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HCN Content Estimation in Different Sorghum Genotypes under Rainfed Conditions

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ABSTRACT

Sorghum is most important fodder in dry land areas. It has ability to tolerate high temperature and grow under minimal soil moisture conditions but under drought stress, the HCN content in sorghum increases which is dangerous for animals when used as fodder. Keeping in mind a study was conducted to measure HCN content in different genotypes of sorghum. The research materials were consisted of fifty-six genotypes and three check varieties. The experiment was laid out in an augmented block design at University Research Farm Chakwal Road during kharif season 2018. Samples were collected thirty days after germination and total cyanide was measured by picrate paper method. Results revealed that concentration of HCN varies significantly from genotype to genotype in comparison with checks. Lowest HCN content was found in genotypes JS-263, I-4 and S-9901 that was 201, 209 and 213 (mg/100g) so these genotypes can be used safely for fodder purposes in rainfed areas. Overall these genotypes JS-263, PARC-SS-2, PARC-SU-2, I-5, I-4, Nilli bar, YSS-4, Fri-04, JS-07, YSS-15 and YSS-98 performed good for all studied morphological traits. Significant negative correlation of HCN was observed with sugar content which shows that genotypes with high sugar content will have least HCN content. The results show significant variation among genotypes. JS-263, FM-147, PARC-SU-2, PARC-SS-2, and Nillibar performed well and can be used as fodder. Genetic parameters confirm potential for improving fodder yield. This study highlights genetic variability, indicating strong potential for trait improvement in sorghum breeding programs.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L. Moench) is commonly known as "*Jawar*" in Indo-Pak subcontinent. It is the fifth most important grain crop after wheat, rice, maize and barely (Smith and Frederiksen, 2000). Sorghum is widely cultivated worldwide for grain and fodder purposes as it is rich in fiber and minerals apart from having an adequate amount of sugars (72 %), proteins (11.6 %) and fat (1.9 %). Sorghum is cultivated in more than 100 countries out of which 59 % of world sorghum area is in Africa and Asian countries involve 25 % (Iqbal et al., 2015). Sorghum flour does not contain gluten, so it is a protected energy source for individuals adversely affected by gluten and good for celiac disease patient. It is generally cultivated as a source of fodder for domesticated animals and it is favored over maize because it tolerates to different types of stresses (Elkhier and Hamid, 2008).

In the year 2021-22 total area under sorghum cultivation was 77 thousand hectares by giving annual production of 64 thousand tonnes, while during the year of 2022-2023 the total area was 59 thousand hectares by giving annual production of about 49 thousand tonnes respectively (GOP, 2023). However, change in total sorghum production over the year witnessed a decrease of 23.4 % (www.pbs.gov.pk). In Pakistan, out of total area under sorghum about 80% is in Punjab which contributes nearly 90 % of the total sorghum yield. Sorghum fodder represents 30 % in total food production in Pakistan and 33 % to the fodder production in Punjab (NARC, 2011).

Sorghum is the inexpensive source of fodder for domesticated animals in Pakistan. The present accessible fodder supply is 54-60 % that does not exactly meet to the actual need. This low fodder production is probably because of less area under fodder production, low per acre yield or low quality fodder (Sarwar et al., 2002). In terms of fodder, low HCN content, sugar content, number of leaves, plant biomass and leaf area are most important traits demonstrating the forage quality and fodder yield. Leaf area is an integral part of fodder yield as it has positive correlation with the plant biomass and forage yield and is the main contributing factor to photosynthesis. Sorghum is considered as low quality fodder because of HCN content and deficient crude protein. HCN content increases in young plants which are diminished to non-poisonous level following 40-45 days of germination (Pandey, Kumar, Yadav, 2011).

