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GENETIC ANALYSIS OF FORAGE QUALITY TRAITS IN SORGHUM-SUDANGRASS HYBRIDS UNDER WATER STRESS

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ABSTRACT

Forage as a feed for livestock in emergency period has always been a dire need of the time. Field experiments were conducted during 2007 and 2008 to estimate the specific and general combining ability effects for forage quality traits in sorghum-sudangrass hybrids by using ten lines of sorghum and five testers of sudangrass using line and tester mating fashion under normal as well as water stress conditions. Generally reduction has been observed in all forage quality components except crude protein and nitrogen free extracts under water stress conditions. The average values were recorded as 31.66% for sugar contents; 11.01% for leaf to stem ratio; 19.23% for crude fibre; 22.69% and 3.37% for ether extract and total ash respectively. While the increase percentage best general combiner genotype was 8614 for leaf to stem ratio, crude protein, nitrogen free extracts and ether extracts under normal as well as water stress conditions. While the best female parent was the genotype 80364 for sugar contents, leaf to stem ratio and crude protein contents. It was concluded that 8614 and 80364 genotypes may be used for the development of good quality sorghum-sudangrass forage hybrids.

Keywords: Forage, quality, sorghum, sudangrass, water stress, GCA, SCA.

INTRODUCTION

About 800 million people living in developing countries (20 percent of the population) are undernourished. In addition, world food production should increase by more than 75 percent in the next 30 years to feed about 8000 million people by 2025 (FAO, 2007). In developing countries availability of food is 2660 kcals/day to each person as compare to developed countries where per person food availability is 3280 kcals/day (FAO, 2009-10). Similarly availability of meat in developing countries is 28.9kg/peron/year compared to 80kg/person/year in developed countries. In spite of possessing 76 % of the total animal heads of the world, developing countries contribute only 57% to the total world's meat production. Whereas developed countries contain only 24% of the total animal heads and they contribute 43% towards total world's meat production (Sial, 1990). The livestock of developing countries is producing below than optimum potential because of unavailability of fodder in terms of quality as well as quantity. According to an estimate demand for milk and meat will be doubled till 2020 (Delgado *et al.,* 1999). Furthermore, epidemic outbreak of bird flu in the recent years has raised question about the use of poultry meat. This is contributing 81.4 million animal numbers towards meat production and has emerged as good subsituent of beef and mutton (Anonymous, 2007). Therefore, need of beef and mutton is increased which directly depends upon the availability of nutritious fodder over a longer period of time. But the required quantity of quality green fodder is not available throughout the year. So, Government of Pakistan is spending more than Rs. 769 million on the import of milk and milk products (Economic Survey of Pakistan, 2007). Although, sweet sorghums have widely used for the production of forage and silage for animal feed besides use as a grain and energy crop; its leaves are broader having high palatability and provide green fodder over a longer period of time but it is not a multi-tillering and multicut. On the other hand, sudangrass is a multicut and multi-tillering fodder but its leaves are narrow having low palatability. Therefore, it is needed to converge the favorable characters of sorghum and sudangrass to develop multicut and multi-tillering producing palatable green fodder.

Sorghum-Sudangrass hybrids offer a solution to producing forage when other fodder crops are not available and emergency occurs. The water requirements of sorghum-sudangrass hybrids are the same as corn. However there is dire need of identifying sorghum-sudan grass hybrids, which are water stress tolerant. Although a lot has been talked about the performance of sorghum-sudangrass hybrids under normal conditions but unfortunately no information is available on these hybrids under water stress conditions. Sorghum-Sudangrass hybrids have the advantage of 2-3 times cutting during the season and can easily be stored as either chopped silage or raped bale silage and green chop. So, present research work was conducted to achieve the desired objectives (multicut and multi-tillering fodder) especially under water stress conditions because of the existing scenario of water deficiency all over the world. It is an urgent requirement very necessary to develop drought tolerant varieties along with high yield and quality. Thus the research work is unique and novel in the sense that previously no work has been done on selection of parents for better forage yield under water stress conditions in sorghum-sudangrass hybrids.

