Research Article Open Access

Agronomic Performance of Sunflower (*Helianthus annuus* L.) Against Different Sources and Levels of Potassium Fertilization

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Received
January 25, 2017

Accepted
May 17, 2018

Published Online
June 20, 2018

Abstract: Agricultural productions can be increased by usage of proper source of chemical fertilizers. This present study investigated the effects of potassium rates and its sources on growth and yield traits of two sunflower (*Helianthus annuus* L) genotypes of Pakistan. The experiment was conducted in factorial split-plot design, repeated thrice. Sunflower genotypes (HO-1 and Hysun-33) were grown in main plots and two sources, sulphate of potash (K_2SO_4) and muriate of potash (KCl) was applied in sub plots at the rates of 0, 50, 100 and 150 kg ha^{-1}. Application of SOP (sulphate of potash) at 150 kg ha^{-1} showed greater results for growth, biomass and seed yield from 5 to 30% and with MOP (muriate of potash) at 150 kg ha^{-1}from 2 to 20% relative to control. Comparatively (5 to 30%) higher results were obtained at SOP (150 kg ha^{-1}) and (2 to 20%) at MOP (150 kg ha^{-1}) for growth, biomass and seed yield traits in comparison to control treated plots. Sunflower genotypes showed significant variations in response to varying levels of potassium and its sources However, potash application rates and sources, sunflower genotypes significantly varied from each other. Hysun-33had enhanced (7-25%) the growth and seed yield components over HO-1. Sulphate of potash was relatively more effective to improve growth and seed yield components of sunflower genotypes as compared to muriate of potash andHysun-33 showed more response in comparison to HO-1. Potash application (150 kg ha^{-1}) produced maximum values for the most of the growth traits and seed yield components of sunflower genotypes. Overall, the findings of the present work accentuate the essentially of potassium supply for the growth, yield and oil content of sunflower, highlight that the growth and seed yield components were significantly affected by the rate and source of K application as well as by the genotypes.

Keywords: Seed index; potash application; growth; oil content; sunflower.

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Cite this article as: Gujar, A., M. Buriro, M.S. Kubar, K.A. Kubar, M. Kamran, M.A. Chajro and A.M. Narejo. 2018. **Agronomic performance of sunflower (*Helianthus annuus* L.) against different sources and levels of potassium fertilization.** Journal of Environmental and Agricultural Sciences. 15: 18-27.

1. Introduction

Sunflower (*Helianthus annuus* L.) is widely cultivated in USA, Canada, Mexico, Brazil, Argentina, Chile and other North and South American countries. This crop is considered as the third largest source of vegetable oil worldwide after soybean and palm. Europe and the Russia produce over 60% of the total sunflower production in the world (Putnam et al., 2013). Sunflower oil contains large amount of vitamin A, D, E, K and considerable proteins (20-40%) are present (Connor and Hall 1997). Sunflower growth is adversely affected by a diversity of abiotic stresses, including nutrients deficiency. Potassium is the major nutrient contributing to the yield and quality in sunflower production (Chhajro et al., 2013, Muhammadi et al., 2013; Salve et al., 2018). The consequent response of many crops to potassium fertilization has been reported, e.g. maize (Tariq et al., 2011; Martineau et al., 2017), rice (Zain and Ismail, 2017), cotton (Zia-ul-hassan et al., 2014), sunflower (Chhajro et al., 2013), tomato (Zia-ul-hassan et al., 2016), sorghum (Saleem et al., 2011) and wheat (Lu et al., 2017). There is a dire need to understand the agronomic performance of sunflower against different rates and sources of K nutrition in sunflower. It is also exciting to know that different sunflower genotypes differ in their agronomic performance with fertilization. The magnitude of a crop's growth and yield response to K fertilization varies with soil available K levels, the K input rate (Munir et al., 2007; Mirza et al., 2018; Rafiullah et al., 2018).

Potassium is known as most versatile element due to its multiple vital functions in plants as well as in the soils (Wang and Wu, 2013; White and Karley, 2010). It is involved in pH maintenance, enzyme activation, photosynthesis, protein synthesis, activating a number of enzymes, stomatal movement, membrane transport, biomass production, leaf growth, CO_2-assimilation, drought resistance, efficient use of water, enhancing product quality and crop yields (Marschner, 2011; Suzer, 2012; Lu et al., 2017; Zain and Ismail, 2017; Muhammad et al., 2018). Currently, potassium levels are going to decline due to exhaustive cropping and growing of high yielding genotypes (Manning, 2010). However, due to depletion in K levels in soils causes negative effects on crop yield and quality in some parts of Pakistan. Unluckily, although the recent reports of potassium deficiency in many soil series of Pakistan, the K status of Pakistani soils is wrongly considered adequate (Zia-ul-Hassan et al., 2016). Sunflower was grown up on an area of 700 thousand hectares producing 378 thousand tons seed and 144 thousand tons oil (2013). This indicates a marked decrease in the area, seed production and oil production as compared to the year 2011-12 (Government of Pakistan, 2012).

