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Research Note

Correlation among fodder yield, quality and morpho-physiological traits under contrasting environments in sorghum

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Abstract
The present study was planned with the objective to find out the correlation of fodder yield, HCN content and quality traits with morpho-physiological traits under two different environments. The environments were created by applying normal five irrigations in one environment (Env-N) *i.e.* normal environment and by skipping the second and fourth irrigation in the other environment (Env-S) *i.e.* water stress environment. The positive and significant correlations were found between green fodder yield and early vigour, plant height, dry matter yield, leaf area index and proline content under both the environments. The negative and statistically significant correlations were found between green fodder yield and leaf stem ratio under both the environments and also with specific leaf weight under Env-N. Positive and significant phenotypic correlations were also found between proline content and early vigor, plant height, green fodder yield and dry matter yield under both the environments. None of the phenotypic correlations of HCN content with morpho-physiological traits under Env-N and Env-S were statistically significant. Among the quality traits studied Total Soluble Sugar (TSS)(%) content showed negative correlation with early vigour under both the environments. The results of correlation analysis revealed that under the situation of increasing water stress globally, selections for high green fodder yield can be carried out by selecting for early vigor and tall plants. The genotypes with high values for leaf area index, photosynthetic capacity and proline content would be more water use efficient and high yielding.

Key words
Fodder yield, hydrocyanic content, quality traits, water use efficiency, sorghum

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important food crops of the world which provide bulk of raw materials for the livestock and human consumption and many agro-allied industries in the world. It is drought tolerant which allows farmers to use less water for its cultivation than similar crops. Sorghum is indigenous to Africa, and was also grown in India before recorded history and in Assyria as early as 700 BC. It can be classified into two types: Forage types (mainly for forage or animal feed) and grain types (mainly for human consumption). Fodder yield is a complex character which is dependent on many other component characters. Knowledge on type of association between yield and its components themselves greatly help in evaluating the contribution of different components towards yield and is essential for the formulation of breeding programmes. The information on the nature of association between yield and its components help in simultaneous selection for many characters associated with yield improvements. The estimates of correlation coefficients among different characters indicate the extent and direction of association. The correlation co-efficient provide a reliable measure of association among the characters. To improve the quality of fodder to be supplied to the cattle, it is imperative to know the association of different quality traits with the morphological and physiological traits of forage sorghum. It is also very important to know the association of HCN content, which is an anti quality trait in forage sorghum, with the morpho-physiological traits affecting water use efficiency. Any stress condition such as drought can increase HCN content in the plant. Also increasing drought tolerance is the major issue for agriculture under global climate change. The reports of correlations of HCN content and quality traits with physiological traits affecting WUE are very scanty in the literature. To fill this gap, the present study was planned to find out the correlation of fodder yield, HCN content and quality traits with morpho-physiological traits affecting water use efficiency.

