Research Article

Sunflower Response to Different Potassium Rates in Artificially Developed Calcareous Soils

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Abstract | The ideal productivity of sunflowers is severely constrained by the dual problems of high soil calcareousness and inadequate potassium (K) availability. This issue needs to be fixed since improving sunflower growth, maximizing the efficiency of K fertilizer and ensuring sustainable crop management in calcareous soil regions all depend on a better knowledge of the interaction between soil calcareousness and K dynamics. The aim of this research was to examine the influence of interactions between soil calcium carbonate levels (CCL) and potassium application rates on the early growth of sunflower plants grown in a wire-house in silty clay soil. The targeted calcium carbonate levels were 5, 10, 20 and 30% as percentage of the soil and K application rates were 60 and 120 kg K_2O ha^{-1} in the form of SoP along with control treatment. The pot experiment was designed in a complete randomized design with four replications. In sunflower seedlings, increasing soil CCL reduced growth metrics. Similarly, increasing soil CCL reduced shoot K content and chlorophyll concentration in leaves in contrast to the control. The higher rate of K fertilizer relieved the limiting effects of soil calcareousness on sunflower chlorophyll concentration, shoot K concentration and growth to some extent. When comparing the control to the higher K application dose (120 kg K_2O ha^{-1}) the shoot height increased by 21.72%, the root length by 21.20%, the fresh shoot weight by 21.06%, the dry shoot weight by 21.95%, fresh root weight by 22.06%, the dry root weight by 46.15%, the shoot K content by 21.91% and the total chlorophyll concentration by 22.56%. The results showed that under calcareous soil conditions, sunflower plants perform better at early stage when fertilized with 120 kg K_2O ha^{-1}.

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Introduction

Potassium (K) inadequate supply in calcareous soils is a major issue for many crop species. It is estimated that calcareous soils cover around 30% (1.5 billion acres) of the global land surface, primarily in arid and semi-arid regions (Taalab *et al*., 2019). These soils types are most common in Pakistan and distributed across the country, in particular in lower Sindh (Rashid, 2005; Wakeel *et al*., 2017; Memon *et al*., 2023). The soil layers or horizons of calcareous soils contain calcium carbonate ($CaCO_3$), with concentrations varying between a few percent and a whopping 95% (Weil and Brady, 2017). Excess $CaCO_3$ changes the chemistry of the soil which reduces crop output by raising pH, preventing nutrients from moving freely and slowing down activity of soil microbes (Taalab *et al*., 2019; Babar *et al*., 2022; Wang *et al*., 2023). K is a vital plant nutrient element that promotes sustainability through supporting plant growth, raising soil health and enhancing agricultural output and quality (Brady and Weil, 2013; Wakeel *et al*., 2017). Since K is necessary for ionic balance, photosynthesis, protein synthesis, nutrient translocation, stomatal control, water use, enzyme activation for ATP, starch in grains, sugar translocation and protein synthesis, crop growth may be hindered when the amount of K available in the soil is suboptimal particularly in high calcareous conditions (Wolde, 2016; Wakeel *et al*., 2017; Das *et al*., 2022; Memon *et al*., 2024). Furthermore, variations in basic cation ratios and K fixation restrict the amount of K available for plant absorption in the soil solution (Wakeel *et al*., 2017). Additionally, the issue of K availability and uptake by plants in calcareous soils has been well observed and documented worldwide mostly because of the antagonistic connection with other basic cations such as Na, Ca and Mg that are present in these soils (Ertiftik and Zengin, 2015; Xie *et al*., 2020; Narayanasamy *et al*., 2023). The ratio of Ca, Mg and K ions in calcareous soils generates an imbalance, resulting in a K deficit to plants (Brady and Weil, 2013). Memon *et al*. (2024) observed an increase in plant growth, K concentration in shoots and leaf chlorophyll content when K supplied under medium to strong calcareous conditions exceeded those optimal under low calcareous conditions, implying that increasing K level may reduce the negative effects of soil calcareousness. Therefore, it is necessary to determine the interaction between calcareousness and K and how they affect the growth of plants.

