How to improve *Sorghum bicolor* (L.) Moench production: An Overview

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Abstract: The sorghum (*Sorghum bicolor* L.) plant has been grown for food and fodder purpose throughout the world. Being a plant of African origin it is mostly cultivated in the northern hemisphere. *Sorghum bicolor* plays pivotal role as a food crop for millions of tenants in the semi-arid tropic temperate regions of Asia and Africa. Sorghum has become one of the most imperative crops in Pakistan as a multicup crop. In this review article, our main focus was to highlight starring role of studying heritability, genotypic and phenotypic association, and their direct and indirect effects along with the part sorghum plays in economy as a green fodder.

[Awan ZK, Naseem Z, Masood SA, Nasir B, Sarwar F, Amin E and Qurban Ali. **How to improve *Sorghum bicolor* (L.) Moench production: An Overview.** *Life Sci J* 2015;12(3s):99-103]. (ISSN:1097-8135). http://www.lifesciencesite.com. 15

Key words: Correlation, path analysis, *Sorghum bicolor*, variability, green fodder yield, grain yield

Introduction

Sorghum bicolor is genetically suited to hot and dry climate with frequent drought stress, where other crops are difficult to grow. Sorghum is mainly grown as dual purpose crop in Pakistan as food (beverages) and forage crop. Therefore, it can deliver a vital role to uplift socioeconomic status of the farmers through development of high yielding cultivars with a reasonable amount of green and dry livestock fodder. The study of association among quantifiable characters of agronomic importance is essential to assess the probability of joint selection of multiple traits and hence for estimating the effect of selecting the secondary traits on genetic gain for the primary trait of main consideration. A significant positive genetic correlation between two desired characters makes the plant breeder's job easy to improve both the characters at the same time (Anwar *et al*., 2013; Azam *et al*., 2014; Jahangir *et al*., 2014; Zameer *et al*., 2015). Contribution of correlation coefficient can be partitioned into direct and indirect effects of different traits towards dependent variable and thence help in evaluating the cause-effect affiliation along with effective selection (Ali *et al*., 2011; Ali *et al*., 2012; Shan *et al*., 2015; Abbas *et al*., 2014; Ali *et al*., 2014;Muhammad *et al*., 2013; Tariq *et al*., 2014). Therefore, this review aimed to study significance of heritability, genetic variability, correlation pattern and its direct and indirect effect (path coefficient) on various traits in forage sorghum breeding (Ali *et al*., 2013; Ali *et al*., 2014abc; Sabbir *et al*., 2014).

Genetic variability

Kainth *et al.* (2004) observed non-significant differences for stem thickness and number of leaves per plant. No. of plants were ranged from 21 to 28 and plant height were ranged from 200cm to 240 cm. JS-263 was the check which was used in the experiment and it was 210 cm tall. Check variety also produced green fodder yield of 58.70 tons/hectare. Reddy *et al.* (2004) investigated the genotype × environmental interaction to identify stable genotypes of rabi sorghum for different environments under rain-fed Alfisols in Andhra Pradesh, India. The irrigated environments were better even though vegetative phase was prolonged under dry land conditions. The number of days to 50% flowering was reduced resulting in lower fodder yields. Genotypes C-126, C-128 and C-133 were relatively more stable under irrigated environments. The genotypes had a significant linear interaction with environments including their differential predictable responses under varying environments. Sridhar *et al.* (2004) evaluated the magnitude and nature of genetic divergence for green fodder yield and yield components in sorghum germplasm and found highly significant differences among genotypes indicating considerable variability. Kishore and Singh (2005) noted significant differences in mean square values for days to 50% flowering and plant height. They also recorded high estimates for phenotypic and genotypic coefficients of variability for green forage yield. They noted high heritability estimates for days to 50% flowering. The traits such as days to 50% flowering and green forage yield exhibited high genetic advance. The selection for tall height, high leaf number and extended leaf area had significant and positive correlation and direct effect on forage yield. Ping *et al.* (2005) evaluated one variety of forage sorghum with seven check varieties. Significant differences were shown by plant height and green forage yield whereas number of leaves per plant showed non-significant differences. Among the varieties Jumbo showed highest green forage yield followed by Jinco-1. Jincao-1 was on top for plant height than other check varieties. So, Jincao-1 is considered fine variety for forage having good number of leaves per plant.

