The Pharma Innovation Journal 2023; 12(12): 3662-3667

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 3662-3667
© 2023 TPI
www.thepharmajournal.com
Received: 08-10-2023
Accepted: 13-11-2023

AG Faltankar
Department of Biochemistry,
PGI, MPKV, Rahuri,
Maharashtra, India

SV Damame
Assistant Professor, Department
of Biochemistry, AICRP on
Forage Crops, MPKV, Rahuri,
Maharashtra, India

HP Pardeshi
Department of Agronomy,
AICRP on Forage Crops, MPKV,
Rahuri, Maharashtra, India

Corresponding Author:
AG Faltankar
Department of Biochemistry,
PGI, MPKV, Rahuri,
Maharashtra, India

Soil application of silicon dioxide on forage quality in relation to lodging in oat (*Avena sativa* L.)

AG Faltankar, SV Damame and HP Pardeshi

Abstract

The present investigation was carried out to find out the soil application of silicon dioxide on forage quality in relation to lodging tolerance in oat genotypes. Initially, in the pot culture experiment, two each lodging and non-lodging type oat cultivars were compared based on quality parameters. The crude protein, acid detergent fibres, neutral detergent fibre, lignin, total minerals, potassium and silica were higher in non-lodging cultivars than lodging, whereas *in vitro* dry matter digestibility was higher in lodging than non-lodging type cultivars. Under field conditions, the effects of silicon dioxide application @ 200 kg ha^{-1} and 400 kg ha^{-1} on forage quality were evaluated in twelve different oat genotypes. The silica application to soil increased crude protein content in all oat genotypes. With the increase in levels of silica application, the cell wall constituents, ADF, NDF, and lignin were increased over the control treatment. After silica application, the highest lignin synthesizing oat genotypes were JO-03-91, RO-11-1-4, RO-11-1-2, UPO-212, and JO-2. The increased levels of silica application resulted in to decrease in IVDMD in all oat genotypes. The total minerals and potassium content were increased with the increased levels of silica application than control. With the increase in levels of silicon dioxide in the soil, the Si content in forage oat was increased. Among the 12 genotypes, the promising genotypes, JO-03-91, followed by RO-11-1-4 and JO-2 were found for lodging tolerance.

Keywords: Forage quality, lodging, lignin, silica, IVDMD

Introduction

Oat (*Avena sativa* L.) is one of the most important cultivated fodder crops in the world. It is grown in India mainly for nutritive grain and fodder purposes. It used as balanced feed for cattle, sheep and other domestic animals. Green fodder of oat contains about 10-12% protein and 30-35% dry matter (Panda, 2007) [12]. Oat crop has higher green forage yield potential than other forage crops under a limited time. The crop is grown mainly on medium to heavy soils under irrigated conditions to obtain maximum yield. Most of the high yielding varieties are tall in nature, crops are lodged due to a heavy load of biomass which results in to loss in green forage yield. The lodging resistance in a plant is determined by two main factors, the weight of the upper part (ears and upper leaves and stems) and the pushing resistance of the lower part. Plant height has been the main target for the improvement of lodging resistance. It is observed that genotypes having higher solid pith area have higher lodging resistance capability which possess thicker sclerenchyma cell layers. The number of vascular bundles is positively correlated with lodging resistance lines because vascular bundles contribute to mechanical strength. To improve lodging resistance a more practical approach is to select shorter and solid stems (Hasnath *et al*., 2013) [8]. However, most of the high yielding varieties are tall in nature. Lodging resistance depends on a stem's resistance against external force, which is expressed as breaking resistance, weight or strength, representing the magnitude of force necessary to break the tissue (Matsuo *et al.*, 1995) [10]. Knowledge about genetic factors controlling stem strength and root anchorage in cereals and their effect on lodging tolerance is scarce, probably because these are complex traits that may be affected by many factors (e.g. stem diameter, stem wall thickness, cell wall composition, root spread, root depth, root diameter, root number), requiring time-consuming phenotyping to be dissected and fully understood (Berry and Berry, 2015) [2] Lodging tolerant varieties in general have higher culm diameter, linear density and physical strength compared to lodging susceptible varieties. The chemical components of rice culm also affect the lodging tolerance nature of rice. Current study in the mutant lines showed that lodging tolerant varieties have higher total potassium and silicon content compared to lodging susceptible varieties (Rao, 2017) [11].

