Research Article

Understanding of Genetic Diversity among Sorghum Hybrids using Morphological Traits

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Abstract | Sorghumis the source of staple food, for human as well as feedor livestock in arid and semi-arid tropical zones of the world; now it is necessary to understand and utilizing the genetic diversity of sorghum hybrids for better crop production. In this study, crossing and selfing was done in parental lines of sorghum hybrids; such as A, B and R line system out of which 14 hybrids were finalized based on its morphological traits and statistically interpreted. Its genetic diversity is most important for exploitation of the genetic resources to develop promising hybrids. The objectives of such experimental study were to assess the best performing hybrids; on the basis of genetic diversity by applying different statistical techniques. Total 14 sorghum hybrids including standard Check, were used and data was collected on morphological traits. Cluster analysis, based on morphological traits revealed five major groups. Maximum cluster distance was observed in group I and V, while minimum cluster distance was observed in group IV and V. Highest emergence (33.7 m^{-2}) was noticed for ICSA220XICSR90, highest leaves per plant (11.68) were reported of hybrid combination ICSA220XICSR90, maximum leaf to stem ratios (0.02) was recorded for hybrid combinations ICSA233XICSR90, high stem weight (327g) was recorded for hybrid combination ICSA216XICSR-1, maximum days to 50% flowering (77) was recorded for hybrid combination ICSA88019XICSR93012,excellentcrop stand depicted by hybrid combinationICSA220XICSR55,maximum panicle length (25.23cm) was recorded for hybrids combinations ICSA254XICSR112, highest leaf area index (2.0) were observed for hybrid combination ICSA88019XICSR90, highest PH (230.0 cm) observed of hybrid combinations ICSA216XICSR-1, maximum total grain weight $panicle^{-1}$ (32.48 g) was recorded for ICSA220XICSR90, highest Harvest index (19.9) was observed for ICSA239XICSR102, maximum leaf weight (134.7g) was estimated for ICSA220XICSR55 . These were the genotypes of cytoplasm male sterility of sorghum hybrids which were selected on the basis of phenotypic data interpret by statistical analysis. Thus in the present investigation morphological traits were able to indicate the existence of a vast genetic diversity among the sorghum hybrids used providing scope for further genetic improvement in the breeding program.

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is agronomically the most important of the 25 species in the genus sorghum (Garber, 1950) which is taxonomically belongs to grass family poaceae. It is fifth major cereal crop; after maize, wheat, rice and barley. Besides being used as staple food, feed and fodder crop it provides raw industrial product; such as alcohol, starch, fiber, dextrose, syrup, biofuels and medicinal products (Ayisi *et al*., 2001). Sorghum is one of the largest cultivated cereal crop; having the ability to grow under rainfed condition and low availability of soil moisture which is not suitable for maize cultivation (FAOSTAT, 2018). In addition to its use as food and feed; also sorghum has cultivation under diverse agro-climatic condition that's why it has maximum genetic diversity (Taylor, 2003; Shen *et al*., 2018).

The total production is 57.96 million tones all over the world (FAO, 2017). In Pakistan, total production is 4.03 million metric tons with average yield 620 kg ha^{-1}, with total area under cultivation is 2.03in 2015-16 (PBS, 2016). The species S. bicolor is native to Sub-Saharan Africa; more over due to its high genetic variability and adoptability it has been spread as staple grain and green fodder in both Asia and Africa. The arrival of the crop dates back to1800 when it became economically important in the semiarid plains of the Central America (Duncan *et al*., 1991). To evaluate the genetic diversity on the basis of different morphological traits is based on conventional breeding, because these are the inexpensive procedures to assess the extent of genetic diversity among sorghum genotypes (Zongo *et al*., 1993).

Genetic diversity at allelic level was defined by weir (1996) as the two randomly selected alleles different from the population (Nguni *et al*., 2011). Although, to improve and maintain sorghum genetic diversity; it is necessary to overcome the problem of genetic erosion by increasing present cultivated area, commercial agricultural practices, industrial activities to attract the farmers and the wide adoptability of advanced cultivars (Reddy *et al*., 2006). However, being as a C4 crop with higher photosynthetic output, maximum nitrogen and water-use efficiency; sorghum is genetically as well as phenotypically suited to hot and dry agro-ecological zones of Pakistan where it is difficult to grow other food crops.