Baskheti *et al.* (2006) conducted the genetic analysis for yield and yield components for the P1, P2, F1, BC1, BC2 and B2 generation of seven crosses between *Sorghum bicolor* and *Sorghum sudanense* genotypes. Pooled analysis of the variance revealed that the variation between progenies within a family was significant for green forage yield per plant. Chohan *et al.* (2006) demonstrated in their studies the performance of varieties of pearl millet for green fodder yield. Plant height was ranged from 248.66 to 291.42. Green fodder yield was ranged from 60 to 80.55 tons per hectare and leaf area was ranged from 171.29 to 239.68 cm^2. Green fodder yield of 62.22 tons was produced by check variety. Nabi *et al.* (2006) investigated that cultivar JS-88 showed significant difference with higher number of leaves per plant (13.5) and leaf area (512.5 cm^2) as compared to check average number of leaves per plant (10.5) and leaf area (445.5 cm^2). Cultivar JS-88 was superior in green forage yield to check Hegari. Zaman *et al.* (2006) bserved significant differences for characters such as plant height, number of leaves, leaf area and green forage yield among the varieties. The varieties JS-263, S-9906 and JS-2001 produced higher green forage yield (55.08, 50.00 and 49.07 tons ha^{-1}, respectively). While lowest green forage yield (30.55 tons ha^{-1}) was recorded for check variety DS-2003. The variety S-9906 produced maximum plant height (283.08 cm), while variety DS-2003 responded for minimum plant height (109.00 cm). Sorghum varieties JS-263, S-9906 and JS-2001 were recommended for commercial cultivation on the basis of superior performance for green forage yield.

Ammanullah *et al.* (2007) assessed ten sorghum varieties for growth character and fodder productivity. Difference among the plant height of sorghum varieties were significant with maximum plant height of 218 cm recorded for JS-88. While the minimum plant height of 88 cm recorded for variety PARC-SS-II. Average leaf area varied significantly between 140 and 247 cm^2. Maximum leaf area of 247 cm^2 was recorded for variety JS-88, followed by 219 $cm^2$for variety S-9601, while the minimum of 140 cm^2 was recorded for the variety Tandojam Local. Maximum fresh fodder yield of 72 tons $ha^{-1}$was obtained from variety Hegari and minimum of 8 tons ha^{-1} noted for the check variety PARC-SS-I. Ali *et al.* (2009) assessed drought tolerance of ten sorghum genotypes on morpho-physiological criteria at seedling and post-anthesis stages. Genotypes showed significant differences for all morpho-physiological traits. Except relative dry weight highest genotypic coefficient of variation, high estimates of broad sense heritability and genetic advance for all traits suggest a good scope for selection of these traits. Correlation analysis at seedling and reproductive stages revealed that all morpho-physiologicall traits could simultaneously improved and exploited as reliable morpho-physiological markers for drought resistance.

Singh *et al.* (2009) concluded that selection based on these indices was the criteria for enhanced performance and improvement in forage sorghum. Path analysis revealed that days to 50%, green forage yield had direct effects on green fodder yield. They observed that days to 50% flowering had indirect effects on green fodder yield per day. Leaf length had indirect effects on green fodder yield per day. They concluded that green forage yield per day and days to milking were effective parameters for enhancement of the green forage yield. Jain *et al.* (2010) investigated 144 genotypes of forage sorghum to study variability, phenotypic and genotypic associations among characters and their direct and indirect effects. They reported highly significant differences among genotypes for all characters. Due to high genetic advance and high h^2 (B.S) the traits like plant height and green forage yield gave a positive response to the selection. Leaf length and plant height were significantly and positively associated with green forage yield $plant^{-1}$. The direct and indirect effects showed significant and positive association and high direct effect of number of leaves $plant^{-1}$on green forage yield $plant^{-1}$. Ayub *et al.* (2010) found that the variety F-9603 produced significantly higher forage and dry matter yield due to larger plant density, plant height and thicker stem.

