ISSN NO: 2771-8840
Date of Publication: 24-01-2023

Effect of Foliar application of Silicon on Oat varieties (*Avena sativa* L.) Grain yield and Components under Silt-affected soil

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Abstract: A field experiment conducted during 2021-2022 season at agricultural research station, College of agriculture, university of Basrah, Basrah, Iraq (30°39'28.2"N 47°44'31.6"E). The aim was to study the effect, partitioning of silicon dosage and silicon concentration and its interaction on grain yield and components for two Oat varieties (*Avena sativa* L.). The experiment include three factors, the first one is two Oat varieties (Shifaa and Ganzania). Second factor is partitioning of silicon dosage (once, twice, three times at tillering, stem elongation and booting stage). Third, one is silicon (SiO_2) at three concentrations (0, 4, and 8 mM l^{-1}). The total number of experimental units is 54 with a distance of 4 m^{-2}. The treatments arranged using split split plot arrangement according to the randomized complete block design with three replicates. Oat varieties were applied at main units, partitioning of silicon dosage was applied at sub plots and silicon concentration applied at sub plots. The results showed there is significant differences between Oat varieties, Shifaa gave highest, panicle m^{-2}, 1000 seed weight, grain yield, biological yield and harvest index by 492.8 panicle m^{-2}, 27.66 g, 2.952 t ha^{-1} , 10.000 t ha^{-1} and 29.38% respectively. The results revealed that, partitioning of silicon dosage has a significant effect on almost traits. Moreover, treatment of three time of silicon application as compared to one time gave significant increase in grain yield and biological yield by 6.92% and 3.64% respectively. The results indicated that, foliar application of silicon significantly increased almost traits that have been studded. Moreover, silicon concentration of 8 mM l^{-1} gave significant increment as compared to control treatment (0 mM l^{-1}), on grain yield, biological yield, by 41.61%, 22.40%, respectively. Moreover, silicon foliar application lead to increase Si and Ki% concentration in plant, while reduced proline content. For the interaction, between Oat varieties and silicon, the results showed that foliar application of silicon lead to increased grain yield, biological yield and harvest index for both Oat varieties. Shifaa under 8 mM l^{-1} gave highest grain yield and biological yield by 3.487 t ha^{-1} and 11.166 t ha^{-1} respectively. In addition, Shifaa under one or two time of foliar application of 8 mM l^{-1} silicon gave highest biological yield by 11.441 and 11.331t ha^{-1} respectively.

Keyword: Oat, silicon, salinity, Grain yield, Potassium, Proline

1: Introduction

Oat (*Avena sativa* L.) is an important and multipurpose crop, with a major use to feed animals and food human at poor countries. Recently, Oat used as nutrition and in medicine due to its seeds are rich in carbohydrate, protein and fiber by 57.8%, 12.2%, 4.3% and 12.1% respectively (Butt *et al.*, 2008). In addition Oats are rich In antioxidants, can lower cholesterol levels and enhance immune response to diseases (Butt *et al.*, 2008; Mushtaq and Mehfuza, 2014). The worldwide area cultivated with Oat in 2021-2022 was 9.34 million hectares with production of 22.44 million tons and by average of 2.38 t ha^{-1} (USDA, 2022). In Iraq Oat production still low by 2.169 t ha^{-1} according to bad field management and low price. Moreover, climate condition change in worldwide especially high temperature and drought, reduce agricultural product for many crops (Lobell *et al.*, 2011; Osborne and Wheeler, 2013; Kissoudis *et al.*, 2016; Urban *et al.*, 2017). So, climate change lead to increased soil salinity which usually accompanies to increased water deficit (Ma *et al.*, 2012; Ahmed, 2020). Climate change also drastically accelerate the land deterioration that is now already occurring due to agricultural intensification and irrigation (DeLong *et al.*, 2015). Predictive study of (Long *et al.*, 2015) indicated that, the yield of three main crops (rice wheat and cassava) will not be sufficient in future due to degradation in agriculture land. Moreover, in next future 2050, global Food demand will increase by 70–110% and will presents a significant challenge to society (Tilman *et al.*, 2011; Long *et al.*, 2015). Oat (*Avena sativa* L.) is one of most important cereal and forage crops ranks sixth in world cereal production after wheat, maize, rice, barley and sorghum (Pinto *et al.*, 2021). There is increasing evidence to use more flexible varieties to mitigate the impact of climate condition change on crop production. In addition, to increase agricultural cereal production it is important and beneficial to cultivate saline effected soil by both tolerant and sensitive's cereal and or forage crops. For the sensitives crops may we can use some nutrition like silicon which could be enhance their ability to tolerate effect of salinity (Liang *et al.*, 2003; Zhu *et al.*, 2004; Ahmad *et al.*, 2011). Silicon (Si) is non-essential elements that can enhance crop yield by promoting several desirable plant physiological processes (Korndörfer and Lepsch, 2001). Effect of climate change on crops can be to a large extent mitigated, or may even become favorable for crop productivity, if appropriate actions are taken. One of these actions is use of resilient cultivars with some nutrition elements (Zhu *et al.*, 2004; Crusciol *et al.*, 2013; Stadnik and Tobiasz-Salach, 2022). The objective of this study was to evaluate the effect of foliar application of silicon on grain yield and component of two Oat cultivars grown in saline affected soil.