The present research experiment was composed of fourteen different sorghum Hybrids including standard check. Quantitative traits were observed to assess the various level of genetic diversity of sorghum hybrids under investigated on the basis of morphological or phenotypic traits. Because genetic diversity is based on wide adoptability and acclimatization of the crop and hence is very important for breeders to make further crosses to fulfill the required demand.

Materials and Methods

Plant material

The plant material comprised of 14 sorghum hybrids, among which eight new combinations and six privet sector sorghum hybrids including one standard sorghum check. The parents of these sorghum hybrids were introduced from international crop research institute in the semi arid dry tropical (ICRISAT) India.

The fourteen sorghum materials were planted at NARC in April 2019, under randomized complete block design with three replications. The parents germplasm of above sorghum hybrids such as cytoplasm male sterile (A) line, Maintainer (B) line and restorer (R) line of the above sorghum hybrids were introduced from ICRISAT (International crop research institute in the semi arid tropical). The purpose was to select the best performing hybrid combination on the basis of phenotypes. Each plot consisted of two rows of four meter length with a row to row distance of 75 cm and plant to plant spacing of 15 cm. Nitrogen and phosphorus fertilizers were applied @ 90-45 kg ha^{-1} as urea and DAP at the time of sowing respectively. To maintain the desired plant population thinning was done manually. Hoeing and weeding were carried out manually twice during the cropping season. Five randomly plants were selected in each replication and observations were recorded on 12 quantitative traits at maturity except days to 50% flowering. Data on Emergence (m^{-2}), Leaves $Plant^{-1}$, Leaf Stem Ratios (LSR), Stem Weight (g), Days to 50% Flowering, Crop Stand , Panicle Length (cm), Leaf Area Index (LAI), Plant Height (cm), Grain Weight $Panicle^{-1}$ (g), Harvest Index , Leaf Weight (g)were recorded from each plot in three replications. The data recorded were analyzed using analysis of variance technique.

Statistical analysis

Before analysis, the data was standardized to zero mean and unit variance; the reason is various traits

were recorded in different unit scale. The analysis of variance (ANOVA), heat map and cluster analysis were performed using Microsoft excel 2003.

Result and Discussion

Statistical analysis of variance of the data using randomized complete block design, depicted significant variation for all 12 morphological traits of 14 sorghum hybrids. High level of genetic diversity among the sorghum accessions. The fourteen genotypes were grouped into five clusters on the basis of average linkage and dendrogramas split at a distance of 3.5 are presented in Figure 1. The cluster analysis sequestrates genotypes into different groups which depict high homogeneity inside a cluster and high heterogeneity between clusters. The cluster I, II, III and IV having one genotype each viz., ICSA88019X-ICSR102, ICSA434XICSR114, ICSA88019X-ICSR93012 and ICSA254XICSR112 respectively. The cluster V composed of ten genotypes which are ICSA220XICSR55, ICSA735XICSR93019, ICSA216XICSR-1, ICSA220XICSR90, and check sorghum, ICSA712xICSR93012, ICSA257x-ICSR714, ICSA88019XICSR114, ICSA88019X-ICSR90, ICSA239XICSR102 and ICSA233X-ICSR90. Distribution pattern of all the genotypes into five clusters group depict the existence of considerable genetics diversity among the genotypes for most of the traits under experimental study. The clustering pattern depicted that there was significant genotypic diversity among the sorghum genotypes tested that indicated the presence of excellent opportunity to bring about improvement through crossing genotypes from different clusters and assemble desirable traits. Thus, cluster analysis and in this present set of the experiment provided facilitation in the classification of genotypes and identification of the subset of genotypes having quantitative difference between yield and yield associated traits. It is quite clear from cluster analysis to hybridize in different cluster groups for the improvement of grain and fodder yield and its associated which will be helpful in designing breeding program.

Cluster analysis

Agglomerative hierarchical clustering of the data interpreted on the basis ofEuclidean distance matrix by utilizing the Ward's linkage protocol and presented in Figure 1. The total 14 sorghum hybrids which formed five cluster groups of morphological characteristics. The size of the cluster group is ranged from 1 to 3, hence it is clear that the pattern of cluster variability depicting us the genetic diversity among sorghum hybrids.

