UNDER PEER REVIEW

~~STUDIESON~~ GENETICVARIABILITY,CORRELATIONAND PATH ANALYSIS IN FORAGE SORGHUM

ABSTRACT

Comment [T1]: The author/s didn't mentioned nothing about specific genotypes. Which genotype is better than which in which parameter?

Ten genotypes *i.e.*, CSV-15, Pusa Chari-6, HC-308, Pant Chari-4, G-48, HJ-513, UP Chari-4, HC-171, SSG-59-3 and ICSV-700 studied for genetic variability, correlation and path analysisfor days to 50 % flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids, protein content, fiber content, HCN content and green fodder yield. The analysis of variance for the experiment with fifty five treatments for all the thirteen attributes *viz.*, days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids, protein content, fiber content, HCN content and green fodder yield revealed significant differences among the material used in the present investigation, which indicated that wide spectrum of variation among the genotypes. Genotypicandphenotypiccoefficientofvariation washigh(morethan25%)observedforleafstem ratio and green fodder yield, which indicating that more variability and scope for selection in improving these characters. High heritability accompanied with high genetic advance as percent of mean noted for leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids and green fodder yield. This indicated that these traits were highly heritable and selection of high performing genotypes is possible to improve these attributes. Green fodder yield exhibited significant stableand positivecorrelation with days to 50%flowering,plant height, leaf length, leaf breadth, stem girth, leaves per plant and leaf area at genotypic and phenotypic level. These characters may be considered as important yield component in forage sorghum. Leaf breadth displayed high order of direct effect on green fodder yield per plant followed by leaves per plant, leaf length and stem girth at phenotypic and genotypic level, which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programmefor developing for high yielding varieties.

