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SOIL AND ASSOCIATED PLANT POTASSIUM STATUS OF SUNFLOWER IN LOWER SINDH (PAKISTAN)

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Abstract

Increasing present level of Potassium (K^+) in calcareous soils improve sunflower yield. Soil and plant K^+ status as yield-limiting factor for sunflower crop in calcareous soils was investigated through a survey study in the areas of lower Sindh (Sujawal, Badin and Hyderabad). Soil and crop productivity data from thirty sunflower farms were surveyed to assess soil-plant K^+ status, some basic physicochemical properties, seed yield, and to get information on common crop husbandry practices. Composite samples of soil and sunflower leaf tissue were gathered from randomly chosen locations and analyzed for K^+ content. Besides, the soil samples (0–20 cm depth) were also analyzed for some basic physicochemical properties. Furthermore, information about seed yield and common fertilization practices for each farm was also collected. The seed yield of sunflower in the study farms ranged from 1.63 to 1.86 tonnes ha^{-1} with an average of 1.73 tonnes ha^{-1}. It was found that soils had a marginal to adequate K^+ content (105–247 mg kg^{-1}) with 47 % having marginal K^+ content (100–150 mg kg^{-1}) and 53% having sufficient K^+ content (>150 mg kg^{-1}). Most of the soils were found clayey in texture, moderately to strongly alkaline ($pH_{1:5}$ 7.7–8.8) in reaction, non-saline ($EC_{1:5}$ 0.12–0.24), moderately to strongly calcareous ($CaCO_3$ 8.45–17.65 %) in nature, and low to adequate (0.38–1.82%) in organic matter content. Exchangeable Ca^{2+} remained as the dominant cation, followed by Mg^{2+}, K^+, and Na^+. Due to the high clay content, the CEC of the soils ranged between 15.34 and 33.48 $cmol_c$ kg^{-1}. The leaf tissue K^+ concentration varied between 1.38 and 3.41%, with a mean of 2.43. Around 60% of leaf samples were below a critical value (2.6%), 37% were above critical, and only 3% were found adequate. In sampling farms, soil K^+ contents indicated a significant, positive, and linear relationship with the leaf tissue K^+ concentration. Similarly, Soil K^+ activity ratio had a significant, positive, and linear relationship with the K^+ concentration in sunflower leaf tissue and seed yield. Appropriate field studies maybe planned and conducted in the future to formulate general K^+ recommendations for sunflower farming in the region.

Key words: K nutrition, Calcareous soils, Soil properties, Farming practices, Sunflower, Lower Sindh.

Introduction

Sunflower (*Helianthus annuus* L.) is non-traditional and commercial oil seed crop in Pakistan. It can play the significant role in shrinking the large gap between production of edible oils and imports in the country. Crop yield fluctuated substantially in recent years. However, the average sunflower yield of Pakistan is noticeably lower 1184 kg ha^{-1} (Anon., 2020) than the attainable yield of 3083-3073 kg ha^{-1} recorded at agriculture research stations and centers (Nasim *et al*., 2012; Sadozai *et al*., 2013). In the Sindh province, Sujawal, Badin and Hyderabad are categorized as the major districts, where the crop is extensively cultivated. Generally, the soils of lower Sindh are observed to be moderately to strongly calcareous, contain wide range of soluble salts, are low in organic matter, and lacking sufficient uptake of K by plants for their growth (Ali *et al.*, 2014; Chohan *et al*., 2015; Talpur *et al*., 2016; Arain *et al*., 2017). High calcium levels in the soil solution reduce K uptake by the plants possibly due to K^+ fixation as well as cation ratios (Wakeel *et al*., 2017; Weil & Brady, 2017). Research studies in these regions indicated that high calcareousness is the major factor for lowering K^+ availability (Ali *et al.*, 2014; Chohan *et al*., 2015; Talpur *et al*., 2016). In Sindh, approximately 40% of the soils are deficient in K^+ and the imbalanced use of fertilizers is also another factor that contributes to poor crop growth and yield (Ahmad & Rashid, 2004). Most of the sunflower growers are applying only nitrogen (N) and phosphorus; however, K^+ fertilization is completely ignored.