Silicon is the second most abundant element abundantly available on earth's crust. Its content in soils varies greatly ranging from less than 1 to 45% by dry weight (Sommer *et al.* 2006) [16]. Silicon applied as silicon dioxide (SiO_2) in fields is absorbed and appears to accumulate in leaves and promote mechanical strengthening of plant structures. Silicon in rice plants can increase photosynthesis, decrease susceptibility to disease and insect damage, prevent lodging, and alleviate water and various mineral stresses (Epstein, 1999) [7].

Materials and Methods

In pot culture experiment, two non-lodging type oat cultivars, *viz*., Kent, RSO-8, and two lodging type oat cultivars, *viz*., Phule Harita (RO-19), Phule Surabhi (RO-11-1) were grown in the earthen pots up to at 50% flowering stage to assess differences in their fodder quality characteristics.

A field experiment was conducted at AICRP on Forage Crops and Utilization, MPKV, Rahuri during *Rabi* 2019. This zone comes under the semi-arid, sub-tropical and geographically situated between 19°47′ to 19°57′ North latitude and 74°32′ to 74°19′ East longitude and at altitude of 657 meters above mean sea level. Figure 1 represents the weekly weather parameters *i.e*. minimum and maximum temperature (ºC), morning and evening relative humidity (%) and rainfall (mm) during the years 2018-19. The soil of the experimental field was clay loam in texture, with pH (8.3), EC (0.29 dS/m) and organic carbon (0.39%). Twelve promising oat genotypes *viz*., JO-1, JO-2, JO-03-91, JO-03-93, OS-6 and UPO-212 were collected from J. N. K. V. Jabalpur and RO-11-1-2, RO-11-1-3, RO-11-1-4, RO-11-1-5, RO-11-2-2, and RO-11-2-6 from AICRP on Forage Crops & Utilization, MPKV, Rahuri. These oat genotypes were grown in the field with three different treatments i.e. control (without silica application), application of silica @ 200Kgha^{-1} and 400Kg ha^{-1} in the form of silicon dioxide. The silicon was applied as basal dose i.e. at the time of sowing of oat along with the recommended dose of N, P and K fertilizers. At 50% flowering stage of the crop, samples were collected for estimation of quality parameters. The samples collected from the field were dried in hot air oven at 55 ^{0}C temperature till constant weight.The dried samples were ground to fine power and it was used to analyse fodder quality parameters. The crude protein and total minerals were analysed using standard A.O.A.C. (1990) [1] method. The acid detergent fibres (ADF) and neutral detergent fibres (NDF) were evaluated from oven dried samples using method developed by Van Soest (1963) [18]. The *in vitro* dry matter digestibility carried out by standard procedure of Tilley and Terry (1963) [17]. The lignin content was evaluated using method adopted by Hussain *et al.* (2002) [9]. The potassium content was recorded using flame photo meter as described by Chapman and Pratt (1961) [4]. The silica content was determined by method of Dai *et al.* (2005) [3]. The statistical analysis of the present experiment was carried using the Randomized Block Design (RBD) using three replications (Panse and Sukhatme, 1995) [13].