Keywords:*sorghumbicolor*,variability,correlation,pathcoefficientanalysis

INTRODUCTION

Sorghum, scientifically known as *Sorghum bicolor*, is a versatile and resilient cereal grain that has been cultivated formillennia.Originating from Africa, it has spread acrosstheglobedueto its adaptability to diverse climates and its numerous uses ranging from food and feed to industrial applications. It belongs to the grass family, Poaceae, and is classified under the genus *Sorghum*. Sorghum is an annual plant that typically grows between 2 to 5 meters in height, although dwarf varieties exist. The plant has a robust root system, which aids in its ability to withstand drought and grow in regions with limited water availability. Sorghum produces large terminal panicles that contain seeds varying in size and color, depending on the variety. The cultivation of sorghum dates back thousands of years, primarily in Africa where it was domesticated. From there, it spread to Asia and eventually to the Americas during the Columbian Exchange. Sorghum played a crucial role in food security in regions with harsh climates and poor soil conditions, where other crops struggled to thrive. Its ability to grow in semiarid and arid regions made it a staple crop for many communities around the world. There are numerous varieties of sorghum cultivated globally, each adapted to different environmental conditions and intended uses. These varieties can be broadly categorized into grain sorghum, sweet sorghum and forage sorghum. Grain sorghum is primarily grown for its seeds, which are used for human consumption, animal feed and industrial purposes. Sweet sorghum is grown for its sweet juice, which can be processed into syrup or fermented into biofuels. Forage sorghum, on the other hand, is used as fodder for livestock. Sorghum is cultivated in a variety of agroecological zones, from tropical to temperate regions. The crop is adaptable to different soil types but thrives in well drained soils with good organic matter content. Its tolerance to heat and drought makes it suitable for regions where other cereal crops might fail. Sorghum is typically sown directly into the soil, either broadcast or in rows, depending on the farming system and equipment available. The economic importance of sorghum extends beyond its role as a staple food. It is used in various industrial applications such as the production of biofuels, biodegradable plastics and alcoholic beverages. In recent years, sorghum has gained attention as a potential crop for sustainable bioenergy production due to its high biomass yield and efficient use of water. Sorghum is highly nutritious, containing essential nutrients such as carbohydrates, proteins, fiber, vitamins,andminerals.Itisglutenfree,makingitsuitableforindividualswithglutenintoleranceor celiac disease. The grain's nutritional profile varies slightly among different varieties, with some varieties being richer in certain nutrients than others. Its deep root system improves soil structure and water retention, reducing erosion and enhancing soil fertility. Additionally, sorghum's efficient use of water makes it a resilient crop in the face of climate change and water scarcity, offering food security to millionsofpeopleworldwide. Indiais oneofthelargest producersofjowarglobally and productioninIndiahasfluctuatedovertheyearsbasedonvariousfactorssuchasweather conditions, government policies, and market demand. Productivity of sorghum in India variesacross different regions and is influenced by agricultural practices, irrigation availability and use of modern farming techniques. The area under sorghum cultivation in India has seen some fluctuations, but it remains an important cropin several states,particularly Maharashtra, Karnataka, Telangana, and Madhya Pradesh. Uttar Pradesh also cultivates sorghum, although it is not the dominant crop compared to states in central and southern India. Sorghum production in U.P. contributes to the overall national production figures, but specific data for recent years would be needed to provide precise numbers and area under sorghum cultivation in UP is comparatively smallerthaninstateswheresorghumisamajorstaplecrop. Ithasgoodnutritionalvalue,especially when harvested at the right stage of growth, offering protein, fiber, and other essential nutrients. The need for genetic improvement of sorghum for increased yields and nutritive value of fodder is having high priority. It can be used as part of a crop rotation strategy to improve soil health and reduce pests and diseases in subsequent crops. Some varieties of sorghum have been studied for their potential in biofuel production, contributing to its versatility and potential economic benefits beyond traditional forage use. It can contribute to soil conservation and reduce erosion due to its extensive root system, helping to maintain soil structure and fertility over time. The foddersorghum is grown in 8.3 million ha mainly in Western U.P., Haryana, Punjab and Rajasthan and fulfils more than 65 per cent of the fodder demand during *kharif* season. The area under fodder cultivation is estimated to be about four per cent of the gross cropped area, which remained static for the last four decades. The traditional grazing lands are gradually diminishing because of urbanization, expansion of cultivable area, grazing pressure and industrialization *etc*. In India, only 4.4% area is under fodder crops, out of which fodder sorghum is grown on 2.3 million ha. India faces a net deficit of 36% and 11% of green fodder and dry fodder, respectively. To reduce the demand and supply gap,the production and productivity of fodder crops needs to be enhanced. The horizontal expansion of cultivable area under fodder crops is difficult due to severe competition from food crops. Apart from vertical expansion, utilization of non cultivable areas for pastures is one of the most viable options to balance the demand. Seed are the best propagating material for wide spread regeneration of marginal and uncultivable lands. One of the reasons reported tostumble the green fodder production is non availability of quality seed in sufficient quantities. As per estimation only 25-30 per cent of required quantity of quality seed is available in cultivated foddersandproduceabundant.Thegreatqualityseedispre-essentialtoimprovetheproductionand fodder yield of sorghum **(Kumar *et al.*, 2022)**.

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MATERIALSANDMETHODS

The experimental material for the present investigation was comprised of ten promising diverse parents *viz*., CSV-15, Pusa Chari-6, HC-308, Pant Chari-4, G-48, HJ-513, UP Chari-4, HC-171, SSG-59-3 and ICSV-700 and their all possible 45 F_1's, developed through crossing tenparental lines in diallel mating design (excluding reciprocals). All genotypes were evaluated in a complete randomized block design with three replications at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, during *kharif* season 2022 and 2023. The observations were recorded on ten traits *viz*., days to 50 % flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids, protein content, fiber content, HCN content and green fodder yield. The data recorded on all these traits were subjected to various statistical and biometrical analyses like to work out analysis of genetic variability, correlation and path analysis. Seeds of ten parents and F_1's sown by hand dibblingmethodandthe lengthofeach rowwaskept4mwithinterand intrarowdistancesof30cm and 10cm, respectively. The coefficients of variation, correlation and path coefficient analysis calculated by the formula given by **Burton (1952)** and **Johnson *et al.* (1955), Crumpacker and Allard (1962), Robinson *et al.* (1949), Fisher (1918)** and **Dewey and Lu (1959)**

Comment [T2]: Put the citations from old to recent. Example**Fisher (1918),Robinson *et al.* (1949), Burton (1952),Johnson *et al.* (1955), Lu (1959) and Allard (1962). However, yor references are too old!**