2 Material and Methods

A field experiment were conducted during winter season 2021-2022 at Alhartha agricultural research and Experimental station, college of agriculture, University of Basrah, located north of Basra governorate (N 30.65783 47.74210E) in saline affected soil. The objectives was to evaluate the effect of foliar application of silicon and partitioning of silicon dosage and their interaction on growth and forage yield of two oat varieties cultivated in saline affected soil. The experiment include three factors, the first one is two Oat cultivars (Shifaa and Ganzania) which they are symbolized by V_1 and V_2. Second factor is partitioning of silicon dosage, (once, twice, three times which they are symbolized by C_1, C_2 and C_3) at tillering, stem elongation and booting stage. Third one is silicon (SiO_2) at three concentrations (control, 4, 8%) which they are symbolized by S_0, S_1 and S_2 respectively. The total number of experimental units is 54 with a distance of 4 m^{-2}. A split split plot experiment was applied according to the randomized complete block design with three replicates. Oat varieties were applied at main units, partitioning of silicon dosage was applied at sub plots and silicon concentration applied at sub sub plots. Experimental soil was prepared by two orthogonal tillages and then, the soil leveled and grained by disc harrows. Random samples were taken from soil before planting (depth of 0-30cm), dried and passed in a 2 mm sieve to determine some physical and chemical properties of field (Table 1). Nitrogen fertilizer was added to the soil in form of urea, 46% N at 120 kg h^{-1} at two equal timing, the first one a week after seed sowing and the second one at stem elongation stage. Phosphate fertilizer was added to the soil at seed sowing in form of triple superphosphate 21% P_2O_5 at 100 kg h^{-1}. Potassium fertilizer was added to the soil at 120 kg h^{-1} at two equal times, sowing and stem elongation stage in form of potassium sulfate 52% (Alabedy, 2011). Seeds were sowing a strip, 20 cm between line and another. Silicon was used in form of SiO_2 and spired at the concentrations and timing that have determined. Tween 20 was used to decrease the surface tension of solution. Panicle m^{-2} , 1000 seeds weight, kernels spike-1 grain yield biological yield, harvest index, Si%, K% and proline content were measured. Data were collected and analyzed statistically by GenStat statistical software 12. Averages of data were compared by using least significant difference (LSD) at probability level of 0.05 (LSD ($P<0.05$).The data collected and analyzed statistically using GenStat statistical software 12. Averages of data were compared by least significant difference (LSD) at probability level of 0.05 (LSD ($P<0.05$).

Table 1 some physical and chemical properties of experimental soil before seeds sowing

Trait	code	Value	unite
Acidity	pH	7.45	-
Conductivity	EC	15.16	dS m^{-1}
Calcium	Ca	8.8	mg kg^{-1}
Magnesium	Mg	3.7	
Sodium	Na	53.7	
Bicarbonate	HCO3	5	
Chloride	CL	138.7	
Sulfate	SO4	5.4	
Potassium	K	56.3	
Phosphate	PO4	30.07	
Nitrogen	(NO3+NH4)	49.6	
Total organic carbon	TOC	2.95	%
soil texture Clay loam	sand	260.45	g kg^{-1} soil
	silt	420.70	
	mud	318.85	

