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LINE X TESTER ANALYSIS ACROSS YEARS TO STUDY COMBINING ABILITY IN FORAGE SORGHUM (*Sorghum bicolor* L. MOENCH)

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ABSTRACT

The aim of this study is to determine the magnitude of GCA and SCA effects as well as the genetic parameters involved in forage yield and its component in sorghum. This study was carried out at the Sakha Agriculture Research Station during 2007, 2008 and 2009 summer seasons. Two male and four females were crossed according to line x tester mating design in 2007 growing season to assess combining ability and nature of gene action. The results of variance over the two years revealed that highly significant differences among tested crosses for all the studied traits. This results indicating the existence of wide variability among the genotypes. The general combining ability effects cleared that positive values were observed for both male and female for most of studied traits indicating to this genotypes is a good combiner for inheritance of this traits. The results for contribution of lines , testers and line x tester cleared that the contribution of testers were greater than lines and line x tester for all the studied traits with except green leaf / stem ratio and dry leaf / stem ratio at the three cuts. Also, the results indicated that the additive genetic variance ($δ^2$A) were larger than the corresponding values non additive genetic variance including dominance ($δ^2$D) for most of studied traits. These results suggested that the additive genetic variance played the major role in the genetic expression for all traits with few exceptions. However, heritability in broad sense (h^2 b.s %) was larger than heritability in narrow sense (h^2 n.s %) for all the studied traits indicating also to the role of non- additive genetic variance in the expression of these traits. Therefore, from the previews results it could be suggesting the recurrent selection program is important for improving these traits.

INTRODUCTION

Sorghum plays a very important role in providing nutrition to human race along with wheat, rice, maize and barley in many countries of the world. Its one of the most import at food and fuel crops in many countries .Thus, improvement of sorghum is much emphasized owing to its importance as food and fodder crop. The demand for fodder sorghum is fast increasing. Improvement of the genetic potential of the crop in order to maximize the economic gain per unit of input remains the most possible means of increasing the production. (Dhillon, 1975 Sanderson *et al* 1993 and Mohammed and Talib, 2008).

Forage sorghum (*Sorghum bicolor* (L). Moench) has recent by witnessed an increasing importance in the semi arid tropics and dried parts of the world where livestock constitutes a major component of the production system, compared to other cereals, especially maize, sorghum is more droughts tolerant and can thrive better than under several conditions. One of the program objectives was to develop locally adapted forage sorghum hybrids.

Knowing general (GCA) and specific (SCA) combining abilities effects of genetic materials is of practical value in breeding programs. Both components play an important role in selecting superior parents for hybrid combinations (Duvick, 1999, Reddy *et al* 2004 , Iyonar and Khan 2005 , Mohammed 2007 and Mohamed *et al* 2008) and represent a powerful method to measure the nature of gene action involved in quantitative traits (Baker, 1978 , Maunder, 1992 and Gore et al 2004) .G.CA effects represent the fixable component of genetic variance, and are important to develop superior genotypes. SCA represents the non- fixable component of genetic variation, its is important to provide information on hybrid performances.

The mating design (line x tester) suggested by Kempthorne (1957) has been extensively used to estimate GCA and SCA variance and their effects. Also, it is used understanding the nature of gene action involved in expression of economically important quantitative traits.

The objective of this study were to investigate combining ability for yield and its components traits in Sorghum genetic stocks using line x tester analysis to identify parents with desirable GCA effect and crass combinations with desirable SCA effects and to study the nature of gene action.

MATERIALS AND METHODS

Plant materials:-

The plant material consisted of four lines which selected from breeding program viz, T.X.399, ICS.52, ICS. 1836 and 2002-46 which were used as females (lines) and two tester viz, IS. 3214 and Piper black were used as male. These parents were crosses in a line x tester mating design during 2007 summer season. The refine, the genetic materials involved in this investigation included six parental lines and there eight hybrids.