Genetic improvement of any genotype directly depends upon the availability of genetic variations. And the selection from those useful genetic variations helps us in selecting appropriate genotypes and their specific combinations on the basis of combining ability. The success to identify parents that will combine well and produce productive progenies mainly depends on the gene action that controls the trait under improvement (Tabassum *et al*., 2007). Information on quantitative characters in terms of general and specific combining ability effects for a set of parents can be obtained from line x tester analysis. Combining ability studies provide the information on genetic mechanism controlling quantitative traits and enable us to select suitable parents. Estimate of general (GCA) to specific combining ability (SCA) variance ratio is useful to evaluate the variability either due to additive or non-additive or both types of gene actions (Farshadfar *et al.,* 2002). The objective of the present studies was to select the best parents under water stress conditions and then utilized them in interspecific hybridization programme to produce sorghum-sudangrass hybrids that could provide palatable green fodder over longer period of time. Ultimately improve the health of livestock and their contribution to meat and milk production to reduce the import cost. So, present research work was conducted to achieve the desired objectives (multicut and multi-tillering fodder) especially under water stress conditions because in the existing scenario of water deficiency all over the world, it is very necessary to develop drought tolerant varieties along with high yield and quality. That research work was unique and novel in that sense that previously no research work has done on selection of parents for better forage quality under water stress conditions in sorghum-sudangrass hybrids. This is a step forward in identifying the best hybrid combinations among these two species which will be relatively high yielding as well as more palatable for the livestock in comparison with either of the species alone.

MATERIALS AND METHODS

Water analysis: The irrigation water applied to the plants in field was fit for irrigation. It contains traces of nitrogen, 0.092 mg/l phosphorus, 9.00 mg/l potash, 3.00 meq/l $CaCO_3$+$CaHCO_3$, 2.6 meq/l Ca+Mg, 0.4 meq/l RSC, 0.4 m.mol EC, 260 mg/l TSS and 7.00 mg/l P.H.

Physical and chemical characteristics of soil: The soil in the field was loamy, (depth 15-30cm) with average electric conductivity 1.14 dSm^{-1}, pH 7.8, organic matter content 0.53%, saturation 31.25%, total nitrogen 0.035; available phosphorus 7.25 ppm; and available potassium 155 ppm.

Fertilization, irrigation and insecticide: Fertilizer (N-P) was applied at the rate of 100-75 and 75–75 kg/ha. Irrigation interval varied depending upon the requirements in control block. Whereas, under water stress block irrigation was applied only once just for germination. Crop was sprayed with a suitable insecticide to prevent economic injury due to insect pests.

Field evaluation: 10 sorghum and 5 sudangrass accessions were crossed using sorghum as female lines and sudangrass as male in a line x tester mating design in the field in 2007 to generate the breeding material (Hybrid seed). All the selected parents and the hybrids (F_1) were evaluated under control as well as under water stress for different forage quality parameters along with local varieties (Hegari and JS-2002) as standard for genetic analysis; evaluated in the field in Aug 2008 for forage quality components. Seeds of selected parents and F_1 hybrids were grown in research field in 2008 keeping plant to plant and row to row distances of 15cm and 75cm, respectively. The experiment was laid out in a randomized complete block design with three replications under control as well as under water stress. At the emergence of heads five plants of each genotype were marked randomly in each replication and data were recorded for sugar contents and leaf to stem ratio. Detail methodology for different parameters is given below.

Leaves and stems of five marked plants were collected and weighed separately for each genotype in each replication and then leaf to stem ratio was calculated as Leaf to stem ratio = weight of the leaves/weight of stem Syrup was extracted from randomly marked five plants from each replication and their brix value was calculated with the help of refractometer. Then average value was calculated separately from control and stress treatment. While fresh plant samples of the parents, hybrids and standard varieties were collected from each replication and evaluated for the remaining forage quality parameters (crude protein, crude fibre, nitrogen free extracts, ether extract and total ash). The plant samples were chopped mixed thoroughly and ground to fine powder and was divided into three groups for estimations of the following quality components by using proximate analysis (AOAC, 1996).

Crude Protein (%)

Kjeldahl method:

i) Digestion: 1-2 g of oven dried sample is placed in a 500 ml long neck Pyrex glass kjeldahl flask. 25-30 ml of concentrated sulphuric acid is added in the weighed sample in the flask. 5 g of digestion mixture containing K_2SO_4, $CuSO_4$ and $FeSO_4$ (100, 10 and 5 parts by weight, respectively) is added and the mixture is boiled until it becomes light green or almost colorless and then for about an hour longer. Too strong heating is avoided at this point, to prevent loss of acid. The digestion mixture has many functions during digestion. K_2SO_4 raises the boiling point of acid, whereas, $CuSO_4$ serves as catalyst and $FeSO_4$ helps in avoiding any bumping if present.