Plant produces cyanide, which could be harmful to animals depending on the concentration of HCN. For instance, HCN concentration generally considered safe from 0-200 mg/100 g, 200-250 mg/100g is less toxic and 250-300 is potentially toxic while >300 mg/100g is dangerous for cattle (Karthika & Kalpana, 2017). The harmful impact of HCN is observed in animals when hydrocyanic acid is quickly absorbed into the blood streams of animals. It triggers difficult breathing, suffocation resulting increased rate of breath and heartbeat, froth from the mouth, blue shading around mouth and afterward death happens from respiratory loss (Jadav, C. N., et al 2020).

A lot of dhurrin is produced quickly when plants experience any environmental stress and interruption of leaf tissues. The HCN content in sorghum differ depending upon plant development stage, genotype and climatic conditions i.e., heat, drought or any other stress. Any stress that disturbs regular growth can contribute toward increased HCN content. Leaves of forage sorghum are the valuable part of the plant, which liked by the animals because of its palatability and is influenced by drought before any other portion of the plant (Vough and Cassel, 2000). Consequently, it's a dire need of the hour to identify sorghum cultivars with higher fodder productions and low prussic acid content in rainfed areas. A little attention was paid to identify the genotypes with low HCN content from available germplasm.

MATERIALS AND METHODS

Research was carried out at University Research Farm Chakwal Road, Rawalpindi during *Kharif* season in the year of 2018. Research material was consisting of fifty-six genotypes and three check varieties. The experiment was laid out in an augmented design. The samples were collected thirty five days after germination. Determination of total cyanide was done by picrate paper method and concentration values were recorded by spectrophotometer at 510 nm as depicted by Bradbury et al. (1999). The total cyanide was determined as under: Total cyanide content (mg kg^{-1}) = 396 x absorbance reading

Experimental Material

Sugar brix values were estimated with the help of digital refractometer by the method of Yun-Long et al. (2006). Moisture Content, Dry Matter Content, leaf area, no. of leaves and plant biomass were also recorded and data was subjected to analysis of variance.

Statistical Analysis

Recorded data was subjected to statistical (SPSS) analysis according to the procedure outlined by Steel and Torrie (1980). Data were also analyzed for Pearson's correlation (r). On the basis of information from ANOVA coefficients of variation, genotypic and phenotypic variances, broad sense heritability and genetic advance were calculated.

RESULT AND DISCUSSION

HCN Content

The HCN content in forage sorghum is a major risk contributor to productivity of farm animals while sugar content is an imperative feature to decide the forage sorghum quality in rainfed regions. Means from all sorghum genotypes for HCN content was recorded. Analysis of variance of trait was statistically significant among genotypes implying that genotypes differed from one another. HCN content ranged from 201.9 mg/100g (JS-263) to 318.6 mg/100g (No-337). These differences for HCN content among genotypes might be influenced by genetic makeup, environmental effects or high HCN hydrolysis due to enzymatic activity. As compared to three checks, this variety (JS-263) has shown 12 % (SDG-2011), 14 % (JS-2011), 35 % (Hegari) less HCN content results are aligned with Pushpa, K., & Madhu, P. (2019). This cultivar can be used for fodder purpose safely in dryland areas. Moreover, it may be beneficial in further breeding process to develop new sorghum varieties possessing lower HCN content.

Graph 1

Mean values for HCN content of different sorghum genotypes

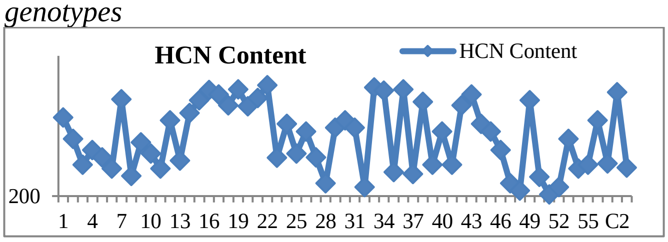


Table 1

Analysis of variance for various characters of different sorghum genotypes

SOV	HCN	SC	MC	DMC	LA	PB	NOL
Block	95.156**	1.989*	5.784**	6.4302*	2566.7**	4947.3**	10.10**

Check	1640*	0.375**	9.555^{ns}	11.895^{ns}	777.7^{ns}	6995.9**	4.18**
Entry	1021.5**	6.177^{ns}	8.506*	14.141**	1290.4*	1357.6**	5.31*
Error	103.18	2.913	3.535	4.34	597.6	421.52	2.37