Iyanar *et al.* (2010) showed that all the traits except HCN, crude protein and total soluble solids had significant and positive correlations with green forage yield per plant. High correlation coefficient was exhibited by dry fodder yield per plant with green forage yield followed by plant height, number of leaves and leaf length. Parkash *et al.* (2010) found that plant height, number of tillers, leaf length, and stem diameter were significantly and positively correlated while days to 50 % flowering showed negative association with green fodder yield per plant. Present study indicated that these characters may be considered as selection indices in sorghum breeding program. Ikanovic *et al.* (2011) showed that more precise and full insight into relations was analyzed for the studied traits. Durrishahwar *et al.* (2012) showed significant variability for days to 50% flowering, leaf area, plant height and green forage yield, while the differences of smaller magnitude were observed for number of leaves. Acc.1692 showed maximum plant height (232 cm), while Acc.1827 maximum leaf area of 427cm^2 and at 50% maturity Acc.1763 gives maximum green fodder yield. Ghasemi *et al.* (2012) evaluated fifteen forage sorghum cultivars to determine the high yielding cultivars. There was variability between forage yields of cultivars ranged between 153.427-102.019 tons ha^{-1}. Significant differences were shown by the varieties for green forage yield and its related components. Highest green forage yield was showed by variety KFS3 of 153.427 tons ha^{-1}.

Hussain *et al.* (2012) investigated 24 CMS (A) and their counter (B) lines and 16 restorer lines of Sudan grass to determine the forage yield performance of hybrids. The 14 hybrids were evaluated against standard hybrid (Pak-Sudax). High green forage yield were recorded for NARC Hybrid-3, NARC Hybrid-2 and NARC Hybrid-5 in the range of 143.23-153.13 tons per hectare against Pak-Sudax (check hybrid) 109.54 tons per hectares. Jain and Patel (2012) reported 102 land races of sorghum for genetic variability. They concluded that forage yield has a positive correlation with number of leaf per plant, leaf width and leaf length. They observed heritability along with higher GA for days to 50% flowering revealing positive direct effect on forage yield. The characters such as number of leaf per plant, number of days to reach 50% flowering and leaf width showed positive direct effect on fodder yield. The accession E-159 was observed best for leaf characters, EJN-11 and E-143 were best for earliness, GUB-50 for plant height and GGUB-39 and E-203 for fodder yield.

Jankovic *et al.* (2012) found that in phenotypic and genetic analysis, differences were observed for morphological and productive traits. Results indicated significant and very significant variation was present. Coefficients of simple correlation indicate that very high significant and positive correlation was present. For yield of green biomass, number of leaves and green biomass were indirectly significant. Tariq *et al.* (2012) found higher genotypic as well as phenotypic variances were observed for fresh weight plant^{-1}, plant height and green fodder yield. There were strong positive genotypic and phenotypic correlation between green fodder yield and fresh weight per plant. Jain and Patel (2013) found higher genotypic coefficient of variation (GCV) was higher for green fodder yield than dry fodder yield. High GA with high heritability and high GCV was observed for green fodder yield and it's per day productivity, leaf breadth and plant height. Significant correlation was present for green fodder yield per day, number of leaves per plant, plant height and leaf length. Singh *et al.* (2013) found different magnitudes of GCV, PCV, heritability, dry matter accumulation and genetic gain at different cuts. These characters also had correlation between them at different cuts. Root volume, stem girth and leaf length had positive and high direct effect on green fodder yield per plant per day at third cut. The results showed the importance of these characters that could be used to increase the green fodder yield of sorghum. Kumar (2013) studied the genetic variability, association among the yield components and their direct and indirect effects on the yield in sorghum. Parameters like grain yield and fodder yield coupled with high heritability showed high genetic advance indicating the dominance of the non-additive gene action; signifying that hybridization breeding will be effective. Ear head length and fodder yield showed the higher magnitude of genotypic correlation than phenotypic correlation. Days to 50% flowering, ear head length and test weight had positive direct influence on yield at both genotypic and phenotypic level. It showed the importance of these characters to increase the yield of sorghum. Krishna *et al.* (2014) studied 50 genotypes of fodder oat (*Avena Sativa* L.) to measure correlation, path and diversity during Rbi-2011-12. Leaf: stem ratio contributed maximum positive direct effect on green fodder yield and green fodder yield was positively correlated with most of the traits studies except number of leaves, plant height and leaf length showed positive correlation with maximum number of traits studied.