Sunflower (*Helianthus annuus* L.) is major edible oil producing crop that is widely grown in lower Sindh of Pakistan, where the majority of soils are medium to strongly calcareous in nature (Talpur *et al*., 2016; Memon *et al*., 2023). Sunflower is a heavy feeder crop that removes a significant quantity of K from soils when compared to N and P (Naidu *et al*., 2011; Li *et al*., 2014; Rana *et al*., 2022). Sunflower NPK needs vary with respect to variety and area; nevertheless, K is always required in greater quantity than N or P (Li *et al*., 2014). The high yield potential of sunflower required high supplying K fertilizer (Li *et al*., 2014; Zamani *et al*., 2020). The main factors limiting yield in calcareous soils may be the limited availability of K and inadequate K management (Taalab *et al*., 2019; Soumare *et al*., 2022).

The novelty of this research is that it measures the significant improvements in sunflower early development and nutrient content parameters that are brought about by increasing K applications at different soil calcareous levels. This provides new information about the precise amount of K required to get over the constraints caused by varying calcium carbonate levels resulting in a more targeted fertilization plan for areas with calcareous soils. The aim of this research was to analyze the effects of calcium carbonate and K fertilizers on the early growth and development of sunflower plants cultivated in a wire-house in silty clay soil, as well as to find the optimum K application rate.

Materials and Methods

Site description and experimental design

This study was conducted in a wire-house of the Department of Soil Science, Sindh Agriculture University, Tandojam, Pakistan, in natural sunlight in order to enhance sunflower growth in artificially developed calcareous soils at an early stage. In 2018, the period of growth spanned February through April. Average temperatures for the experiment ranged from 28.6 to 39.5 °C at their greatest point, from 20.6 to 28.5 °C at their lowest point and from 31 to 49% relative humidity. The treatments included two K application rates (60 kg K_2O ha^{-1} and 120 kg K_2O ha^{-1}) and four $CaCO_3$ levels (CCL) (5, 10, 20 and 30%) in addition to the control. The research employed a factorial Complete Randomized Design (CRD) with 4 repetitions.

Artificial preparation of different levels of calcareous soils

The research field of Latif Farm in Tandojam provided the soil used in the study (Table 1). The study used four CCLs: 5, 10, 20 and 30%. Calcareous soils were prepared artificially using the technique described in Osman (2012). The required proportions of pure

Table 1: *Selected physico-chemical properties of the soil used in the pots.*

Parameters	Unit	Values	Categorizations	Reference
Sand	%	32	Medium texture	Bouyoucos Method (1962)
Silt	%	25		
Clay	%	43		
Texture class (USDA)		Silty clay		
EC_e	(dS m^{-1})	1.65	Non saline	FAO (USDA)
pH		7.59	Slightly to mildly alkaline	Rayment and Lyons (2011)
Organic matter content	%	0.67	Low	FAO (1980)
Lime content	%	4.99	Slightly-calcareous	Sahai (2004)
Exchangeable K (NH_4OAc)	mg kg^{-1}	97	Low	Estefan *et al*, (2013)
Phosphorus (AB-DTPA)	mg kg^{-1}	1.04	Low	Estefan *et al*, (2013)
Nitrogen	%	0.033	Low	Estefan *et al*, (2013)
Soluble Ca	meq L^{-1}	2.75	-	-
Soluble Mg	meq L^{-1}	1.09	-	-
Soluble K	meq L^{-1}	0.41	-	-
K activity ratios	$([K^+])/\sqrt{([Ca^{2+}]+[Mg^{2+}])}$	0.21	-	Basak (2007)
	$([K^+])/\sqrt{([Mg^{2+}])}$	0.39	-	Basak (2007)
	$([K^+])/\sqrt{([Ca^{2+}])}$	0.25	-	Basak (2007)

$CaCO_3$ were added to the soil of each treatment. Sand was used to maintain a consistent weight of 5 kg. To get the artificial calcareous soils in balance, they were repeatedly watered and dried. Each treatment's 5 kg of soil material were put in plastic pots that were 28 cm deep and 24 cm in diameter. The pots were then put in wire-house. To keep soil moisture at 70% of its field capacity, all plants which were cultivated in plastic pots were irrigated every day with tap water.