3- Results and Discussion

3:1 Panicles m^{-2}

The results of Table 2 revealed that Oat varieties have significant effect on panicles m^{-2} and Shifaa gave highest average by 492.8 panicles m^{-2} as compared to Ganzania which gave the lowest average by 468.4 panicles m^{-2}. Oat variety differ in their genetic ability and Shifaa gave highest average of tillers m^{-2} as compared to Ganzania data showed in (Hassan and Alsulaiman, 2022), this reflected positively on panicles m^{-2}. This results is convenience with results of (Maral *et al.*, 2013). The results of table 2 indicated that partitioning of silicon dosage have a significant effect on panicles m^{-2}. Moreover C3 treatment gave highest average by 487.1 panicles m^{-2} without any significant differences from C2 treatment by 484.0 panicles m^{-2}. While, C1 gave the lowest average by 439.0 panicles m^{-2}. Partitioning of silicon dosage lead to increase period of silicon availability for Oat, especially during rapid growth when the plant needs. In addition partitioning of silicon lead to increase tillers m^{-2}, and this reflected positively on panicles m^{-2}, by correlation equal to 0.9995** data showed in (Hassan and Alsulaiman, 2022). The results of table 2 showed significant effect for silicon concentrations on panicles m^{-2}. Foliar application of silicon lead to increased panicles m^{-2}, and S2 gave highest average by 513.4 panicles m^{-2} as compared to the control treatment (S0) by 439.0 panicles m^{-2}. Foliar application of silicon helped to maintain a balanced and efficient absorption and translocation of mineral elements required for better growth, in addition enhance growth by improving K^{+} which was reduced salt stress (Table2). The current findings were also supported by (Anser *et al.*, 2012) who found an increase in panicles m^{-2} with increased rate of Si nutrition in Wheat crop. The results of table 3 indicated that there is significant effect for the interaction of Oat varieties and silicon concentration. Foliar application of silicon lead to increased panicles m^{-2} for both Oat varieties, so Shifaa and Ganzania under foliar application of S2 gave the highest average by 518.5 and 508.2 panicles m^{-2} respectevely. While Ganzania under S0 concentration gave lowest average by 430.3 panicles m^{-2}.

3:2 Kernels Panicale^{-1}

The results of Table 2 showed that Oat varieties differ significantly in Kernels panicale^{-1}. Ganzania gave highest average by 36.22 Kernels panicale^{-1}. While Shifaa variety gave the lowest by 32.57 Kernels panicale^{-1}. Oat varieties differ in their genetic ability. The results of table 2 indicated that there is significant effect for silicon concentrations on Kernels panicale^{-1}. Foliar application of silicon lead to increased Kernels panicale^{-1}, and S2 gave highest average by 36.33 Kernels panicale^{-1} as compared to the control treatment (S0) by 32.30 Kernels panicale^{-1}. Foliar application of silicon helped to maintain a balanced and efficient absorption and translocation of mineral elements required for plant growth and this reflected positively on Kernels panicale^{-1} (Liang *et al.*, 2007; Imtiaz *et al.*, 2016).

3:3 1000 Kernels weight (g)

The results of Table 2 revealed that Oat varieties differed significantly in 1000 kernels weight and Shifaa gave highest average by 27.66 g as compared to Ganzania which gave the lowest average by 26.91 g. This results convenient with the study of (Soratto *et al.*, 2012) which indicated that Oat varieties differ in their genetic ability. The results of table 2 indicated that partitioning of silicon dosage have a significant effect on 1000 kernels weight. Moreover C3 treatment gave highest average by 28.24 g without any significant differences from C2 treatment by 28.53 g. While, C1 gave the lowest average by 25.08 g. Partitioning of silicon dosage lead to increase period of silicon availability for Oat, especially during rapid growth when the plant needs. The results of table 2 showed significant effect for silicon concentrations on 1000 kernels weight. Foliar application of silicon lead to increased 1000 kernels weight, and S3 gave highest average by 30.68 g without any significant differences from S2 treatment by 29.45 g as compared to the control treatment (S0) which gave the lowest average by 21.72 g. Silicon is efficient in increasing mineral nutrition and reducing some abiotic stresses, thus improves the growth and yield of many plants (Crusciol *et al.*, 2013; Gonzalo *et al.*, 2013). The results of table 3 indicated that there is significant effect for the interaction of Oat varieties and silicon concentration. Foliar application of silicon lead to increase 1000 kernels weight for both Oat varieties, Shifaa under foliar application of S2 gave the highest average by 32.68 g. While both Shifaa and Ganzania under S0 concentration gave lowest average by 21.56 and 21.89 g respectively.