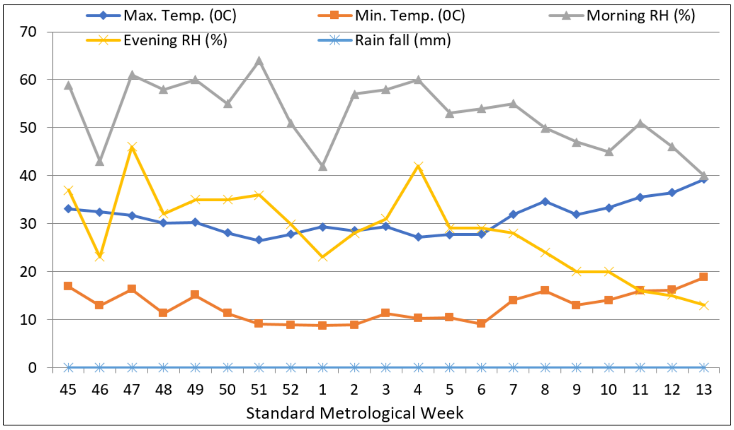

Fig 1: Metrological data: Rabi- 2018-19 (MW 45 to 13).

Results and Discussion

Screening lodging and non-lodging oat cultivars for quality parameters

The results of the experiment conducted in pot culture are presented in Table 1. It was found that crude protein, acid detergent fibres (ADF), neutral detergent fibres (NDF), lignin, total minerals, potassium (K) and silica (Si) content were higher in non-lodging than lodging cultivars. Whereas, *in vitro* dry matter digestibility was higher in lodging than non-lodging cultivars. These quality parameters studied in pot culture experiments are used to screen out promising genotypes of oat along with the application of silicon dioxide.

Table 1: Assessment of lodging and non-lodging oat varieties in pot culture experiment

Sr. No.	Cultivars	Parameters							
		Crude protein (%)	ADF (%)	NDF (%)	Lignin (%)	IVDMD (%)	Total minerals (%)	K (%)	Silica (%)
I.	Lodging type cultivars								
1	Phule Harita	7.26	36.3	61.1	6.30	60.10	7.30	0.50	1.36
2	Phule Surabhi	7.58	36.5	61.3	5.15	60.42	6.75	0.57	1.25
	Mean	7.42	36.40	61.20	5.72	60.26	7.02	0.53	1.33
II.	Non-lodging type cultivars								
3	Kent	8.46	40.3	65.4	7.84	58.21	8.55	0.85	2.14
4	RSO-8	7.73	38.9	63.6	7.41	57.50	8.20	1.12	1.98
	Mean	8.09	39.6	64.5	7.63	57.85	8.37	0.98	2.06

Effect of application of silicon dioxide on forage quality parameters under field condition

The effect of silicon dioxide application in soil @ 200 and 400 kg ha^{-1}on forage quality parameters under field condition depicted in Table 1 and 2.

Application of silicon @ 200 and 400 kg ha^{-1} increased crude protein content in all genotypes. The crude protein content in control was the highest of 8.45 percent in JO-03-91 genotype, followed by RO-11-1-4 (8.08%). The mean crude protein content on silicon application in genotypes RO-11-1-4 was highest of 8.64 percent, which was followed by JO-03-91 (8.60%). The highest crude protein content of 8.66 percent was observed in genotype RO-11-1-4 at 400 kg ha^{-1} silicon treatment. The other oat genotypes, UPO-212 and OS-6 were also recorded higher crude protein content after silicon application. Damame *et al.* (2020) [6] reported similar results in a oat cultivar Phule Harita that, percent crude protein was increased significantly and lodging percent declined after the application of silica @ 400 Kg ha^{-1}. Patil *et al.*, (2018) [14] reported application of silicon along with general recommended dose of fertilizers to rice plants resulted in the significant increase in nitrogen in straw. Patil *et al.* (2018a) [15] reported silicon application by different sources increased dry matter and uptake of nitrogen in rice straw.