ii) Distillation: When oxidation of the sample is complete, the flask is allowed to cool and dilute the contents with ammonia free water in 250 ml volumetric flask. 10 ml of this diluted solution is put in micro kjeldahl distillation apparatus and concentrated solution of NaOH is added in excess. A receiving flask containing 10 ml of 2% boric acid solution containing a few drops of methyl red indicator is placed in such a way that the delivery tube after coming through condenser dips into it. The steam generator plug is opened and let the content of the distillation tube be boiled until whole ammonia is liberated. Partly neutralized 2% boric acid solution in the receiving flask is titrated by means of N/10 H_2SO_4 acid and calculates the amount of H_2SO_4 neutralized by NH_3.

$$\text{Nitrogen \%} = \frac{\text{ml N/10 } H_2SO_4 \text{ neutralized by } NH_3 \times 0.0014 \times \text{total vol. made (250 ml)}}{\text{Weight of sample} \times \text{ml of dil. digested material distilled}} \times 100$$

Crude protein = N % x 6.25.

Crude Fibre (%) : After the removal of water and fatty material from a given sample of feed, it was boiled with weak acid (200 ml of 1.25% H_2SO_4) and then with weak alkali (200 ml 1.25% NaOH) for the same time. This procedure removed the proteins, sugars and starches leaving a residue comprising most of the cellulose and other complex polysaccharides along with some mineral material. The loss on ignition of this residue was taken as the crude fibre. Crude fibre consisted primarily of cellulose and other complex polysaccharides.
Crude fibre % =100{(Weight of dried residue – weight of ash)/Weight of moisture free sample}

Nitrogen Free Extract (NFE): *NFE % = 100 - (% crude protein + % ether extract + % crude fibre + % ash)*

Ether Extract (%): Thimble was fitted in Soxhlet apparatus having cold water circulation arrangement at the top (condenser). The water was heated to evaporate the ether. The ether from receiver was transferred to glass dish and the ether was evaporated in an oven at low temperature. The dish was cooled in desiccators and weighed quickly to calculate the weight of residue (ether extract).
Ether extract % = 100 (Weight of residue / Weight of the sample)

Total Ash (%): The mineral elements as a group were determined in a sample by burning off the organic matter and weighing the residue, which was called ash.
Ash % = 100 (Weight of ash / Weight of sample)

Statistical analysis: The data recorded were subjected to analysis of variance (Steel *et al*. 1997) for the mentioned characteristics to determine the significance of differences among hybrids and parents. Estimates of combining ability were computed by using "Line x Tester" analysis as outlined by Kempthorne (1957). Information about general combining ability (GCA), specific combining ability (SCA) was also sorted out.

RESULTS

It is persuaded from Table 1 and Table 2 that significant differences for SC, LSR, CP, CF, NFE, EE and TA were shown among the treatments, parents, hybrids, parents, line x tester under control as well as under water stress. These significant differences among accessions, parents for all forage quality components indicated genetic variations among the genotypes. It was observed that water stress reduced the SC in sorghum, sudangrass and their hybrids. Average reduction in SC under water stress was 31.66%. Maximum reduction in SC in parents was 32.06% (80204), in testers was 47.93% (8614) and in hybrids was 50.93% (80364 x Line 7). Similarly, LSR of the parents and crosses decreased as a result of water stress. Average reduction in LSR under water stress was 11.01%. Maximum reduction in LSR in parents was 27.97% (80158) in tester was 16.57% (8614) and in crosses was 30.11% (80114 x Succro). While, average increase in CP under water stress was 15.58%. Highest increase in CP in parents was 12.4% (80353), in testers was 11.33% (Succro). On the other hand highest increase in CP was recorded in hybrids 80365 x 958 (27.68%) under water stress conditions. The percent contents of CF of the parents and crosses also decreased as a result of water stress as compare to normal water conditions. Average reduction in CF under water stress was 19.23%. Maximum reduction in CF in lines was 27.83% (80174), in testers was 22.60% (958). Maximum reduction in CF was observed in hybrids 80077 x 4158 (29.73%) under water stress conditions. Just similar to CP, NFE of the parents and crosses also increased as a result of water stress as compare to control water conditions. Average increase in NFE under water stress was 12.42%. Maximum increase in NFE was 19.17% in hybrids (80204 x 8614). EE of the parents and crosses decreased as a result of water stress as compare to normal water conditions. Average reduction in EE due to water stress was 22.69%. Maximum reduction in EE in lines was 39.88% (80376), in testers Line 7(13.23%) and in hybrids 80174 x 8614 (36.17%). Similarly, TA of the parents and crosses decreased as a result of water stress as compare to control water conditions. Average reduction in TA due to water stress was 3.37%. Maximum reduction in TA in parents was 40.00% in lines (80376), in testers was 13.19%. (Line 7) and in hybrids was 36.36% (80158 x Succro).

