sher et al. (2018) reported tillage system significantly affected 1000-achene weight. Subsoiling ameliorates the provision of sufficient amount of nutrients for plant growth and development. It also facilitates the accumulation of macro nutrient in the upper plant parts which ultimately increases the grain weight of oilseed crops. Soil strength and compaction alter the root distribution and proliferation which ultimately reduce crop yields (Botta et al., 2006). Amongst various P levels, higher 1000-achene weight (53.8 g) was noticed in experimental units supplied with P @ 90 kg ha^{-1}, followed by P @ 60 and 120 kg ha^{-1} which produced at par thousand achene weight values of 52.8 and 50.8 g respectively. Lower achene weight (40.7 g) was observed in experimental units where P was not applied. The results were strongly supported by the finding of Tomar et al. (1999) but disagreed with Tripathi et al. (1980) who found maximum 1000-achene weight of sunflower with lower doses of P. They also suggested that P increased 1000-achene weight of sunflower which finally revealed higher seed yield. With the increase in P levels, 1000-achene weight enhanced which might be due to increase in seed filling efficiency and seed development as stated by Karadogan et al. (2009). These finding are at par with observation of Ali et al. (2014) and Malik et al. (2006) who reported valuable improvement in 1000-achene weight of sunflower with the increasing of P levels.

Table 2: *Thousand achenes weight, achene yield, oil contents and oil yield of sunflower planted using different tillage implements (TI) and phosphorus (P) levels during summer-2017.*

Tillage Implements (TI)	1000 achenes weight (g)	Achene yield (kg ha^{-1})	Oil contents (%)	Oil yield (kg ha^{-1})
Mouldboard Plough	51.4 a	2080 a	36.8	873 a
Rotavator	47.1 b	2075 a	36.6	850 a
Cultivator	50.5 a	1885 b	36.6	783 b
LSD (0.05)	3.0	158	Ns	66.9
P levels (kg ha^{-1})				
0	40.7 c	1408 d	35.6 cd	521 d
30	50.0 b	1782 c	36.6 bc	674 c
60	52.8 ab	2138 b	37.5 ab	871 b
90	53.8 a	2527 a	38.5 a	1146 a
120	50.8 ab	2210 b	35.2 d	963 b
LSD (0.05)	3.5	244	0.37	103.4
TI × P	Ns	Ns	Ns	Ns

Ns= Non-significant; Means followed by different letters with in a category and columns are considerably varies from each other ($p \leq 0.05$) by using Least Significant difference (LSD) test.

Phosphorus (P) levels and tillage implements (TI) had a significant effect on achene yield of sunflower, while the interactive effect of TI × P was found non-significant (Table 2). Among P levels, experimental units fertilized with P @ 90 kg ha^{-1} produced maximum achene yield (2527 kg ha^{-1}). Lower achene yield (1408 kg ha^{-1}) was obtained from control plots treatments. This might be due to the reason that fertilization of sunflower with higher levels of P enhanced growth and development and ultimately production of sunflower (Muralidharuduet al., 2003). Higher levels of P improved seeds capitulum^{-1}, increased capitulum size, and 1000-grain weight (Sadiq et al., 2000; Malik et al., 2004) which contributed to increased grain yield of sunflower. Vaseghmanesh et al. (2013) noticed that higher achene yield of sunflower was produced with the application of 200 kg ha^{-1} triple super phosphate (TSP). In case of tillage, experimental units ploughed with MB plough and rotavator resulted in higher achene yield (2080 and 2075 kg ha^{-1} respectively) compared to cultivator. The increase in dry matter production could be due to breaking of soil compaction, soil strength and elongation of roots. Compacted soil reduced water absorption rate and root proliferation and hence restricted the growth of plants (Nizami et al., 2004). Several researchers reported that tillage operations improved achene yield and oil quality under various agro-climatic conditions in sunflower (Barros et al., 2004; Ekin et al., 2005). Bennie and Botha (1986) reported that deep tillage operations in coarse texturized soil helped in reducing soil compaction, strength, improving root distribution and penetration which helped in maximum water uptake from soil.