Sunflower has been reported as heavy feeder crop, it removes considerable amount of K^+ from soils as compared to N and P (Naidu *et al*., 2011; Li *et al*., 2014). The low availability of K^+ in calcareous soils along with poor K^+ management could be the major yield limiting factor (Taalab *et al*., 2019). Increased crop yield response to added K^+ under field experiments are reported by some scholars (Chajjro *et al.*, 2013; Kubar *et al*., 2017). These studies indicated NPK balance applications can improve the yield of crops (Rashid, 2005). Soil testing along with specific crop tissue analysis is more appropriate to assess the nutritional sufficiency of the soil-plant system and to design the correct nutrient requirements of the crop (Gary, 1998; Memon *et al*., 2005).

In order to identify nutritional problems, analysis of the soil and related plant tissues might be a helpful tool, which can help in establishing goals for increased productivity (Rashid, 2005; Kuzhivilayil *et al*., 2015). Thus, this research study was carried out to access the K availability of sunflower growing farms and to provide baseline information on sunflower crop productivity on calcareous soils of lower Sindh, as a case study. The following purposes were set: 1) document type of common crop husbandry practices being followed on sunflower farms including fertilization practices (source, rate, time and method of application), farming practices (soil analysis, weed control, FYM addition, seed selection, incorporation of crop residues in the field) and subsequent yield etc. for each farm; 2) assess soil-plant K^+ status on sunflower farms; and 3) to document some basic physico-chemical properties of sunflower farms.

Materials and Methods

Description of sampling locations: In order to assess soil and associated plant K^+ status, thirty major sunflower growing farms were selected from Sujawal, Badin and Hyderabad Districts. Soil and sunflower leaf samples were collected from each farm as listed in Table 1. Global Positioning Systems was used for the identification of geographic locations (Fig. 1).

Table 1. Sampling locations with Latitude and Longitude.

Site no.	Location	Latitude (N)	Longitude (E)
1.	Sujawal-1	24°23'20.4"	68°00'18.6"
2.	Sujawal-2	24°21'39.1"	68°02'14.2"
3.	Sujawal-3	24°23'20.0"	68°00'22.9"
4.	Sujawal-4	24°20'39.7"	68°04'09.2"
5.	Sujawal-5	24°22'54.2"	67°56'21.5"
6.	Sujawal-6	24°25'25.5"	67°59'21.4"
7.	Sujawal-7	24°31'40.2"	68°02'51.0"
8.	Sujawal-8	24°20'15.4"	68°16'08.9"
9.	Sujawal-9	24°20'12.3"	68°16'24.8"
10.	Sujawal-10	24°20'42.5"	68°17'15.9"
11.	Sujawal-11	24°21'41.2"	68°16'57.9"
12.	Sujawal-12	24°35'51.1"	68°03'55.9"
13.	Sujawal-13	24°37'32.7"	68°06'26.7"
14.	Golarchi-1	24°38'17.7"	68°50'19.8"
15.	Golarchi-2	24°37'50.7"	68°50'19.0"
16.	Golarchi-3	24°38'52.5"	68°32'45.7"
17.	Golarchi-4	24°38'32.3"	68°31'38.3"
18.	Golarchi-5	24°40'07.3"	68°31'12.4"
19.	Golarchi-6	24°47'04.6"	68°57'30.6"
20.	Golarchi-7	24°46'50.3"	68°58'06.8"
21.	Golarchi-8	24°47'30.0"	68°58'17.1"
22.	Golarchi-9	24°52'39.4"	68°49'03.9"
23.	Golarchi-10	24°53'19.6"	68°49'05.9"
24.	Golarchi-11	24°53'34.0"	68°48'26.7"
25.	Golarchi-12	25°02'47.7"	68°38'38.0"
26.	Golarchi-13	25°02'31.7"	68°40'04.9"
27.	Latif farm-4	25°26'19.3"	68°32'55.6"
28.	Latif farm-5	25°26'32.5"	68°32'26.7"
29.	Oil seed section-1	25°25'15.2"	68°32'32.0"
30.	Oil seed section-2	25°25'13.0"	68°32'31.5"

Collection of crop productivity information: A minimum farm size of one acre was used in selecting the farms. Sampling locations of the farms with their coordinates are presented in the Table 1. For detailed survey a questionnaire was developed and filled with the information covering crop productivity information: Fertilization practices (Table 2), farming practices (Table 3) and seed yield (Table 4) for each farm. The farmers of lower Sindh provided information. Data of seed yields were also obtained from the seed companies and Agriculture Extension Department for comparison purposes.