Plant material, growth conditions and fertilizer application

The local cultivar of sunflower HO-1 was used for this research study. The Oil Seed Research Institute, Agriculture Research Sindh Tandojam was the source of seed. In order to enhance germination of seed and prevent certain microbial contaminants from growing, initial surface sterilization of the seed was done using the solution of 5% sodium hypochlorite (NaOCl). Nine sunflower achene were planted in each pot, spaced evenly apart and about 2 cm deep. Plants were thinned to produce five seedlings of almost equal size in each pot after two weeks of emergence. The plants were regularly irrigated with tap water. Application of the recommended dose (140-70 NP kg ha^{-1}) was made using urea and diammonium phosphate. Potassium sulfate was used to apply at two different rates (60 kg K_2O ha^{-1} and 120 kg K_2O ha^{-1}) at the at the start of the trial.

Data collection

Forty days after the seedlings emerged, two plant samples were taken out of the pots in accordance with standard procedures to document their growth characteristics. In order to determine the fresh weight of the roots and shoots, the shoots were taken out of the roots and measured immediately with an electronic balance. The samples were dried for 48 hours at 70 °C in order to achieve a consistent weight.

Chlorophyll concentration measurement

Fresh leaf samples were gathered and 0.5 g from each sample was taken and chopped into pieces then sample was homogenised with 80% (v/v) acetone using a mortar and pestle that had been pre-cooled. It was centrifuged for 15 minutes at at 3,000 rpm, 80% (v/v) prepared up to 25 mL using 80% (v/v) acetone. The absorbance of the supernatant was measured at wavelengths of 645, 663 and 480 nm with a spectrophotometer (Hitachi-220 Japan). The formulas developed by Arnon (1949) were used to determine the concentrations of chlorophyll.

Measurement of K concentration

K concentration analysis was conducted using the Estefan *et al.* (2013) approved method. The plant tissue samples were cleaned with distilled water prior to drying then kept in an oven at 70 °C for 48 hours. After being dried, the plant tissue samples were crushed in a grinder to powder. The K content of sunflower plant tissue was analyzed using dry ash methods. 1.0 g ground sample was ashed for 5 hours at 550 °C in a muffle furnace. The material was then dissolved in 2N HCl and then distilled water was added to get the volume up to 100 mL. The substance was then diluted and utilized to measure K concentration using Jenway PFP-7 flame photometer.

Statistical analysis

Minitab (Ver. 17) was used to do an analysis of variance (ANOVA) on the interaction effects of the experiment components (K rates, CCL and Interaction K rates x CCL). Parameters (shoot height, root length, fresh and dry shoot weight, fresh and dry root weight, total chlorophyll and shoot K concentration) means were compared using LSD at $p<0.05$.

Results

Effects of potassium and calcareousness on shoot height

Table 2 shows the influence of soil calcareous levels and K rates on shoot height. In calcareous soils, variations in K application rates led to significant differences ($p<0.05$) in sunflower shoot height. In comparison to the control, the tallest shoot height was produced from 120 kg K_2O ha^{-1} followed by 60 kg K_2O ha^{-1}. The study found a highly significant ($p<0.05$) effect of CCL on shoot height. There was a negative correlation between shoot height and the soil's calcium carbonate concentration. Shoot height dropped when CCL rose by 5, 10, 20 and 30%. The interaction of K rates and CCL resulted in no significant difference ($p>0.05$) in shoot height. The results showed that applying higher K rates to soils with higher CCL resulted in increased shoot height than untreated control soils. The result indicated that application of 120 kg K_2O ha^{-1} produced substantially longer shoots (18.55 cm) and lowest shoot height (15.91 cm) was observed in soils with 30% CCL on an individual basis.