General combining ability effects: Table 3 and Table 4 indicated GCA effects for lines and testers for forage quality components under control and water stress conditions. Among testers 958 and 337 showed positive and significant GCA effects for sugar contents under control conditions, while 958 and Succro was best under water stress. Similarly 8614 showed positive and significant GCA for leaf to stem ratio under both conditions. For crude protein GCA effects Line 7 and 8614 performed excellent under both conditions. In addition to this Line 7 also showed positive and highest GCA effects for crude fibre under control as well as water stress. The tester 8614 gave positive GCA effects for nitrogen free extracts and ether extracts under both situations. No one gave significant GCA for total ash under control conditions but 958 and 8614 gave significant GCA effects under water stress. Among lines 80364 gave highest positive and significant GCA effects for sugar contents, leaf to stem ratio and crude protein and 80199 for crude fibre under control and water stress conditions. While 80158 showed significant GCA effects for nitrogen free extracts and ether extracts under normal and for total ash under water stress. And 80376 for total ash under control conditions.

Specific combining ability effects: Variable magnitude and direction of SCA effects of hybrids for forage quality components is evident from Table 5 and Table 6 under control as well as water stress conditions. The highest value of SCA effects was recorded for 80319 x Succro and 80353 x Line 7 for sugar contents under control conditions. While for leaf to stem ratio the best specific cross along with highest SCA effects was 80199 x 958, 80365 x 337 and 80319 x 8614. For crude protein, crude fibre and nitrogen free extracts the best specific crosses with highest SCA effects were 80114 x Succro, 80199 x Succro and 80114 x 337 respectively under control conditions. The hybrid 80376 x 337 and 80214 x 958 showed highest positive and significant SCA effects for ether extracts and total ash under control conditions.

Table 1. Mean squares from analysis of variance for forage quality components under control conditions

S.O.V	DF	SC	LSR	CP	EE	CF	NFE	TA
Replications	2	0.02 ^{NS}	0.002**	0.01*	0.071^{NS}	0.10*	0.09 ^{NS}	0.00007
Entries	64	38.61**	0.04**	1.47**	0.04**	3.96**	10.08**	0.04
Parents	14	79.80**	0.03**	3.79**	0.06**	0.92**	12.71**	0.06
Parents vs. Hybrids	1	1162.40**	0.03**	7.08**	0.52**	10.45**	167.47**	0.52
Hybrids	49	3.91**	0.04**	0.70**	0.02**	4.70**	6.12**	0.02
Lines	9	1.22**	0.01**	0.13**	0.02**	0.89**	2.37**	0.02
Testers	4	0.41**	0.01**	0.50**	0.01**	1.20**	4.99**	0.01
Lines x Testers	36	4.98**	0.05**	0.86**	0.03**	6.04**	7.18**	0.03
Error	128	0.04	0.0002	0.01	0.03	0.03	0.04	0.0003

* = Significant at 0.05% probability level, ** = Significant at 0.01% probability level, SOV = Source Of variation, DF = Degree of freedom, SC = Sugar contents, LSR = Leaf to stem ratio, CP = Crude Protein, EE = Ether Extract, CF = Crude Fibre, NFE = Nitrogen free extract and TA=Total ash.

Table 2. Mean squares from analysis of variance for forage quality components under water stress

S.O.V	DF	SC	LSR	CP	EE	EE	CF	NFE	TA
Replications	2	0.02 ^{NS}	0.07**	0.0001	0.003*	0.003*	0.06 ^{NS}	0.07 ^{NS}	0.004 ^{NS}
Entries	64	24.09**	0.03**	2.38	0.03**	0.03**	8.31**	14.60**	1.23**
Parents	14	61.32**	0.03**	4.98	0.03**	0.03**	2.17**	6.02**	1.73**
Parents vs. Hybrids	1	345.33**	0.06**	44.47	0.32**	0.32**	68.89**	392.04**	40.02**
Hybrids	49	6.91**	0.04**	0.77	0.02**	0.02**	8.83**	9.35**	0.30**
Lines	9	2.32**	0.01**	0.46	0.02**	0.02**	0.87**	1.94**	1.05**
Testers	4	0.70**	0.33**	0.44	0.01**	0.01**	1.41**	2.86**	0.52**
Lines x Testers	36	8.75**	0.05**	0.89	0.02**	0.02**	11.64	11.92**	0.08**
Error	128	0.02	0.02	0.0006	0.0007	0.0007	0.06	0.08	0.002

* = Significant at 0.05% probability level, ** = Significant at 0.01% probability level, SOV = Source Of variation, DF = Degree of freedom, SC = Sugar contents, LSR = Leaf to stem ratio, CP = Crude Protein, EE = Ether Extract, CF = Crude Fibre, NFE = Nitrogen free extract and TA=Total ash.