References

1. Kainth, R.A., M. Naeem, M.S.M. Chohan and A.H. Khan. 2004. Fodder yield potential of advance lines of sorghum under irrigated conditions. J. Agri. Res. 42(3-4):277-281.
2. Abbas, SQ, MUl Hassan, B Hussain, T Rasool and Q Ali. 2014. Optimization of zinc seed priming treatments for improving the germination and early seedling growth of *Oryza sativa*. Adv. life sci., 2(1) pp: 31-37.
3. Ali A, Muzaffar A, Awan MF, Ud Din S, Nasir IA. 2014. Genetically Modified Foods: Engineered tomato with extra advantages. Adv. Life Sci., 1 (3): 139-152.
4. Ali MA, Rehman I, Iqbal A, Din S, Rao AQ, Latif A, Samiullah TR, Azam S, Husnain T. (2014). Nanotechnology, a new frontier in Agriculture. Adv. life sci., 1(3): 129-138.
5. Ali Q, Ahsan M, Ali F, Aslam M, Khan NH, Munzoor M, Mustafa HSB, Muhammad S. 2013. Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. Adv. life sci., 1(1): 52-63.

6. Ali Q, Ali A, Ahsan M, Ali S, Khan NH, Muhammad S, Abbas HG, Nasir IA, Husnain T. 2014c. Line × Tester analysis for morpho-physiological traits of Zea mays L. seedlings. Adv. life sci., 1(4): 242-253.
7. Ali, M.A., A. Abbas, S. Niaz, M. Zulkiffal and S. Ali. 2009. Morpho-physiological criteria for drought tolerance in sorghum (*Sorghum bicolor*) at seedling and post-anthesis stages. Int. J. Agri. Biol. 11: 674–680.
8. Ali, Q., A. Ali, M. Tariq, M.A. abbas, B. Sarwar, M. Ahmad, M.F. Awaan, S. Ahmad, Z.A. Nazar, F. Akram, A. Shahzad, T.R. Samiullah, I.A. Nasir, and T. Husnain 2014a. Gene Action for Various Grain and Fodder Quality Traits in *Zea Mays*." *Journal of Food and Nutrition Research*, 2(10): 704-717.
9. Ali, Q., M. Ahsan, M.H.N. Tahir and S.M.A. Basra, 2012. Genetic evaluation of maize (*Zea mays* L.) accessions for growth related seedling traits. *IJAVMS,* 6: 164-172.
10. Ammanullah, A.A. Khan, K. Nawab, A. Khan and B. Islam. 2007. Growth characters and fodder production potential of sorghum varieties under irrigated conditions. Sarhad J. Agri. 23(2):265-268.
11. Anwar M, Hasan E, Bibi T, Mustafa HSB, Mahmood T, Ali M, 2013. TH-6: a high yielding cultivar of sesame released for general cultivation in Punjab Adv. life sci., 1(1): 44-57.
12. Ayub, M., M.A. Nadeem, M. Tahir, A. Ghafoor, Z. Ahmad and M. Naeem. 2010. Comparative studies on the growth, forage yield and quality of sorghum (*Sorghum bicolor* L.) varieties under irrigated conditions of Faisalabad. Pak. J. Life Soc. Sci. 8(2): 94-97.
13. Azam S, Samiullah TR, Yasmeen A, Din S, Iqbal A, Rao AQ, Nasir IA, Rashid B, Shahid AA, Ahmad M, Husnain T. 2013. Dissemination of Bt cotton in cotton growing belt of Pakistan. Adv. life sci., 1(1): 18-26.
14. Baskheti, D.C. and A. Bhatt. 2006. Genetic analysis for yield and yield components in seven crosses among sorghum and sudangrasses. Int. J. Agri. Sci. 1(1):7-10.