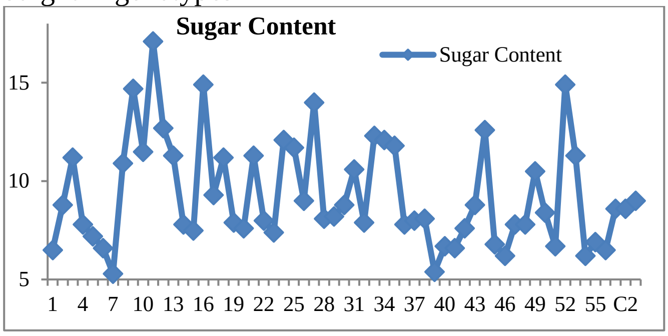
**highly significant, *significant, NS-non significant, HCN=Hydrocyanic acid, SC=Sugar content, MC=Moisture content, DMC=Dry matter content, NOL= No. of leaves, LA=Leaf Area, PB: Plant biomass

Sugar Content (Bx°)

Sugar content mean values ranged from 5.3 Bx^0 (FM-48) - 17.1 Bx^0 (I-5), moisture content ranges from 56 % (PARC-SS-2) – 72 % (FM-147) and Dry matter content from 23.2 % (No-1623) to 44 % (PARC-SS-2) as shown in graphs similar results were found by Sher, A., et al (2023).

Graph 2

Mean values for sugar content (Bx°) of different sorghum genotypes

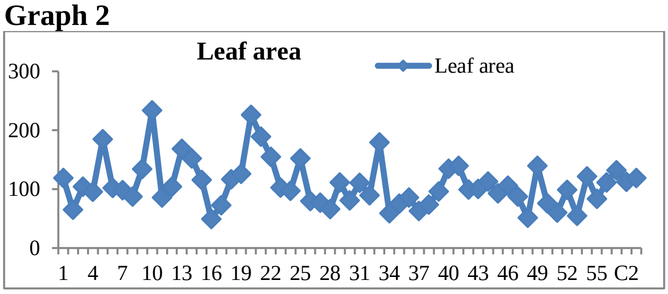


Variation may be due to difference of genetic variability and stem thickness. The genotypes with highest sugar content and high moisture can be preferred as green fodder purposes.

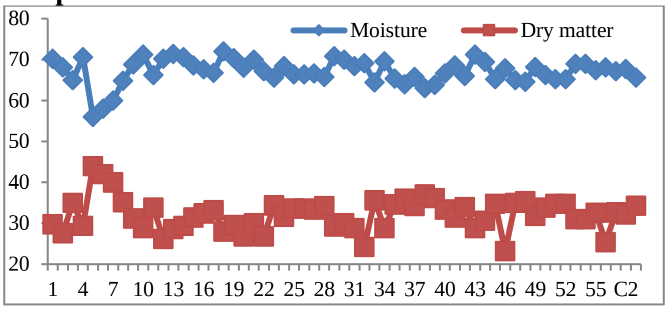
Morphological Traits

Mean values for leaf area, Number of leaves and plant biomass was ranged from 43.8 cm^2 (FRI-4) to 233.8 cm^2 (No-1803), 6 (Ballo) -19.1 (Nillibar) and 405.1 (No-39501) - 223.4 (I-4) and same results were recorded by Nawaz, S., et al (2017). It depicted that this trait of leaf area is strongly associated with photosynthetic phenomena, plants with higher leaf area will contain a huge canopy and extra sunlight will be absorbed, ensuing increased dry matter and enhanced yield. Increase in plant biomass yield of genotype (No-39501) mainly depends upon plant height, no. of leaves, dry matter content and leaf area. It had showed direct relationship among respective traits.