The experimental design:-

The four lines and two testers were grown together with eight hybrids were evaluated in two years viz, 2008 and 2009 growing seasons at Sakha Agric Res. Station. The treatments were arranged in a randomized complete blocks design with 3 replications. The plot size 5 rows x 4 meters along and 60 cm wide (the total size plot is 12 m^2)

Three cuts were taken during the two growing season, where the first cut was taken after 50 days after planting , the second and the third cuts taken at 35 days intervals. Data recorded were:-

1-Fresh forage yield. Kg. per plot
2-Dry forage yield. Kg. per plot
3-Total fresh forage yield. Kg. per plot
4-Dry total fresh forage. Kg. per plot
5-Plant height in centimeters.
6- Stem diameter in centimeters.
7-Fresh leaf / stem ratio.
8-Dry leaf /stem ratio.

Statistical analysis:-

The combined data over two seasons were subjected to analysis of variance for all studied traits. The mean squares were subdivided into variations due to hybrids which were partitioned into variations due to lines, testers and line x testers. Estimates of general (GCA) and specific (SCA) combining ability based an data combed over years, were deferment as follow

δ^2 G.C.A. = Cov. (H. S.)

δ^2 S.C.A. = Cov. F.S. -2 Cov.(H.S)

Combining ability affect for each line and tester was calculated as follow:-

For line $g_i = \frac{x_i}{tr} - \frac{x_{---}}{ltr}$

For testers $g_i = = \frac{x_{j.}}{lr} - \frac{x_{---}}{ltr}$

specific Combing abilities effects were calculated as follow:-

$s_{ig} = \frac{x_{.ij.}}{r} - \frac{x_{i..}}{tr} - \frac{x_{.j.}}{lr} - \frac{x_{---}}{l+r}$

Estimates of heritability

Heritability in broad (h^2 b.s) and narrow (h^2 n.s) senses were calculated according to Allord (1960) and Mother (1949):

$$h^2 \text{ b.s } \% = \frac{\delta^2 A + \delta^2 D}{\delta^2 A + \delta^2 D + \delta^2 e} \times 100$$

$$H^2 \text{ n.s } \% = \frac{\delta^2 A}{\delta^2 A + \delta^2 D + \delta^2 e} \times 100$$

RESULTS AND DISCUSSION

Variances and mean squares

The combined statistical analysis of variance (Table 1 and Table 2) over the two years revealed highly significant differences among tested crosses for all studied traits indicating the existence of wide variability among the genotypes. Hence, the feasibility for genetic improvements using genetic pools of sorghum.

Analysis of variance for combining ability revealed that variances due to lines were significant and highly significant for all the traits except first cut for fresh yield, plant height in first cut, the first , second and total dry forage yield this indicates all traits other than dry yield contribute much for genetic diversity among these lines. The variance due to testers was significant for all the traits except third cut of green and dry leaf/ stem ratio. The interaction effect (L x T) was also highly significant for all the characters studied except first cut of green leaf/stem ratio; it indicates significant difference of SCA effects among the hybrids. The interaction between lines or testers with years is insignificant for most of studied traits and these results cleared that the all genotypes is stable with any year.

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Combining Ability

The selection of parental lines for hybrid programs was one of the objectives of this study. Thus, the estimates of the general combining ability of a parent provide important indication of its potential for generating superior lines. A low GCA estimate, whether positive or negative indicates that the mean of apparent in crossing with the other, dose not differ greatly from the general mean of the crosses. On the other hand, a high GCA estimate indicates that the parental mean is superior or inferior to the general mean. This gives information about the concentration of predominant genes with additive effects (Kenga *et al*., 2004)

General Combining Ability for Female Lines

Estimates of GCA effects for all studied traits for four females lines used in this study from combined data over two years are shown in Fig.1-6.

