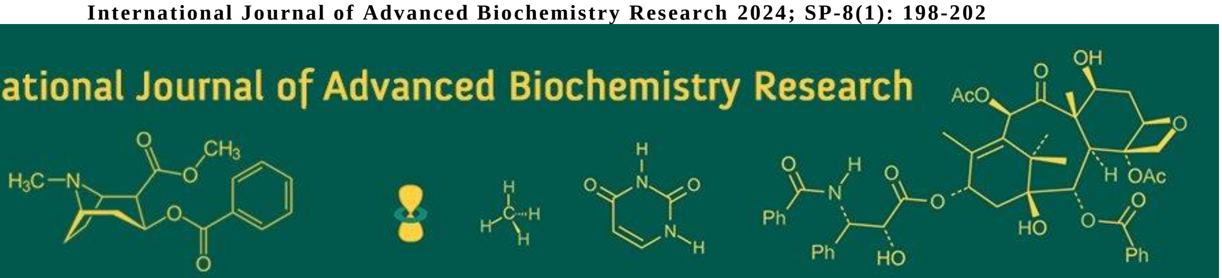
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(1): 198-202
www.biochemjournal.com
Received: 14-11-2023
Accepted: 23-12-2023

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Effect of silica application on biochemical parameters in relation to lodging tolerence in oat (*Avena sativa* L.)

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DOI: https://doi.org/10.33545/26174693.2024.v8.i1Sd.307

Abstract

The present investigation was carried out to understand effect of soil application of silica on biochemical parameters in relation to lodging tolerance in oat. Initially, two each lodging and non-lodging type oat cultivars were compared based on biochemical parameters in the pot culture experiment. The guaiacol peroxidase activity, polyphenols, lignin, potassium and silica were found higher in non-lodging than lodging type cultivars, whereas malondialdehyde content was found higher in lodging type cultivars. The effect of silica application @ 200 kg ha^{-1} and @ 400 kg ha^{-1} on biochemical parameters was recorded in 12 different oat genotypes under the field condition. With the increase in silica application from 200 to 400 kg ha^{-1}, the activity of guaiacol peroxidase enzyme, total polyphenols, lignin, potassium and silica contents were increased, while malondialdehyde content was decreased over the control in all oat genotypes. Among the twelve oat genotypes, JO-03-91, RO-11-1-4, UPO-212 and JO-2 were found promising genotypes for lodging tolerance.

Keywords: Peroxidase, polyphenols, lodging tolerance, lignin, silica

Introduction

Oat (*Avena sativa* L.) is most important cultivated fodder crops in the world. It is grown in India for grain and fodder purposes. It gives balanced feed for domestic animals. Oat fodder contains about 10-12% protein and 30-35% dry matter. Oat crop has higher green forage yield potential. The crop is grown mainly on medium to heavy soils under irrigated conditions to obtain maximum yield. Generally, the high yielding varieties are tall, which are lodged due to a heavy load of upper part of biomass causes loss in green and dry forage yield. The solid pith area or number of vascular bundles is positively correlated with lodging resistance because vascular bundles contribute to mechanical strength. To improve lodging resistance more practical approach is to select shorter and solid stems (Hasnath *et al.*, 2013) [16]. 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, requiring time-consuming phenotyping to be dissected and fully understood (Berry and Berry, 2015) [4]. Silicon is associated with sturdiness and rigidity. Silica applied in fields is absorbed and appears to accumulate in leaves, root and stem promote mechanical strength to plant structures. Silica in rice plants can increase photosynthesis, decrease susceptibility to disease and insect damage, prevent lodging, and alleviate water and various mineral stresses (Epstein, 1999) [12]. 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) [29]. Thus, present study was aimed to find out changes in biochemical parameters associated with application of silica to oat plant in relation to lodging tolerance.