There are numerous factors that are responsible for lower productivity in sunflower which include improper dosage and management of inputs required by sunflower crop. Among the restraints, less and unbalanced usage of chemical fertilizers is the main obstacle towards low productivity (Siddiqui et al., 2011; Malihe et al., 2013;Mirza et al., 2018). Chemical fertilizers are applied in different forms and sources, each type and sources has its benefits and drawbacks so famers should think for the right choice of chemical fertilizers of soils (Kapourchal et al., 2011; Khan et al., 2012; Amanullah et al., 2016). Judicious use of fertilizer is considered as one of the most important factor which could increase sunflower yield on per unit area basis. Among nutrients applied, potassium is one of the most essential elements for plant growth. Its role is well documented in photosynthesis enzyme activity, synthesis of protein, carbohydrates and enabling to resist against pest and diseases (Daniel et al., 2016; Fayyaz et al., 2017).

Intensification of the crops and the acceptance of high yielding genotypes have caused considerable drainage of potassium and crops are responding to potassium fertilization (Amanullah et al., 2016; Rafiullah et al., 2018). Potassium is essential nutrient for the growth of plants and necessary for plants in larger quantities. Mostly Pakistani soils contains significant amount of total K as compared to available K in the form of insoluble minerals. However, it is well reported that only a minor portion of K is present in the convenient way to plants (Khan et al., 2012; Zia-ul-Hassan et al., 2016).

Though, under current conditions where the release of potassium is not sufficient to meet the needs of the crops, the small amount of K should be supplemented. Supplementation of K-fertilizers is usually done as a muriate of potash and sulphate of potash. Sulphate of potash (SOP) is a good source of potassium, with low salt index, and also increases plant resistance against various diseases. However, it is very expensive and unfortunately farmers of this region are poor and cannot afford it. Muriate of potash is cheaper source of potassium (60% K) higher solubility as compared to sulphate of potash (50% K). Due to higher chloride content (45-47%), which is already reaching upper threshold in our soils due to arid and semi-arid climate, addition of chloride source fertilizer potentially hinder plant growth and development (Farooq et al., 2018). Application of muriate of potash increases salt index, chloride level in the soil will increase to touch the climax and this more chloride will damage the crops instead of getting benefit and the poor farmers may face heavy economic losses (Tariq et al., 2011).

Limited information is available regarding impacts of different sources and rates of potassium on the growth and yield of sunflower. Therefore, to identify the much suitable, inexpensive, useful source for the sustainability of sunflower crop production. Keeping in mind these facts, we conducted a field experiment to investigate the influence of different levels and sources of potash on yield and oil content of sunflower genotypes of Pakistan.

Table 1. Physico-chemical properties of soil

Soil Characteristics	Units	Mean value
Soil texture	–	Silty clay loam
Clay	%	35
Silt	%	20
Sand	%	45
Soil pH	–	8.3
Electrical conductivity	dS m^{-1}	1.45
Bulk density	g /cm^3	0.52
Soil organic matter	%	0.68
Wilting point	cm^3 water/cm^3 soil	0.224
Field capacity	cm^3 water/cm^3 soil	0.378
Saturation	cm^3 water/cm^3 soil	0.522
Drainage rate	cm/hr	0.266
Available water	water/foot soil	1.856
Available nitrogen	mg kg^{-1}	0.26
Available phosphorus	mg kg^{-1}	2.1
Available potassium	mg kg^{-1}	135