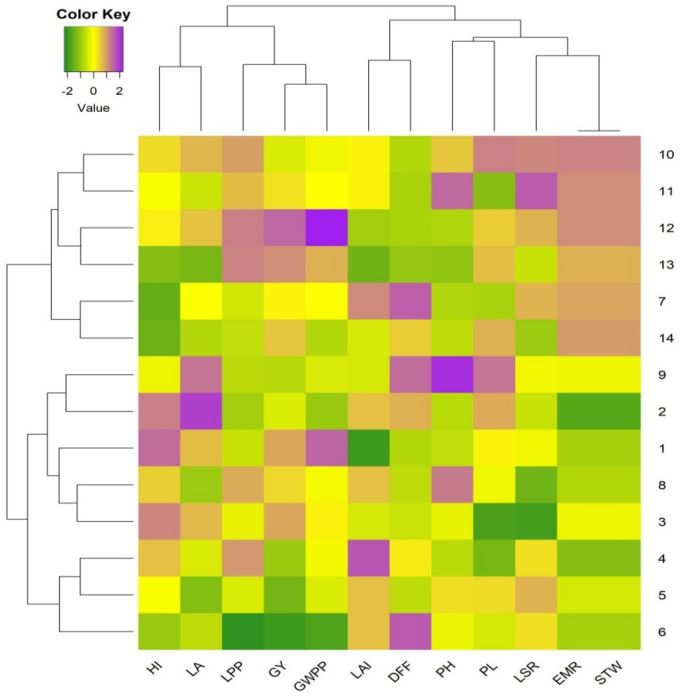

Figure 1: *Cluster analysis and Heat map of 14 sorghum hybrids based on 12 morphological traits.*

Emergence (m^{-2})

Poor seed emergence is mainly due to hard soil crust and small insect that digging for seed, such problem can be eradicated away by resistance genotypes to insect and strong penetrance ability. Variation in days to emergence (m^{-2}) of various sorghum hybrids combinations is due to genetic difference and as well as changing climates. Analysis of the data shows that emergence (m^{-2}) is non-significantly affected by various sorghum hybrids. Its mean data shows the greatest emergence (33.7 m^{-2}) are noticed for ICSA220X-ICSR90 whereas smallest amount of emergence (19.3m^{-2}) were practiced of ICSA712XICSR93012. Mean data for check vs. rest shows that maximum emergence (33.7 $^{-2}$) was recorded for rest but least emergence (28.31^{-2}) was recorded for check. In our results 4 sorghum hybrids produced more emergence (m^{-2}) than check whilst9 sorghum hybrids was shown less emergence (m^{-2}) than check. The differences in emergence (m^{-2}) aredue to different level of genetic diversity among sorghum hybrid combinations and their variety of cross compatibility with each other Chohan *et al.* (2003) also reported is similarity for emergence among different germplasms of sorghum.

Leaves Plant^{-1}

Leaves plant^{-1}is associated trait of green fodder yield, more number of leaves will high photosynthetic product also enhance fodder yield. Various sorghum hybrid combinations was non-significant. Mean data shows that highest leaves per plant (11.68) were reported of hybrid combination ICSA220XICSR90 but lowest number is for LP (8.43) were mentioned from hybrid combination ICSA233XICSR90. Mean data for check vs. rest shows that number of leaf (10.38plant^{-1}) was recorded for rest while minimum number of leaf plant^{-1} (11.36) was recorded for check. In our results six sorghum hybrids produced more leaf area index than check while seven sorghum hybrids was shown less leaf area index than check. The differences in number of leaf plant^{-1} are due to various level of genetic diversity among sorghum hybrid combinations and their various cross compatibility with each other. Naeem *et al*. (2002) also reported variation for number of leaves per plant among different cultivars of sorghum.

Leaf Stem Ratios (LSR)

Data recorded on leave to stem ratios of different sorghum hybrids combinations. Statistical analysis of the data revealed that leaf to stem ratios is significantly affected by under experimental sorghum hybrid combinations. Mean data shows that maximum leaf to stem ratios (0.02) was recorded for hybrid combinations ICSA233XICSR90, ICSA239XICSR102, ICSA88019XICSR90, ICSA93012XICSR93019, ICSA712XICSR93012, CSA254XICSR112 and ICSA220XICSR90. Mean data for check JS200 and remaining hybrids shows that leaf to stem ratios (0.01) was recorded for rest while minimum number of leaf to stem ratios (0.01) was recorded for check JS200. In our results seven sorghum hybrids produced more leaf to stem ratios than check while six sorghum hybrids was shown less leaf to stem ratios than check. The differences in leaf to stem ratios are due to various Level of genetic diversity among sorghum hybrid combinations and their various cross compatibility with each other. Same results were supported by (Mitchell *et al*., 2001).