Materials and Methods

In pot culture experiment, two non-lodging type oat cultivars, Kent, RSO-8, and two lodging type oat cultivars, Phule Harita, Phule Surabhi were grown in the earthen pots up to 50% flowering stage to assess differences in their biochemical parameters such as GPX, polyphenols, lignin, potassium, silica and, malondialdehyde in relation to lodging tolerance. The field experiment was conducted at AICRP on Forage Crops and Utilization, MPKV, Rahuri, 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 were taken 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 @ 200 Kg ha^{-1} and 400 Kg 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, the plant samples were collected for estimation of biochemical parameters. The fresh samples were used to analyze guaiacol peroxidase activity and malondialdehyde. The plant samples were dried in hot air oven at 55^{0}C temperature. The dried samples were ground to fine power and it was used to analyze polyphenols, lignin, potassium and silica content. For guaiacol peroxidase activity (GPX), the rate of decomposition of hydrogen peroxide by peroxidase, with guaiacol as a hydrogen donor was measured by the increase in absorbance at 470 nm per min as per the method described by Castillo *et al.* (1984). The level of lipid peroxidation rate was measured in terms of malondialdehyde as thiobarbituric acid reactive substance (Heath and Packer, 1968) [17]. Estimation of total polyphenols was carried out with Folin-Ciocalteu reagent by method of Bray and Thorpe (1954) [5]. The lignin content was evaluated using method adopted by Hussain *et al.* (2002) [18]. The potassium content was recorded using Flame photo meter as described by Chapman and Pratt (1961) [7]. The silica content was determined by method of Dai *et al.* (2005) [8]. The statistical analysis of the present experiment was carried using the Randomized Block Design (RBD) using three replications (Panse and Sukhatme, 1995) [24]. Meteorological observations graphically depicted in Fig. 1 showing climatic condition during the period of present investigation. During Rabi-2019 the maximum temperature was ranged between 26.5 to 39.39 °C, minimum temperature was ranged between 8 to 18.8 °C, morning relative humidity was 40 to 64%, evening relative humidity was 13 to 46 and total rainfall was nil.

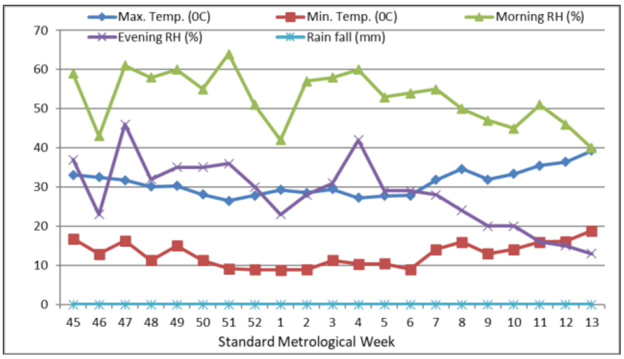

Fig 1: Metrological data: Rabi- 2018-19 (MW 45 to 13)

Results and Discussion

Screening of lodging and non-lodging oat cultivars for biochemical parameters in relation to lodging tolerance in oat

Two lodging and two non-lodging type oat cultivars were screened in pot culture experiment for various biochemical parameters in relation to lodging tolerance in oat. The results of the experiment presented in Table 1. It was found that guaiacol peroxidase activity, total polyphenols, lignin, potassium (K) and silica (Si) content were higher in non-lodging than lodging cultivars, whereas malondialdehyde content was higher in lodging than non-lodging type 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					
		GPX (µ moles of tetra guaiacol formed min^{-1} mg^{-1} protein)	MDA (η moles g^{-1}fr. wt)	Total polyphenols (mg g^{-1} dry wt.)	Lignin (%)	K (%)	Silica (%)
I.	**Lodging type cultivars**						
1	Phule Harita	0.86	36.97	8.06	6.30	0.50	1.36
2	Phule Surabhi	0.73	34.66	6.14	5.15	0.57	1.25
	Mean	0.79	35.81	7.10	5.72	0.53	1.33
II.	**Non-lodging type cultivars**						
3	Kent	1.26	26.78	11.10	7.84	0.85	2.14
4	RSO-8	1.08	29.58	10.75	7.41	1.12	1.98
	Mean	1.17	28.18	10.92	7.63	0.98	2.06

Effect of silica application on biochemical parameters in relation to lodging tolerance in oat under field condition

The effect of silica (silicon dioxide) application in soil @ 200 and @ 400 kg ha^{-1} on biochemical parameters in relation to lodging tolerance in oat under field condition is depicted in Table 2 and 3.