Soil and plant sampling: Three composite surface soil samples at the depth of 0-20 cm collected from each sunflower field at the study farms. Each composite soil sample contained three sub samples in diagonal pattern within each block and mixed thoroughly according to standard method for soil sample processing (Estefan *et al*., 2013). Two composite leaf samples were gathered from each field of the study farms following the technique of Flynn *et al.*, (1999) at R2 stage when inflorescence separated from youngest foliage leaf (Lancashire *et al*., 1991). A total of ninety surface soil and sixty composite leaf samples were taken from the study farms.

Soil and plant samples analysis: The samples of soil and plant leaves were taken to the laboratory of Department of Soil Science, Sindh Agriculture University (SAU) Tandojam. All the samples of soil were air dried, grounded in and passed through 2 mm sieve. After processing soil samples were protected in tight lid plastic jars and shifted to Soil Salinity and Reclamation Research Institute Tandojam for analysis. The soil samples were used for determination of texture by following the standard procedures of hydrometer (Bouyoucos, 1962). For 1:5 soil water suspension, 50.0 g air dry soil (<2mm) was poured into 500 ml conical flask added with 250 distilled water. The suspension was shook on mechanical shaker for one hour at 15 rpm filtered from whatman filter No. 40. The filtrate was used for determination of pH and electrical conductivity (EC). The digital pH meter (Suntex Model SP-34) was used to record pH extract and electrical conductivity by conductivity meter (Model HI-8333) as described by Rayment and Lyons (2011). Moreover, $CaCO_3$ content was determined following the standard procedure of Acid-neutralization (Estefan *et al*., 2013). K^+ through method using flame photometer (Estefan *et al*., 2013). Titration methods as described in Anon., (1954) were followed for the analyses of Ca^{2+} and Mg^{2+}; whereas Na^+ was determined through same flame photometer. Cation exchange capacity was calculated following the formula CEC = % OM x 2.5 + % Clay x 0.57. The K^+ activity ratio was calculated using the following formula suggested by Basak (2007):

$$K^+ \text{ activity ratio} = \frac{[K^+]}{\sqrt{[Ca^{2+}] + [Mg^{2+}]}}$$

The collected leaf samples were washed with distilled water. Analyses of K^+ concentration in sunflower leaf tissues were determined through dry ash methods as suggested by Estefan *et al*., 2013. Each sample was placed in an oven in 70°C and allowed to be dried for 48 hours. Oven-dried leaf tissues were crushed manually with pestle mortar. 1000 mg from each crushed sample were dry-ashed at 550 °C for 5 hours in muffle furnace. Ashed samples were dissolved in 2*N* hydrochloric acid (HCl) and made up with distilled water to volume of 100 ml. The sample was then diluted and used for K^+ analyses. The K^+ concentration was calculated according to calibration curve as given in following formula:

$$\frac{\text{K (ppm)} = (\mathit{Curve\ value}) \times \underline{V} \times \text{Dilution factor}}{\text{Wt}}$$

(Whereas V= Total extract volume and Wt = Weight of sample taken)