2. Materials and Methods

The field experiment was conducted during the year 2012-13 to examine the influence of different rates and sources of potassium on growth and yield components of sunflower at the experimental fields of oilseeds section, Agriculture Research Institute, Tandojam, Sindh, Pakistan. The experimental area was plowed for seedbed preparation thoroughly; channels were prepared according to layout plan. Each plot was leveled thoroughly to allow normal irrigation water. Field experiment was laid out with factorial arrangement in split-plot design with three replicates, keeping the plot size of 4 ×6m (24m^2). The treatments included two K sources and three K levels. Factor A included sunflower genotypes (HO-1 and Hysun-33) which were grown in main plots and factor B, two sources sulphate of potash (K_2SO_4) and muriate of potash (KCl) was applied @ 0, 50, 100 and 150 kg ha^{-1} in sub-plots. In addition to different levels of K, crop was fertilized with the recommended doses of nitrogen (N, 140 kg ha^{-1} as urea) and phosphorus (70 kg ha^{-1}, as diammonium phosphate, DAP). Total N was applied, in three equal splits, at the time of sowing, at 2nd and at 3rd irrigations. Basal dose of N (33%) and P were applied at the time of planting by broadcasting to the soil and then thoroughly mixed. Potash was applied in each specific treatment plots in the form of sulphate of potash (SOP) and muriate of potash (MOP).

Table 2. Plant height (cm) of sunflower varieties under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	Hysun-33	
Control (CK)	29.62	32.88	31.25 d
K_2O 50 kg ha^{-1} (SOP)	32.60	36.18	34.39 c
K_2O 100 kg ha^{-1} (SOP)	34.17	37.93	36.05 b
K_2O 150 kg ha^{-1} (SOP)	37.10	41.19	39.14 a
K_2O 50 kg ha^{-1} (MOP)	32.11	35.64	33.87 c
K_2O 100 kg ha^{-1} (MOP)	33.66	37.36	35.51 b
K_2O 150 kg ha^{-1} (MOP)	36.55	40.57	38.56 a
Mean	33.69 b	37.39 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	1.6094	0.8603	2.2760
LSD 0.05	3.3082	1.7683	-
LSD 0.01	4.4721	2.3904	-

Table 3. Stem girth (cm) of sunflower varieties under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	4.51	4.60	4.55 d
K_2O @50 kg ha^{-1} (SOP)	4.96	5.06	5.01 c
K_2O @100 kg ha^{-1} (SOP)	5.20	5.30	5.25 b
K_2O @150 kg ha^{-1} (SOP)	5.65	5.76	5.70 a
K_2O @50 kg ha^{-1} (MOP)	4.89	5.98	4.93 c
K_2O @100 kg ha^{-1} (MOP)	5.12	5.22	5.17 b
K_2O @150 kg ha^{-1} (MOP)	5.56	5.68	5.62 a
Mean	5.13 b	5.23 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	0.0472	0.0252	0.0667
LSD 0.05	0.0970	0.0518	-
LSD 0.01	0.1311	0.0701	-

Table 4. Head diameter (cm) of sunflower varieties under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	16.68	18.19	17.43 d
K_2O @50 kg ha^{-1} (SOP)	18.36	20.02	19.19 c
K_2O @100 kg ha^{-1} (SOP)	19.25	20.98	20.12 b
K_2O @150 kg ha^{-1} (SOP)	20.91	22.79	21.85 a
K_2O @50 kg ha^{-1} (MOP)	18.09	19.72	18.90 c
K_2O @100 kg ha^{-1} (MOP)	18.96	20.67	19.82 b
K_2O @150 kg ha^{-1} (MOP)	20.59	22.44	21.52 a
Mean	18.98 b	20.69 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	0.0500	0.2673	0.7071
LSD 0.05	1.0278	0.5494	-
LSD 0.01	1.3894	0.7427	-

Table 5. Seeds $head^{-1}$ of sunflower varieties under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	1317.80	1462.70	1390.20 d
K_2O @50 kg ha^{-1} (SOP)	1377.30	1528.80	1453.10 c
K_2O @100 kg ha^{-1} (SOP)	1443.90	1602.80	1523.30 b
K_2O @150 kg ha^{-1} (SOP)	1567.90	1740.30	1654.10 a
K_2O @50 kg ha^{-1} (MOP)	1356.70	1505.90	1431.30 c
K_2O @100 kg ha^{-1} (MOP)	1422.30	1578.70	1500.50 b
K_2O @150 kg ha^{-1} (MOP)	1544.40	1714.20	1629.30 a
Mean	1432.90 b	1590.50 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	25.690	13.732	36.332
LSD 0.05	52.807	28.227	-
LSD 0.01	71.386	38.157	-

The physcio-chemical properties of experimental soil are presented in (Table 1). The crop was sown by dibbling method on a well-prepared seedbed. The sunflower genotypes (HO-1 and Hysun-33) were sown by maintaining a plant spacing of 1.0 ft. The rows were kept 1.5 ft. apart. All the required cultural and management practices were applied during the study period. Plant growth and yield traits were recorded, for recording the observation on different agronomic parameters five plants were selected randomly from each plot and tagged. Data for grain yield (kg ha^{-1}) in each plot was recorded after harvesting the sunflower grains.

