Research Article

Response of Sunflower to Integrated Management of Nitrogen, Phosphorus and Sulphur

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Abstract | Oil seed production is important for Pakistan, while Pakistan invests the 2nd highest foreign exchange on the import of edible oil. Sunflower is one of the best options to work due to its better oil quality and fit well in the cropping system of environment. Combined effect of N, P and S on sunflower is essential to review. Field experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2016. Nitrogen (40, 80 and 120 kg ha^{-1}), P (30, 60 and 90 kg ha^{-1}) and S (10, 20 and 30 kg ha^{-1}) were compared in a randomized complete block design in three replications. Plot (4m x 4.2m) with six rows were made and planted at 0.7m spacing on ridges. Results revealed that N 120 kg ha^{-1} resulted in the maximum days to flowering, leaf chlorophyll content, capitulum diameter and grains including their weight, which resulted in higher grains yield. Likewise, the increased in P rates have shown better results for all the observed traits with P 90 kg ha^{-1}. Sulphur application of 30 kg ha^{-1} also showed better performance on sunflower yield traits. At some observations S 20 and 30 kg ha^{-1} were found non-significant. Situation like field remains longer under cereal crops cultivation, the integrated effect of nutrients i.e. N 80 with P 90 kg and S 30 is the best option to grow sunflower for better oil and protein. The study suggests that N, P and S at the rate of 80, 90 and 30 kg ha^{-1} is the best combination for soils remained with cereal crops in cultivation to plant with sunflower good quality of oil and protein.

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Introduction

Sunflower (*Helianthus annuus* L.) is important oil crop. It is characterized for high oil quality (Nasim et al., 2011; Khan el al., 2014). In Pakistan, its introduction started on limited scale in 1960. It is currently planted on about 9% cropped area every year (FAO, 2013). Sunflower occupies 4th position among oilseeds crops after soybean, palm oil and canola in the world (Ahmad et al., 2011). Growing sunflower is interesting for seeds, which is rich source of oil (36-52%) and protein (28-32%) in addition to its production twice in a year (Rosa et al., 2009). Due to its recent introduction in the cropping system in Khyber Pakhtunkhuwa, its harvestable yield is low which is due to many reasons. One of the major causes of low production is imbalance fertilizer application (Sharma et al., 2008). Improvement in production technology is resolving through research efforts by improvement in the cultivation i.e. identification of a suitable hybrids in the agro-ecological condition. Hysun-33 is a suitable genotype for Peshawar's climate and soil (Khan et al., 2014). Nonetheless, proper input combination for the crop is essential for its optimum production as well as seed quality i.e. oil and protein content (Haq and Mallarino, 2005).

Sunflower has a wider scope for adaptation in the existing cropping system of Pakistan, which is due to its local edible oil extraction facility at village level (Arshad et al., 2009). Use of inorganic fertilizers in appropriate amount and combination are important aspects to document growth and development of sunflower focusing seed yield and quality. Yield and yield traits of sunflower are mainly associated with proper nutrient management addressing the crop production technology (Sadras, 2006). Imbalance fertilizer application not only increase the production cost but also adversely affects the environment (FAO, 2007).

Nitrogen (N) is essential for plant biochemical processes including protein building with increase in biomass (Lawlor, 2002). Appropriate soil N-content at vegetative and reproductive stages ensures quality grains (Muhammad, 2006). Similarly, phosphorus (P) is essential for biological process. Soils contain high amount of P, which is not available to plants due to its sources of application and/or soil pH (Shenoy and Kalagudi, 2005). It also plays important role in flower formation, seed production and crop maturity (Osman and Awed, 2010). Both grain weight and number increased with optimum P (Khan et al., 2014). In addition to N and P, Sulphur plays important role in improving seed oil content (Tandon and Messick, 2002). It also enhances use efficiency of N and P (Najar et al., 2011). Keeping in view the importance of synthetic nutrient management in agriculture crop, increasing production cost and adverse effects on the environment, the study focused on optimizing the integrated responses of nitrogen, phosphorus and sulphur rates on sunflower production.