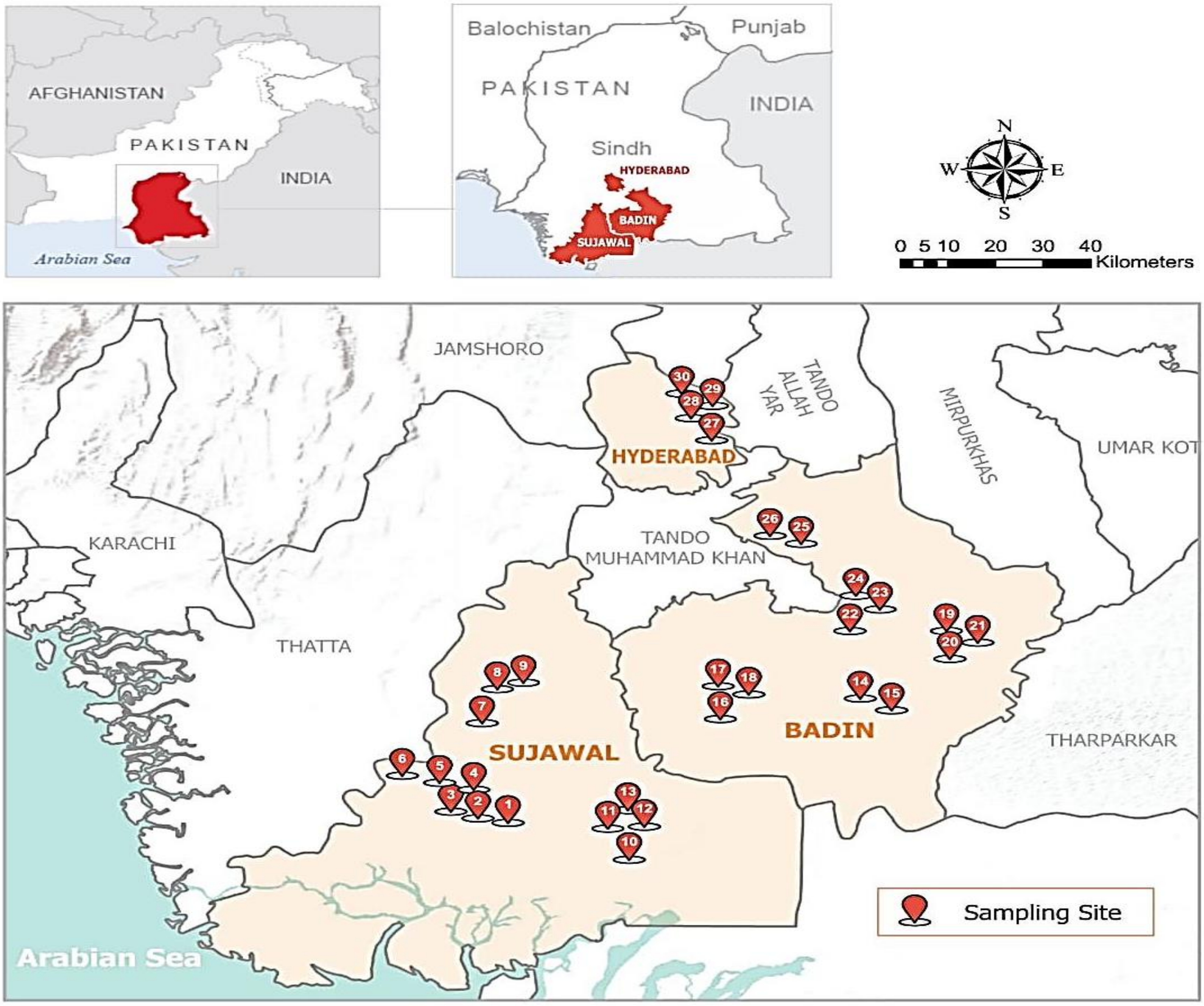

Fig. 1. Site map of study area with geo-referenced soil-plant sampling points.

Table 2. Fertilization practices of sunflower growers at study farms and frequency distribution (n=30).

Application		Nitrogen (N)	Phosphorus (P)	Potash (K)	Other
Rate	< advised	8 (27)	10 (33)	-	-
advised common rates	advised	16 (53)	6 (20)	-	-
(140-70-70 kg N-P_2O_5-K_2O ha^{-1})	> advised	3 (10)	4 (13)	-	-
	Did not use	3 (10)	10 (33)	-	-
Time	Before sowing	-	20 (67)	-	-
	At 1st Irrigation	27 (90)	-	-	-
	At 2nd irrigation	-	-	-	-
	Did not use	3 (10)	10 (33)	-	-
Method	Broadcasting	27 (90)	20 (67)	-	-
	Other	-	-	-	-
	Did not use	3 (10)	10 (33)	-	-

Note: The values outside and in parenthesis denote number and percent samples respectively