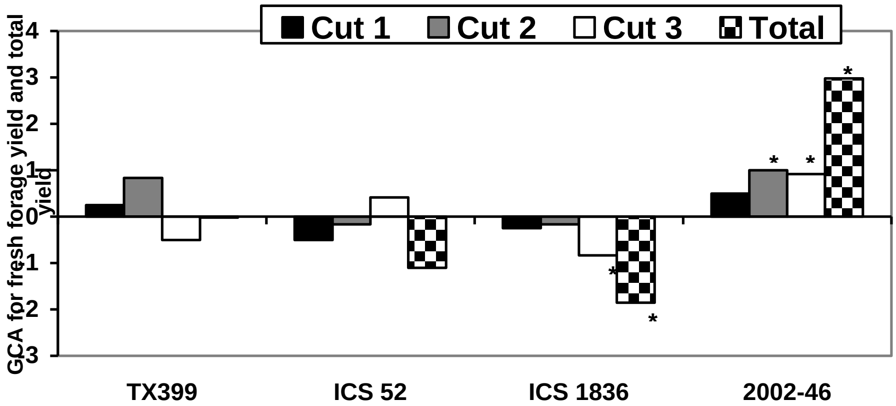

Fig.1: Estimates of GCA effects of female lines for three cuts of fresh forage yield and total yield from the combined data over two years

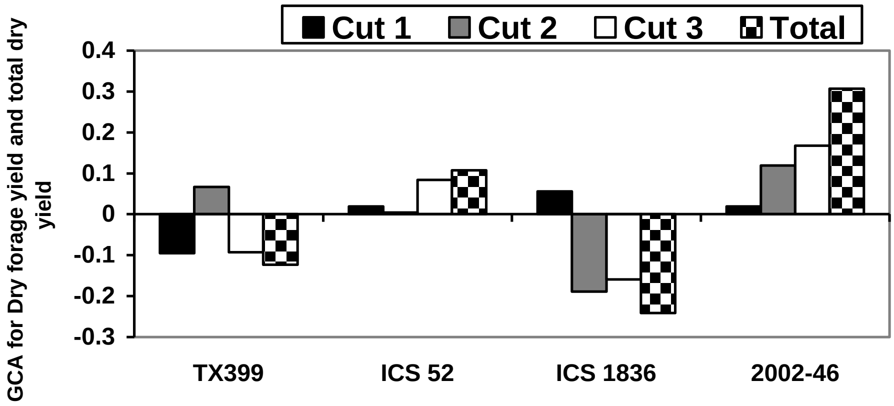

Fig. 2: Estimates of GCA effects of female lines for dry forage yield of three cuts and total yield from the combined data over two years

Female line 2002-46 was the best general combiner through three cuts with respect to fresh yield and total fresh forage yield which shoesd significant and positive GCA effects. On the other hand, female line ICS1836 showed significant and negative GCA effects in third cut and total fresh forage yield.

In Fig 2: it could be notice that female lines had non-significant GCA effects in the case of total dry forage yield traits through three cuts except for female line 2002-46 which appeared to be a good combiner for this trait.

Also results in Fig.3 and 4 showed that, female line 2002-46 was the best general combiner through three cuts for stem diameter and plant height with significant and positive GCA effects.

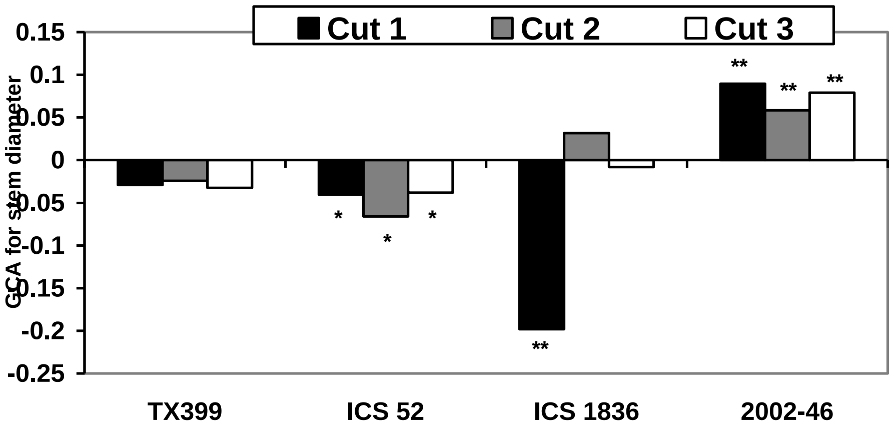

Fig. 3: Estimates of GCA effects of female lines for stem diameter of three cuts from the combined data over two years