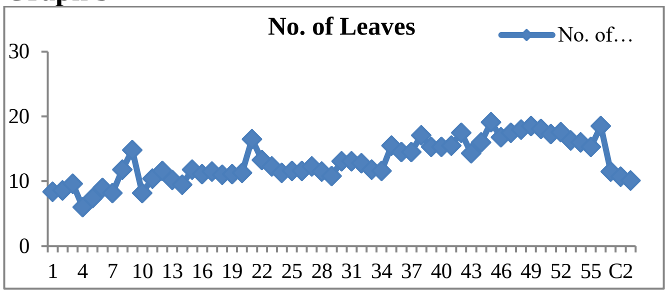
Graph 2



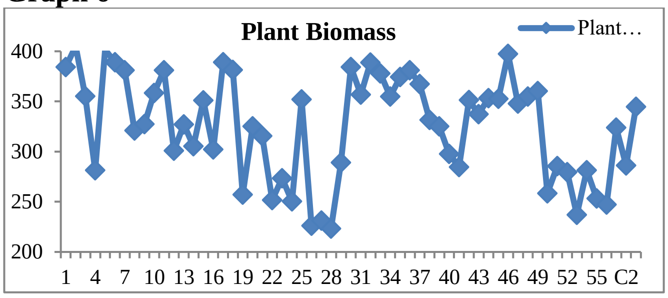
Graph 4



Graph 5



Graph 6



Quantitative Characters of Sorghum Genotypes

The magnitude of genotypic and phenotypic variances for the entire studied traits has been provided in table 3. The genotypic and phenotypic variance ranges from 1.5-459.2 and 3.8-889.5 indicating variation among genotypes. Genotypic, phenotypic and environmental coefficients of variation for all studied traits showed significant results depicting that variations are present among the genotypes. Coefficients of variation (GCV, PCV, and ECV) for all traits were found significant. HCN content (8.2%, 9%, and 3.8%) showed significant value of coefficient of variation given in table 3. Values for coefficients of variation indicate that variation does exist in data and data is more reliable. However, sugar content and leaf area showed genotypic coefficient of variation 13.9%, 17.5%. Moderate genotypic coefficient of variation showed that there is comparatively higher variation among the traits specifying that improvement in these traits with the help of selection will be more efficient due to higher variation among genotypes.

Heritability and expected genetic advance for different traits studied which showed a significant variation among studied traits. According to Jonhson et al. (1955) if heritability is < 30 % (low), between 30 – 60 % (moderate) and > 60 % (higher) while for genetic advance < 10 % (low), between 10 – 20 % (moderate) and > 20 % (higher).

Heritability estimates for all traits ranges from 81.6% - 35.9% and genetic advance values varies from 2.5-44.6 showing that trait is mainly controlled by additive genes. Sugar content, number of leaves, and moisture content showed moderate heritability with low genetic advance among genotypes. Leaf area and plant biomass depicted moderate heritability estimates 36.6%, 52.6% coupled with higher expected genetic advance 38.3%, 44.6% indicating a good genotype and environment interaction in the expression of trait and selection for this trait may be effective. Heritability value 53% with expected genetic advance 4.5% was estimated for dry matter content. Low heritability coupled with low genetic advance indicating the predominance effect of non-additive gene action that is highly influenced by environment. The divergence between the results might be due to the environmental fluctuations in which the experiment was conducted and variation in the genotypes used in study.