Guaiacol peroxidase activity

Under field condition, in control treatment the highest GPX activity was recorded in genotypes JO-03-91, followed by RO-11-1-4 and JO-2. The GPX activity was increased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over control. The highest mean GPX activity on silica treatments was recorded by oat genotypes, JO-03-91, followed by RO-11-1-4 and JO-2. The guaiacol peroxidase activity is responsible for lignification's process which directly related to lodging character. The physiological function of enzyme peroxidase is plant growth, development, lignification, suberization and cross-linking of cell wall compounds (Passardi *et al.*, 2005) [25]. Begovic *et al.* (2017) [3] showed that in more mature internodes, the first and the second one, had significantly higher peroxidase activity and lignin content. Li *et al.* (2003) [20] reported enzyme peroxidase catalyzes the final step in the biosynthesis of lignin. Ahmad and Haddad (2011) [1] stated that in wheat, application of Si increased peroxidase activity from 0.332 to 0.573 µM H_2O_2 formed min^{-1} mg^{-1} protein. Gong *et al.* (2003) [14] reported silicon increases the activity of peroxidase in the wheat plant by the detoxifying mechanism.

Table 2: Effect of soil application of silicon dioxide on GPX activity, MDA and total polyphenols content in oat

Sr. No.	Genotypes	GPX activity (µ moles of tetra guaiacol formed min^{-1} mg^{-1} protein)				MDA (ɳ moles g^{-1}fr. wt)				Total polyphenols (mg/g dry wt.)			
		Control	200 $Kgha^{-1}$	400 Kg ha^{-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	0.78	0.81	0.96	0.78	70.42	61.83	40.32	51.07	10.02	12.03	12.93	12.48
2	JO-2	1.24	1.36	1.41	1.24	43.14	38.75	28.75	33.75	10.32	13.38	13.67	13.53
3	JO-03-91	1.66	1.72	1.88	1.66	27.71	25.82	21.05	23.44	12.22	14.18	15.31	14.74
4	JO-03-93	0.76	1.05	1.11	0.76	73.26	59.11	41.82	50.46	10.96	11.24	13.27	12.26
5	OS-6	0.75	0.82	0.92	0.75	52.43	47.54	35.70	41.62	9.91	13.48	13.43	13.46
6	UPO-212	0.92	0.98	1.38	0.92	55.63	37.76	39.80	38.78	12.08	13.57	14.78	14.17
7	RO-11-1-2	0.82	0.88	1.07	0.82	60.85	47.74	36.24	41.99	10.34	13.45	13.45	13.45
8	RO-11-1-3	0.73	0.89	1.04	0.73	53.20	52.94	39.24	46.09	9.66	13.68	13.67	13.67
9	RO-11-1-4	1.26	1.38	1.47	1.26	32.31	30.33	24.25	27.29	10.94	13.97	14.92	14.45
10	RO-11-1-5	0.72	0.78	0.92	0.72	85.14	70.85	56.74	63.80	9.11	11.02	12.74	11.88
11	RO-11-1-2	0.88	0.96	0.98	0.88	82.65	51.33	30.81	41.07	9.68	13.77	14.08	13.93
12	RO-11-2-6	0.86	0.94	0.97	0.86	67.31	60.32	39.22	49.77	9.32	12.91	13.23	13.07
	Mean	0.95	1.05	1.18	0.95	58.67	48.69	36.16	42.43	10.38	13.06	13.79	13.42
	Range	0.72-1.66	0.78-1.72	0.92-1.88	0.72-1.66	27.71-5.14	25.82-70.85	21.05-56.74	27.71-85.14	9.11-12.22	11.02-14.18	12.74-15.31	
	Source	Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.		Treat. (T)	Variety (V)	Inter.	
	S.E. +	0.01	0.03	0.06		0.15	0.30	0.52		0.03	0.06	0.11	
	CD at 5%	0.05	0.10	0.18		0.42	0.85	1.48		0.09	0.18	0.31	

Malondialdehyde

The lowest malondialdehyde (MDA) was recorded in genotypes, JO-03-91, followed by RO-11-1-4 and JO-2 in control treatment under field condition. The MDA was decreased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over control. The lowest mean MDA on silica treatments was recorded by oat genotypes, JO-03-91 followed by RO-11-1-4 and JO-2. During lipid peroxidation, products are formed that include small hydrocarbon fragment such as ketones, malondialdehyde. Yusuf *et al.* (2016) [33] reported association of leaf MDA and lignin content. The leaf lignin content tended to be higher in the more resistant RILs, while the opposite was the case for leaf malondialdehyde content. In present study showed decline in MDA with silica application indicating lignifications in oat genotypes. Similar results were reported by Gunes *et al.* (2008) [15] that silicon applied in sunflower cultivars under drought stress, declined MDA content from 8.33 to 7.38 ɳ moles g^{-1} fr.wt. Liang (1999) [21] reported that MDA production in salt treated plants was more depressed by added Si in the salt-sensitive cultivar than in salt-tolerant cultivar. The genotypes, JO-03-91, RO-11-1-4 and JO-2 recorded the lowest MDA content on silica application indicates lower lipid peroxidation rate were promising oat genotypes concerning lodging tolerance.