Materials and Methods

Field experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2016 focusing the combined effect of N, P and S on yield and oil content of sunflower as summer season crop. The altitude of experimental location was 359 m above sea level, semi-arid, sub-tropical climate; receiving annual precipitation not less than 360 mm. Field was subsequently irrigated with Warsak canal irrigation system as per crop water demand during the season. Soil pH of the experimental site was 8.3 with clay-loam texture.

Treatments and layout

Field was prepared as per recommended practices adapted for sunflower crop after wheat harvesting. Sunflower (cv. Hysun-33) hybrid was planted on Jun 25, 2016. Experiment comprised of three factors i.e. N (40, 80 and 120 kg ha^{-1}), P (30, 60 and 90 kg ha^{-1}) and S (10, 20 and 30 kg ha^{-1}) including one control. Experiment was a randomized complete block in three replications. Each experimental unit was 4.0 m x 4.2 m. Planting was made on ridges at 0.70 m distances spaced within row for 20 cm within an experimental unit. Field was remained fallow after wheat harvesting from mid-May till the sowing of the sunflower crop. Seedbed was prepared using a cultivator runs twice at proper field capacity state. Seed rate of 5 kg ha^{-1} was used for the crop. Nitrogen was applied in two equal splits i.e. 50% at sowing during seedbed preparation and other 50% about 30 days after emergence. Phosphorous and sulphur were applied at the time of seedbed preparation. Thinning was done about two weeks after sowing by removing extra plants from rows manually that were in duplicates or emerged unwanted in rows to sustain a population of about 70000 per hectare. In addition to rainfall, three irrigations were applied as per crop water demand under the flood irrigation system (the irrigation was measured equal to about 56 mm rainfall). Weather data with rainfall of the crop growth season is shown in Figure 1. Plant protection measures i.e. weeding were done twice in the first 40 days after sowing to eradicate all weeds.

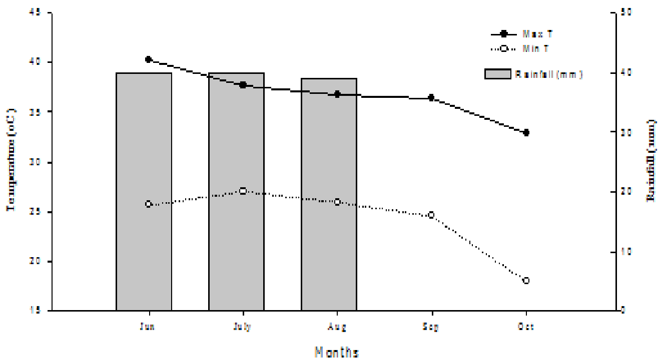

Figure 1: *Mean monthly temperature (both maximum and minimum °C) and precipitation of the experimental site for the crop growth period (Source Pak. Met. Department, Peshawar).*

Measurements and observation

Days to flowering was recorded by counting days from sowing to the date when 80% flowers produced in a plot. Plant height (cm) was noted with measuring tape on 10 randomly selected representative plants in a plot, measured from base to the top edge. Leaf chlorophyll content was recorded at flowering stage using SPAD G-28 meter (Minolta Japan). The capitulum diameter (cm) was recorded by selecting 10 representative capitulums in each plot. Measurements were made with the help of line gauge in center of each capitulum and then averaged. Grain number per capitulum was manually counted on 10 randomly selected samples from each experimental unit. Grains were shelled and counted manually. Data on 1000 grains weight (g) was calculated from threshed clean grains in a treatment by taking random samples, counted 1000 grains and weighted (g) on a digital balance. Two central rows in an experimental unit were harvested. After sun drying in field for two weeks, biomass was weighed on a field spring balance. Same 2 central rows harvested for biological yield were used for grain yield after threshing and cleaning. Oil content (%) in grains was estimated with Nuclear Magnet Resonance (NMR) at NIFA, Peshawar. The NMR provides fast and precise determination of SFC (Solid Fat Content) in grains used in cups (unshelled). The machine was calibrated at start using already calibrated equations standardized and samples of sunflower. On successful reading after calibration with standard, the experiment samples were run in duplicate having a standard after each 28 samples.