Experiment was carried out at Forage and Millet Research Farm, Punjab Agricultural University, Ludhiana which is situated 256 m LR at 30° 91’ N and 75° 85’ E in the Punjab state of India. The experiment was carried out during summer season 2012 to study the character association in sorghum under two different environments. Fifteen CMS lines were crossed to four random mating populations to produce 60 top cross hybrids. For the adequate production of top cross seed, staggered planting of both CMS lines and random mating populations was done. Twenty ears of each top cross from each CMS line were harvested. Sixty top crosses and the parents i.e. CMS lines and populations were evaluated along with hybrid check in a randomized block design with three replications over two environments *viz.*, normal and water stress. The environments were created by applying normal five irrigations in one environment (Env-N) i.e. normal environment and by skipping the second and fourth irrigation in the other environment (Env-S) *i.e.* water stress environment. The top crosses were planted in 2012. All the entries were planted in a plot size of 3m x 1.25m (3 meter row length and 0.25 meter distance between the rows) with 5 rows each. Recommended doses of nitrogen and phosphorus fertilizers were applied @ 60 and 30 kg ha^{-1} (Anonymous, 2016) to raise a good crop. The observations were recorded on ten random plants in both the environments for seven morphological traits *viz.*, early vigor, plant height (cm), leaf stem ratio (LSR), green fodder yield (kg/plot), dry fodder yield (kg/plot) and regenerability; six physiological traits affecting WUE *viz.*, number of leaves per plant, relative leaf water content (RWC) (%), leaf area index (LAI), photosynthetic capacity (SPAD reading), specific leaf weight (SLW) and proline content (n-moles/g of dry sample); and four quality and anti-quality traits *viz,* total soluble solids (TSS) content (%), hydrocyanic acid (HCN) content (ppm), crude protein (%) and *in vitro* dry matter digestibility (IvDMD) (%) as standard procedure given by Tilley and Terry (1963). The HCN content (ppm) was determined by picrate paper method. Relative leaf water content was calculated (Weatherley, 1950) as RWC = [(Fresh weight - Dry weight) / (Saturated weight - Dry weight)] x 100. Leaf area index (LAI) was measured using canopy analyzer (Sunscan-type SS1) in each row of all lines in a plot, under field condition. Photosynthetic capacity in terms of chlorophyll content was recorded by soil plant analytical development (SPAD) chlorophyll meter in five intact plants per plot (using third/fourth leaf from top of the plant) in each replication from all genotypes. Specific leaf weight (SLW) was measured as the ratio of dry matter of leaves per plant (g) divided by leaf area per plant. Proline content was estimated as per procedure by Bates *et al.* (1973). Phenotypic and genotypic correlation coefficients were worked out by the formulae suggested by Al –Jibouri *et al.* (1958).

(i) Phenotypic correlation coefficient (r_p)

$$r_p = \frac{\sigma_{pxy}}{\sqrt{\sigma^2_{px} \times \sigma^2_{py}}}$$

Where,

σ_{pxy} = Phenotypic covariance between two characters

σ^2_{px} = Phenotypic variance of the ‘x’ character

σ^2_{py} = Phenotypic variance of the ‘y’ character

(ii) Genotypic correlation coefficient (r_g)

$$r_g = \frac{\sigma_{gxy}}{\sqrt{\sigma^2_{gx} \times \sigma^2_{gy}}}$$

Where,

σ_{gxy} = genotypic covariance between two characters

σ^2_{gx} = genotypic variance of the ‘x’ character

σ^2_{gy} = genotypic variance of the ‘y’ character

The significance of phenotypic correlation coefficients were tested against r values from the r table of Fisher and Yates at (v - 2) degree of freedom at P = 0.05 and P = 0.01, where the v is the number of samples.

The phenotypic (r_p) and genotypic (r_g) correlation coefficients among the different characters in Env-N and Env-S are given in Table 1 and 2, respectively.

Correlation of fodder yield with morpho-physiological traits: The positive and statistically significant phenotypic and genotypic correlations were found between green fodder yield and early vigour, plant height, leaf area index and proline content under both the environments i.e. in Env-N and Env-S, respectively. However, positive and statistically significant correlation was also found between green fodder yield and number of leaves per plant in Env-S. Phenotypic correlations were also found to be significant and positive between green fodder yield and photosynthetic capacity. Similar results were also reported by Godbharle *et al.* (2010). The negative and statistically significant correlations were found between green fodder yield and leaf stem ratio under both the environments and also with specific leaf weight under Env-N. Significant and positive correlations were observed between green fodder yield and dry fodder yield which is in accordance with the findings of Iyanar *et al.* (2010) and Tariq *et al.* (2012) who depicted strong positive genotypic and phenotypic correlations between green fodder yield and number of tillers/plant, stem thickness, fresh weight/plant, dry weight/plant and dry matter yield. As there was positive and significant correlation between green fodder yield and dry fodder yield, all the correlations found between dry fodder yield and morpho-physiological traits were similar to correlations between green fodder yield and morpho-physiological characters in the respective environments. Hamed *et al.* (2015) also reported highly significant positive correlation of dry matter yield with plant height (0.999) and positive correlation with stem weight (0.553), number of leaves/plant and leaf weight.