Total polyphenols

It was observed that under field condition, in control treatment the highest total polyphenols was recorded in genotypes, JO-03-91, followed by RO-11-1-4 and UPO-212. The RO-11-1-5 was recorded the lowest total polyphenols of in control treatment, further mean total polyphenols was also low after Si application in same genotype. The total polyphenols was increased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over the control. The highest mean total polyphenols on silica treatments was recorded by oat genotypes, JO-03-91, followed by RO-11-1-4 and UPO-212 were promising genotypes for lodging tolerance than other genotypes as soluble phenol accumulation is result of over production of peroxidase. The results are reported by Mehata and Jood (2017) [22] carried out experiment on five varieties of oat forage, the total phenol content was 1.80 to 2.62 percent. Rajkumar *et al.* (2015) [27] reported 1.20 percent total phenols in oat fodder. Rangaraj *et al.* (2014) [28] reported that nano silica-treated plant shows a higher expression of phenolic compounds. The results obtained in the present investigation are in agreement with the results reported by earlier workers.

Lignin

It was observed that in control treatment the highest, lignin content was recorded in genotypes, JO-03-91, followed by RO-11-1-4 and JO-2. The lignin content was increased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over control. The highest mean lignin content on silica treatments was recorded by oat genotypes, JO-03-91 (8.08), followed by RO-11-1-4 (7.98), UPO-212 (7.80) and JO-2 (7.69). Similar values were reported by various researchers. Reported that lignin content of 6.63, 5.72 and 5.16 percent in Kent, JHO-99-2 and JHO-2010-1 oat varieties, respectively. Palo *et al.* (2017) [23] reported that 7.1 percent lignin content in oat hay. Kafilzadeh *et al.* (2012) [19] studied eighteen varieties of oats, reported lignin content ranged from 5.19 to 9.24 percent. Dorairaj *et al.* (2020) [11] reported that acid detergent lignin was highest when silicon was applied at the reproductive and maturity stages in rice. Dorairaj and Ismail (2017) [10] reported that, silicon treated rice plants showed an increase in lignin content, and formation of silicified microstructures. Damame *et al.* (2020) [9] reported that in oat cultivar, Phule Harita percent lignin was increased significantly and lodging percent declined after the application of silica @ 400 Kg ha^{-1}. The oat genotypes, JO-03-91, RO-11-1-4, UPO-212 and JO-2 recorded the highest lignin content after silica treatments were promising genotypes for lodging tolerance.

Potassium

It was found that, under field condition, in control treatment the highest potassium (%) was recorded by the genotypes, JO-03-91, followed by RO-11-1-4, and JO-2, JO-03-93 (1.61, 1.59, 1.58 and 1.58%, respectively). The RO-11-1-5 was recorded the lowest potassium in control treatment. The potassium was increased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over control. The highest mean potassium (%) content on silica treatments was recorded by oat genotypes, JO-03-91, followed by RO-11-1-4 and UPO-212 which are promising genotypes for lodging tolerance as K is tangled in the cellulose and lignin contents of the cell wall providing stem strength. Similar findings were reported by Singh *et al.* (2018) [30] that average of potassium content of thirteen varieties of oat was 1.11 percent, it was differed between 1.26 to 0.97 percent. Gill and Omokanye (2018) [13] evaluated potassium content in oat varieties during 2009, 2010 and 2011, it was 1.65, 1.49 and 1.86 percent, respectively. Alsaeedi *et al.* (2019) [2] reported that higher content of potassium was found in all parts of plant applied with silica nano particles. These increases could be due to alerting nutrient uptake as SiNPs clearly increased contents of nitrogen (by 30%), potassium (by 52, 75 and 41% in root, stem and leaf, respectively).