3:4 Grain yield (t ha^{-1})

The results of Table 2 revealed that Oat varieties differed significantly in grain yield. Shifaa gave highest average by 2.952 t ha^{-1} as compared to Ganzania which gave the lowest average by 2.471 t ha^{-1}. Shifaa gave highest average of panicles m^{-2} and 1000 kernels weight by 492.8 panicles m^{-2} and 27.66 g respectively (table 2) which reflect positively on grain yield. This is consistent with what found by (Alzarkani, 2017) which indicated that Shifaa gave highest grain yield as compared to other varieties. The results of table 2 indicated that partitioning of silicon dosage have a significant effect on grain yield. The treatment of C3 and C2 gave highest average by 2.797 and 2.723 t ha^{-1} respectively (table 2). While, C1 gave the lowest average by 2.616 t ha^{-1}. The partitioning of silicon dosage lead to increase grain yield component (panicles m^{-2} Kernels panicale^{-1} and 1000 kernels weight). Which reflect positively on grain yield (Table 2). The results of table 2 showed significant effect for foliar application of silicon on grain yield. Foliar application of silicon lead to increased grain yield. The S2 concentration gave highest average by 3.131 t ha^{-1} as compared to the control (S0) which gave the lowest yield by 2.211 t ha^{-1}. Foliar application of silicon increased grain yield by increase panicles m^{-2} , Kernels panicale^{-1} and 1000 kernels weight (Table 2). The results of table 3 showed significant interaction for Oat varieties and silicon concentration. Foliar both Oat varieties foliar application of silicon increase grain yield. Shifaa and Ganzania under S2 treatment gave the highest average by 3.487 and 2.776 t ha^{-1} respectively. Foliar application of silicon increased grain component for both varieties (Table2).

3:5 Biological yield (t ha^{-1})

The results of Table 2 revealed that Oat varieties differed significantly in biological yield. Shifaa gave highest average by 10.000 t ha^{-1} as compared to Ganzania which gave the lowest average by 8.977 t ha^{-1}. Shifaa produced highest average of grain yield (table 2), crop growth rate and dry forage yield (data showed in Hassan and Alsulaiman, 2022) which reflect positively on biological yield. The results of indicated that Oat varieties significantly differed in biological yield. The results of table 2 indicated that partitioning of silicon dosage gave a significant effect on biological yield. The treatment of C2 and C3 gave highest average by 9.626 and 9.538 t ha^{-1} respectively (table 2). While, C1 gave the lowest average by 9.299 t ha^{-1}. The partitioning of silicon dosage lead to increase grain yield (table 2), crop growth rate and dry forage yield (data showed in Hassan and Alsulaiman, 2022) which reflect positively on biological yield. The results of table 2 showed significant effect for foliar application of silicon on grain yield. Foliar application of silicon increased biological yield and S2 concentration gave highest average by 10.577 t ha^{-1} as compared to the control (S0) which gave the lowest yield by 8.737 t ha^{-1}. Foliar application of silicon increased grain yield (table 2), crop growth rate and dry forage yield (data showed in Hassan and Alsulaiman, 2022) which reflect positively on biological yield. The results of table 3 showed significant interaction for Oat varieties and foliar application of silicon. For both Oat varieties, foliar application of silicon significantly increase biological yield. Shifaa under S2 treatment gave the highest average by 11.166 t ha^{-1}. While Ganzania under S0 treatment gave the lowest average by 8.243 t ha^{-1}. Foliar application of silicon lead to increased grain yield for both Oat varieties (Table 2). Moreover, increased tillers m^{-2}, Crop growth rate, flag leaf area and other growth traits, data showed in (Hassan and Alsulaiman, 2022). The results of table 3 showed significant interaction for partitioning of silicon dosage and silicon concentrations. The interaction of (C3xS2), (C2xS2) and (C1xS2) gave the highest average by 10.497, 10.882 and 10.351 respectively. Whereas, the interaction of (C1xS0), (C2xS0), (C3xS0) and (C1xS2) gave the lowest average by 8.664, 8.740, 8.808 and 8.883 t ha^{-1} respectively. May be this indicated for the effect of single treatments. The results of table 5 indicated that there is significant effect for interaction of Oat varieties partitioning of silicon dosage and silicon concentrations. Shifaa under C2 S3 treatment and the same variety under the effect of C1S3 produced highest biological yield by 11.441 and 11.331 t ha^{-1} respectively. While Ganzania under (C3S0), (C1S0) and (C2S0) gave the lowest average by 8.226, 8.246, 8.257 respectively.