RESULTSANDDISCUSSION

The analysis of variance for the experiment with fifty five treatments for all the thirteen attributes *viz.*, days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio, total soluble solids, protein content, fiber content, HCN content and green fodder yield revealed significant differences among the material used in the present investigation, which indicated that wide spectrum of variation among the genotypes. The variance duetotreatmentswasfurtherpartitionedintotheirorthogonalcomponents *i.e.*,parents,crossesand parents vs crosses. Parents and crosses recorded highly significant differences for all the thirteen traits whereas parent's vs crosses were found highly significant differences for all the characters except protein content and fiber content (Table-1). Estimates of coefficient of variation *viz*., genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) along with heritability and genetic advance as percent of mean for different characters arepresented in table-2. High percentage of genotypic coefficient of variation (more than 25%) observed for leaf stem ratio (28.31) and green fodder yield (37.69) whereas moderate (10-25%) noted for leaf breadth (16.36), stem girth (16.80), leaves per plant (13.38), leaf area (21.34) and total soluble solids (16.51). Low genotypic coefficient of variation (<10%) recorded for days to 50% flowering (5.94), plant height (8.45),leaflength (7.54), protein content (7.31), fibercontent (2.00)and HCNcontent (5.11)which indicating that more variability and scope for selection in improving these characters. Similar resultswerefoundby**Singh*etal.*(2023)**and**Shafiqurrahaman*etal.*(2024).**Highpercentageof

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phenotypic coefficient of variation (more than 25%) estimated for leaf stem ratio (30.39) and green fodder yield (38.31) while moderate (10-25%) showed for leaf breadth (16.79), stem girth (17.65), leaves per plant (14.95), leaf area (21.77) and total soluble solids (17.77). Low genotypiccoefficient of variation (<10%) revealed for days to 50% flowering (6.39), plant height (8.97), leaf length (8.16), protein content (7.79), fiber content (3.26) and HCN content (7.11), indicated that thesetraitsaremoreinfluencedbyenvironmentalfactors.Earlierresearchers **Wadikar*etal.*(2018)** and **Dev *et al.* (2019)**. High heritability (> 60%) exhibited for days to 50% flowering (86.52), plant height (88.69),leaflength (85.29),leafbreadth (94.94), stem girth (90.67), leaves perplant (80.09), leaf area (96.08), leaf stem ratio (86.75), total soluble solids (86.34), protein content (88.04) and greenfodderyield(96.82)whereasrecordedmediumheritability(30-60%)forfibercontent(37.66) and HCN content (51.72) suggested that these characters are under genotypic control. Similar observations were also reported by **Diwakar *et al.* (2016), Singh *et al.* (2016)** and **Jain *et al.* (2017)**. Expected genetic advance expressed as percentage of mean revealed high (> 20%) for leaf breadth (32.84), stem girth (32.96), leaves per plant (24.67), leaf area (43.09), leaf stem ratio (54.31), total soluble solids (31.36) and green fodder yield (76.40) while moderate genetic advance as percentage of mean (10-20%) observed for days to 50% flowering (11.39), plant height (16.39), leaf length (14.34) and protein content (14.12). Low genetic advance expressed as percentage of mean (<10%) was found for fiber content (2.53) and HCN content (7.57). This indicated that these traits were highly heritable and selection of high performing genotypes is possible to improve these attributes. High heritability coupled with high genetic advance for these characters have also been reported earlierby**Srivastava*etal.*(2019),Singh*etal.*(2019)andSirohi*etal.*(2019)**.Resultson correlation coefficients, computed at phenotypic and genotypic both levels for all possible paired combinations among ten attributes and the values are given in Table-3. The genotypic correlation,in general was similarin sign and slightly higherin magnitudethantheirphenotypiccorrelation. At the genotypic level, the estimates of correlation coefficients were generally similar to that observed at the phenotypic level, though, their magnitude was slightly lower than the corresponding phenotypic correlations. Here, also green fodder yield per plant showed significant and positive corralation with stem girth (0.76) followed by leaf area (0.67), leaf breadth (0.63), leaves per plant (0.61), leaf length (0.53), plant height (0.39) and days to 50% flowering (0.15) whereas showed significant negative correlation with leaf stem ratio (-0.17) and protein content (-0.19). Greenfodder yield exhibited significant stable and positive correlation with days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant and leaf area at genotypic and phenotypic level. These characters may be considered as important yield component in forage sorghum. These results are similar to earlier reports of **Dubey *et al.* (2016), Singh *et al.* (2017), Sirohi*etal.*(2019)**and**Dev*etal.*(2019)**.Theresultsobtainedatbothgenotypicandphenotypic levels arepresented in table-4. At genotypiclevel, leaf breadth (0.67) displayed high order ofdirect effect on green fodder yield followed by leaves per plant (0.65), leaf length (0.60) and stem girth (0.43). However the character which contributed indirect effects toward green fodder yield perplant observed stem girth through leaf area; leaves per plant via leaf length, leaf breadth, stem girth and leaf area; leaf area through days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant, leaf stem ratio and HCN content. At phenotypic level, leaf length (0.59) displayed high order of direct effect on green fodder yield followed by stem girth (0.47), leaf breadth (0.43) and leaves per plant (0.42) whereas, the attribute which contributed indirect effects toward green fodder yield per plant observed leaf breadth through stem girth, leaves per plant and leaf area; stem girth via plant height and leaf area; leaf area through days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant and HCN content. Magnitudes of residual effects at both phenotypic and genotypic level were found to be low. Leaf breadth displayed high order of direct effect on green fodder yield per plant followed by leaves per plant, leaf length and stem girth at phenotypic and genotypic level, which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programmefor developing for high yielding varieties. These findings are in accordance with the resultsobtained in sorghum by **Malik *et al.* (2013), Girish *et al.* (2016), Malaghan and Kajjidoni(2019), Sirohi *et al.* (2019)** and **Srivastava *et al.* (2019)**.