Silica

Under field condition, in control treatment the highest silica (%) content were recorded in genotypes, JO-03-91, followed by RO-11-1-4, and RO-11-1-2 (3.32, 3.11 and 2.53%, respectively). The silica (%) content was increased with the application of silica @ 200 and 400 kg ha^{-1} treatments in all oat genotypes over control. The highest mean silica (%) content on silica treatments was recorded by oat genotypes, JO-03-91 (4.90) followed by RO-11-1-4 (4.79) and UPO-212 (4.20). Similar findings were reported by Singh *et al.* (2018) [30] reported that average of silica content of thirteen varieties of oat was 3.07 percent. The silica content greatly differed between the highest value of 3.68 percent in JHO 2004 and the lower of 2.54 percent in JHO 822 varieties of oat forage. Thiago and Roy (1982) reported that silica content in stem, leaf sheath and head oat straw was 0.2, 1.8 and 1.4 percent, respectively. Damame *et al.* (2020) [9] 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) [26] 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. Toledo *et al.* (2012) [32] reported that silicon leaf application increases root and total length of white oat seedlings as an effect of higher Si level in leaves. Dorairaj *et al.* (2020) [11] reported that rice plants treated with Si at the reproductive stage showed the highest Si content which was significantly different from those treated at maturity and vegetative. Dorairaj and Ismail (2017) [10] reported that silicon treated rice plants showed an increase in silicon content, and formation of silicified microstructures. The genotypes, JO-03-91, RO-11-1-4 and UPO-212 recorded the highest Si content on silica treatments were promising genotypes for lodging tolerance as Si is responsible for conferring strength, rigidity and also manages many abiotic stresses including physical stresses like lodging.

Conclusion

In conclusion, the results of pot culture experiment revealed higher levels of guaiacol peroxidase activity, polyphenols, lignin, potassium and silica, whereas lower level of malondialdehyde in non-lodging type cultivar than lodging type. Twelve genotypes studied for these parameters after soil application of silica @ 200 Kg ha^{-1} and 400 Kg ha^{-1} showed similar trend in oat genotypes, JO-03-91, RO-11-1-4, UPO-212 and JO-2. Thus, these oat genotypes are promising for lodging tolerance. Among the various parameters studied, GPX, MDA and lignin could be used as biochemical markers to screen oat germplasm for non-lodging character.

References

1. Ahmad ST, Haddad R. Study of silicon effects on antioxidant enzyme activities and osmotic adjustment of wheat under drought stress. J Genet Plant Breed. 2011;47(1):17–27.
2. Alsaeedi A, El-Ramady H, Alshaalb T, El-Garawanyc M, Elhawat N, Al-Otaibie A. Silica nanoparticles boost growth and productivity of cucumber under water deficit and salinity stresses by balancing nutrients uptake. J Plant Physiol Biochem. 2019;139:1-10.
3. Begovic L, Lepidus H, Lalic A, Stolfal I, Jurkovic Z, Kovacevic J, Cesar V. Involvement of peroxidases in structural changes of barley stem. J Bragantia, Campinas. 2017;76(3):352-359.
4. Berry PM, Berry ST. Understanding the genetic control of lodging-associated plant characters in winter wheat (*Triticum aestivum* L.). Euphytia. 2015;205:671-689.
5. Bray G, Thorpe WV. Analysis of phenolic compounds of interest in metabolism. Method Biochem Anal. 1954;1:27-52.
6. Castillo FI, Pen I, Greppin H. Peroxidase release induced by ozone in *Sedum album* leaves. J Plant Physiol. 1948;74:846-851.
7. Chapman HD, Pratt PF. Methods of analysis for soils, plants and water. Division of Agriculture Science, University of California, Berkeley. 1961;169-176.
8. Dai W, Zhang K, Duan B, Sun C, Zheng K, Cai R, Zhuang J. Determination of silicon content in rice. Rice Sci. 2005;12(2):145-147.
9. Damame SV, Pardeshi HP, Tambe AB. Effect of silica application and cutting management on fodder quality of oat (*Avena sativa* L.) cv. Phule Harita. Forage Res. 2020;46(2):187-190.
10. Dorairaj D, Ismail MR. Distribution of silicified microstructures, regulation of cinnamyl alcohol dehydrogenase and lodging resistance in silicon and paclobutrazol-mediated *Oryza sativa*. J Front Physiol. 2017;8(491):01-19.
11. Dorairaj D, Ismail MR, Sinniah UM, Tan BK. Silicon-mediated improvement in agronomic traits, physiological parameters, and fiber content in *Oryza sativa* L. J Acta Physiologiae Plantarum. 2020;42(38):1-11.
12. Epstein E. The anomaly of silicon in plant biology. Proc Natl Acad Sci USA. 1999;91:11-17.
13. Gill K, Omokanye A. Potential of spring barley, oat, and triticale intercrops with field peas for forage production, nutrition quality, and beef cattle diet. J Agric Sci. 10(4):01-17.