Fertilization practices at studied farms: The information regarding fertilization practices by the sunflower growers are presented in Table 2. Most of the farmers are using only nitrogenous and phosphatic fertilizers in the form of urea and single super or di-ammonium phosphate at 1st irrigation and before sowing. Generally, all the fertilizers are broadcasted. Most of farmers did not follow the advised rate of fertilizer application 140-70-70 kg N-P_2O_5-K_2O ha^{-1} as suggested by Ahmad & Rashid (2004). It was noted in survey that the growers of were not using K^+ and other micronutrients fertilizers. In case of nitrogen, only 53% growers used full advised of N (140 kg N ha^{-1}), 27% less than advised dose and 10% above the advised dose, remaining 10% did not used N in crop. In case of phosphorus, 20% growers used advised dose P_2O_5 (70 kg P_2O_5 ha^{-1}), 33% used less than advised dose and 13% were above the advised dose and remaining 33% was not applying the P to crop. So, it can be concluded from the survey that growers of the area are applying imbalance fertilizer to crop, which could be major reason for low yield. It was concluded from the survey that farmers of the targeted areas not applied K^+ fertilizer to crop.

Table 3. Summary of some farming practices of sunflower growers at study farms and frequency distribution (n= 30).

Practice	Frequency
Soil analysis from labs	
Yes	12 (40)
No	18 (60)
Weed control	
Yes	16 (53)
No	14 (47)
FYM addition	
Yes	14 (47)
No	16 (53)
Seed selection	
Hybird	23 (77)
Local	7 (23)
Incorporation of residue in the field	
Yes	4 (13)
No	26 (87)

Note: The values outside and in parenthesis denote number and percent samples respectively

Table 4. Seed yield (tonnes ha-1) statistics of sunflower crop at study farms (n=30).

Range	Average	Standard deviations	Coefficient of variation (%)
1.63-1.86	1.73	0.070	3.99

Table 5. Particle (sand, silt and clay) size distribution and textural classes of the soil sample taken at 0-20 cm depth from study farms (n=30).

Particle size	Range	Mean ± SD
Sand (%)	16.00-46.50	30.83 ± 9.20
Silt (%)	16.25-53.25	31.48 ± 10.52
Clay (%)	25.25-50.75	37.69 ± 6.24
Textural class	**Frequency of samples**	**Per centage of samples**
Clay	11	37
Clay loam	9	30
Sandy clay	3	10
Sandy clay loam	2	7
Silt loam	2	7
Silt clay	1	2
Silt clay loam	2	7

Farming practices at the studied sunflower farms: The information regarding to farming practices in area was presented in Table 3. It was observed that 77% growers used different hybrid varieties of sunflower and 23% used convention varieties for cultivation. Moreover, 60% growers were unknown about soils testing. Similarly, 53% growers did not practice controlling the weeds in crop about, 53% growers did not add farm yard manure and 87% do not incorporate residue in the studied farms.

Seed yield at the studied farms: The information regarding seed yield tonnes ha^{-1} is presented in Table 4. The sunflower seed yield at the studied farms ranged from 1.63 to 1.86 tonnes ha^{-1} with an average of 1.73 tonnes ha^{-1}.

Statistical analysis: Soil, plant and questionnaire/ information data were processed for statistical analysis including descriptive statistics like standard deviation, means, maximum, minimum, percentage etc.by using Microsoft Excel 2013 (Freund *et al*., 2015). In addition to statistical analysis, the data of soil and plant tissue K^+ content were compared with the already established critical levels.

Results and Discussion

Particle (sand, silt and clay) size distribution and textural classes: The selected physicochemical properties of surface soil of targeted farms are presented in Table 5. According to the results of the analysss, 37, 30, 10, 7, 7, 2 and 7% soil samples were clay, clay loam, sandy clay, sandy clay loam, silt loam, silt clay and silt clay loam, respectively. The soils are relatively high in clay content, the results are in accordance with findings of Khuhro *et al*., 2005; Memon *et al*., 2012; Chohan *et al*., 2015 who stated that clay was the dominant particle in the soils of lower Sindh. Moreover Ali *et al*., 2014 & Arain *et al*., 2017 also stated that upper surface of soils of lower Sindh contain 30-40 % clay.

Soil reaction and electrical conductivity: Analytical results showed that the soils of area were slightly to strongly alkaline in reaction. The $pH_{1:5}$ of soils varied from 7.5 to 8.8 with an average of 8.13. According to Rayment & Lyons, 2011 classification, 20, 67 and 13% of the soil samples were slightly, moderately and strongly alkaline, respectively (Table 6). The $EC_{1:5}$ of soils ranging from 0.12 to 0.24 dS m^{-1} with an average of 0.17 dS m^{-1} indicating that these soils have a low content of soluble salts and therefore are non-saline. According to FAO (USDA) classification, 100% of soil samples were non-saline (Table 6). The similar ranges of pH and EC results were obtained by Memon *et al*., 2012; Ali *et al*., 2014; Chohan *et al*., 2015 while assessing soils of these districts.