Conclusion

Genotypic and phenotypic coefficient of variation was high (more than 25%) observed for leaf stem ratio and green fodder yield, which indicating that more variability and scope forselection in improving these characters. High heritability accompanied with high genetic advanceas percent of mean noted for leaf breadth, stem girth, leaves per plant, leaf area, leaf stem ratio,total soluble solids and green fodder yield. This indicated that these traits were highly heritable and selection of high performing genotypes is possible to improve these attributes. Green fodder yield exhibited significant stable and positive correlation with days to 50% flowering, plant height, leaf length, leaf breadth, stem girth, leaves per plant and leaf area at genotypic and phenotypic level. These characters may be considered as important yield component in forage sorghum. Leaf breadth displayed high order of direct effect on green fodder yield per plant followed by leaves per plant, leaf length and stem girth at phenotypic and genotypic level, which indicated that the contribution of individual attributes to fodder yield is of importance in planning a sound breeding programmefor developing for high yielding varieties.

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Table-1.Analysisofvarianceforfodderyield andyieldcomponents inforagesorghum(*Sorghumbicolor*L. Moench)

Sourceof variation	df	Daysto 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Stem girth (mm)	Leaves per plant	Leafarea $(cm)^2$	Leaf stem ratio	Total solublesolid (%)	Protein content(%)	Fiber content (%)	HCN content (ppm)	Grean fodder yield (g/plant)
Replication	2	0.55	403.46	2.73	0.26	0.29	0.11	663.47	0.03	2.54	1.04	0.57	694.66	1718.96
Treatment	54	86.70**	2544.44**	115.95**	2.76**	18.78**	9.47**	15063.03**	0.08**	12.49**	1.21**	1.39**	406.01**	42492.95**
Parents	9	106.95**	2163.56**	89.90**	1.45**	11.25**	9.37**	10106.12**	0.05**	13.10**	1.21**	1.77**	1093.41**	8641.11**
Crosses	44	74.69**	1940.55**	106.80**	2.71**	17.86**	8.83**	13615.09**	0.07**	12.51**	1.23**	1.34**	252.15**	40343.43**
Parents vs Crosses	1	432.99**	32533.03**	753.40**	16.74**	127.09**	38.56**	123384.44**	0.02**	5.85**	0.22	0.04	989.16**	441735.78**
Error	108	4.28	103.77	6.31	0.05	0.62	0.72	202.20	0.04	0.63	0.05	0.49	96.34	460.62

*,** significantat 5%and1%level, respectively

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Table-2.Phenotypiccoefficientofvariation(PCV),genotypiccoefficientofvariation(GCV),heritabilityand genetic advance as % of mean in forage sorghum (*Sorghum bicolor* L. Moench)