3:6 Harvest index%

The results of Table 2 revealed that Oat varieties differed significantly in harvest index. Shifaa gave highest average by 29.38% as compared to Ganzania which gave the lowest average by 27.48%. Shifaa variety produced highest grain yield and biological yield as compared to Ganzania (Table 2) which positively reflect on harvest index. In addition this indicate that Shifaa variety has more physiological efficiency and ability to convert total dry matter into economic yield under silt affected soil (Sharifi *et al.*, 2009; Asefa, 2019). The results of table 2 showed significant effect for foliar application of silicon on harvest index (HI). Foliar application of silicon increased harvest index as compared to control. Moreover, the concentration of S1 and S2 of silicon gave highest HI% by 30.44 and 29.50% respectively. This because foliar application of silicon increased grain yield (Table 2) and some growth properties, data showed in (Hassan and Alsulaiman, 2022). The results of table 3 showed significant interaction for Oat varieties and foliar application of silicon. For both Oat varieties, foliar application of silicon significantly increased harvest index. Shifaa under S1 and S2 treatment gave the highest average by32.12 and 31.27% respectively. While Shifaa and Ganzania under S0 treatment gave the lowest average by 25.31 and 25.92% respectively.

3:7 Silicon% (Si%)

The results of table 2 indicated that partitioning of silicon dosage has a significant effect on silicon present (Si%) in Oat. The partitioning of silicon dosage for two and three times gave highest silicon concentration in plant by 6.132 and 5.988% respectively. While addition of silicon for one time gave lowest Si% in plant by 5.083%. Partitioning of silicon dosage lead to increase period of silicon availability for Oat up to the sampling time. The results of table 2 showed significant effect for foliar application of silicon on Si%. Foliar application of silicon increased Si% and S2 treatment gave highest average by 7.737% as compared to the control (S0) which gave the lowest yield by 2.471%. The study of (Fan *et al.*, 2019) indicated that application of Si lead increased Si% in plants. The results of table 4 indicated that there is significant effect for interaction of partitioning of silicon dosage and silicon foliar application. Increased of silicon concentration for each silicon dosage lead increase Si% in Oat. The interaction of C2S2 and C3S2 produced highest Si% content by 8.226 and 7.798% respectively. While the interaction of C2S0, C1S0 and (C3S0) gave the lowest average by 2.321, 2.451 and 2.642% respectively.

3:8 Potassium% (K%)

The results of table 2 indicated that partitioning of silicon dosage has a significant effect on potassium concentration (K%) in Oat. The partitioning of silicon dosage for two and three times gave highest (K%) by 3.497 and 3.219% respectively. While, the addition of silicon for one time gave lowest (K%) in plant by 2.553% (table 2). The results of table 2 showed significant effect for foliar application of silicon on (K%) in plants. Foliar application of silicon increased (K%) and S2 treatment gave highest average by 4.387% as compared to the control (S0) which gave the lowest yield by 1.590%. Silicon foliar application increased concentration of potassium in plant, and this is consistent with (Crusciol *et al.*, 2013; Fan *et al.*, 2019). The results of table 4 indicated that there is significant effect for interaction of partitioning of silicon dosage and silicon foliar application. The increased of silicon concentration for each silicon dosage lead increase (K%) in

Oat. The interaction of C2S2 and C3S2 produced highest Si% content by 5.092 and 4.623% respectively. While the interaction of C3S0, C1S0 and (C2S0) gave the lowest average by 1.434, 1.580 and 1.755% respectively.