Soil organic matter (%): There was a variation in soil organic matter among studied farms (Table 6). Generally, soils were low in organic matter. The data in Table 6 further indicated that 80% of the soil samples were low, 13% were medium and 7% were adequate at the soil depth 0-20 cm of studied farms. Based on the rankings of soil-test standards established by FAO,1980 the values are similar to most cultivated soils of Pakistan (Khalid *et al*., 2012), reflecting that the most of the soils of country being inherently low in organic matter (less than 1%) which is attributed to low soil nitrogen (Rashid, 2005).

Table 6. Chemical characteristics ($EC_{1:5}$, $pH_{1:5}$, SOM% and Lime content%) of the soil samples taken at 0-20 cm depth from study farms (n=30).

Soil pH							
Range	**Mean ± SD**	**Neutral**	**Slightly to Mildly alkaline 7.4-7.8**	**Moderately alkaline 7.9-8.4**	**Strongly alkaline 8.5-9.0**		**Rayment & Lyons, 2011**
7.7-8.8	8.13 ± 0.33	-	6(20)	20(67)	4(13)		
EC_e (dS m^{-1})							
Range	**Mean ± SD**	Non saline (0-2)	Low salinity (2-4)	Mild salinity (4-8)	High salinity (8-16)	Severe salinity >16	**FAO (USDA)**
0.12-0.24	0.17 ± 0.04	30(100)	-	-	-	-	
Soil organic matter (%)							
Range	**Mean ± SD**	**Low <0.86**	**Medium 0.86-1.29**	**Adequate >1.29**	-		**FAO, 1980**
0.38-1.82	0.75 ± 0.05	24(80)	4(13)	2(7)	-		
$CaCO_3$ (%)							
Range	**Mean ± SD**	**Slightly calcareous <5**	**Moderately calcareous 6-10**	**Strongly calcareous 10-20**	**Very strongly calcareous >20**		**Sahai, 2004**
8.45-17.65	11.51 ± 2.45	-	10(33)	20(67)	-		-

Note: The values outside and in parenthesis denote number and percent samples respectively

Table 7. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and CEC of the samples of soil taken (0-20 cm) from study farms (n=30).

Soil property	Range	Mean ± SD
Ca^{2+} ($cmol_c$ kg^{-1})	1.37-3.41	2.25 ± 0.57
Mg^{2+} ($cmol_c$ kg^{-1})	0.49-1.21	0.73 ± 0.16
K^+ ($cmol_c$ kg^{-1})	0.27-0.63	0.40 ± 0.09
Na^+ ($cmol_c$ kg^{-1})	0.12-0.18	0.14 ± 0.02
CEC ($cmol_c$ kg^{-1})	15.34-33.48	23.37 ± 4.16

Calcium carbonate (%): The results shown soil samples in the studied farms were moderately to strongly calcareous in nature. The value of $CaCO_3$ varied between 8.45 and 17.65% with an average of 11.51%. According to Sahai (2004) categorization, 33 and 67% of the soil samples were moderately calcareous and strongly calcareous, respectively (Table 6). It, therefore, follows that soils of the study farms were moderately to strongly calcareous in their lime status. This supports earlier studies in the area by Ali *et al*., 2014, Chohan *et al*., 2015, Arain *et al*., 2017. In dry regions, calcareous soils formed in situ by weathering of parent's rock material. The rainfall in arid and semi-arid region is not sufficient to leach out weathering soluble products to the ground water. In dry weather, the salts elevated with the capillary movement of water and eventually deposited on surface soil (Weil & Brady, 2017).

Exchangeable cations (Ca^{2+}, Mg^{2+} and Na^+): Result in Table 7 showed that exchangeable Ca^{2+} was the dominant cation as compared to other base cations on surface soils of studied farms. Exchangeable calcium of ranged from 1.37-3.41 $cmol_c$ kg^{-1} with an average value of 2.25 $cmol_c$ kg^{-1}. Exchangeable magnesium ranged from 0.49-1.21 $cmol_c$ kg^{-1} with an average value of 0.73 $cmol_c$ kg^{-1}. Exchangeable sodium ranged from 0.12-0.18 $cmol_c$ kg^{-1} with an average value of 0.14 $cmol_c$ kg^{-1}.