Effects of potassium and calcareousness on root length

Table 2 displays the sunflower root length data on calcareous soils as changed by K fertilizer rates. Overall, Kr had highly significant ($p<0.05$) effect on root length. In comparison to the control, both K application rates (120 kg K_2O ha^{-1} and 60 kg K_2O ha^{-1}) treatments increased root length; however, the 120 kg K_2O ha^{-1} treatment yielded the longest root length. As compared to the lower concentrations of 5, 10 and 20% CCL, root length was considerably decreased at 30% CCL, indicating a highly significant ($p<0.05$) influence of CCL on root length. K rates x CCL interaction had a statistically non-significant ($p>0.05$) effect on root length. The findings showed that on an individual basis, CCL (30%) produced the smallest root length (6.40 cm) and that the application of 120 kg K_2O ha^{-1} developed the most root length (7.49 cm).

Effects of potassium and calcareousness on fresh shoot

Table 3 shows the data on sunflower fresh shoot weight on calcareous soils as impacted by two K fertilizer rates. Fresh shoot weight was highly significant ($p<0.05$) impacted by K fertilizer rates of 120 kg K_2O ha^{-1} and 60 kg ha^{-1}. In comparison to the control, the maximum fresh shoot weight was achieved with 120 kg K_2O ha^{-1} followed by 60 kg K_2O ha^{-1}. The findings demonstrated that CCL highly significant ($p<0.05$) impact on fresh shoot weight as well. The fresh shoot weight at CCL (30%) was substantially lower

Table 2: *Effects of potassium and calcareousness on shoot height and root length.*

K rates (K_2O kg ha^{-1})	$CaCO_3$ (%)									
	Shoot height (cm)					Root length (cm)				
	<5	10	20	30	Means	<5	10	20	30	Means
Control	15.95	15.36	14.98	14.68	15.24[b]	6.62	6.17	6.02	5.91	6.18[b]
K_{60}	19.43	17.98	16.95	16.12	17.62[a]	8.11	7.22	6.82	6.47	7.16[a]
K_{120}	20.54	18.93	17.82	16.92	18.55[a]	8.38	7.60	7.17	6.81	7.49[a]
Means	18.64[a]	17.42[ab]	16.58[bc]	15.91[c]	-	7.71[a]	7.00[b]	6.67[bc]	6.40[c]	-
				K rates		CCL		K rates × CCL		
Shoot height (cm)		SED		0.442		0.511		0.884		
		LSD		0.746***		0.862***		NS		
Root length (cm)		SED		0.185		0.213		0.369		
		LSD		0.312***		0.360***		NS		

Table 3: *Effects of potassium and calcareousness on fresh and dry shoot weight.*

K rates (K_2O kg ha^{-1})	$CaCO_3$ (%)									
	Fresh shoot weight (g)					Dry shoot weight (g)				
	<5	10	20	30	Means	<5	10	20	30	Means
Control	7.36	7.02	6.84	6.68	6.98[b]	0.86	0.83	0.81	0.79	0.82[c]
K_{60}	8.98	8.26	7.83	7.30	8.09[a]	1.05	0.97	0.91	0.86	0.95[b]
K_{120}	9.14	8.69	8.19	7.78	8.45[a]	1.10	1.05	0.96	0.91	1.00[a]
Means	8.49[a]	7.99[ab]	7.62[bc]	7.25[c]	-	1.00[a]	0.95[ab]	0.89[bc]	0.85[c]	-
				K rates		CCL		K rates × CCL		
Fresh shoot weight		SED		0.207		0.239		0.415		
		LSD		0.350***		0.404***		NS		
Dry shoot weight		SED		0.022		0.026		0.045		
		LSD		0.038***		0.044***		0.076*		