Significant correlations between plant height and green fodder yield and indirect effect on dry fodder yield were also reported by Iyanar *et al.* (2010). In the present investigations, significant and positive correlations were observed between plant height and early vigor, number of leaves per plant and proline content under both the environments while plant height was also found to be significantly correlated with leaf area index under Env-S. The correlation between plant height and leaf stem ratio and specific leaf weight was found to be negative but significant in Env-N. Significant correlations were also found among sorghum morphological traits with stover yield in Nigeria by Abubakar and Bubuche (2013). Significant correlation was reported by Jain and Patel (2013) for green fodder yield per day, number of leaves per plant, plant height and leaf length.

The correlation between leaf stem ratio and early vigor, plant height, photosynthetic capacity and proline content was found to be significant but negative in Env-N, while in Env-S, the significant and negative correlation was observed only between leaf stem ratio and early vigor. Significant and positive correlation was observed between leaf stem ratio and specific leaf weight in Env-N. Number of leaves per plant was found to be negatively correlated with specific leaf weight under both the environments, while positively correlated with relative water content in Env-S. Relative water content and leaf area index was observed to be positively correlated with photosynthetic capacity in Env-N. The results of present investigation revealed positive and significant phenotypic correlations between proline content and early vigor, plant height, green fodder yield and dry matter yield under both the environments. In Env-S the proline content was also found to be positively correlated with leaf area index while in Env-N, it was found to be negatively correlated with leaf stem ratio.

Correlation of HCN with morpho-physiological traits: None of the phenotypic correlations of HCN content with morpho-physiological traits under Env-N and Env-S were statistically significant. In general, genotypic correlations were high as compared to phenotypic correlations. It has been reported in the literature that the HCN proportion lowers as the height of the plant increases due to which it is harmful for the livestock at initial stages because of more cyanide concentration and toxicity decreases with maturity of plant (Pistoia *et al.*, 2003). Tariq *et al.* (2012) depicted strong negative genotypic and phenotypic correlations between total cyanide content and number of tillers/plant, stem thickness, fresh weight/plant, dry weight/plant and green fodder yield. But in the present investigations the HCN content does not reveal any correlation with any morph-physiological trait under both the environments.

Correlation of quality traits with morpho-physiological traits: Only few correlations were found to be statistically significant between quality traits and morpho-physiological traits. Total Soluble Sugar (TSS)(%) content showed negative correlation with early vigour under both the environments, though under normal environment *i.e.* Env-N, TSS showed highly significant negative correlation with plant height and green fodder yield. The genotypic correlations followed the same trend as phenotypic correlations in both the environments. Though in the present investigations no significant correlations were observed between crude protein and morpho-physiological traits or between *in vitro* dry matter digestibility and morpho-physiological traits but Millner *et al.* (2011) revealed that crude protein is strongly and negatively associated with plant height. On the other hand Bibi *et al*. (2016) reported significant and positive correlation between green fodder yield and crude protein. The difference in results may be due to the involvement of different genotypes under study. There are no reports available in the literature pertaining to the correlations between quality characters and water use efficiency traits.

The results of correlation analysis revealed that the selections for high fodder yield under both the environments can be carried out by phenotypically selecting for early vigour, plant height, leaf area index, photosynthetic capacity, proline content and total soluble sugar content in the desired forage sorghum population.