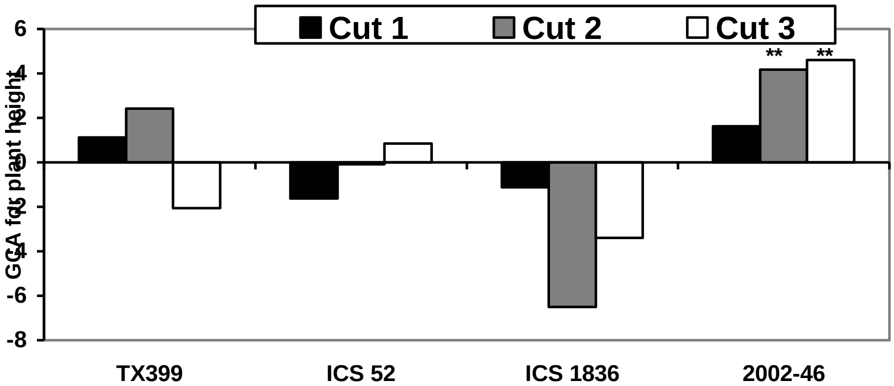

Fig. 4: Estimates of GCA effects of female lines for plant height of three cuts from the combined data over two years

In green leaf/stem ratio trait, female line TX 399 was the best general combiner through three cuts with highly significant and positive GCA effects. On the other hand, female line ICS 1836, 2002-46 and ICS 52 showed highly significant and negative GCA effects for the first, second and third cuts, respectively,

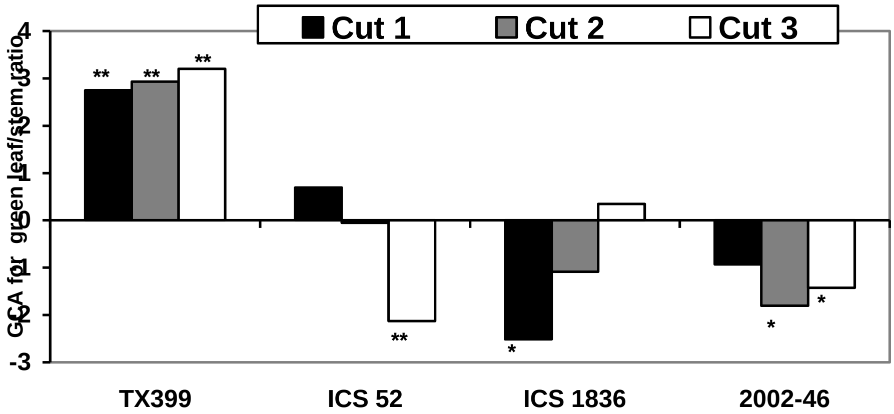

Fig. 5: Estimates of GCA effects of female lines for green leaf/stem ratio of three cuts from the combined data over two years

Fig. 6: Estimates of GCA effects of female lines for dry leaf/stem ratio of three cuts from the combined data over two years

Results presented in Fig 6 exhibit that female line TX.399 was the best general combiner for dry leaf/stem ratio with highly significant positive GCA effects for second cut and third cut. While female line ICS.1836 was the best general combiner for first cut with significant and positive GCA effects. Similar results were obtained for female lineICS.52 was significant and positive GCA effects for first cut of leaf/stem ratio. While, female line 2002-46 was significant and positive GCA effects for second and third cuts. Similar results were obtained by Degu *et al* (2009) and Adel, M. M. and Talaat A.A (2010).