The acid detergent fibre in control was the highest of 42.3 percent in JO-03-91 genotype, followed by RO-11-1-4 (41.7%). The genotypes JO-03-91 recorded the significantly highest mean ADF of 48.9 percent, which was followed by genotypes, RO-11-1-4 (47.5%) and JO-2 (48.2%) after the application of silicon. The highest ADF of 51.3 percent was observed in genotype JO-03-91 at 400 kg ha^{-1} silicon treatment. The lowest ADF was recorded in oat genotypes, RO-11-1-5 with 42.6 percent after silicon application. The neutral detergent fibre in control was the highest of 62.2 percent in JO-03-91 genotype, followed by RO-11-1-4 (61.3%). The genotypes JO-03-91 recorded the significantly highest mean NDF of 70.1 percent, which was followed by genotypes RO-11-1-4 (68.8%) and OS-6 (67.0%) after the application of silicon. The highest NDF of 71.5 percent was observed in genotype JO-03-91 and the lowest NDF was recorded in oat genotypes, RO-11-1-5 with 63.2 percent after application silicon @ 400 kg ha^{-1}. Similar results are reported by Damame *et al.* (2020) [6] in the oat cultivar Phule Harita that percent ADF and NDF were increased significantly and lodging percent declined after the application of silica @ 400 Kg ha^{-1}.

The lignin content significantly differed due to silicon application, genotypes and interaction. The lignin content at control was significantly highest of 7.13 percent in JO-03-91 genotype, followed by RO-11-1-4 (7.05%) and JO-2 (6.84%). The genotype JO-03-91 recorded significantly highest mean lignin content 8.08 percent, which was followed by RO-11-1-4, UPO-212, RO-11-2 and JO-2 at silicon treatments (200 and 400 kg ha^{-1}) than mean of two lodging cultivars. The significantly highest lignin content of 8.33 percent was recorded by genotype JO-03-91 at 400 kg ha^{-1} silicon treatment. Similar results are reported by Damame *et al.* (2020) [6] in the oat cultivar Phule Harita that percent lignin was increased significantly and lodging percent declined after the application of silica @ 400 Kg ha^{-1}.

The IVDMD was significantly lowest at control of 55.7 percent in genotype, JO-03-91, followed by RO-11-1-4 (56.4%). The IVDMD was it declined with application of silicon. The mean values after application of silicon was declined in significantly in genotype JO-03-91to 50.4 percent, which was followed by RO-11-1-4 (51.5%). The lowest IVDMD of 48.6 percent was recorded in 400 kg ha^{-1}silicon treatment in genotype JO-03-91 while, the highest IVDMD was recorded in genotype RO-11-1-5 in control (60.3%) and also in silica treatments. Similar results are reported by Damame *et al.* (2020) [6] in the oat cultivar Phule Harita that percent IVDMD decreased significantly after the application of silica @ 400 Kg ha^{-1}.

It was observed that the total minerals content significantly differed due to silicon application, genotypes and interaction. The total minerals content at control was significantly highest of 9.31 percent in JO-03-91 genotype, followed by RO-11-1-4 with 9.15 percent. The genotype JO-03-91 recorded significantly highest mean total minerals content 11.56 percent, which was followed by RO-11-1-4 with 11.24 percent at silicon treatments 200 and 400 kg ha^{-1}. The significantly highest total minerals content of 12.17 percent was recorded in genotype JO-03-91 at 400 kg ha^{-1} silicon treatment. All genotypes showed increase in content of total minerals after application of silicon. Total minerals in control and silicon treatments were higher than non-lodging cultivars. Coblentz *et al.* (2017) [5] recorded 10.7 and 12.7 percent total minerals in oat forage harvested in early November during 2013 and 2014, respectively.

The potassium content was found to be increased after application silicon in all genotypes. The potassium content at control was the higher of 1.61 percent in JO-03-91 genotype, followed by RO-11-1-4 with 1.59 percent. The genotypes JO-03-91 recorded the significantly highest mean potassium content of 2.25 percent, which was followed by RO-11-1-4 with 2.09 percent in silicon treatments (200 and 400 kg ha^{-1}). The highest potassium content of 2.38 percent was observed in genotype JO-03-91 at 400 kg ha^{-1} silicon treatment. All genotypes showed higher potassium in control and silicon treatments than non-lodging cultivars.