Stem Weight (g)

Phenotypically observed data of Stem weight (g) related to various sorghum hybrids combinations. Analysis of such data is highly significantly influenced by various sorghum hybrid. Average data revealed that high stem weight (327g) of hybrid combination-ICSA216XICSR-1 was recorded, while minimum stem weight (211g) for ICSA220XICSR90 of hybrid combination. Mean data for check vs. rest shows that stem weight (270g) were reported for all whereas least SY (283g) was noticed of check. In this calculation three sorghum hybrids produced more stem weight than check whereas ten sorghum hybrids was shown less stem weight than check. The differences in stem weight are due to various level of genetic diversity among sorghum hybrid combinations and their various cross compatibility with each other. Our results were supported by the same findings of (Goldsworthy, 1970).

Days to 50% Flowering

Data regarding days to 50% flowering is a trait to bring uniformity in maturity for easy mechanical harvesting of all sorghum hybrids combinations. Statistical analysis of the data shows that Days to 50% flowering was highly significantly affected by various sorghum hybrid combinations. Mean data shows those maximum days to 50% flowering (77) was recorded for hybrid ICSA88019XICSR93012 while minimum days to 50% flowering (62) was recorded for hybrid combinations ICSA88019XICSR93012. Mean data for check vs. rest shows that DF (69) was reported for rest while minimum Days to 50% flowering (65) was recorded for check JS200. Over all data shows that 3.84 % more Days to 50% flowering was noted in hybrid combinations as compared to check. In our results eight sorghum hybrids produced increase DF over check while five sorghum hybrids was shown less days to 50% flowering compare to check JS200. Differences in Days to heading is due to various level of genetic diversity among sorghum hybrid combinations and their various cross compatibility with each other. Same results were fined by (Mitchell, 2001).

Crop Stand

Crop stand was visually observed and data were collected of various sorghum hybrids combinations presented in Table 2 and then manually rearranged. The crops stand of various hybrids combinations were categorized in four groups *i.e*. Excellent, very good, good and satisfactory. Crop stand of data shows that three sorghum hybrids (ICSA233XICSR90, ICSA220X-ICSR55, ICSA712XICSR93012) showed excellent crops stand in filed, two hybrids (ICSA88019X-ICSR93012, ICSA257XICSR114) showed very good crop stand in field, three hybrids combination (ICSA239XICSR102, ICSA254XICSR112,

Table 1: *Maximum average Mean data of different traits of various sorghum hybrids.*

GENOTYPES	EMR	LA	LAI	LPP	LSR	STW	DFF	PH	PL	GWPP	GY	HI
ICSA233XICSR90	28	2043.7	1.3	9.91	0.21	28	63.7	120.4	21.7	29.2	1151.7	20.2
ICSA239XICSR102	25.7	2531.0	1.8	9.55	0.20	25.7	72.7	118.8	23.7	17.3	954.0	19.9
ICSA434XICSR114	30	2070.2	1.6	10.23	0.17	30	65	133.3	16.5	22.7	1152.3	19.8
ICSA88019XICSR90	27	1647.2	2.0	11.45	0.22	27	69.3	118.7	17.7	21.6	847.0	18.9
ICSA257XICSR114	29.3	1310.9	1.8	10.09	0.23	29.3	64.3	151.5	22.4	20.5	783.0	17.9
ICSA88019XICSR93012	28	1537.3	1.8	8.43	0.22	28	77.7	134.7	20.3	13.9	694.3	16.4
ICSA735XICS93019	33	1791.0	1.9	10.01	0.23	33	77.3	115.7	19.1	22.0	1026.3	15.6
ICSA712XICSR93012	28.3	1411.1	1.8	11.25	0.18	28.3	64.3	183.1	21.0	21.7	1073.7	18.7
ICSA254XICSR112	30	2327.7	1.6	9.80	0.21	30	76.7	207.3	25.2	20.3	893.7	17.7
Check of sorghum	34	2075.2	1.7	11.36	0.24	34	63.7	158.7	24.8	21.5	952.0	18.5
ICSA216XICSR-1	33.7	1589.1	1.7	11.08	0.25	33.7	63.3	188.1	18.1	22.1	1059.7	17.9
ICSA220XICSR90	33.7	2024.9	1.5	11.68	0.23	33.7	63.3	115.5	22.8	32.5	1257.7	18.2
ICSA88019XICSR93012	32.7	1271.3	1.4	11.64	0.2	32.7	62	104.5	23.2	25.7	1191.7	16.1
ICSA220XICSR55	33.3	1497.5	1.6	9.84	0.19	33.3	71	119.9	23.5	18.6	1101.7	15.7