Data were statistically analyzed using appropriate analysis of variance (ANOVA) techniques suitable for the randomized complete block design. Significant differences among treatments means were made using least significant difference (LSD) test at probability 5% (Steel and Torrie, 1980).

Results and Discussion

Data regarding days to flowering, plant height (cm) and Chlorophyll content in leaves under integrated N, P and S application rates are shown in Table 1. The ANOVA results indicated significant changes in days to flowering of sunflower with various N, P and S rates. Nonetheless, all possible interactions of treatments were non-significant but N × P ($p \leq 0.05$). Treatment N applied at 120 kg ha^{-1} delayed ($p \leq 0.05$) flowering, whereas, N 80 and 40 kg ha^{-1} application did not show any change in days to flowering. Days to flowering did not differ for P applied 30 and 60 kg ha^{-1} or 60 and 90 kg ha^{-1}. Contrary to N and P, different S rates did not show ($p \leq 0.05$) any changes in days to flowering of sunflower. Interactive effect of treatments (N × P) revealed that increased P-rate to the crop showed a stable reduction in days to flowering for N 120 kg ha^{-1}, while a strong reduction in days to flowering with increasing P from 30 to 60 or 90 kg ha^{-1} with N-rates 80 and/or 40 kg ha^{-1} (Figure 2a). Days to flowering of sunflower was significantly affected by N-rates due to increase in vegetative growth by higher N-rate which subsequently delay flowering (Oyinlola et al., 2010). Optimum N supports vegetative growth under optimal growth condition, which was observed between 80 and 120 but not between 40 and 80 due to lower rate for the soil (Bakht et al., 2010). Contrary to this, days to flowering did not differ between 30 and 60 as well as 60 and 90 which in support of increasing N-rates to the crop showed that both N and P are interdependent (Hammad et al., 2011). In case of P application rates, optimum N demand also increases which in turn improved the crop vegetative development and hence suppressed crop to flower early (Wabekwa et al., 2014). Due to repeated cereals-based cropping system on the soil, interactive effects of the treatments N and P is well expressed for days to flowering in Figure 2a (Maity et al., 2003). Sulphur did not show any visible changes in days to flowering (Martre et al., 2009; Oyinlola et al., 2010).

Table 1: *Flowering (d), plant height (cm) and leaf chlorophyll (mg cm^{-2}) as affected by Nitrogen (N), Phosphorus (P) and Sulphur (S) application rates to sunflower.*

Treatments	Nutrient Uptake (kg ha^{-1})	Application rates (kg ha^{-1})	Flowering (days)	Plant height (cm)	Chlorophyll in leaf (mg cm^{-2})
Nitrogen	3.7-6.1	40	63 b	147.74 b	52.48 b
	-	80	63 b	155.85 a	54.60 b
	-	120	65 a	158.11 a	64.17 a
LSD			1.19	4.61	2.89
Phosphorus	1.2-2.8	30	65 a	146.67 b	55.47 b
	-	60	64 ab	156.56 a	56.05 b
	-	90	62 b	158.48 a	59.72 a
LSD			1.19	4.61	2.89
Sulphur	0.39-0.58	10	64 ab	153.85	55.23 b
	-	20	64 ab	154.37	56.99 ab
	-	30	63 b	153.48	59.04 a
LSD	-		1.19	NS	2.89
Interaction	-				
N × P	-		*	NS	NS
N × S			NS	NS	*
P × S			NS	*	NS
N × P × S			NS	NS	NS

Means followed by common letter within a category in a column are non-significant ($p<0.05$) using least significant difference (LSD) test.