Table 3. General combining ability effects of lines and testers for various forage quality components under control conditions

	Sugar contents	Leaf to stem Ratio	Crude protein	Crude fibre	Nitrogen free extract	Ether extract	Total ash
Testers							
958	0.31*	-0.003	-0.08	-0.11	0.03	0.01*	0.31
Succro	-0.39	-0.063	-0.19	-0.54	0.18	0.005	0.17
337	0.46*	-0.02	-0.19	-0.05	-0.13	-0.07	0.03
Line 7	-0.12	-0.04	0.17*	0.77*	-0.33	0.004	-0.29
8614	-0.26	0.13*	0.30*	-0.07	0.25*	0.05*	-0.23
Standard Error	0.03	0.002	0.004	0.05	0.12	0.003	0.25
Lines							
80353	-0.36	-0.003	0.17*	-0.62	-0.25	-0.02	-0.33
80365	-0.53	-0.01	-0.56	-0.32	-0.32	-0.03	-0.09
80199	-0.15	-0.08	-0.10	1.06*	0.33	0.003	-0.07
80204	0.24*	-0.07	-0.16	0.05	-0.12	-0.06	-0.04
80319	0.19*	-0.05	-0.002	0.68*	-0.18	0.02*	-0.15
80214	-0.08	0.01*	0.02*	0.32*	0.23*	0.02*	0.22*
80114	0.19*	0.05*	0.16*	-0.52	0.26*	-0.02	0.01
80364	0.36*	0.08*	0.47*	-0.55	-0.66	0.01*	0.01
80158	-0.12	0.03*	0.15*	-0.10	0.59*	0.06*	0.21*
80376	0.25*	0.05*	-0.14	-0.01	0.12	0.03*	0.22*
Standard Error	0.05	0.003	0.01	0.05	0.09	0.005	0.02

Table 4. General combining ability effects of lines and testers for various forage quality components under water stress conditions.

	Sugar contents	Leaf to stem Ratio	Crude protein	Crude fibre	Nitrogen free extract	Ether extract	Total ash
Testers							
958	0.53*	-0.03	0.01	-0.21	1.58*	0.003	0.27*
Succro	0.78*	-0.07	-0.12	0.04	-1.37	0.03*	-0.004
337	-0.02	-0.02	-0.12	-0.15	-3.26	-0.04	-0.12
Line 7	-0.84	-0.01	0.15*	1.52*	1.51*	-0.03	-0.27
8614	-0.44	0.12*	0.07*	-1.19	1.54*	0.03*	0.13*
Standard Error	0.02	0.002	0.02	0.04	0.16	0.004	0.01
Lines							
80353	-0.99	-0.01	0.04*	1.13*	-0.42	-0.03	-0.04
80365	-1.05	0.001	-0.49	0.43*	1.08*	-0.09	-0.06
80199	-0.71	-0.07	-0.16	0.22*	0.60*	0.04*	-0.05
80204	-0.37	-0.07	-0.05	-0.98	0.08	0.01	0.001
80319	0.17*	-0.04	-0.05	0.58*	-0.34	0.01	0.02*
80214	0.78*	0.01*	0.20*	-0.25	-0.77	0.04*	0.10
80114	0.26*	0.04*	0.22*	-0.30	0.67*	0.03*	-0.08
80364	0.64*	0.06*	0.12*	-0.43	-0.37	0.02*	-0.004
80158	0.55*	0.02*	0.47*	0.11	-0.49	-0.02	0.06*
80376	0.73*	0.05*	-0.28	-0.53	-0.04	0.01	0.05*
Standard Error	0.04	0.003	0.02	0.06	0.22	0.01	0.01

Table 5: SCA effects for various forage quality components under normal conditions