Sl. No.	Genotypes	GCV (%)	PCV (%)	Heritability(%)	Genetic Advance	GeneticAdvance as %of mean
1.	Daysto50%flowering	5.94	6.39	86.52	10.04	11.39
2.	Plantheight (cm)	8.45	8.97	88.69	55.33	16.39
3.	Leaflength(cm)	7.54	8.16	85.29	11.50	14.34
4.	Leafbreadth(cm)	16.36	16.79	94.94	1.91	32.84
5.	Stem girth (mm)	16.80	17.65	90.67	4.83	32.96
6.	Leavesperplant	13.38	14.95	80.09	3.15	24.67
7.	Leafarea $(cm)^2$	21.34	21.77	96.08	142.12	43.09
8.	Leafstem ratio	28.31	30.39	86.75	0.10	54.31
9.	Totalsoluble solid (%)	16.51	17.77	86.34	3.81	31.60
10.	Proteincontent(%)	7.31	7.79	88.04	1.20	14.12
11.	Fibercontent(%)	2.00	3.26	37.66	0.69	2.53
12.	HCNcontent(ppm)	5.11	7.11	51.72	15.05	7.57
13.	Greanfodderyield (g/plant)	37.69	38.31	96.82	239.92	76.40

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Parameters		Daysto 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Stem girth (mm)	Leaves per plant	Leaf area $(cm)^2$	Leaf stem ratio	Total soluble solid (%)	Protein content (%)	Fiber content (%)	HCN content (ppm)	Grean fodder yield (g/plant)
Daysto 50% flowering	G	1.00	0.07	0.20**	0.19*	0.15*	0.09	0.20**	0.22**	-0.06	-0.19*	-0.05	-0.03	0.15*
	P	1.00	0.07	0.17*	0.17*	0.15*	0.09	0.18*	0.21**	-0.09	-0.18*	-0.02	-0.02	0.15*
Plant height (cm)	G		1.00	0.24**	0.33**	0.44**	0.13	0.34**	-0.23**	-0.07	-0.08	-0.03	-0.10	0.39**
	P		1.00	0.20**	0.31**	0.40**	0.13	0.32**	-0.20**	-0.04	-0.06	-0.05	-0.13	0.36**
Leaf length (cm)	G			1.00	0.47**	0.60**	0.43**	0.74**	-0.04	-0.02	-0.10	-0.04	-0.01	0.53**
	P			1.00	0.42**	0.54**	0.34**	0.69**	-0.04	-0.09	-0.09	-0.08	0.02	0.48**
Leaf breadth (cm)	G				1.00	0.73**	0.55**	0.94**	0.22**	-0.16*	-0.14	0.09	0.09	0.63**
	P				1.00	0.69**	0.48**	0.91**	0.20**	-0.14*	-0.12	0.04	0.08	0.61**
Stemgirth (mm)	G					1.00	0.63**	0.80**	-0.01	-0.07	-0.04	-0.14	0.14	0.76**
	P					1.00	0.52**	0.76**	-0.02	-0.06	-0.02	-0.05	0.11	0.73**
Leavesper plant	G						1.00	0.55**	0.10	-0.01	0.05	0.03	0.13	0.61**
	P						1.00	0.50**	0.12	-0.05	0.05	0.03	0.07	0.54**
Leafarea $(cm)^2$	G							1.00	0.12	-0.11	-0.15	0.03	0.11	0.67**
	P							1.00	0.12	-0.10	-0.13	-0.03	0.07	0.64**
Leafstem ratio	G								1.00	-0.18*	-0.05	-0.09	0.10	-0.17*
	P								1.00	-0.15*	-0.04	-0.04	0.08	-0.18*
Total soluble solid (%)	G									1.00	0.01	-0.07	0.13	-0.07
	P									1.00	0.09	-0.06	0.09	-0.06
Protein content (%)	G										1.00	-0.13	-0.04	-0.19*
	P										1.00	-0.08	-0.08	-0.16*
Fiber content (%)	G											1.00	-0.58**	0.01
	P											1.00	-0.20**	0.01
HCN	G												1.00	-0.08

content (ppm)	P	1.00	-0.06
Grean fodder yield (g/plant)	G		1.00
	P		1.00

Table-3.EstimatesofGenotypic(G)andPhenotypic(P)correlationcoefficientsfordifferenttraitsinforagesorghum (*Sorghum bicolor* L. Moench)