14. Gong H, Chen K, Chen G, Wang S, Zhang C. Effects of silicon on growth of wheat under drought. J Plant Nutr. 2003;26:1055–1063.
15. Gunes A, Pilbeam DJ, Inal A, Coban S. Influence of silicon on sunflower cultivars under drought stress, I: growth, antioxidant mechanisms, and lipid peroxidation. Commun Soil Sci Plant Anal. 2008;39:1885–1903.
16. Hasnath Karim MD, Jahan MA. Study of lodging resistance and its associated traits in bread wheat. ARPN J Agril Biol Sci. 2013;8(10):683-687.
17. Heath R, Packer L. Photoperoxidation in isolated chloroplasts: kinetics and stoichiometry of fatty acid peroxidation. J Arch Biochem Biophys. 1968;125:189-198.
18. Hussain MA, Huq ME, Rahman SM, Ahmed Z. Estimation of lignin in jute by titration method. Pak J Biol Sci. 2002;5(5):521-522.
19. Kafilzadeh F, Heidary N. Chemical composition, in *vitro* digestibility and kinetics of fermentation of whole-crop forage from 18 different varieties of oat (*Avena sativa* L.). J Appl. Anim. Res. 2013;41(1):61-68.
20. Li Y, Kajita S, Kawai S, Katayama Y, Morohoshi N. Down-regulation of an anionic peroxidase in transgenic aspen and its effect on lignin characteristics. J Plant Res. 2003;116:175-182.
21. Liang Y. Effects of silicon on enzyme activity and sodium, potassium, and calcium concentration in barley under salt stress. J Plant Soil. 1999;209:217–224.
22. Mehata B, Jood S. Antioxidant activity and nutritional properties of different oat (*Avena sativa* L.). J Int. Agric. Sci. 2017;9(28):4366-4367.
23. Palo P, Tateo A, Maggiolino A, Marino R, Ceci E, Nisi A, Lorenzo J. Martina Franca donkey meat quality: Influence of slaughter age and suckling technique. J Meat Sci. 2017;134:128–134.
24. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. ICAR, New Delhi; c1995.
25. Passardi F, Cosico C, Penel C, Dunand C. Peroxidases have more functions than a Swiss army knife. J Plant Cell Rep. 2005;24:255-65.
26. Patil VN, Pawar RB, Patil AA, Pharande AL. Influence of rice husk ash and bagasse as sources of silicon on growth yield and nutrient uptake of rice. Int. J Chem Stud. 2018;6(1):317-320.
27. Rajkumar K, Bhar R, Kannan A, Jadhav R, Singh B, Mal G. Effect of replacing oat fodder with fresh and chopped oak leaves on *in vitro* rumen fermentation, digestibility and metabolizable energy. Veter World. 2015;8(8):1021-1026.
28. Rangaraj S, Gopalu K, Kandiah K, Rathinam Y, Venkatachalam R, Narayanasamy K. Application of silica nanoparticles in maize to enhance fungal resistance. 2014;8(3):133-137.
29. Rao NA, Shreekant B, Madhav SM, Reddy SN. Physio-chemical characterization of lodging tolerance in rice (*Oryza sativa* L.). Intl J Curr Microbiol App Sci. 2017;6(9):1770-1778.
30. Singh D, Chauhan A, Chaudhary A. Relative performance of oat forage varieties for seed production, economics, and fodder yield under central Gujarat conditions. J Forage Res. 2018;44(3):185-191.
31. Thiago LR, Roy C. Kellaway. Botanical composition and extent of lignification affecting digestibility of wheat and oat straw and paspalum hay. J Anim Feed Sci Tech. 1982;7:71-81.
32. Toledo MZ, Castro GS, Crusciol CA, Soratto RP, Claudio Cavariani C, Ishizuka MA, *et al*. Silicon leaf application and physiological quality of white oat and wheat seeds. J Semina: Ciencias Agrarias, Londrina. 2012;33(5):1693-1702.
33. Yusuf CS, Chand R, Mishra VK, Joshi AK. The association between leaf malondialdehyde and lignin content and resistance to spot blotch in wheat. J Phyto Patho. 2016;164:11-12.