Table 2: *Crops stand of sorghum hybrids as affected by genotypes combinations.*

S. No	Genotypes	Crops Stand
1	ICSA233XICSR90	Excellent
2	ICSA239XICSR102	Good
3	ICSA434XICSR114	Satisfactory
4	ICSA88019XICSR90	Satisfactory
5	ICSA257XICSR114	Very Good
6	ICSA88019XICSR93012	Satisfactory
7	ICSA735XICS93019	Satisfactory
8	ICSA712XICSR93012	Excellent
9	ICSA254XICSR112	Good
10	Check of sorghum	Good
11	ICSA216XICSR-1	Good
12	ICSA220XICSR90	Satisfactory
13	ICSA88019XICSR93012	Very Good
14	ICSA220XICSR55	Excellent

ICSA216XICSR-1) performed good and five showed satisfactory (ICSA434XICSR114, ICSA88019X-ICSR90, ICSA88019XICSR93012, ICSA735X-ICS93019, ICSA220XICSR90) performed in field. The check hybrid showed good crops stand in field. In the same way, was noting the sorghum hybrids.

Panicle Length (cm)

Data regarding panicle length (cm) of various sorghum hybrids combinations. Statistic of Data shows that panicle length (cm) highly influenced by various sorghum hybrid combinations which was significantly analyzed. Mean data shows that maximum panicle length (25.23cm) was recorded for hybrids combinations ICSA254XICSR112 while minimum panicle length (17.73cm) was recorded for hybrids combinations ICSA88019XICSR90. Mean data for check vs. rest shows the largest PL (21.17cm) are observed from rest while minimum PL (24.79cm) also reported for check. In our results one hybrid produced more panicle length (cm) than check while eleven sorghum hybrids produced less panicle length (cm) than check-JS2000. The variation in panicle length (cm) is due to genetic variability of sorghum hybrid combinations and low temperature with each other. Craufurd *et al.* (1998) was noted same results for panicle length.

Leaf Area Index (LAI)

Data regarding leaf area index of different sorghum hybrids combinations. It is incurred from statistical analysis of the data that leaf area index is highly significantly affected by diverse sorghum hybrid combinations. Mean data indicate that highest leaf area index (2.0) were observed of hybrid combination ICSA88019XICSR90 whereas lowest LAI (1.3) were mentioned for hybrid combination ICSA233X-ICSR90. Mean data for check vs. rest revealed that greatest LA index (1.68) were reported from rest, although smallest amount leaf area index (1.7) was recorded for check. The rest of the data observed that 1% increase in leaf area index was noted for hybrid combinations over check. In our above results six sorghum hybrids formed more leaf area index than check while seven sorghum hybrids was revealed low leaf area index than check JS2000. The variation in leaf area index is due to various level of genetic diversity

among sorghum hybrid combinations and their various cross compatibility with each other Ong (1984) and Lafarge and Hammer (2002) they were also find out differences for leaf area index among diverse varieties of sorghum.

Plant Height (cm)

The data given in Table 1 showed that sorghum plant height was significantly affected by the planting techniques. The sorghum sown alone by broadcast method produced taller plants and was significantly different from all The maximum plant height in case of sole crop of forage sorghum may be due to better penetration of light, circulation of air and comparatively more nutritional area available to sole corp.

Statistical analysis of the data shows that plant height (cm) was highly significantly affected by a variety of sorghum hybrid combinations. Mean data revealed the highest PH (230.0 cm) observed of hybrid combinations ICSA216XICSR-1 while lowest PH (103.80 cm) observed to hybrid combinations ICSA220X-ICSR90.Average data for check vs. rest depicted that Plant Height (147.09cm) were reported for rest at the same time lowest plant height (130cm) was recorded for check JS200. Over all data shows that 11.62% more plant height (cm) was noted in hybrid combinations as compared to check. In our results eight sorghum hybrids produced more plant height (cm) than check while five sorghum hybrids was shown less plant height (cm) than check and also the strong significant results were reported by Chohan*et al.* (2003), they also studied PH potential for different varieties of sorghum.