Cation exchange capacity of soil: Results in Table 7 showed The CEC of the soils of study farms were ranging between 15.34 and 33.48 $cmol_c$ kg^{-1} with an average value of 23.37 $cmol_c$ kg^{-1}. The high value of CEC is generally as a result of high clay content.

K^+ content of soil: Result in Table 8 showed that Exchangeable K^+ ranging from 0.27-0.63 $cmol_c$ kg^{-1} with an average value of 0.40 $cmol_c$ kg^{-1}. In well buffered soils, divalent cation Ca^{2+} occupy the most parts of exchangeable sites in the soil colloids followed by exchangeable Mg^{2+}, whereas the monovalent cations K^+ and Na^+ occupy only few per cent of sites, and K^+ withheld more strongly than Na^+, therefore, K^+ ions only leak out by drainage in small quantity until the soil is over fertilized by K^+ (Jakobsen, 1993).

K^+ concentration in sunflower leaf tissues: The results of K^+ concentration in leaf tissues of sunflower illustrated in Table 8. The data showed K^+ concentration in leaves varied from 1.38 to 3.41%. The average K^+ concentration in leaves was 2.43%. According to interpretation of Reuter & Robinson, 1997, 60% of leaf samples were below critical value (2.6%). This indicated that soils of the targeted area were not supplying sufficient quantity of K^+ for optimum growth and production. Furthermore, about 37% leaves samples were above the critical value and only 3% found as adequate in K^+ concentration. In calcareous field conditions, to increase K^+ availability for sunflower farming, agriculture activities should emphasis on proper K^+ management i.e. application of K^+ fertilizers using right source, time, rate and method of application. Application of potash fertilizer with proper source and rate improve the K^+ status, quality and yield of sunflower crops (Chajjro *et al*., 2013; Dar *et al*., 2021).

Table 8. K^+ concentration (%) of sunflower plant tissue and associated soils of study farms (0-20 cm) (n=30).

Soil exchangeable K^+ content (mg kg^{-1})						
Range	**Mean ± SD**	**Low <100**	**Marginal 100-150**	**Adequate >150**		**Reference**
105-247	154.37 ± 36.81	-	14 (47)	16 (53)		Estefan *et al*., 2013
K^+ concentration of sunflower leaves (%)						
Range	**Mean ± SD**	**Deficient 1.1**	**Marginal 1.1-2.6**	**Critical 2.6**	**Adequate 3.4-6.6**	**Reference**
1.38-3.41	2.43 ± 0.43	-	18 (60)	11 (37)	1 (3)	Reuter & Robinson, 1997

Note: The values outside and in parenthesis denote number and percent samples respectively

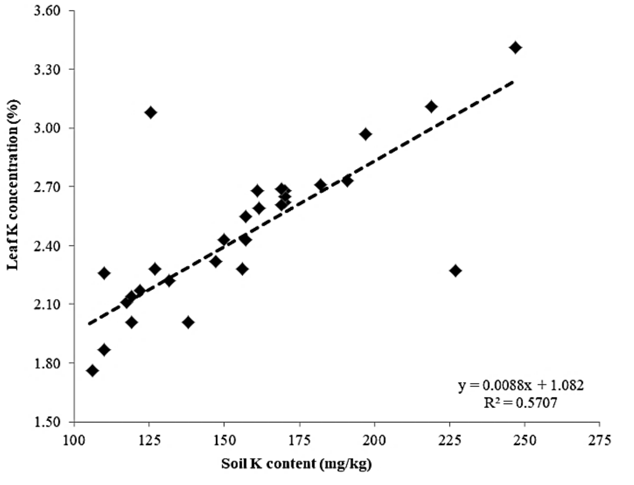

Fig. 2. Correlation of soil K^+ content with leaf K^+ concentration (%) of selected study farms of lower Sindh.