General Combining Ability for male Lines

GCA effects of the two mal**e** parents from the combined data over two years for all studied traits are show in Fig.7a-f. The estimates of GCA effects for two male parents (I.S.3214 and Piper black) exhibit that male parent Piper black was the best general combiner for fresh forage yield, total fresh forage yield, dry yield, total dry yield stem diameter and plant height, because this parent had positive effects in these cases.

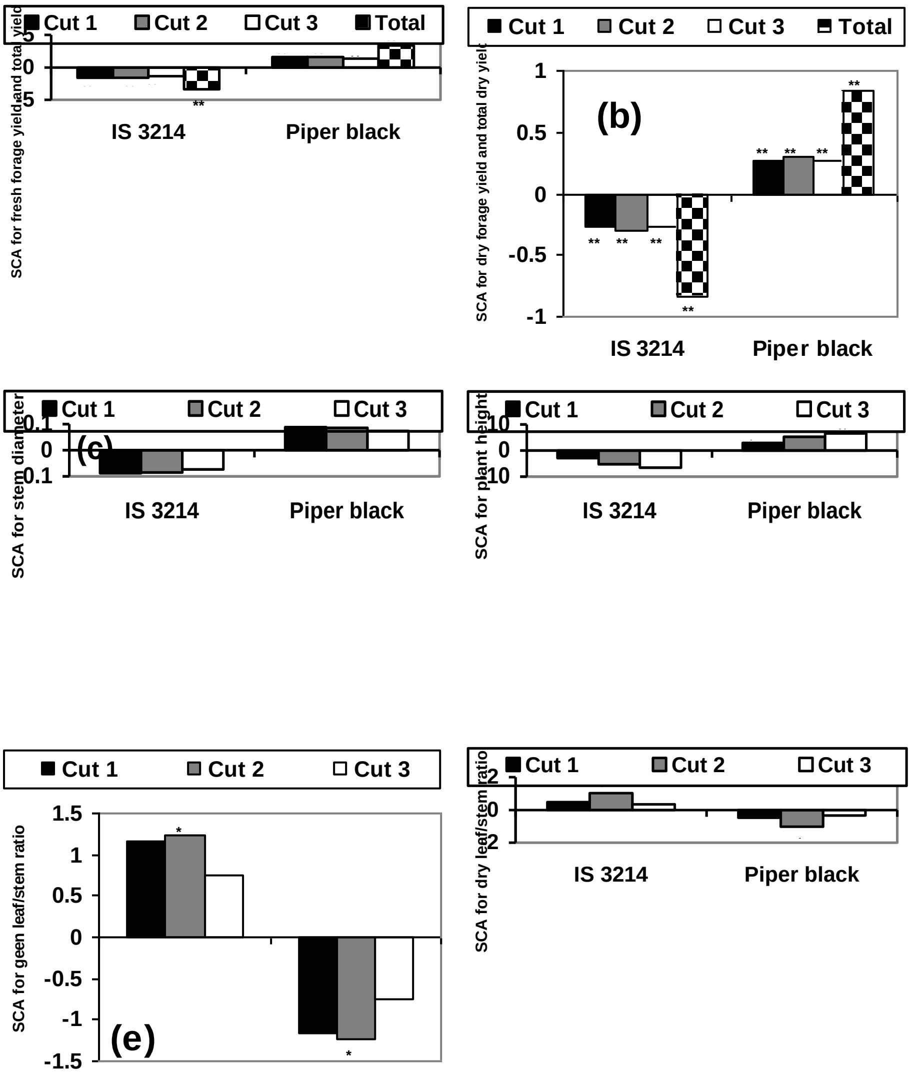

Fig.7a-f: Estimates of GCA effects of male parent for studied traits from the combined data over two years

While, parent I,S.3214 had negative GCA effects values for these traits, but in green leaf/stem ratio and dry leaf/stem ratio, it was a good combiner with positive GCA effects. This result mean that, male parent piper black had favorable genes action for most studied traits and will be considered a good general combiner for development of hybrids of forage sorghum.