It was observed that the silica content significantly differed due to silicon application, genotypes and interaction. The silica content at control was significantly highest of 3.32 percent in JO-03-91 genotype, followed by RO-11-1-4 with 3.11 percent. The genotype, JO-03-91 recorded significantly highest mean silica content 4.90 percent, which was followed by RO-11-1-4 with 4.79 percent at silicon treatments (200 and 400 kg ha^{-1}). However, the interaction effect showed the significantly highest silica content of 5.67 percent in genotype JO-03-91 at 400 kg ha^{-1} silicon treatment. The genotypes**,** JO-03-91, RO-11-1-2, RO-11-1-3 and RO-11-1-4 recorded significantly higher silica content after silicon application. Damame *et al.* (2020) [6] reported similar results in the oat cultivar Phule Harita that percent silica content was increased significantly and lodging percent declined after the application of silica @ 400 Kg ha^{-1}. Patil *et al.*, (2018) [14] reported application of silicon along with general recommended dose of fertilizers to rice plants resulted in the significant increase in uptake of silica and potassium in straw. Patil *et al.* (2018a) [15] reported silicon application by different sources increased uptake of nitrogen, phosphorus, potassium and silica in rice straw.

Table 2: Effect of soil application of silicon dioxide on crude protein, ADF, NDF and lignin content in oat

Sr. No.	Genotypes	Crude protein (%)				Acid detergent fibre (%)				Neutral detergent fibre (%)				Lignin (%)			
		Control	**200 Kgha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treat-ments**	**Control**	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treat-ments**	**Control**	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treat-ments**	**Control**	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treat-ments**
1	JO-1	7.21	7.43	7.55	7.49	37.4	43.4	44.9	44.1	54.2	58.4	63.6	61.0	5.78	6.98	7.27	7.13
2	JO-2	7.24	7.44	7.86	7.65	38.9	44.3	48.2	46.3	59.2	65.5	66.2	65.9	6.84	7.15	8.23	7.69
3	JO-03-91	8.45	8.56	8.64	8.60	42.3	46.6	51.3	48.9	62.2	68.76	71.5	70.1	7.13	7.83	8.33	8.08
4	JO-03-93	7.22	7.66	7.86	7.76	38.2	42.7	45.2	44.0	56.3	60.2	63.8	62.0	6.13	7.03	7.88	7.45
5	OS-6	8.13	8.08	8.53	8.31	38.8	44.4	47.2	45.8	60.1	65.6	68.3	67.0	6.58	7.56	7.64	7.60
6	UPO-212	8.32	8.41	8.53	8.47	36.6	42.8	45.1	44.0	59.9	62.6	63.9	63.2	6.27	7.73	7.86	7.79
7	RO-11-1-2	7.43	7.88	8.08	7.98	38.5	42.6	48.3	45.4	60.3	64.1	65.4	64.8	6.47	7.22	7.66	7.44
8	RO-11-1-3	7.22	7.85	8.04	7.94	36.8	41.8	44.7	43.2	53.6	58.2	64.1	61.2	6.37	7.23	7.75	7.49
9	RO-11-1-4	8.08	8.62	8.66	8.64	41.7	45.5	49.4	47.5	61.3	67.4	70.2	68.8	7.05	7.78	8.18	7.98
10	RO-11-1-5	7.01	7.14	7.32	7.23	36.3	40.9	44.2	42.6	53.2	57.3	63.2	60.2	5.65	6.87	7.11	6.99
11	RO-11-1-2	7.18	7.21	7.65	7.43	40.2	41.9	48.7	45.3	56.8	59.4	65.3	62.4	6.07	7.07	8.50	7.79
12	RO-11-2-6	7.29	7.43	7.62	7.53	37.8	42.9	45.3	44.1	57.3	59.3	65.3	62.3	5.93	6.98	7.39	7.19
	Mean	7.57	7.81	8.03	7.92	38.6	43.3	46.9	45.1	57.9	62.2	65.9	64.1	6.36	7.29	7.82	7.55
	Range	7.01-8.45	7.14-8.62	7.32-8.66		36.3-42.3	40.9-46.6	44.2-51.3		53.2-62.2	57.3-68.8	63.2-71.5		5.65-7.13	6.87-7.83	7.11-8.33	
	Source	Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.	
	S.E. +	0.003	0.006	0.011		0.01	0.02	0.04		0.011	0.023	0.04		0.01	0.03	0.06	
	CD at 5%	0.009	0.019	0.033		0.03	0.07	0.12		0.032	0.065	0.112		0.05	0.10	0.17	
	Mean of two lodging cultivars				7.42				36.4				61.2				5.72
	Mean of two non-lodging cultivars				8.09				39.6				64.5				7.63

Table 3: Effect of soil application of silicon dioxide on IVDMD, total minerals, potassium and silica content in oat.