Table 2

Estimation of genetic parameters for different traits of sorghum

Traits	V_g	V_P	GCV (%)	PCV (%)	ECV	h^2(BS)	GA	GA (%)
HCN	459.2	562.4	8.2	9.05	3.8	81.6	44.1	16.8
SC	1.6	4.5	13.9	23.3	18.7	35.9	2.6	28.5
NOL	1.5	3.8	9.7	15.6	12.2	38.3	2.5	19.2
MC	2.5	6.0	2.6	3.7	2.8	41.2	3.2	4.8
DMC	4.9	9.2	6.8	9.4	6.4	53.0	4.5	13.9
LA	346.4	944	17.5	28.9	23.0	36.6	38.3	34.1
PB	468.0	889.5	6.7	9.3	6.4	52.6	44.6	13.8

Correlation (Pearson)

The correlation analysis of data carried out in order to determine interrelationship of the characters under evaluation at pearson correlation coefficients for quality, biochemical and morphological traits given in Table 4. Traits under evaluation have shown significant positive and negative relationship. Results indicated that HCN content showed negative and highly significant correlations with sugar content. This indicated that an increase in sugar content might decrease the total cyanide content and improve the fodder quality. Above mentioned associations depicted that total cyanide content had positive and significant correlations with plant biomass which shows that any enhancement in plant biomass and its components would ultimately increase the cyanide content at early that might result in quality deterioration of sorghum fodder.

Leaf area has positive association with moisture content and negative correlation with number of leaves and sugar content as (Table 4.00) is indicating that by an increase in leaf area moisture content will also increase while more increase in no. of leaves will ultimately reduce leaf area and sugar content in leaves. Number of leaves had significant positive association with plant height (Table 4.20). This depicted that cultivars with higher plant height may have higher number of leaves leading to huge canopy results in higher photosynthesis that leads to improvement in sorghum fodder and grain yield.

Evaluation of (Table 4.00) demonstrated that plant biomass has positive significant association with hundred grain weight and plant height. Results revealed that there is strong but negative correlation between moisture content and plant biomass.

Table 3

Correlation coefficients for various traits among different sorghum genotypes

Trait	Biomass	DMC	HCN	LA	LAn	MC	NOL
DMC	0.13						
HCN	0.05*	-0.24**					
LA	0.06	-0.16	0.212				
LAn	-0.06	0.14	-0.12	-0.22			
MC	-0.18**	-0.86**	0.26	0.14*	-0.15		
NOL	-0.21	-0.07**	-0.13	-0.26*	0.20	0.04*	
PH	0.29*	-0.06	0.06	0.13	-0.16	0.08	0.11*
SC	-0.05	0.09**	-0.03**	-0.04*	-0.01**	0.22	-0.07

-Highly significant, *-significant, **HCN-hydrocyanic acid, **SC**-sugar content, **DMC**-dry matter content, **LA**-leaf area, **LAn**-leaf angle, **MC**-moisture content, **NOL**-No.of leaves, **PB**-plant biomass

Assessment of (Table 4) indicated that dry matter content had negative and highly significant correlation coefficient for HCN content and moisture content. This pointed out that an increase in dry matter content might lessen the total cyanide content and would improve the fodder yield and quality. From these correlations studies, it was evident that dry matter content had positive and highly significant correlation with sugar content and number of leaves. It indicated that an increase in number of leaves might be increase dry matter content and its components would ultimately reduce the cyanide content that might result in quality improvement of sorghum fodder. Tariq et al. (2007) and Prabhakar (2003) stated equivalent result for dry matter yield in sorghum.

The association between moisture content and dry matter content was observed as strong and negative (Table 4.20). Correlations between moisture content and dry matter content were recorded as negative and highly significant (Table 4.20). These Findings showed that moisture content negatively affected the dry matter content and an increase in this parameter might decrease the dry matter content ultimately. Analogous out comes were demonstrated by two authors (Thawari et al. 2000) and (Mallinath et al. 2004) for moisture content in sorghum.

CONCLUSION

It is concluded from the results that genotypes vary significantly from one another so overall these genotypes JS-263, FM-147, PARC-SU-2, PARC-SS-2, Nillibar performed good and can be safely used as fodder and have higher scope of selection for fodder quality and yield that could be used in different sorghum breeding program. Estimation of genetic parameters confirms that potential for improving fodder yield in sorghum does exist. This study verified wide range of genetic variability among the genotypes used for all characters tested, thus indicating high potential for use in trait improvement.

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