Data for plant height (cm) of sunflower were also influenced by N and P rates but not with S rates. Interaction of treatment (P × S) affects ($p \leq 0.05$) plant height. The maximum plant height was noted in the N-rate 80 kg ha^{-1}, which did not differ than the 120 kg ha^{-1}. Contrary to this, N 40 kg ha^{-1} showed the lowest plant height. Similar responses in plant height were observed for P-rates with no changes ($p \leq 0.05$) for P 60 and 90 kg ha^{-1} but lowest ($p \leq 0.05$) plant height for P 30 kg ha^{-1}. Interaction of treatments (P × S) revealed that plant height increased with increasing P-rates from 30 to 90 kg ha^{-1} for all the three S-rates with more consistently for 10 and 20 kg ha^{-1} to sunflower crop (Figure 2b). However, increasing in P from 30 to 60 kg ha^{-1} with S 30 kg ha^{-1} plant height did not change but thereafter it increased for P 60 and 90 kg ha^{-1}. Plant height affected by N and P levels is quite obvious. Nitrogen is the major component of proteins, chlorophyll and nucleotides, which are necessary for metabolic functions of crop development. When both N and P were optimum, plants have to attained their optimum height and were observed under N 80 and P 60 kg ha^{-1}, that did not differ with further increase but did find lower than the lower rates of both N and P (Ali et al., 2004; Rasool et al., 2013). Application of P rate favors plant height simultaneously with N-increments (Gaur et al., 2003). Sulphur its self did not express any change in plant height, however, in relation with P affected height of the plant. Increase P from 60 to 90 kg ha^{-1} expressed height of sunflower with S 10 and 20 kg ha^{-1} as compared to S 30 kg ha^{-1}. This may be due to interactive effects of nutrients (Patra et al., 2013).

Leaf chlorophyll contents (SPAD) affected ($p \leq 0.05$) with N, P and S-levels. The only interaction (N × S) was found significant for leaf chlorophyll content. Leaf chlorophyll content was non-significant for N 80 and 120 kg ha^{-1} but found lower ($p \leq 0.05$) for N 40 kg ha^{-1}. Similarly, the P 60 and 90 kg ha^{-1} did not vary in leaf chlorophyll content but found lower ($p \leq 0.05$) with P 30 kg ha^{-1}. Leaf chlorophyll content increased with increasing S levels with the highest for S 30 kg ha^{-1} with a non-significant difference from the S 20 kg ha^{-1} and significantly ($p \leq 0.05$) lower for S 10 kg ha^{-1}. Interaction of treatments (N × S) exhibited stable increase in leaf chlorophyll content for S 30 kg ha^{-1} by increasing N-rates from 40 to 120 kg ha^{-1} (Figure 2c). The S 20 kg ha^{-1} showed moderate to stark increments in leaf chlorophyll content with increase N from 80 to 120 kg ha^{-1} and more or less similar response was observed for S 10 kg ha^{-1} for increased N-rates from 40 to 120 kg ha^{-1}. Optimum production ensures by the optimum nutrients rates. Application of the 120 kg N ha^{-1} and 90 kg P ha^{-1} with 20 kg S ha^{-1} has ensured the desired nutrients availability for sunflower growth and hence results the highest green chlorophyll in plant parts. Under the prevailing soil conditions with crops in cultivation, sunflower hence ensured better reflection of the SPAD meter readings (Rousseaux et al., 2000).