Crosses	SC	LSR	CP	CF	NFE	EE	TA
80353 x 958	0.70*	0.01	0.24*	0.37*	1.28*	0.06*	0.42*
80365 x 958	1.02*	-0.11	0.46*	0.81*	0.14	0.10	-0.37
80199 x 958	0.84*	0.16*	-0.12	-0.76	0.51	0.03*	-0.43
80204 x 958	1.31*	0.06*	0.25*	0.13	0.71*	0.02	-0.32
80319 x 958	-1.16	-0.04	0.19*	-0.62	-1.09	-0.10	0.47*
80214 x 958	-0.75	-0.07	0.25*	-0.56	-1.15	-0.04	0.51*
80114 x 958	-1.01	0.06*	0.51*	0.11	-0.89	0.03*	-0.27
80364 x 958	-0.64	-0.05	-1.08	-0.05	-0.42	0.05*	-0.65
80158 x 958	-0.14	-0.05	-0.51	0.38*	0.74*	0.04*	0.28*
80376 x 958	-0.19	0.02	-0.17	0.19*	0.18	-0.15	0.35*
80353 x Succro	-1.55	-0.05	-0.02	-3.00	1.48*	-0.03	0.07
80365 x Succro	-0.84	0.02	-0.24	-3.33	0.08	-0.01	-0.47
80199 x Succro	-0.69	0.03*	-0.29	3.13*	0.86*	0.07*	-0.15
80204 x Succro	-0.54	0.06*	0.35*	0.84*	0.23	0.02	0.02
80319 x Succro	2.14*	-0.01	-0.11	1.34*	-0.02	-0.07	-0.59
80214 x Succro	2.06*	0.10*	-0.05	0.90*	-0.19	-0.09	0.32*
80114 x Succro	-0.35	-0.12	0.61*	1.36*	-0.85	0.09*	0.23*
80364 x Succro	-0.43	-0.09	0.13*	0.33*	0.28	0.01	0.46*
80158 x Succro	0.09	-0.01	0.15*	-0.78	-0.62	-0.01	0.06
80376 x Succro	0.12	0.06*	-0.53	-0.79	-1.25	0.04*	0.06
80353 x 337	-1.09	-0.03	0.23	1.06*	-2.33	-0.04	0.39*
80365 x 337	0.64*	0.16*	-0.25	0.84*	-1.36	-0.04	0.10
80199 x 337	0.23	-0.01	-0.21	-0.77	-1.08	-0.05	-0.03
80204 x 337	0.73*	-0.06	-0.67	-0.32	0.48	0.10*	-0.17
80319 x 337	0.50*	-0.04	-0.18	0.01	0.45	0.03*	0.22
80214 x 337	-1.97	-0.11	0.51*	0.22*	1.05*	-0.05	-0.48
80114 x 337	1.27*	-0.01	0.30*	-0.16	2.45*	-0.07	-0.21
80364 x 337	0.16	0.13*	0.06*	-0.25	-0.80	-0.11	-0.20
80158 x 337	-2.05	0.04*	-0.35	-0.35	0.31	0.12*	-0.11
80376 x 337	1.58*	-0.07	0.55*	-0.27	0.82*	0.13*	0.48*
80353 x Line 7	2.14*	-0.01	-0.24	0.03	0.86*	0.04*	-0.78
80365 x Line 7	-0.99	0.12*	0.06*	1.23*	0.62*	-0.09	0.38*
80199 x Line 7	-1.29	-0.09	0.03*	-0.66	-0.25	-0.02	0.39*
80204 x Line 7	-1.74	-0.01	-0.09	-0.86	-0.89	-0.17	0.38*
80319 x Line 7	-0.95	-0.08	0.22*	0.80*	-0.29	0.11*	-0.15
80214 x Line 7	1.33*	-0.03	-0.47	0.20	-0.96	0.11*	-0.01
80114 x Line 7	0.82*	-0.03	-0.54	-0.59	0.18	0.05*	0.11*
80364 x Line 7	0.50*	-0.02	0.38*	-0.63	0.69*	0.01	0.22*
80158 x Line 7	1.04*	0.06*	0.26*	0.40*	-0.21	-0.08	-0.20
80376 x Line 7	-0.85	0.08*	0.40*	0.08	0.26	0.05*	-0.33
80353 x 8614	-0.21	0.08*	-0.20	1.55*	-1.29	-0.03	-0.10
80365 x 8614	0.17	-0.20	-0.03	0.44*	0.51	0.03*	0.37*
80199 x 8614	0.91*	-0.09	0.60*	-0.92	-0.04	-0.03	0.23*
80204 x 8614	0.25*	-0.05	0.16*	0.20	-0.53	0.03*	0.09
80319 x 8614	-0.53	0.16*	-0.12	-1.53	0.95*	0.06*	0.05
80214 x 8614	-0.66	0.11*	-0.24	-0.76	1.26*	0.08*	-0.33
80114 x 8614	-0.73	0.10*	-0.88	-0.72	-0.88	-0.10	0.14*
80364 x 8614	0.41*	0.03*	0.51*	0.60*	0.24	0.03*	0.16*
80158 x 8614	1.06*	-0.04	0.44*	0.34*	-0.21	-0.04	-0.03
80376 x 8614	-0.66	-0.10	-0.25	0.78*	-0.01	-0.03	-0.56
Standard error	0.12	0.01	0.01	0.10	0.28	0.01	0.05