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Table 1. Estimates of correlation coefficients of different characters under Env-N

Characters	Early Vigour	Plant Height	Leaf Stem Ratio	Green Fodder Yield	Dry Fodder Yield	Regene-rability	No. of leaves per Plant	Relative Water Content	Leaf Area Index	Photo-synthetic Capacity	Specific Leaf Weight	Proline	TSS	Crude Protein	HCN	IVDMD
Early Vigour	1.00	**0.42****	**-0.36****	**0.57****	**0.54****	**-0.01**	**0.12**	**0.02**	**0.15**	**0.12**	**-0.12**	**0.23***	**-0.24***	**-0.17**	**-0.07**	**-0.10**
Plant Height	0.60	1.00	**-0.43****	**0.48****	**0.42****	**0.06**	**0.33****	**0.05**	**0.06**	**0.18**	**-0.29***	**0.35****	**-0.30****	**-0.22**	**0.03**	**-0.10**
Leaf Stem Ratio	-0.54	-0.49	1.00	**-0.42****	**-0.34****	**0.05**	**-0.23**	**-0.16**	**-0.11**	**-0.26***	**0.27***	**-0.26***	**0.09**	**0.19**	**0.15**	**0.20**
Green Fodder Yield	0.86	0.56	-0.49	1.00	**0.80****	**-0.05**	**0.10**	**0.01**	**0.25***	**0.26***	**-0.18**	**0.41****	**-0.30****	**-0.17**	**-0.19**	**-0.14**
Dry Fodder Yield	0.77	0.46	-0.38	0.76	1.00	**-0.06**	**0.16**	**0.03**	**0.24**	**0.30***	**-0.13**	**0.35****	**-0.20**	**-0.19**	**-0.11**	**-0.11**
Regenerability	-1.13	0.42	-0.16	0.35	0.02	1.00	**0.07**	**-0.01**	**0.045**	**0.03**	**0.00**	**-0.05**	**0.09**	**0.15**	**-0.00**	**0.12**
No. of leaves per Plant	0.22	0.36	-0.26	0.14	0.20	0.17	1.00	**0.07**	**0.09**	**0.15**	**-0.53****	**0.05**	**-0.01**	**-0.05**	**0.02**	**-0.04**
Relative Water Content	0.05	0.08	-0.18	0.02	0.06	0.13	0.11	1.00	**0.01**	**0.28***	**-0.07**	**-0.07**	**-0.05**	**-0.04**	**-0.01**	**-0.10**
Leaf Area Index	0.22	0.07	-0.12	0.29	0.27	0.82	0.11	0.02	1.00	**0.24***	**-0.10**	**0.14**	**-0.09**	**-0.01**	**-0.04**	**0.19**
Photosynthetic Capacity	0.22	0.23	-0.31	0.30	0.33	0.92	0.17	0.45	0.31	1.00	**-0.08**	**0.03**	**-0.04**	**-0.01**	**-0.04**	**0.06**
Specific Leaf Weight	-0.24	-0.34	0.32	-0.24	-0.17	-0.35	-0.57	-0.13	-0.11	-0.06	1.00	**-0.19**	**-0.02**	**0.09**	**0.00**	**0.07**
Proline	0.42	0.39	-0.28	0.47	0.39	0.12	0.07	-0.07	0.15	0.02	-0.22	1.00	**-0.08**	**-0.10**	**-0.14**	**-0.18**
TSS	-0.36	-0.34	0.12	-0.37	-0.23	0.12	-0.03	-0.07	-0.13	-0.09	0.04	-0.09	1.00	**0.08**	**-0.10**	**0.13**
Crude Protein	-0.23	-0.28	0.22	-0.20	-0.22	0.60	-0.08	-0.07	-0.02	0.00	0.12	-0.10	0.09	1.00	**0.09**	**0.20**
HCN	-0.11	0.03	0.18	-0.21	-0.11	0.38	0.04	-0.01	-0.04	-0.04	-0.02	-0.15	-0.11	0.10	1.00	**0.16**
IVDMD	-0.14	-0.12	0.23	-0.15	-0.11	0.87	-0.05	-0.13	0.21	0.06	0.11	-0.21	0.18	0.24	0.18	1.00

*, **significant at 5 and 1 per cent levels, respectively.
Values above diagonal are phenotypic correlations (r_p) and below diagonal are genotypic correlations (r_g).