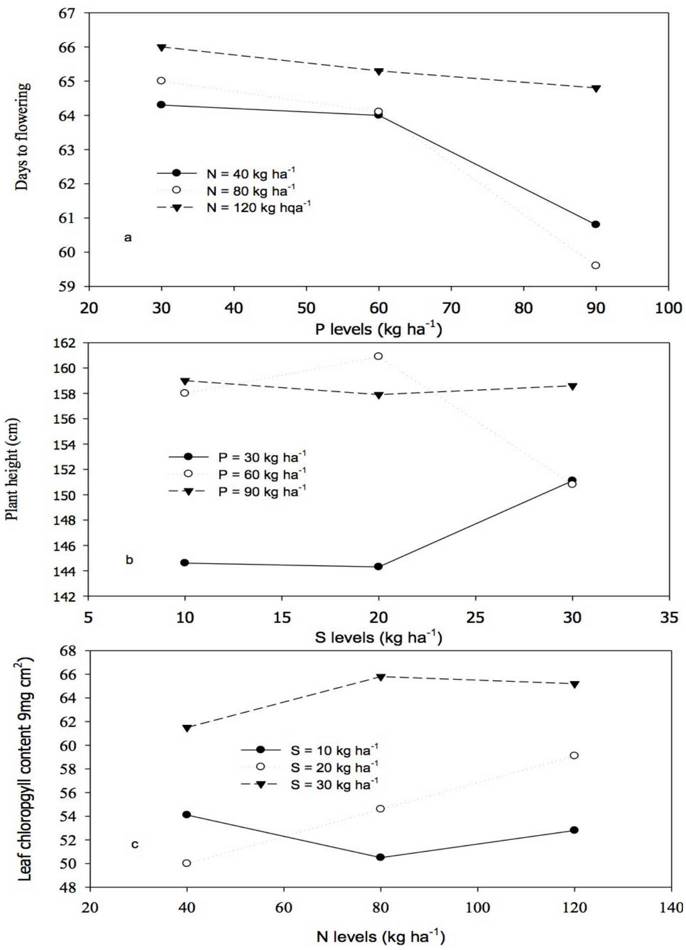

Figure 2: *Interactive effect of treatments (a) N x P on days to flowering, (b) P x S on plant height (cm) and (c) N x S on leaf chlorophyll content of sunflower.*

Data concerning sunflower capitulum diameter (cm), grain per capitulum and grains weight (g) influenced by treatments N, P and S rates are shown in (Table 2). The ANOVA results indicated that increased N-rates from 40 to any subsequent level i.e. 80 and 120 kg ha^{-1} increased ($p \leq 0.05$) capitulum diameter of the sunflower. In contrast, P 90 and 60 did not show ($p \leq 0.05$) any change in capitulum diameter but did decrease ($p \leq 0.05$) capitulum diameter ($p \leq 0.05$) at P 30 kg ha^{-1}. The effect of the S-rates from 10 to 30 kg ha^{-1} was non-significant on sunflower capitulum diameter. All possible interactions were non-significant for capitulum diameter of sunflower plants. Capitulum diameter of sunflower increased with increasing N levels. It is due to the role of N, which stimulate growth (Nasim et al., 2011). According to findings of the Ali and Noorka (2013), optimum N application has increased ($p \leq 0.05$) capitulum diameter of sunflower. Limitation of N, as expected in 80 and 40 kg ha^{-1}, has results reduction in growth of capitulum, which adversely affected capitulum diameter (Jahangir et al., 2006; Ali et al., 2012).

Table 2: *Capitulum diameter (cm), grains capitulum^{-1} and 1000 grain weight (g) as affected by Nitrogen (N), Phosphorus (P) and Sulphur (S) application rates to sunflower.*

Treatments	Application rates (kg ha^{-1})	Capitulum diameter (cm)	Grains capitulum^{-1}	1000 grain weight (g)
Nitrogen	40	10.78 c	788 c	37.37 c
	80	12.16 b	846 b	42.48 b
	120	13.71 a	949 a	45.70 a
LSD		0.71817	38.5196	2.07411
Phosphorus	30	11.36 b	824 b	40.30 b
	60	12.68 a	833 b	42.30 ab
	90	12.61 a	925 a	42.96 a
LSD		0.71817	38.5196	2.07411
Sulphur	10	12.53	840 b	42.52
	20	11.85	855 ab	41.7
	30	12.27	888 a	41.33
LSD		NS	38.5196	NS
Interaction				
N × P		NS	NS	NS
N × S		NS	NS	NS
P × S		NS	NS	NS
N × P × S		NS	NS	NS

Means followed by common letter within a category in a column are non-significant (p<0.05) using least significant difference (LSD) test.