Sr. No.	**Genotypes**	**IVDMD (%)**				**Total minerals (%)**				**Potassium (%)**				**Silica (%)**			
		Control	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treatments**	**Control**	**200 Kg ha-^{1}**	**1**	**Mean of Si treatments**	**Control**	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treatments**	**Control**	**200 Kg ha-^{1}**	**400 Kg ha-^{1}**	**Mean of Si treatments**
1	JO-1	59.4	54.7	53.6	54.2	8.39	8.91	9.35	9.13	1.37	1.54	1.58	1.56	2.21	3.07	3.34	3.20
2	JO-2	58.2	53.9	51.0	52.4	8.81	9.94	10.25	10.10	1.58	1.82	2.12	1.97	2.38	3.12	3.49	3.31
3	JO-03-91	55.7	52.2	48.6	50.4	9.31	10.95	12.17	11.56	1.61	2.12	2.38	2.25	3.32	4.12	5.67	4.90
4	JO-03-93	58.8	55.3	53.2	54.3	8.95	9.11	10.25	9.68	1.58	1.76	1.92	1.84	2.34	3.88	3.83	3.86
5	OS-6	58.3	54.0	51.8	52.9	8.49	10.43	11.21	10.82	1.52	1.66	1.74	1.70	2.16	3.06	4.58	3.82
6	UPO-212	60.1	55.1	53.3	54.2	9.02	10.46	11.24	10.85	1.56	1.93	2.13	2.03	2.44	2.97	4.35	3.66
7	RO-11-1-2	58.6	55.4	51.0	53.2	8.54	9.45	11.51	10.48	1.38	1.46	1.59	1.53	2.53	3.46	4.95	4.20
8	RO-11-1-3	59.9	56.0	53.8	54.9	8.59	10.25	11.06	10.66	1.43	1.52	1.84	1.68	2.34	3.92	4.44	4.18
9	RO-11-1-4	56.4	53.0	49.9	51.5	9.15	10.53	11.95	11.24	1.59	1.92	2.25	2.09	3.11	4.01	5.56	4.79
10	RO-11-1-5	60.3	56.7	54.0	55.4	8.20	8.75	9.11	8.93	1.35	1.44	1.50	1.47	2.10	2.60	3.20	2.90
11	RO-11-1-2	57.2	55.9	50.6	53.3	8.50	9.95	10.40	10.17	1.51	1.62	1.64	1.63	2.26	3.53	3.87	3.70
12	RO-11-2-6	59.2	55.2	53.3	54.2	8.45	9.60	9.62	9.61	1.56	1.81	1.86	1.84	1.67	3.41	3.55	3.48
	Mean	58.5	54.8	52.0	53.4	8.70	9.86	10.68	9.51	1.50	1.72	1.88	1.80	2.41	3.85	4.32	4.08
	Range	55.7-60.3	52.2-56.7	48.5-54.0		8.20-9.31	8.75-10.95	9.11-12.17		1.35-1.61	1.44-2.12	1.50-2.38		2.10-3.32	2.60-4.12	3.20-5.67	
	Source	Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.	
	S.E. +	0.01	0.03	0.06		0.02	0.04	0.07		0.01	0.03	0.05		0.11	0.23	0.4	
	CD at 5%	0.05	0.1	0.17		0.05	0.11	0.2		0.04	0.09	0.15		0.32	0.65	1.13	
	Mean of two lodging cultivars				60.26				7.02				0.53				1.33
	Mean of two non-lodging cultivars				57.85				8.37				0.98				2.06