3:9 Proline content (mg g^{-1})

The results of table 2 showed significant effect for foliar application of silicon on proline content (mg g^{-1}) in plants. Foliar application of silicon reduced proline content, and S2 treatment gave lowest average by 1.915 mg g^{-1} as compared to the control (S0) which gave the highest average 3.827 mg g^{-1}. Normally the proline accumulated in leaves when plants are exposed to salt stresses (Hakim *et al.*, 2014). Moreover, increasing the concentration of proline in the plant finally leads to disruption of growth and production (Koca *et al.*, 2007; Kumar *et al.*, 2008; Hakim *et al.*, 2014)

Conclusion

We conclude that Shifaa is more resilient to grow under silt affected soil as compared to Ganzania. Foliar application of silicon and partitioning of its dosage ameliorate harsh effect of salinity for both Oat varieties.

Acknowledgements

We thanks the cadre of Alhartha Research Station and department of Science of Field Crops, University of Basrah for their help and support during study period. In addition, we thanks the staff of soil laboratory, department of Soil and Water Resources for their help to estimate the percentage of protein Moreover we thanks Dr. Hassan A.F. and Dr. Montaha A. A. from Date palm research center for their help in measuring proline content.

Table 2 Effect of partitioning of silicon dosage and of foliar application of silicon on grain yield, components, biological yield, harvest index and Si%, K%, and proline content for two Oat varieties under Silt-affected soil

Treatment	Traits measured								
	panicle.m^{-2}	Kernels $Panicle^{-1}$	1000 Kernels weight (g)	Grain Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index %	Si%	K%	Proline μg g^{-1}
Janzania	468.4	36.22	26.91	2.471	8.977	27.48	5.818	3.130	2.752
Shifaa	492.8	32.57	27.66	2.952	10.000	29.38	5.650	3.049	2.850
LSD ($P<0.05$)	13.22	2.004	0.587	0.1634	0.0872	1.965	N.S	N.S	NS
C1	470.6	34.44	25.08	2.616	9.299	27.37	5.083	2.553	2.885
C2	484.0	34.57	28.53	2.723	9.626	28.13	5.988	3.497	2.777
C3	487.1	34.18	28.24	2.797	9.538	29.18	6.132	3.219	2.741
LSD ($P<0.05$)	8.15	NS	1.080	0.1046	0.1690	NS	0.2716	0.5422	NS
S0	439.0	32.30	21.72	2.211	8.737	25.33	2.471	1.590	3.827
S1	489.4	34.57	29.45	2.792	9.149	30.44	6.995	3.292	2.482

S2	**513.4**	**36.33**	**30.68**	**3.131**	**10.577**	**29.50**	**7.737**	**4.387**	**1.915**
LSD (P<0.05)	**6.58**	**1.142**	**1.528**	**0.139**	**0.130**	**1.416**	**0.307**	**0.289**	**0.215**

Table 3 Interaction effect of two Oat varieties, partitioning of silicon dosage on grain yield, components, biological yield, harvest index, Si%, K%, and proline content

Treatment		**Traits measured**								
		Panicle m^{-2}	**Kernels Panicle^{-1}**	**1000 Kernels weight (g)**	**Grain Yield (t ha^{-1})**	**Biological Yield (t ha^{-1})**	**Harvest index %**	**Si%**	**K%**	**Proline µg g^{-1}**
Janzania	**C1**	**463.3**	**36.40**	**25.11**	**2.355**	**8.725**	**27.00**	**5.345**	**2.594**	**2.849**
	C2	**469.2**	**36.24**	**28.46**	**2.508**	**9.093**	**27.53**	**6.063**	**3.417**	**2.713**
	C3	**472.6**	**36.03**	**27.15**	**2.550**	**9.114**	**27.90**	**6.047**	**3.378**	**2.694**
	C1	**478.0**	**32.49**	**25.06**	**2.876**	**9.880**	**28.95**	**4.820**	**2.511**	**2.920**

Shifaa	C2	498.8	32.90	28.60	2.938	10.158	28.74	5.913	3.577	2.841
	C3	501.5	32.33	29.33	3.043	9.962	30.46	6.217	3.060	2.789
LSD (P<0.05)		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Janzania	S0	430.3	30.19	21.89	2.136	8.243	25.92	2.385	1.701	3.869
	S1	466.6	32.96	30.15	2.502	8.701	28.76	7.254	3.267	2.296
	S2	508.2	34.57	28.68	2.776	9.988	27.75	7.816	4.422	2.092
Shifaa	S0	447.7	30.19	21.56	2.287	9.238	24.75	2.557	1.479	4.054
	S1	512.1	32.96	28.75	3.083	9.596	32.12	6.736	3.317	2.575
	S2	518.5	34.57	32.68	3.487	11.166	31.27	7.657	4.352	1.921
LSD (P<0.05)		10.67	N.S	1.782	0.7004	0.156	1.919	N.S	N.S	NS