Data for grain per capitulum were significantly affected by N, P and S rates. All possible interactions of treatment were non-significant for grain per capitulum. Maximum grain per capitulum was recorded for N 120 kg ha^{-1}, followed by N 80 kg ha^{-1} with minimum for N 40 kg ha^{-1}. Treatment P 90 kg ha^{-1} resulted the maximum grain per capitulum, followed by P 60 and 30 kg ha^{-1}. Grain per capitulum did not differ for P 60 and 30 kg ha^{-1}. Likewise, grain per capitulum was higher for S 30, which did not vary with S 20 and 10 kg ha^{-1}. Grains per capitulum are subsequent results of the surface area. As the capitulum diameter decreased the surface area of sunflower capitulum also decreased and hence showed a lower grain number per unit area i.e. per capitulum or plant with limiting both N and P (Oyinlola et al., 2010). Grains per capitulum increased gradually with N increment from 80 to 120 kg ha^{-1}, which is due to overall improvement in plant synthesis towards grains (Awasthi et al., 2011). Plots fertilized with 90 kg P ha^{-1} resulted more grains. It is due to optimum growth with sufficient N and P (Mohammed et al., 2003). Jahangir et al. (2006) have also reported in their research paper that the maximum number of grains per capitulum increased with S application to the sunflower crop. Among the applied S-rates, higher grains capitulum^{-1} was associated to 20 kg S ha^{-1} that did not vary from the 30 kg S ha^{-1}. This showed that S 20 kg ha-1 with other nutrients (i.e. N and P) is the optimum rate for the sunflower crop in the area and for the cropping system (Rasool et al., 2013). Higher S level may have resulted in proper partitioning of assimilates from source to sink, which resulted in significant effects on overall development of the reproductive parts (Ravi et al., 2008).

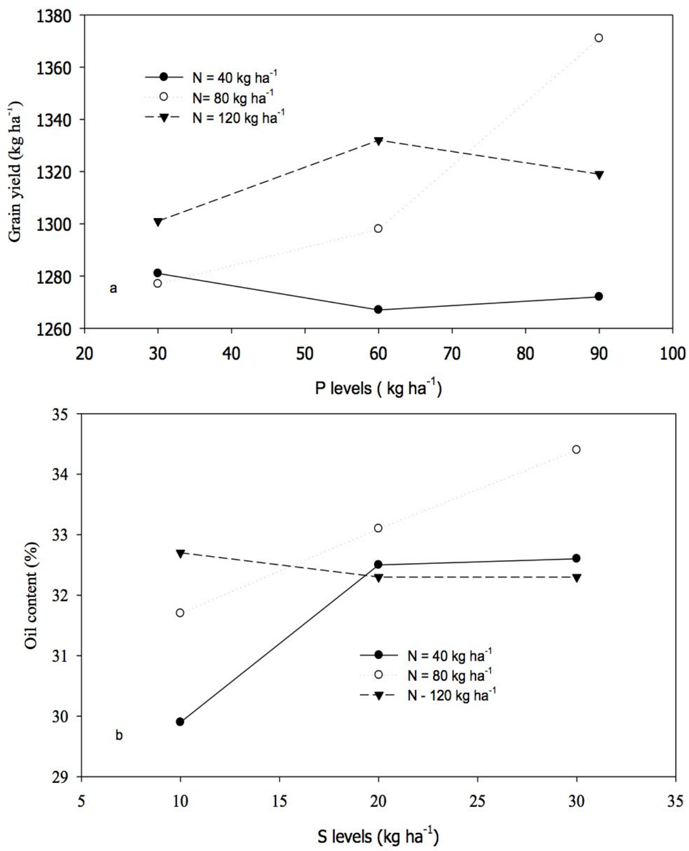

Figure 3: *Interactive effect of treatments (a) N × P on grain yield and (b) N × S on grain oil content of sunflower.*