Table 4: *Effects of potassium and calcareousness on fresh and dry root weight.*

K rates (K_2O kg ha^{-1})	$CaCO_3$ (%)									
	Fresh root weight (g)					Dry root weight (g)				
	<5	10	20	30	Means	<5	10	20	30	Means
Control	0.73	0.69	0.66	0.66	0.68[b]	0.27	0.26	0.26	0.26	0.26[c]
K_{60}	0.87	0.80	0.76	0.72	0.79[a]	0.36	0.32	0.30	0.26	0.31[b]
K_{120}	0.92	0.84	0.80	0.76	0.83[a]	0.42	0.39	0.36	0.33	0.38[a]
Means	0.84[a]	0.78[ab]	0.74[bc]	0.71[c]	-	0.35[a]	0.33[ab]	0.31[bc]	0.29[c]	-
				K rates		CCL		K rates × CCL		
Fresh root weight		SED		0.021		0.024		0.042		
		LSD		0.035***		0.041***		NS		
Dry root weight		SED		0.008		0.010		0.017		
		LSD		0.014***		0.016***		0.028*		

than that at CCL 5, 10 and 20%. K rates x CCL interaction had non-significant (p>0.05) impact on fresh shoot weight. Nevertheless, fresh shoot weight at CCL (30%) was lower than CCL 5, 10 and 20%. The results indicated that CCL (30%) resulted in a minimum fresh shoot weight of 7.25 g on an individual basis, whereas the application of 120 kg ha^{-1} boosted fresh shoot weight to a larger extent (8.45 g). However, the fresh shoot weight increased to 9.14 g when the treatment combination of rate 120 kg K_2O ha^{-1} x CCL 5% was employed.

Effects of potassium and calcareousness on dry shoot weight

Shoot dry weight was significantly (p<0.05) impacted by rate and the interaction of K rates x CCL (Table 3). In comparison to the control, plants fertilized with 60 and 120 kg K_2O ha^{-1} exhibited increases in shoot dry weight of 0.95 g and 1.00 g, respectively. The plants grown at 10, 20 and 30% CCL yielded lower shoot dry weights 0.95, 0.89 and 0.85 g, respectively, than the with 5% CCL.

Effects of potassium and calcareousness on fresh root

Data on sunflower fresh root weight as impacted by various CCL and K fertilizer rates are displayed in Table 4. The findings showed that the impact of K rates and CCL on fresh root weight was highly significant (p<0.05). The interaction between K rates and CCL, however was non-significant at (p>0.05). In 120 kg K_2O ha^{-1} the fresh root weight of sunflower was higher (0.83 g) than in the control (0.68 g). Under varying CCL, fresh root weight was higher (0.92 g) in 120 kg ha^{-1} at CCL 5% and lower (0.66 g) in the control group at CCL 30%. Fresh shoot weight decreased as CCL increased overall. Between rates 120 kg K_2O ha^{-1} had the highest fresh shoot weight (0.83 g) followed by 60 kg K_2O ha^{-1} (0.79 g) and Control (0.38 g).

Effects of potassium and calcareousness on dry root weight

A statistical analysis of the dry root weight data for sunflowers in Table 4 revealed significant differences (p<0.05) in the effects of CCL, K rates and the interaction of CCL x K rates. In comparison to the

Table 5: *Effects of potassium and calcareousness on total chlorophyll and shoot K concentration.*

K rates (K_2O kg ha^{-1})	$CaCO_3$ (%)									
	Total chlorophyll concentration (mg g^{-1} fw)					Shoot K concentration (%)				
	<5	10	20	30	Means	<5	10	20	30	Means
Control	1.622	1.593	1.548	1.520	1.571[b]	3.71	3.61	3.51	3.44	3.56[b]
K_{60}	1.903	1.811	1.740	1.633	1.772[a]	4.56	4.20	3.96	3.78	4.12[a]
K_{120}	1.988	1.888	1.800	1.697	1.843[a]	4.84	4.42	4.17	3.96	4.34[a]
Means	1.838[a]	1.764[ab]	1.696[bc]	1.617[c]	-	4.37[a]	4.07[ab]	3.88[bc]	3.73[c]	-
				K rates		CCL		K rates × CCL		
Total chlorophyll concentration		SED		0.037		0.043		0.074		
		LSD		0.063***		0.073***		NS		
Shoot K concentration		SED		0.082		0.071		0.102		
		LSD		0.145***		0.124***		NS		