Table 6: SCA effects for various forage quality components under water stress conditions

Crosses	SC	LSR	CP	CF	NFE	EE	TA
80353 x 958	-0.98	0.05*	0.39*	-0.73	-0.40	0.08*	0.51*
80365 x 958	0.30*	-0.10	-0.56	0.40*	-0.17	0.10*	-0.15
80199 x 958	-1.43	0.13*	0.10	-0.36	0.21	0.03	-0.04
80204 x 958	0.36*	0.04*	0.01	-0.18	0.77	-0.10	0.23*
80319 x 958	-0.83	-0.01	0.28*	-0.04	-0.62	-0.03	-0.12
80214 x 958	-1.37	-0.04	0.05	-0.95	1.95*	-0.06	0.02
80114 x 958	0.31*	0.03*	0.52*	0.25	-0.46	-0.07	-0.35
80364 x 958	2.02*	-0.03	-0.63	0.36*	-1.33	-0.12	0.04
80158 x 958	0.51*	-0.07	-0.22	1.66*	1.30*	0.08*	-0.04
80376 x 958	-0.98	0.01	0.04	-0.40	-1.26	0.08*	-0.12
80353 x Succro	-0.32	-0.08	-0.03	-2.90	2.69*	-0.05	-0.21
80365 x Succro	-0.20	0.03*	0.10	-1.71	2.67*	-0.03	-0.55
80199 x Succro	-1.75	0.07*	-0.43	2.19*	2.05*	0.07*	-0.20
80204 x Succro	-1.10	0.05*	0.93*	-0.32	2.07*	0.12*	-0.22
80319 x Succro	3.76*	-0.01	0.05	-1.13	-2.72	0.01	0.17*
80214 x Succro	2.27*	0.10*	-0.10	0.07	-3.50	-0.03	0.29*
80114 x Succro	-1.44	-0.15	0.47*	1.55*	0.98	0.08*	0.27*
80364 x Succro	0.29*	-0.07	-0.24	0.73*	1.52*	0.08*	0.18*
80158 x Succro	-0.45	-0.01	-0.55	0.71*	-3.59	-0.19	0.12*
80376 x Succro	-1.05	0.07*	-0.20	0.81*	-2.19	-0.04	0.13*
80353 x 337	0.37*	0.04*	0.36*	-0.77	-3.76	0.08*	-0.10
80365 x 337	-0.76	0.14*	-0.62	-0.94	-1.00	-0.01	0.02
80199 x 337	3.30*	-0.04	0.08	-1.48	-2.84	-0.13	0.07*
80204 x 337	0.82*	-0.05	-0.84	1.40*	-1.35	-0.02	-0.11
80319 x 337	-1.97	-0.06	-0.05	0.99*	0.42	0.03	0.18*
80214 x 337	-0.62	-0.13	0.42*	2.93*	-1.61	0.06*	-0.11
80114 x 337	0.34*	-0.04	0.19*	-0.33	1.08*	0.06*	-0.03
80364 x 337	-0.12	0.12*	0.25*	-1.01	0.45	0.02	-0.09
80158 x 337	-0.65	0.05*	0.04	-1.32	5.04*	-0.01	-0.06
80376 x 337	-0.70	-0.04	0.17*	0.53*	3.59*	-0.09	0.22*
80353 x Line 7	0.61*	-0.03	-0.40	3.69*	1.29*	-0.09	-0.51
80365 x Line 7	1.00*	0.11*	0.26*	0.72*	-1.30	-0.11	-0.10
80199 x Line 7	0.46*	-0.10	0.27*	-0.28	-1.57	0.05*	-0.04
80204 x Line 7	0.42*	0.04*	0.01	-0.21	-2.27	-0.01	-0.05
80319 x Line 7	-0.04	-0.02	-0.06	2.44*	1.74*	-0.01	-0.12
80214 x Line 7	0.57*	-0.06	-0.57	-0.83	1.54*	0.02	-0.08
80114 x Line 7	0.58*	0.02	-0.69	-1.35	0.21	-0.03	0.21*
80364 x Line 7	-2.73	-0.04	0.50*	-1.25	0.15	0.02	0.23*
80158 x Line 7	-0.21	0.04*	0.68*	-2.47	-0.63	0.06*	0.27*
80376 x Line 7	-0.66	0.07*	0.03	-0.46	0.87	0.09*	0.18*
80353 x 8614	0.31*	0.06*	-0.34	0.71*	0.18	-0.03	0.30*
80365 x 8614	-0.35	-0.19	0.82*	1.52*	-0.20	0.04	0.77*
80199 x 8614	-0.57	-0.07	-0.02	-0.07	2.15*	-0.01	0.20*
80204 x 8614	-0.50	-0.03	-0.10	-0.69	0.78	0.01	0.15*
80319 x 8614	-0.92	0.09*	-0.22	-2.27	1.19*	-0.003	-0.10
80214 x 8614	-0.85	0.12*	0.21*	-1.23	1.62*	0.01	-0.13
80114 x 8614	0.21*	0.10*	-0.50	-0.12	-1.81	-0.04	-0.11
80364 x 8614	0.55*	0.03*	0.12*	1.18*	-0.79	-0.01	-0.36
80158 x 8614	0.81*	-0.01	0.05	1.43*	-2.12	0.07*	-0.29
80376 x 8614	1.32*	-0.11	-0.02	-0.48	-1.01	-0.04	-0.42
Standard error	0.09	0.01	0.05	0.14	0.50	0.02	0.03