Data concerning thousand grains weight differed for N and P-rates. As N rates increased to sunflower, the thousand grains weight significantly ($p \leq 0.05$) increased. Nonetheless, P 30 and 60 kg ha^{-1} did not differ in 1000 grains weight and likewise P 60 and 90 kg ha^{-1}. Treatments S-rates from 10 to 30 kg ha^{-1} exhibited a non-significant effect on thousand grains weight. All possible interactions of N, P and S-rates did not show any significant change in 1000 grains weight of sunflower. Thousand grains weight was the maximum at N 120 kg ha^{-1} due to the N role activate growth and yield components (Rana et al., 2015). The 1000 grains weight also increased with P 90 kg ha^{-1} due to increasing grain filling efficiency (Karadogan et al., 2009). Both optimum N and P ensures the risk reduction of unfilled grains in sunflower (Ali et al., 2006; Malik et al., 2006).

Table 3: *Grain yield (kg ha^{-1}), oil (%) and protein (%) content as affected by Nitrogen (N), Phosphorus (P) and Sulphur (S) application rates to sunflower.*

Treatments	Application rates (kg ha^{-1})	Grain yield (kg ha^{-1})	Oil in seed (%)	Protein in seeds (%)
Nitrogen	40	1273.49 c	31.65 b	14.81 c
	80	1315.55 b	33.04 a	16.12 b
	120	1317.14 a	32.42 ab	18.78 a
LSD		26.5597	0.95828	0.61465
Phosphorus	30	1286.33 b	31.63 b	16.29
	60	1298.99 a	32.19 b	16.79
	90	1320.87 a	33.29 a	16.63
LSD		26.5597	0.95828	NS
Sulphur	10	1279.67 b	31.40 b	16.57
	20	1299.65 ab	32.63 a	16.5
	30	1326.87 a	33.08 a	16.64
LSD		26.5597	0.95828	NS
Interaction				
N× P		*	NS	NS
N × S		NS	*	NS
P ×S		NS	NS	NS
N × P × S		NS	NS	NS

Means followed by common letter within a category in a column are non-significant (p<0.05) using least significant difference (LSD) test.

Data regarding yield (kg ha^{-1}), oil (%) and protein (%) contents in sunflower grains were significantly (p≤0.05) affected with application of different N, P and S-rates (Table 3). The maximum grain yield recorded under the application of N 120 kg ha^{-1}, followed by N 80 and the minimum yield by 40 kg ha^{-1}. Phosphorus given at 90 and 60 kg ha^{-1} did not show any change in grain yield but did decrease grain yield with 40 kg ha^{-1}. Grain yield did not differ (p≤0.05) for S-rates 10 with 20 kg ha^{-1} and for S-rates 20 with 30 kg ha^{-1}. Treatment interaction (N × P) was significant for grain yield (Figure 3a). Increasing P rates from 30 to 90 kg ha^{-1}, different N-rates changed the grain yield of sunflower. Nitrogen 80 kg ha^{-1} showed manifold increments in grain yield with increasing P-levels. Similarly, N 120 kg ha^{-1} showed increase in yield with P 30 to 60 but thereafter leveled off. Contrary to this, N 40 kg ha^{-1} did not show any remarkable changes in grain yield with increasing P-levels from 30 to 60 or 90 kg ha^{-1}. Grain yield of sunflower was significantly higher at the N-rates and increased with increasing N-rates. It is due to positive response of yield attributes i.e. capitulum diameter and number of grains per capitulum (Syed et al., 2006; Sarkar and Mallick, 2009). Growth and yield components significantly increased with increasing N, which ultimately produced higher grain yield (Osman and Awed, 2010). The P 90 kg ha^{-1} showed the maximum yield (Allam, 2000; Osman and Awed, 2010). They reported that P is necessary for the formation, filling and ripening of grains, which resulted in higher yield at 90 kg ha^{-1}. In addition to N and P, the S applied 20 kg ha^{-1} did not differ than S 30 kg ha^{-1}, but did found better than S 10 kg ha^{-1} confirmed the rates application to the soil under the existing nutrients status (Ravi et al., 2008). The availability of optimum S has favorable effect on yield and its traits (Raja et al., 2007). Optimum rates of integrated N, P and S influenced capitulum diameter, grains per capitulum and grains weight (Agrawal et al., 2000), which resulted in the higher grains yield (Ozer et al., 2004).