control which generated 0.26 g, 120 kg K_2O ha^{-1} produced a considerably higher dry root weight (0.38 g), followed by 60 kg K_2O ha^{-1} (0.31 g). At CCL 5% the dry root weight was greater 0.35 g and at 10, 20 and 30% CCL, it decreased by 0.33, 0.31 and 0.29 g respectively. Comparing rates under various CCL results also showed that 120 kg K_2O ha^{-1} at CCL 5% had the highest dry root weight (0.42 g), while the control group had the lowest (0.26 g) at CCL 30%.

Effects of potassium and calcareousness on chlorophyll concentration

The effects of varying CCL and K fertilizer rates on the total chlorophyll amount of sunflower seedlings are summarized in Table 5. Highly significant increases (p<0.05) in sunflower seedlings chlorophyll concentrations were observed for both K rates. CCL had highly significant effect (p<0.05) on sunflower leaves, which led to a decrease in chlorophyll concentration. As CCL rose relative to controls, the chlorophyll concentration steadily dropped. The chlorophyll concentration in seedlings decreased by 1.79, 4.56 and 6.29% with 10, 20 and 30% CCL, respectively. The findings indicate that the concentration of chlorophyll increased by 17.32 and 22.56%, respectively, when 60 kg K_2O ha^{-1} and 120 kg K_2O ha^{-1} of the control were applied.

Effects of potassium and calcareousness on shoot K concentration

The effects of different CCL and K fertilizer rates on the K concentration in shoot of sunflower seedlings are displayed in Table 5. The findings showed that while the interaction between CCL and K rates was non-significant (p>0.05), the effect of CCL and K rates was highly significant (p<0.05). As CCL increased the trend for K buildup in shoots decreased. The plants that were grown in soils that had received 120 kg K_2O ha^{-1} had the highest concentration of K. Nevertheless, K buildup was decreased by 14.65% in CCL 30% as opposed to CCL 5%. Both the K rates had highly significant (p<0.05) effect on the K concentration in shoots. In comparison to the control, the shoot K concentration increased by 15.73% with 60 kg K_2O ha^{-1} and 21.91% with 120 kg K_2O ha^{-1}.

Discussion

This study found that soil calcareous levels (CCL) and various K fertilizer treatments had a substantial impact on early growth of sunflower. Since the availability of K directly affects development and productivity, the vegetative growth period is crucial for plants.

The findings demonstrated that K fertilization increased both shoot height and root length; the tallest shoots and longest roots were produced by applying 120 kg K_2O ha^{-1}, suggesting that K has a beneficial effect on growth. The concentration of shoot K and chlorophyll was also increased by K fertilization, which is consistent with its role in photosynthesis and overall plant health. These results are in line with the fundamental studies advanced by Trankner *et al.* (2018), Brady and Weil (2013) and Santos *et al.* (2023) which states that a sufficient supply of nutrients provided by fertilizers promotes plant development. Fresh and dry shoot weight as well as fresh and dry root weight rose after potassium fertilization, suggesting that K encourages biomass accumulation and the growth of a robust root system. As also noted in the reference studies of Chajjro *et* *al.* (2013), Bhowmick *et al.* (2015) and Ahmad *et al.* (2017) this is in line with the knowledge that balanced fertilizing increases plant productivity. Potassium deficiency, which is linked to poor tissue growth and cell wall thinning contributed to the seedlings poor performance when grown in control (without K treatment) pots (Beltagi *et al.*, 2023). According to Bukhari *et al.* (2022) the uptake of K by plants is influenced by its availability in the root zone.