The 80319 x Succro hybrid showed highest value of SCA effects for sugar contents under water stress conditions. While for leaf to stem ratio the best specific cross along with highest SCA effects was 80365 x 337 under water stress. For crude protein, crude fibre and nitrogen free extracts the best specific crosses with highest SCA effects were 80204 x Succro, 80353 x Line 7 and 80158 x 337 respectively under water stress conditions. The hybrid 80204 x Succro and 80365 x 8614 showed highest positive and significant SCA effects for ether extracts and total ash under water stress conditions.

DISCUSSION

Realizing the complex nature and interdependence of livestock health with palatable fodder availability; it was imperative to carry out hybrid development studies after selecting the better parents under water stress conditions. Variation in the breeding material for various forage quality components in the present studies is well supported by the reports in literature. Rios *et al.,* (1984) and Viana *et al.,* (1990) reported significant differences among the genotypes for crude protein. Mehndiratta *et al.,* (1993) recorded significant differences for crude protein and IVDMD among sorghum x sudangrass hybrids. Thakare *et al.,* (1987), Bruno *et al.,* (1992), Torres Cepeda *et al.,* (1996) and Hicks *et al.,* (2002) observed significant differences for crude protein, oil/fat, crude fat, starch and total ash.

SuePea *et al.,* (1995), Pandian and Doss (2002) and Hicks *et al.,* (2002) had also reported variable magnitude and direction of general combining ability effects for males and female parents for forage quality components under control conditions. Variable magnitude and direction of both GCA and SCA effects were also reported by Kamaluddin *et al.,* (2007) and Betran *et al.,* (2003) under water stress conditions. The effects of both GCA and SCA are the result of genetic make up of the breeding material, the genetic differences in the present breeding material have been statistically significant and the variation in the effects observed could be attributed to the genetic differences of the breeding material. The higher values of GCA indicated additive type of gene action for respective traits. The traits with higher GCA effects may be helpful in the improvement of forage quality.

Conclusion: The best general combiner was 8614 as male parent for leaf to stem ratio, crude protein, for nitrogen free extracts and ether extracts under control as well as water stress conditions. While the best female parent as general combiner was 80364 for sugar contents, leaf to stem ratio and crude protein. The similar parental behavior under both the conditions proves that the consistency of genetic inheritance was not influenced by any environmental factor. As per major theme of the study, availability of such material is a step forward is working on sorghum-sudangrass hybrid development with special reference to the water stress conditions. It is also concluded that research work on quality improvement especially with respect to protein contents and sugar percentage under water stress conditions was done for the first time because most of the literature regarding references was from other forage crops of the same family not from sorghum-sudan grass hybrids under stress for combining ability. It would be very helpful for the farming community, where most of the forage crops were on marginal lands having less available water and ultimately would improve the situation regarding throughout availability of green fodder in the year.

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