*,** significantat 5%and1%level, respectively

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Table-4.Estimatesofdirectandindirecteffect ofdifferentcharactersongreenfodderyieldperplantinforagesorghum (*Sorghumbic* L.Moench)

Parameters		Daysto 50% flowering	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Stem girth (mm)	Leaves per plant	Leaf area $(cm)^2$	Leaf stem ratio	Total soluble solid (%)	Protein content (%)	Fiber content (%)	HCN content (ppm)
Daysto 50% Flowering	G	**0.08**	-0.05	0.03	-0.05	0.02	0.06	0.83	-0.04	0.04	0.04	0.02	0.02
	P	**0.03**	-0.01	0.02	0.07	0.07	0.02	0.60	-0.05	0.03	0.03	0.01	0.03
Plant height (cm)	G	0.07	**-0.06**	0.09	-0.06	0.06	0.09	0.44	0.04	0.04	0.01	0.01	0.11
	P	0.02	**-0.01**	0.03	0.13	0.19	0.03	0.16	0.05	0.02	0.01	0.02	0.02
Leaf length (cm)	G	0.01	-0.05	**0.60**	-0.17	0.08	0.38	0.99	0.09	0.03	0.02	0.01	0.01
	P	0.05	-0.02	**0.59**	0.18	0.09	0.08	0.26	0.01	0.04	0.01	0.03	-0.04
Leaf breadth (cm)	G	0.01	-0.02	-0.06	**0.67**	0.01	0.36	0.92	-0.04	0.08	0.03	-0.03	-0.05
	P	0.05	-0.03	-0.06	**0.43**	0.02	0.11	0.29	-0.05	0.05	0.02	-0.02	-0.01
Stemgirth (mm)	G	0.01	-0.02	-0.27	-0.12	**0.43**	0.41	0.36	0.03	0.04	-0.01	0.05	-0.09
	P	0.05	-0.04	0.08	0.30	**0.47**	0.12	0.24	0.07	0.02	0.02	0.02	-0.01
LeavesPer Plant	G	0.08	-0.08	-0.20	-0.09	0.08	**0.65**	0.30	-0.02	0.01	-0.01	-0.01	-0.08
	P	0.03	-0.01	0.05	0.21	0.09	**0.42**	0.16	-0.03	0.01	-0.01	-0.01	-0.01
Leafarea (cm)2	G	0.01	-0.02	-0.19	-0.10	0.51	0.36	**-0.17**	-0.02	0.06	0.03	-0.01	-0.07
	P	0.06	-0.03	0.11	0.39	0.35	0.12	**-0.32**	-0.03	0.03	0.02	0.02	-0.01
Leafstem	G	0.01	0.01	0.06	-0.06	-0.02	0.06	0.53	-	0.01	0.01	0.03	-0.06

ratio									**0.21**				
	P	0.07	0.02	-0.07	0.09	-0.01	0.03	0.04	**-0.25**	0.05	0.08	0.02	-0.01
Total soluble solid(%)	G	-0.06	0.05	0.03	0.05	-0.01	0.04	-0.47	0.03	**-0.05**	0.03	0.06	-0.10
	P	-0.03	0.01	-0.01	-0.06	-0.02	-0.01	-0.03	0.03	**-0.03**	-0.02	0.03	-0.01
Protein content (%)	G	-0.01	0.05	0.16	0.04	0.01	0.03	-0.05	0.01	0.01	**-0.22**	0.05	0.02
	P	-0.05	0.01	-0.01	-0.05	-0.01	0.01	-0.04	0.01	0.01	**-0.18**	0.04	0.01
Fiber content (%)	G	-0.05	0.02	0.06	-0.26	-0.02	0.02	0.16	0.02	0.09	0.03	**-0.08**	0.37
	P	-0.01	0.01	-0.01	0.02	-0.02	0.07	0.01	0.01	0.02	0.01	**-0.03**	0.03
HCN Content (ppm)	G	-0.03	0.01	0.01	-0.26	0.01	0.08	0.49	-0.02	-0.09	0.01	0.22	**-0.40**
	P	0.05	0.01	0.04	0.03	0.05	0.01	0.52	-0.02	-0.03	0.02	0.08	**-0.56**

Residual values (G) = 0.02, Residual values (P) = 0.02 Bold values indicate direct effects *,**significantat5%and 1% level, respectively

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