15. Butt SJ, Varis S, Nasir IA, Sheraz S, Shahid A, Ali Q. Micro Propagation in Advanced Vegetable Production: A Review. (2015). Adv. Life Sci. 2(2). pp: 48-57.
16. Chohan, M.S.M., M. Naeem, A.H. Khan and S.S. Ud-Din. 2003. Performance of newly developed forage varieties of sorghum (*Sorghum bicolor* L. Moench) Asian J. Plant Sci. 2(1):48-50.
17. Dar AI, Saleem F, Ahmad M, Tariq M, Khan A, Ali A, Tabassum B, Ali Q, Khan GA, Rashid B, Nasir IA, Husnain T. Characterization and efficiency assessment of PGPR for enhancement of rice (*Oryza sativa* L.) yield. (2014). Adv. Life Sci. 2(1). pp: 38-45.
18. Durrishahwar, M. Noor, H. Rehman, Ihteramullah, I.A. Shah, F. Ali, S.M.A. Shah and N. Mehmood. 2012. Characterization of sorghum germplasm for various morphological and fodder yield parameters. Afr. J. Biotechnol. 11(56):11952-11959.
19. Ghasemi, A., M.H. Karim, and M.M. Ghasemi. 2012. Green fodder yield performance of different varieties of sorghum grown in an arid region. Int. J. Agri. Crop Sci. 4(13):839-843.
20. Hussain, A., S. Khan and S. Shafeeq. 2012. Development of Sorghum-Sudan grass hybrids for high forage yield and quality. Sci. Tech. Dev. 31(1):19-25.
21. Ikanovic, J., D. Glamoclija, R. Maletic, V. Popovic, D. Sokolovic, M. Spasic and S. Rakic. 2011. Path analysis of the productive traits in *sorghum* species. Genetika 43(2):253-262.
22. Iyanar, K., G. Vijaykumar and A.K.F. Khan. 2010. Correlation and path analysis in multicut fodder sorghum. Elect. J. Plant Breed 1(4): 1006-1009.
23. Jahangir GZ, Nasir IA, Iqbal M. Disease free and rapid mass production of sugarcane cultivars. (2014). Adv. life sci., 1(3): 171-180.
24. Jain, S.K. and P.R. Patel. 2012. Genetic variability in land races of forage sorghum [*Sorghum bicolor* (L.) Moench] collected from different geographical origin of India. Int. J. Agri. Sci. 4(2): 182-185.
25. Jain, S.K. and P.R. Patel. 2013. Variability, correlation and path analysis studies in sorghum (*Sorghum bicolor* L. Moench). Forage Res. 39(1):27-30.
26. Jain, S.K., M. Elangovan and N.V. Patel. 2010. Correlation and path coefficient analysis for agronomic traits in forage sorghum (*Sorghum bicolor* L. Moench). Indian J. Plant Genet. Resour. 23(1): 15-18.
27. Jankovic, S., S. Rakic, J. Ikanovic, J. Kuzevski, L. Zivanovic and Z. Lakic. 2012. Correlation coefficients of morphological-productive traits of species of sorghum genus. Biotechnol. Animal Husb. 28(3):585-593.
28. Khan JA, Afroz S, Arshad HMI, Sarwar N, Anwar HS, Saleem K, Babar MM, Jamil FF (2014). Biochemical basis of resistance in rice against Bacterial leaf blight disease caused by Xanthomonas oryzae pv. oryzae. Adv. life sci., 1(3): 181-190.
29. Kishore, N. and L.N. Singh. 2005. Variabitlity and association studies under irrigated and

rainfed situations in sub-montane region in forage sorghum (*Sorghum bicolor* L.). Crop Res. 29(2):252-258.