Grain Weight Panicle^{-1} (g)

The genotypes of sorghum hybrids data about grain weightpanicle^{-1} (g) of various sorghum hybrids combination. The present data revealed that Grain weight (g panicle^{-1}) was non-significantly influenced by various sorghum hybrid combinations. Mean data shows that maximum total grain weight panicle^{-1} (32.48 g) was recorded for ICSA220XICSR90 while minimum total grain weight (16.43g panicle^{-1}) was recorded for ICSA239XICSR102. Mean data for check vs. rest shows that maximum Total Grain weight (21.65g panicle-1) were recorded for rest while minimum Total Grain weight (14.96g panicle-1) was recorded for check JS200. Over all data shows that 30.95% more Total Grain weight (21.65g panicle^{-1}) was noted in hybrid combinations as compared to check. In our results all hybrid produced more total Grain weight (g panicle^{-1}) than check. The variation in Total Grain weight (g panicle^{-1}) is due to genetic variability of sorghum hybrid combinations and their cross compatibility with each other. Similar results were reported by (Zaman *et al.*, 2005).

Harvest Index

The net grain yield divided by total biological weight give us HI, such data was recorded and statistically calculated. Statistical analysis of the data shows that Harvest index was highly significantly affected by various sorghum hybrid combinations. Mean data shows that highest Harvest index (19.9) was observed for ICSA239XICSR102 while lowest amount of HI (15.2) were observedofICSA216XICSR^{-1}. Mean data for check and hybrids shows of maximum HI (17.99) were revealed from rest while lowest Harvest index (18.5) also reported to check JS200. In our results four sorghum hybrids produced more Harvest index than check while nine sorghum hybrids produced less over sorghum check. The variation in Harvest index is due to heritable variation of sorghum hybrid combinations and their out cross compatibility with each other. Hammer and Broad (2003) studied research experiment on genotype and environment interaction on dynamics of harvest index during grain filling (at maturity) in sorghum and found similar findings.

Leaf Weight (g)

Improvement of green fodder yield is based on taking data regarding leaf weight (g) of various sorghum hybrids combinations presented in Figure 1. Statistical study of the data shows, LW (g) significantly affect by different sorghum hybrid combinations. Mean data shows that maximum leaf weight (134.7g) was estimated for ICSA220XICSR55 while least amount of leaf weight (76g) was recorded for ICSA88019X-ICSR93012. Mean data for check JS200 vs. rest shows that maximum leaf weight (g) also reported of all other although lowest LW (g) were practiced of check JS200. In our results four sorghum hybrids produced more leaf weight (g) than check JS200 while nine sorghum hybrids produced less than sorghum check. The variation in leaf weight (g) is due to genetic variability of sorghum hybrid combinations and their cross compatibility with each other. Sujay *et al.* (2012) found same relationship in sorghum genotypes.

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Conclusions and Recommendations

The cytoplasm male sterility was developed by back cross breeding method in different sorghum accessions from which fourteen dual purposes hybrids were developed. The present experiment was composed of fourteen sorghum hybrids for grain and fodder having high genetic diversity. The quantitative data was collected and then analyzed. After statistical analysis it is concluded that three hybrids depicted hybrid vigorgenetic diversity and performed better than the rest of the hybrids such asICSA216XICSR-1its mean data revealed the highest plant height (230.0 cm) and stem weight (327g) while the lowest PH (30cm) was recorded for check JS-2000 and minimum stem weight (211g) for hybrid combination ICSA220X-ICSR90. Hybrid combination CSA220XICSR55 highest panicle length (25.23cm) while minimum is (24.79cm) for check. maximum grain weight panicle^{-1} (32.48 g) was recorded for ICSA220XICSR90, while lowest (16.43gm) GW was recorded for ICSA239X-ICSR102 due to hybrids 30.95% increase is occurred in grain weight in hybrid in comparison to checkit should be screen out in the future breeding program. Maintaining and use of such sorghum hybrids and its parental lines in future will be of immense help to the breeders, public and private sectors concerned with sorghum breeding research.

Novelty Statement

The present experiment can overcome the problem of fodder forages shortage during lean period and increase the yield of fodder and livestock production.

Author's Contribution

All authors contributed equally in the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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