After harvest of the crop, the weights of the seeds per head were recorded after thorough drying and 1000-seed weight was noted. Five plants from each plot were collected at random and plant height was measured and means value was calculated from those five noted values. Seed oil content was determined by using soxhlet apparatus and diethyl ether as a solvent. Stem girth and head diameter was recorded by taking the average of five plants per plot and 10 heads per plots for head diameter using digital measuring scale. Statistical analysis was carried out using Statistic ver. 8.1. The difference in the means were described by (least significant difference <0.05). The data presented in this study were the average of three replicates. All data were analyzed using ANOVA for factorial design, using ANOVA with post hoc LSD to denote significant difference during the comparison.

3. Results and Discussion

Potassium is one of the nutrients which is essentially required for plant growth and seed development in sunflower. Potassium depletion is reported in agricultural soils of Pakistan and low levels of potassium showing adverse effects on the crop yields (Zia-ul-Hassan et al., 2016). Generally, sulphate of potash and muriate of potash are the forms of potassium fertilizers. Muriate of potash (MOP) is expensive cheaper source of potassium, however contains high amount of chloride. Contrarily SOP is the excellent source of potassium supplement with sulphate, suitable for Pakistani soils which already contain higher concentration of chlorides, but most of the farmer cannot afford due to its higher cost (Tariq et al., 2011; Amanullah et al., 2016).

3.1. Growth Components

Treatment means exposed highly significant results (P<0.05) for plant height and stem girth as compared to control. Plant height was increased gradually with the application of higher doses (120-150 kg ha^{-1}) of different sources of K in both of the varieties. Results indicated that SOP (sulphate of potash) is more reliable source of K_2O regarding plant height and stem girth while Hysun-33 performed better than HO-1 under different levels of K as shown in (Table 2 and 3). SOP demonstrated superiority over MOP (muriate of potash) by exhibiting highest mean value of plant height (39.14 cm) at 150 kg ha^{-1} (SOP) as compared to 150 kg ha^{-1} (MOP), where maximum plant height was (38.56 cm) recorded. Highest average plant height (37.39 cm) was recorded in Hysun-33.

Table 6. Seed weight head^{-1} (g) of sunflower g under different levels and sources of K application

Treatments	Genotypes: HO-1	Genotypes: HYSUN-33	Mean
Control (CK)	41.72	46.31	44.01 d
K_2O @50 kg ha^{-1} (SOP)	45.91	50.96	48.44 b
K_2O @100 kg ha^{-1} (SOP)	48.13	53.42	50.78 b
K_2O @150 kg ha^{-1} (SOP)	52.27	58.01	55.14 a
K_2O @50 kg ha^{-1} (MOP)	45.22	50.20	47.71 c
K_2O @100 kg ha^{-1} (MOP)	47.41	52.62	50.02 b
K_2O @150 kg ha^{-1} (MOP)	51.47	57.14	54.31 a
Mean	47.45 b	52.67 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	1.2616	0.6743	1.7841
LSD 0.05	2.5932	1.3861	-
LSD 0.01	3.5055	1.8738	-

Table 7. Seed index (g) of sunflower genotypes under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	29.62	32.88	31.25 d
K_2O @50 kg ha^{-1} (SOP)	32.60	36.18	34.39 c
K_2O @100 kg ha^{-1} (SOP)	34.17	37.93	36.05 b
K_2O @150 kg ha^{-1} (SOP)	37.10	41.19	39.14 a
K_2O @50 kg ha^{-1} (MOP)	32.11	35.64	33.87 c
K_2O @100 kg ha^{-1} (MOP)	33.66	37.36	35.51 b
K_2O @150 kg ha^{-1} (MOP)	36.55	40.57	38.56 a
Mean	5.13 b	5.23 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	0.8958	0.4788	1.2669
LSD 0.05	1.8414	0.9843	2.6042
LSD 0.01	2.4893	1.3306	3.5204

Similarly, our results revealed that stem girth also showed significant difference with different levels of K application. Most significant improvement in average plant girth (5.70 cm) was observed by 150 kg ha^{-1} dose of SOP as compared to any other dose of MOP or SOP. Alike plant height, Hysun-33 exposed more significant mean stem girth (5.23 cm) as compared to HO-1 variety.