Specific Combining Ability Effects of Hybrids

Specific combining ability effects were estimated for all the studied traits and the results in the Table (3) appeared the importance three hybrids for all the studied traits. Results showed significant positive specific combining ability effects for few crosses. This illustrates the presence of a considerable non- allelic gene action. On the other hand, the significant negative specific combining ability effects revealed the presence of undesirable epistasis type in these combinations

Table 3: Estimates of specific combining ability (SCA) effects of best crosses of all studied traits based on combined data over years

Character	Cut	T.S.933 x IS.3214	ICS.52 x Piper black	2002-46 x Piper black
Fresh forage yield	1	1.875*	0.375	1.875*
Fresh forage yield	2	1.583*	-0.0833	1.750*
Fresh forage yield	3	1.250*	0.6667	0.1667
Total fresh forage yield		4.270**	-0.3540	3.329*
Dry forage yield	1	0.283*	0.0865	0.205
Dry forage yield	2	0.257	0.0073	0.2300
Dry forage yield	3	0.234*	0.1006	0.0450
Total dry forage yield		0.774*	0.1890	0.4750
Stem diameter	1	0.044	0.0023	0.0006
Stem diameter	2	0.0425	-0.0508*	0.0466
Stem diameter	3	0.0795**	0.0346	0.0187
Plant height	1	3.1250	0.3750	2.375
Plant height	2	5.2916*	-0.2917	6.458**
Plant height	3	5.187*	2.729	0.979
Green leaf/stem ratio	1	0.2970	1.9104	-0.9813
Green leaf/stem ratio	2	-0.7583	2.025	-1.175
Green leaf/stem ratio	3	-1.425	-0.2000*	1.333
Dry leaf/stem ratio	1	-1.683	1.358	-2.825*
Dry leaf/stem ratio	2	-0.560	4.014**	-2.406**
Dry leaf/stem ratio	3	-2.133**	1.483**	-2.116**

Contribution of lines, testers, and lines x testers

Contribution of lines, testers, and lines x testers for all studied traits based on combined data over years are shown in Table 4.

Data showed that the contribution of testers was grater than that of lines for all traits except green leaf/stem ratio and dry leaf/stem ratio. The contribution of lines x testers was greater than that of lines for fresh forage yield, total fresh forage yield, dry yield, total dry yield and plant height. While, The contribution of lines was greater than that of lines x testers for stem diameter, green leaf/stem ratio and dry leaf/stem ratio.

Table 4: Contribution of lines, testers, and lines x testers of all studied traits based on combined data over years

Character	CUT	Contribution (%)		
		Lines	Testers	Lines x testers
Fresh forage yield	1	3.38	57.09	39.53
Fresh forage yield	2	22.38	49.86	27.76
Fresh forage yield	3	17.36	63.05	19.58
Total fresh forage yield		15.16	50.41	34.43
Dry forage yield	1	2.94	67.51	29.55
Dry forage yield	2	10.47	67.02	22.51
Dry forage yield	3	15.43	67.98	16.59
Total dry forage yield		5.25	72.42	22.32
Stem diameter	1	23.67	68.29	8.04
Stem diameter	2	19.85	61.53	18.62
Stem diameter	3	22.61	55.52	21.87
Plant height	1	13.54	57.31	29.14
Plant height	2	26.39	45.16	28.45
Plant height	3	15.37	69.34	15.29
Green leaf/stem ratio	1	59.25	20.93	19.82
Green leaf/stem ratio	2	47.06	21.70	31.24
Green leaf/stem ratio	3	73.46	9.77	16.77
Dry leaf/stem ratio	1	47.96	3.56	48.46
Dry leaf/stem ratio	2	16.4	10.98	72.62
Dry leaf/stem ratio	3	23.82	2.67	73.51

The partitioning of the genetic variances for genotypes for all the studied traits are presented in Table 5 and Table 6

The results cleared that the additive genetic variance (σ^2A) were greater than non-additive genetic variance including dominance (σ^2 D) for all the studied traits at the three cuts with few exceptions. The results also indicated that the additive genetic variance played the major role in the inheritance of these traits. This shows that hybridization and selection program could be effective in the improvement of those traits. The important of additive genetic variance were verified by the dominance degree ratio. Which less than unity for all the studied traits.