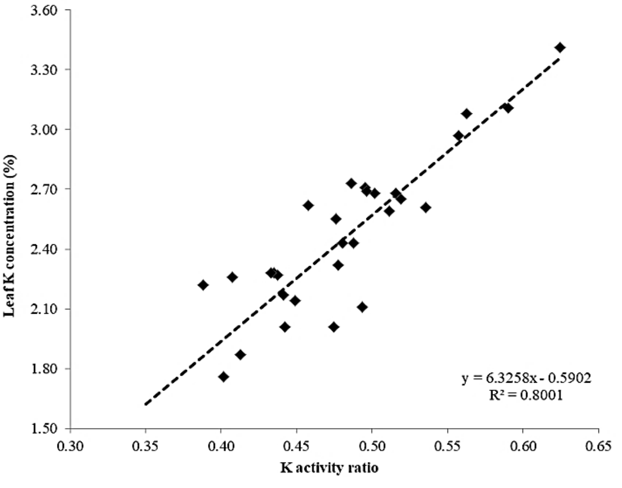

Fig. 3. Correlation of K^+ activity ratio with Leaf K^+ concentration (%) of selected study farms of lower Sindh.

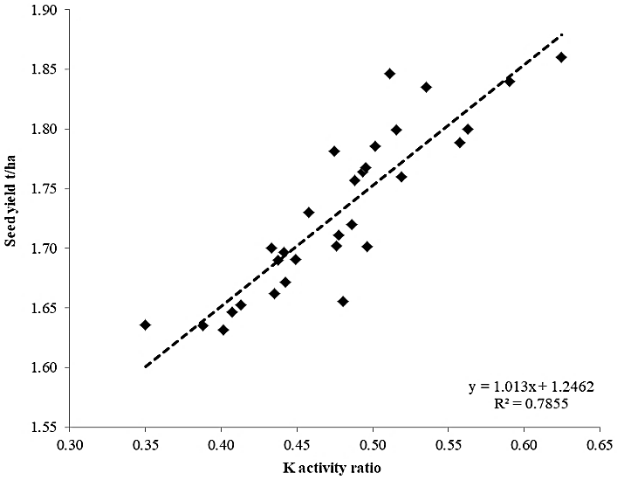

Fig. 4. Correlation of K^+ activity ratio with seed yield t ha^{-1} of selected study farms of lower Sindh.

Soil and sunflower K^+ concentration relationships: Figure 2 presented the soil K^+ content and associated concentration in leaf tissue of sunflower at R2 stage, collected from study farms. Soil K^+ contents indicated a significant, positive and linear relationship with the leaf tissue K^+ concentration. The Pearson correlation coefficient "R^2" was 0.57 point toward its availability to plant from pools other than soluble and exchangeable. Soil and plant tissue nutrient concentration were expected to be correlated positively for most nutrient elements because the concentration of a certain nutrient in the plant tissue is normally more when the content in the soil is higher (Fageria, 2001).

Soil K^+ activity ratio and plant K^+ concentration relationships: The soil K^+ activity ratio and associated K^+ concentration in leaf tissue of sunflower at R2 stage, collected from study farms shown in Figure 3. Soil K^+ activity ratio directed a significant, positive and linear relationship with the leaf tissue K^+ concentration. The Pearson correlation coefficient "R^2" was 0.80 indicating its availability to crop depending on activity of Ca^{2+} and or Mg^{2+} in soil solution which may increase or decrease K^+ uptake by plants. These soils may be corrected with application of K^+ fertilizer (Basak, 2007).

Soil K^+ activity ratio and seed yield relationships: The soil K^+ activity ratio and associated seed yield collected from study farms shown in Figure 4. The average soil K^+ activity ratio had a significant positive and linear relationship with the seed yield of sunflower. The Pearson correlation coefficient "R^2" was 0.79 indicating its increase seed yield depending on activity of K^+ in the soil solution which may increase or decrease K^+ uptake to plants due to presence of Ca^{2+} and or Mg^{2+} in soil. Chajjro *et al.*, (2013); Kubar *et al*., (2017) reported increased seed yield of sunflower with addition of K^+ fertilizer.

Conclusions

The fields of lower Sindh under sunflower cultivation, varied from marginal to adequate in soil K^+ and not supplying the enough K^+ to plants for better growth and yield. The low K^+ levels in sunflower plants could be the one factor for the low yield in these areas. The findings need further confirmation by conducting series of experiment with K^+ sources, rates time and method of application at different locations to formulate the proper recommendations.

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