30. Krishna A, Ahmed S, Pandey HC, Kumar V. Correlation, Path and Diversity Analysis of Oat (Avena Sativa L.) Genotypes for Grain and Fodder Yield. J Plant Sci Res. 2014;1(2): 110.
31. Kumar, B.A. 2013. Studies on genetic parameters and inter-relationships among yield and yield contributing traits in sorghum (*Sorghum bicolor* L.). The Bioscan 8(9): 1311-1314.
32. Muhammad S, Shahbaz M, Iqbal M, Wahla AS, Ali Q, Shahid MTS, Tariq MS. 2013. Prevalence of different foliar and tuber diseases on different varieties of potato. Adv. life sci., 1(1): 64-70.
33. Nabi, C.G., M. Riaz and G. Ahmad. 2006. Comparison of some advance lines of (*Sorghum bicolor* L. Moench) for green fodder yields and Morpho-Economic parameters. J. Agric. Res. 44(3):191-196.
34. Ping, J., F. Zhang, Q. Cheng, Z. Du, X. Lv and Y. Chang. 2005. Performance of one newly developed forage variety Jincao 1 *(Sorghum/sudangrass)* in China. Asian J. Plant Sci. 4(5):527-529.
35. Qamar Z, Nasir IA, Jahangir GZ, Husnain T. 2014a. In-vitro Production of Cabbage and Cauliflower. Adv. life sci., 1(2): 112-118.
36. Qamar, Z, Aaliya K, Nasir IA, Farooq AM, Tabassum B, Qurban A, Ali A, Awan MF, Tariq M and Husnain T. An overview of genetic transformation of glyphosate resistant gene in *Zea mays*. *Nat Sci*. 2015;13(3): 80-90.
37. Reddy.P.R.R., G.R.M. Sankar and N.D. Das. 2004. Genotype × environment interactions in rabi sorghum. J. Maharashtra Agri. Uni. 29(1):21-24.
38. Sabbir MZ, Arshad M, Hussain B, Naveed I, Ali S, Abbasi A and Ali Q, (2014). Genotypic response of chickpea (*Cicer arietinum* L.) for resistance against gram pod borer (*Helicoverpa armigera* (Hubner))**.** Adv. life sci., 2(1): 23-30.
39. Shan MA, Tahira F, Shafique M, Hussnain M, Perveen R, *et al* (2015). Estimation of Different Biochemical Intensities in Drinking Water from Eastern Region of Lahore City. Adv. life sci., 2(3): 131-134.
40. Singh, J., B.R. Ranwah, L. Chaudhary, C. Lal, M.C. Dagla and V. Kumar. 2013. Evaluation for genetic variability, correlation and path coefficient analysis in mutant population of forage (*Sorghum bicolor* L.). The Bioscan 8(4): 1471-1476.
41. Singh, S.K., S. Anil, S. Atar, K. Vipin and K. Uttam. 2009. Studies on correlation and path analysis in forage sorghum (*Sorghum bicolor* L. Moench). Indian J. Progressive Agri. 9(1):86-91.
42. Sridhar, K., B. Gangiah and C.R. Ramesh. 2004. Genetic diversity studies in forage sorghum. Int. Sorghum and Millets Newsl. 44:3-6.
43. Tariq M, Ali Q, Khan A, Khan GA, Rashid B, Rahi MS, Ali, A, Nasir IA, Husnain T. (2014). Yield potential study of Capsicum annuum L. under the application of PGPR. Adv. life sci., 1(4): 202-207.
44. Tariq, A.S., Z. Akram, G. Shabir, M. Gulfraz, K.S. Khan, M.S. Iqbal and T. Mahmood. 2012. Character association and inheritance study of different sorghum genotypes for fodder yield and quality under irrigated and rainfed conditions. Afr. J. Biotechnol. 11(38):9189-9195.
45. Zameer M, Mahmood S, Mushtaq Z, Tabasum B, Ali Q, et al. (2015). Detection of bacterial load in drinking water samples by 16s rRNA ribotyping and RAPD analysis. Adv. Life Sci. 2(3). pp: 135-141.
46. Zaman, Q., K. Hayat, N. Hussain and A. Aziz. 2006. Fodder yield potential of sorghum varieties under D.I.Khan conditions. J. Agri. Res. 43(4): 349-354.

3/25/2015