Oil content in sunflower grains affected (p≤0.05) by N, P and S rates. The application of 80 kg N ha^{-1} showed the highest oil content, which did not differ (p≤0.05) than the applied 120 kg N ha^{-1}. The maximum oil content was reported for N 80 kg ha^{-1}. Phosphorus applied 90 kg ha^{-1} showed the highest oil content, followed by P 60 kg ha^{-1}, which did not differ from P 30 kg ha^{-1}. Oil content was reported the highest at S 20 kg ha^{-1} that did not differ with 30 kg ha^{-1}. The lowest oil content was recorded for S 10 kg ha^{-1}. Interaction of treatment (N × S) was significant for oil content (Figure 3b), which consistently increased for N 80 kg ha^{-1} with increasing S from 10 to 30 kg ha^{-1}. Oil content increased with increasing S from 10 to 20 at N 40 kg ha^{-1} but did not change thereafter with further increasing S from 20 to 30 under the same 40 kg N ha^{-1}. Increasing oil content in grains associated with more vegetative growth and maximum production of carbohydrates for seed development (Hasanzade, 2002; Ishfaq et al., 2009).

Oil content (%) of sunflower has to be decreased with more N but here the N 40 kg ha^{-1} was very less that has not shown any positive effect on grain oil content (Oyinlola et al., 2010). Contrary to that N 120 did not show any positive effect on seed oil content. Likewise, P increased grain oil content at P 90 kg ha^{-1}, which seems to be the optimum level for the crop for the soil and cropping system adapted (Jahangir et al., 2006; Salih, 2013). According to them the oil content in sunflower significantly improved with increasing P to soil. Malik et al. (2006) reported that application of N and P at appropriate combinations significantly increased grain yield with oil content of sunflower. Oil content was also the best at S 20 kg ha^{-1},which did not increase with increase S 30 kg ha^{-1} with the 120 kg N ha^{-1} but did increase with N 80 kg ha^{-1} (Ravi et al., 2008). Sulphur is involved in the activation of enzymes that helps in biochemical reaction within plant and hence increase oil (Subhani et al., 2003). According to finding of the Rasool et al. (2013), interactive effects of N, P and S favors both grain yield and its oil content in sunflower.

Protein is important component of grains, which increased at N 120 kg ha^{-1} but did not differ at N 80 and 40 kg ha^{-1}. Likewise, protein in grains did not change at P 30 and 60 but did increase ($p \leq 0.05$) at P 90 kg ha^{-1}. Similarly, the S applied 10 and 20 kg ha^{-1} did not show any change in protein content of grains. Likewise, the grain protein content under S 20 and 30 were also found non-significant ($p \leq 0.05$). Treatments interaction of the N, P and S did not show any significant change in grain protein content. Generally, plant protein is subject to optimum N-rates application, which in this study was the highest at N 120 kg ha^{-1}, and significantly decreased with decreasing the N-rates to 80 and 40 kg ha^{-1}, respectively. Both the P-rates and the S-levels did not show any significant effects by enhancing their rates to the crop. Neither any of the treatments interaction showed any significant changes in the grain protein content.

Conclusions

It is concluded from results of this experiment that N 80 kg ha^{-1} with P 90 kg ha^{-1} is the best option for sunflower production of soils remain longer in cereal based rotation system. Nonetheless, sulphur has improved grain oil and protein with 30 kg S ha^{-1}. Higher rate of N did not show any significant ($p \leq 0.05$) response as integrated application with P and S. It is recommended that sunflower be planted with N 80, P 90 and S 30 kg ha^{-1} for better performance in Peshawar climate on soils remained longer under cereals crops.

Author's Contribution

Saif Ullah conducted research and compile data analyses and Mohammad Akmal designed experiment and edited the manuscript.

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