According to our findings, shoot height and root length and the weight of both fresh and dried shoots and roots were negatively impacted by escalating soil calcareous levels. Like- wise, increasing CCL, on the other hand, reduced the concentration of chlorophyll and shoot K, suggesting that elevated calcareous levels may impair photosynthetic efficiency and impede K uptake. This may be caused by a number of things, including poor chlorophyll synthesis or nutrient deficits brought on by high soil pH. Moreover, high Ca content in the soil solution may reduce the crop's ability to absorb K (Wolde, 2016). The inverse relationship between all parameters and CCL raises the possibility that elevated CCL could hinder nutrient uptake or produce other unfavorable growth circumstances. This validates previous studies by Sahai (2004), Brady and Weil (2013), Chohan *et al.* (2015), Wakeel *et al.* (2017) who found that high calcareous levels may limit the amount of biomass that sunflowers can produce and hinder the growth and development of their roots, possibly by affecting the soil structure, nutrient availability or the physiological processes of the roots. In our study it was observed that high Ca levels in the soil solution hindered the crop's uptake of K, in addition to other parameters such the cation exchange capacity, high pH and low organic matter. These findings concur with research by Ertiftik and Zengin (2015) and Wolde (2016). K availability is impacted by CCL either directly or indirectly (Sahai, 2004). Inadequate soil K availability in calcareous soil typically restricts plant growth and lowers sunflower production (Li *et al.*, 2014). Chohan *et al.* (2015) and Santos *et al.* (2023) similarly stated that because $CaCO_3$ content in soil solution disrupts soil characteristics, affects nutrient availability and affects soil-water relations, high lime levels may be a contributing factor to these soils' decreased K availability. The amount of K crop needs varies according to its physiological growth stages (Wang *et al.*, 2013; Komal and Razzaq, 2019). Accordingly, the presence of other cations has a considerable impact on K absorption (Dotaniya *et al.*, 2016). The types and concentrations of various other cations that the crop has access to, as well as the type and concentration of individual cations in relation to K, determine these impacts (Wang *et al.*, 2013). This research described the effects of $CaCO_3$ on the application of native soil K and two rates of K fertilizer. The availability of K from soil and fertilizer sources was reduced when the amount of $CaCO_3$ in the soil increased. The primary source of K for plant growth was the natural soil. Even though there is an excess of K in the soil, the ratio of Ca, Mg and K ions in calcareous soils creates an imbalance that causes a K deficit for plants (Brady and Weil, 2013). However, compared to 60 kg K_2O ha^{-1}, K uptake was greater when the rate of K fertilizer was 60 kg K_2O ha^{-1} and the relationship between K rates and CCL was not significant, suggesting that the impact of K fertilization is largely constant throughout different CCL. Our study shows how CCL and K fertilizer have different effects on early development of sunflower. Although K fertilization typically encourages development, elevated calcareous levels can prevent it by altering a number of important factors. These results emphasize the need for proper K management and the necessity of taking soil calcareous levels into account in order to maximize sunflower productivity. The precise processes by which high CCL suppresses sunflower development could be examined in more detail, as well as potential countermeasures.

Conclusions and Recommendations

Sunflower growth is adversely affected by high soil calcareousness; however, these negative effects can be considerably mitigated by higher application of potassium fertilizer particularly with 120 kg K_2O ha^{-1} leading to better early growth stage.

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Novelty Statement

High levels of calcium carbonate in the soil inhibit sunflower growth and K uptake, however; these restrictions can be somewhat mitigated by increased potassium fertilization

Author's Contribution

Abdul Aleem Memon: Conceived the concept, designed the study, carried out experiment chemical analysis, data collection, Editing and drafting manuscript, statistical analysis.
Inayatullah Rajpar: Conceptualization, elaborated the intellectual content and supervised the research work.
Ghulam Murtaza Jamro: Co-supervised the study project and designed the research procedures, plagiarism check.
Muhammad Suleman Memon: Compilation of data, Manuscript Revision
Ambrin Rajput: Interpretation of data, manuscript revision.
Javeed Shah: Provided technical assistance and made technical revisions to the article.
Hafeezullah Babar: Interpretation of data, manuscript revision.

Conflict of interest
The authors have declared no conflict of interest.

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