Table 4 The interaction effect of partitioning of silicon dosage and silicon concentration on grain yield, components, biological yield, harvest index and Si%, K%, and proline content

ISSN NO: 2771-8840
Date of Publication: 24-01-2023

Treatment		Traits measured								
		Panicle m^{-2}	Kernels Panicle $^{-1}$	1000 Kernels weight (g)	Grain Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index %	Si%	K%	Proline µg g^{-1}
C1	S0	435.4	33.04	21.07	2.167	8.664	25.03	2.451	1.580	4.155
	S1	473.3	33.76	25.56	2.680	8.883	30.11	5.770	2.633	2.437
	S2	503.3	36.53	28.62	3.000	10.351	28.77	7.027	3.446	2.061
C2	S0	438.0	32.17	22.63	2.131	8.740	24.45	2.321	1.755	3.902
	S1	498.1	34.53	31.53	2.848	9.255	30.69	7.417	3.644	2.386
	S2	515.9	37.02	31.43	3.189	10.882	29.26	8.226	5.092	2.043
C3	S0	443.6	31.67	21.47	2.336	8.808	26.52	2.642	1.434	3.827
	S1	496.7	35.41	31.26	2.849	9.307	30.51	7.798	3.599	2.482
	S2	521.0	35.45	32.00	3.205	10.497	30.51	7.491	4.623	1.915
LSD ($P<0.05$)		NS	NS	NS	NS	0.2355	NS	0.4914	0.6418	NS

ISSN NO: 2771-8840
Date of Publication: 24-01-2023

Table 5 Effect of interaction of Two Oat varieties and foliar application of silicon, and timing of application on grain yield, components, biological yield, harvest index and Si%, K%, and proline content

Treatment			Traits measured								
			Panicle m^{-2}	Kernels Panicle $^{-1}$	1000 Kernels weight (g)	Grain Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index %	Si%	K%	Proline mg g^{-1}
Ganzania	C1	S0	430.5	35.04	20.97	2.133	8.246	25.87	2.469	1.642	4.11
		S1	457.6	35.88	25.75	2.442	8.557	28.54	6.241	2.664	2.333
		S2	501.7	38.26	28.60	2.491	9.372	26.57	7.325	3.477	2.104
	C2	S0	420.1	34.75	23.18	2.099	8.257	25.43	2.221	1.755	3.887
		S1	476.3	35.67	33.41	2.547	8.699	29.29	7.257	3.539	2.154
		S2	511.1	38.32	28.80	2.877	10.323	27.87	8.711	4.957	2.098
	C3	S0	440.2	33.41	21.53	2.176	8.226	26.46	2.466	1.705	3.608
		S1	465.8	36.98	31.28	2.515	8.847	28.44	8.263	3.597	2.400
		S3	511.9	37.70	28.65	2.959	10.268	28.82	7.412	4.832	2.073
Shifaa	C1	S0	440.3	31.05	21.18	2.201	9.101	24.18	2.432	1.518	4.200
		S1	488.9	31.64	25.37	2.918	9.209	31.69	5.298	2.602	2.542
		S3	504.9	34.79	28.64	3.509	11.331	30.97	6.729	3.415	2.019

	C2	S0	455.8	29.59	22.09	2.163	9.222	23.47	2.421	1.756	3.917
		S1	520.0	33.40	29.65	3.149	9.811	32.09	7.577	3.748	2.619
		S3	520.7	35.72	34.06	3.501	11.441	30.65	7.740	5.228	1.987
	C3	S0	447.1	29.94	21.41	2.497	9.391	26.59	2.817	1.163	4.046
		S1	527.5	33.84	31.23	3.183	9.768	32.59	7.332	3.602	2.565
		S3	530.0	33.21	35.35	3.451	10.727	32.20	8.502	4.415	1.756
LSD (P<0.05)			NS	NS	NS	NS	0.3120	NS	NS	NS	NS

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