These results were further confirmed by Ramzan (1994) who noticed that significant effect of K_2O on plant height and stem girth. This increase may be because K nutrition has apparent effects on export of photosynthates by phloem through carbohydrate partitioning, regarding plant growth and development (Khan et al., 2012; Muhammadi et al., 2013; Amanullah et al., 2016; Zain and Ismail, 2017). Another possible reason is that K is a mobile nutrient in plant body, it moves towards the regions of new growth (buds and flowers) so under severe deficient conditions, the source organs show chlorosis followed by necrosis (Marschner, 2011; Martineau et al., 2017; Muhammad et al., 2018). Pervaiz (1996) reported that plant height and stem girth was affected significantly with different levels of soil-applied potassium. Zain and Ismail, (2017) reported that application of potassium either KCl or K_2SO_4 would minimize the effects on rice growth and physiology. However, Guilherme et al. (2016) reported that potassium doses did not affect sunflower growth at 45 days after sowing neither they altered gas exchange in sunflower plants in the grain filling stage. This contradiction may be due to the variation in soil fertility level or genetic makeup of genotypes.

Table 8. Seed yield (kg ha^{-1}) of sunflower genotypes under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	1457.90	1547.20	1502.60 d
K_2O @50 kg ha^{-1} (SOP)	1542.60	1712.30	1627.40 c
K_2O @100 kg ha^{-1} (SOP)	161720	1795.10	1706.10 b
K_2O @150 kg ha^{-1} (SOP)	1729.70	2041.30	1885.50 a
K_2O @50 kg ha^{-1} (MOP)	1519.50	1686.60	1603.00 c
K_2O @100 kg ha^{-1} (MOP)	1592.90	1768.20	1680.60 b
K_2O @150 kg ha^{-1} (MOP)	1756.00	1949.20	1852.60 a
Mean	1602.30 b	1785.70 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	25.294	13.520	35.771
LSD 0.05	51.992	27.791	73.528
LSD 0.01	70.284	37.569	99.397

Table 9. Oil content (%) of sunflower genotypes under different levels and sources of K application

Treatments	Genotypes		Mean
	HO-1	**HYSUN-33**	
Control (CK)	42.48	42.91	42.70 e
K_2O @50 kg ha^{-1} (SOP)	43.24	43.67	43.46 c
K_2O @100 kg ha^{-1} (SOP)	43.65	44.09	43.87 b
K_2O @150 kg ha^{-1} (SOP)	44.00	44.44	44.22 a
K_2O @50 kg ha^{-1} (MOP)	42.81	43.24	43.02 d
K_2O @100 kg ha^{-1} (MOP)	43.21	43.65	43.43 c
K_2O @150 kg ha^{-1} (MOP)	43.56	44.00	43.78 b
Mean	43.28 b	43.71 a	-
	K Levels (K)	Genotypes (G)	K × G
S.E.±	0.1282	0.0685	0.1813
LSD 0.05	0.2635	0.1409	-
LSD 0.01	0.3562	0.1904	-

3.3. Seed Yield Components

All the data regarding yield traits of sunflower is presented in (Table 4-8) revealed that application of K_2O in the form of MOP and SOP exhibited significant ($P<0.05$) results as compared to control. The dose of SOP @150 kg ha^{-1} showed superiority over all other levels of SOP and MOP including control. The maximum (21.85 cm) and minimum (17.43 cm) head diameter were obtained with application of potash in the form of SOP at150 kg ha^{-1} and control respectively.

Application of 150 kg ha^{-1} K_2O (as SOP) produced more seeds $head^{-1}$ (1654.10) than control (1390.20) and MOP @150 kg ha^{-1} (1629.30). Seed weight $head^{-1}$ were increased with the application of K_2O from 44.01 g (control) to 55.14 g (150 kg ha^{-1} SOP). Similar trend i.e. head diameter, seeds $head^{-1}$ and Seed weight $head^{-1}$ was also observed for seed index value. Just a minute difference was recorded in seed index value for among 150 kg ha^{-1} SOP (39.14 g) and 150 kg ha^{-1} MOP (38.56 g). Highest Seed yield 1885.50 kg ha^{-1} was measured for SOP @150 kg ha^{-1} which was higher than control (1502.60 kg ha^{-1}) and SOP @150 kg ha^{-1} (1852.60 kg ha^{-1}). Hysun-33 showed its superiority with 20.69 cm head diameter, 1590.50 seeds $head^{-1}$, 52.67 g seed weight $head^{-1}$, 5.23 g seed index and 1785.70 kg ha^{-1} seed yield than HO-1 genotype (Table4-8).