Conclusion

The pot culture experiment revealed higher levels of crude protein, acid detergent fibres, neutral detergent fibres, lignin, total minerals, potassium and silica content and lower level of IVDMD in non-lodging type than lodging type cultivars, Twelve genotypes studied for the these parameters after soil application of silica @ 200 Kg ha^{-1} and 400 Kg ha^{-1} showed higher content of crude protein, ADF, NDF, lignin, total minerals, K and Si in oat genotype JO-03-91 and the lower in RO-11-1-5 as against IVDMD was the lowest in JO-03-91 and the highest in RO-11-1-5. The genotypes, JO-03-91, RO-11-1-4 and JO-2 were found better for lodging tolerance parameters after the application of silicon dioxide. Among the various parameters studied, lignin and potassium could be used as biochemical markers to screen of oat germplasm for non-lodging character.

References

1. AOAC. Official methods of analysis. Animal Feeds. 15th edition Association of Official analytical Chemists. Washington, DC, USA; c1990. p. 1-24.
2. Berry PM, Berry ST. Understanding the genetic control of lodging-associated plant characters in winter wheat (*Triticum aestivum* L.). Euphytia. 2015;205:671-689.
3. Dai W, Zhang K, Duan B, Sun C, Zheng K, Cai R, et al. Determination of silicon content in rice. Rice Science 2005;12(2):145-147.
4. Chapman HD, Pratt PF. Methods of Analysis for soils, plants and water. Division of Agriculture Science, University of California, Berkly; c1961. p. 169-176.
5. Coblentz WK, Akins MS, Cavadini JS, Jokela WE. Net effects of nitrogen fertilization on the nutritive value and digestibility of oat forages. Journal of Dairy Science. 2017;100(3):1739-1750.
6. Damame SV, Pardeshi HP, Tambe AB. Effect of silica application and cutting management on fodder quality of oat (A*vena sativa* L.) cv. Phule Harita. Forage Research. 2020;46(2):187-190.
7. Epstein E. The anomaly of silicon in plant biology. Proceedings of National Academy of Science, USA. 1999;91:11-17.
8. Hasnath Karim MD, Jahan MA. Study of lodging resistance and its associated traits in bread wheat. ARPN Journal of Agricultural and Biological Science. 2013;8(10):683-687.
9. Hussain MA, Huq ME, Rahman SM, Ahmed Z. Estimation of lignin in jute by titration method. Pakistan Journal of Biological Science. 2002;5(5):521-522.
10. Matsuo T, Kumazawa K, Ishii R, Ishihara K, Hirata H. Science of the Rice Plant Physiology, Food and Agriculture Policy Research Center, Tokyo, Japan. 1995;2:971-982.
11. Rao NA, Shreekant B, Madhav SM, Reddy SN. Physio-chemical characterization of lodging tolerance in rice (*Oryza sativa* L.). Microbiological Application Science. 2017;6(9):1770-1778.
12. Panda SC. Hand book of Agriculture, Forage Crops and Grasses. ICAR, New Delhi. 2007, 1353-1417.
13. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. ICAR, New Delhi. 1995.
14. Patil AA, Durgude AG, Pharande AL. Influence of rice husk ash and bagasse ash as a source of silicon on growth yield and nutrient uptake of rice. International Journal of Chemistry Students. 2018;6:260-266.
15. Patil VN, Pawar RB, Patil AA, Pharande AL. Influence of rice husk ash and bagasse as source of silicon on growth yield and nutrient uptake of rice. International Journal of Chemistry Students. 2018a;6:317-320.
16. Sommer MD, Fuzyakov, Breuer J. Silicon pools and fluxes in soils and landscapes, a Review. Journal of Plant Nutrition & Soil Science. 2006;169:310-329.
17. Tilley JM, Terry RA. A two stages technique for *in vitro* digestion of forage crops. The Journal of the British Grassland Society. 1963;18:104-11.
18. Van Soest PJ. Use of detergents in analysis of fibrous feeds. A rapid method for determination of fibre and lignin. Journal of the Association of Official Agricultural Chemist. 1963;45(5):829-835.