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Table 2. Estimates of correlation coefficients of different characters under Env-S

Characters	Early Vigour	Plant Height	Leaf Stem Ratio	Green Fodder Yield	Dry Fodder Yield	Regene-rability	No. of leaves per Plant	Relative Water Content	Leaf Area Index	Photo-synthetic Capacity	Specific Leaf Weight	Proline	TSS	Crude Protein	HCN	IVDMD
Early Vigour	1.00	0.21	-0.24*	0.38**	0.34**	0.04	0.08	-0.05	0.09	0.01	-0.12	0.41**	-0.24*	0.05	-0.02	-0.04
Plant Height	0.43	1.00	-0.30	0.42**	0.37**	-0.01	0.42**	0.08	0.34**	0.14	-0.22	0.33	0.03	0.13	-0.16	-0.10
Leaf Stem Ratio	-0.41	-0.41	1.00	-0.24*	-0.20	-0.03	-0.17	-0.11	-0.01	-0.08	0.02	-0.11	0.07	0.09	0.22	0.12
Green Fodder Yield	0.64	0.59	-0.30	1.00	0.91**	-0.00	0.34**	0.08	0.36**	0.21	-0.13	0.75**	-0.21	-0.06	-0.27	0.03
Dry Fodder Yield	0.55	0.51	-0.25	0.88	1.00	0.03	0.32**	0.08	0.37**	0.20	-0.08	0.74**	-0.22	-0.08	-0.18	0.06
Regenerability	-0.37	-0.01	-0.89	-0.89	-0.09	1.00	-0.19	-0.07	0.09	-0.02	-0.03	0.02	0.01	0.06	0.02	0.06
No. of leaves per Plant	0.13	0.54	-0.21	0.47	0.43	-1.27	1.00	0.23*	0.11	0.16	-0.24*	0.23	-0.01	0.02	0.07	-0.16
Relative Water Content	-0.12	0.08	-0.14	0.10	0.09	-0.20	0.28	1.00	-0.03	0.23	-0.16	-0.01	0.07	-0.08	-0.03	0.09
Leaf Area Index	0.24	0.41	0.01	0.48	0.47	0.30	0.12	-0.02	1.00	0.19	-0.01	0.35**	0.11	0.15	-0.21	-0.01
Photosynthetic Capacity	0.02	0.27	-0.14	0.51	0.50	0.30	0.40	0.51	0.37	1.00	-0.01	0.11	-0.05	-0.01	-0.14	0.20
Specific Leaf Weight	-0.20	-0.26	0.00	-0.17	-0.10	-0.43	-0.22	-0.19	0.01	0.02	1.00	-0.18	0.05	-0.05	0.01	0.08
Proline	0.59	0.41	-0.12	0.90	0.88	-0.22	0.29	0.00	0.40	0.26	-0.21	1.00	-0.21	-0.07	-0.20	-0.04
TSS	-0.41	0.03	0.11	-0.27	-0.29	1.06	-0.02	0.07	0.13	-0.13	0.08	-0.23	1.00	0.12	-0.02	-0.08
Crude Protein	0.01	0.18	0.10	-0.03	-0.06	0.86	0.04	-0.11	0.18	-0.07	-0.04	-0.07	0.14	1.00	0.02	0.03
HCN	-0.06	-0.19	0.27	-0.34	-0.22	0.63	0.08	-0.02	-0.24	-0.37	0.01	-0.21	-0.01	0.02	1.00	0.08
IVDMD	-0.07	-0.12	0.14	0.03	0.08	0.74	-0.21	0.09	-0.02	0.49	0.11	-0.03	-0.08	0.03	0.08	1.00

*, ** significant at 5 and 1 per cent levels, respectively.
Values above diagonal are phenotypic correlations (r_p) and below diagonal are genotypic correlations (r_g).