Pervaiz (1996) reported that plant height, head diameter, 1000-achene weight, number of achene $head^{-1}$ and seed yield were affected significantly with different levels of K application. He concluded that seed yield was significantly increased by increase in potash level up to 100 kg ha^{-1}. Our results were also in agreement with the findings of (Chhajro et al., 2013; Amanullah et al., 2016; Zia-ul-hassan et al., 2016). Asadi (2010) reported that the best yield of sunflower was obtained at 200 kg ha^{-1} level of K_2SO_4 treatment and the lowest yield was noticed with 50 kg ha^{-1} of the KCl treatment. Our results are in line with those of Tariq et al. (2011) who applied potassium as 0, 50, 100 and 150 kg K_2O ha^{-1} as muriate (MOP) and sulphate of potash (SOP) along with a basal dose of N 120 and P_2O_5 80 kg ha^{-1} on maize. Suzer (2012) suggested that 100 kg ha^{-1} of potassium can be used for achieving desired sunflower yields along with NP fertilizers at recommended rates. Saleem et al. (2011) reported that maximum grain yield of sorghum was observed at 120 kg ha^{-1} K_2O. While, Buahet al. (2012) reported N, P, and K fertilizer did not significantly affected the growth and yield parameter of sorghum, which might be due to the difference in genotypes used in the two studies. Malihe et al., (2013) revealed that 150 kg ha^{-1} significantly affected quantitative and qualitative characteristics of sunflower. Many researchers reported that the best way to increase the quantity and quality of yield per area by means of adding the micro and macro elements, particularly the potassium element, which plays an essential role in increase and improve the quality of yield (Malihe et al., 2013; Guilherme et al., 2016; Faisal et al ., 2017).

3.3. Oil Contents

Our results indicated that with increase in K_2O supply in the form of MOP and SOP, the seed oil contents (%) were increased significantly (Table 9). The highest percentage of oil content (44.22%) was observed at 150 kg ha^{-1} level of SOP as compared to any other level of SOP and MOP. Considering genotypes, Hysun-33 was found superior with 44.0%

oil content at 150 kg ha^{-1} application of MOP fertilizer as compared to HO-1 genotype. The minimum oil content (42.70%)was obtained by control treatment. This decrease in control treatment can be attributed to the imbalanced levels of nutrients. However, increased oil content was probably due the higher grain yields of sunflower genotypes at 150 kg ha^{-1} of K_2O. Results also showed that low application rate of K_2O in the form of MOP and SOP decreased oil contents in sunflower. Previously, it was proved in sunflower (Suzer et al., 2012; Chhajro et al., 2013) in maize (Martineau et al., 2017), Rice (Zain and Ismail, 2017), cotton (Zia-ul-hassan et al., 2014) and sorghum (Saleem et al., 2011). Alike to our results Zheljazkov et al. (2008) reported that significant variation in oil contents was observed among different sunflower hybrids across various sites. They reported that although N application reduced oil concentration in sunflower grains but oil yields increased significantly with higher N rates because of higher grain yields.

4. Conclusion

The findings of this study have clearly highlighted that the application of sulphate of potash (K_2SO_4) significantly affected the growth, biomass and seed yield of sunflower genotypes. A dose of 150 kg K_2O ha^{-1} was enough to increase the growth and seed yields of sunflower. Therefore, it was concluded that potash application in the form of SOP (sulphate of potash) was relatively more effective to improve growth, seed yield and oil content of sunflower genotypes as compared to MOP (muriate of potash); while sunflower genotype Hysun-33 showed its superiority in all the yield contributing traits and oil content over sunflower genotype HO-1. However, sunflower genotype HO-1 was superior in plant height over Hysun-33. This study suggested that the right source and rate of K_2O fertilization is necessary for potassium genotypic variation of sunflower.

List of abbreviations: SOP: Sulphate of potash, MOP: Muriate of potash.

Acknowledgments: The Authors gratefully acknowledge the help and facilities provided by Oilseed Section, Agriculture Research Institute, Tandojam, Sindh, Pakistan.

Conflict of Interest: The authors declare that they have no conflict of interest.

Author Contribution: AG and MSK experimented, initiated and wrote manuscript; MB: supervise the project and critical discussion of the paper; KAK and MAC helped in data analysis; KAK and MK wrote manuscript and statically analyzed; and AMN helped in data collection and statistical analysis.

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