Seed oil contents (%) of sunflower was considerably affected by P levels while tillage implements and the interaction of TI × P was found non-significant (Table 2). Maximum oil content (38.5%) was reported in plots fertilized 90 kg P ha^{-1} and significantly smaller oil content (35.6%) was noticed in experimental units where no P was applied. P fertilization increase seed oil content (%) compared to no P applied. Increase in sunflower oil content might be due to the effective role of P in increasing achene yield (Jahangir et al., 2006). These findings are also in agreements with finding of Salih (2013) who remarked that with constant application of P, oil contents were significantly increased in sunflower achene. Karadogan et al. (2009) earlier reported that the potentials for increasing seed dry matter contents seemed to be associated with increased phosphorus application. Rodriguez et al. (1998) maintained that phosphorus application had direct effect on grain properties due to its role in the supply of assimilates. Malik et al. (2006) reported that P application considerably increased oil content of sunflower.

Sunflower oil yield was considerably influenced by P levels and tillage implements while the interaction of TI × P was found non-significant (Table 2). Amongst various P levels, more oil yield (1146 kg ha^{-1}) was noticed in experimental plots treated with P @ 90 kg ha^{-1} and lowest oil yield (521 kg ha^{-1}) was observed in control experimental units. Our findings indicated that phosphorus fertilization increased seed oil content at varying levels compared with no P application which clearly suggests the positive role of phosphorus in oilseed crops. In case of tillage implements, maximum sunflower oil yield (873 kg ha^{-1}) was noticed in experimental units tilled with mouldboard plough (MB Plough), which was statistically at par with oil yield (850 kg ha^{-1}) where rotavator was practiced. However, lowest value for oil yield (783 kg ha^{-1}) was noticed in experimental units ploughed with cultivator. These findings are in conformity with Ali et al. (2014) who reported that tillage system had a considerable effect on oil yield of sesame. Yol et al. (2010) confirmed that maximum oil yield was recorded where conventional and deep tillage operation compared to minimum and shallow tillage systems were practiced.

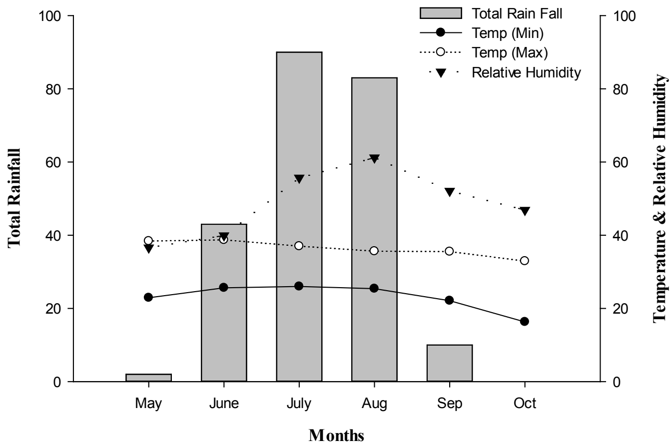

Figure 1: *Mean monthly maximum and minimum temperature (°C), rainfall (mm) and relative humidity (%) of the experimental site of Peshawar during the experiment conduction.*

Conclusions and Recommendations

It was concluded that deeper tillage implements mouldboard (MB) plough and rotavator produced higher achene or grain and oil yields. Similarly, amongst various phosphorus (P) levels, plots fertilized with P @ 90 kg ha^{-1} had higher grain and oil yield. It is therefore recommended that phosphorus should be applied @ 90 kg ha^{-1} with rotavator for higher yield and productivity of sunflower. In this situation, MB plough is not recommended because rotavator is less expensive than MB plough.

Authors' Contribution

Saud Khan conducted the research and prepared draft the manuscript. Dr. Inamullah gave the idea of the research, determined the factors, made the layout and finalized this manuscript.

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