Heritability values in broad and narrow senses were calculated and the all results shown in Table 3. The results showed that the heritability in broad sense (H^2_b) estimates were larger than their corresponding values of narrow sense heritability (H^2_n) for all studied traits at the three cuts and the heritability in broad sense ranged from 47.91% to 91.30% for green leaf/stem ratio and stem diameter, respectively, while the heritability in narrow sense ranged from 0.00% for dry leaf/stem ratio at the three cuts to 76.92% for stem diameter at the cut 3.

In general, from the previous results which indicated to the importance of both additive and non-additive gene action in the inheritance of the most of studied traits with varied contributions, it could be suggested that, the recurrent selection program is proper for improvement these traits.

Table 5: The partitioning of the genetic variances for fresh and dry forage yield from data combined over two years

Genetic and heritability	Fresh forage yield				Dry forage yield			
	1st cut	2nd cut	3rd cut	Total fresh yield	1st cut	2nd cut	3rd cut	Total dry yield
G.C.A.	1.97	2.60	2.10	9.67	0.07	-0.24	0.09	0.78
S.C.A.	4.52	3.14	1.20	19.23	0.07	1.06	0.04	0.58
σ^2A	3.94	5.2	4.20	19.34	0.14	-0.48	0.18	1.56
σ^2D	4.52	3.14	1.20	19.23	0.07	1.06	0.04	0.58
$(\sigma^2D./\ \sigma A)^{1/2}$	1.07	0.777	0.535	0.997	0.707	0.000	0.471	0.610
$\sigma^2G.$	8.46	8.34	5.4	38.57	0.21	1.06	0.22	2.14
$\sigma^2e.$	2.116	3.485	1.628	7.604	0.076	0.139	0.064	0.375
σ^2Ph	10.58	11.825	7.028	46.174	0.286	1.199	0.284	2.515
H^2_b	79.96	70.53	76.84	83.53	73.43	88.41	77.46	85.09
H^2_n	37.24	43.97	59.76	41.89	48.95	0.00	63.38	62.03

Table 6: The partitioning of the genetic variances for other characters from data combined over two years

Genetic and heritability	Stem diameter			Plant height			Green leaf/stem ratio			Dry leaf/stem ratio		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
G.C.A.	0.01	0.01	0.01	8.12	28.93	52.55	2.36	1.53	1.77	-1.10	-4.10	-2.35
S.C.A.	0.001	0.01	0.001	8.84	43.85	22.22	2.15	4.79	1.91	7.15	17.47	8.62
σ^2A	0.02	0.02	0.02	16.24	57.86	105.1	4.72	3.06	3.54	-2.20	-8.20	-4.70
σ^2D	0.060	0.01	0.001	8.84	43.85	22.22	2.15	4.79	1.91	7.15	17.47	8.62
$(\sigma^2D./\ \sigma A)^{1/2}$	0.070	0.070	0.070	0.73	0.760	0.460	0.675	1.251	0.735	0.00	0.00	0.00
$\sigma^2G.$	0.021	0.030	0.02	25.08	101.71	127.32	6.87	7.85	5.45	7.15	17.47	8.62
$\sigma^2e.$	0.002	0.003	0.005	14.72	19.128	16.69	7.472	5.838	4.004	7.606	6.84	2.21
σ^2Ph	0.023	0.033	0.026	39.80	120.84	144.01	14.34	13.688	9.454	14.756	24.31	10.83
H^2_b	91.30	90.91	80.77	63.02	84.17	88.84	47.91	57.35	57.65	48.45	71.86	79.59
H^2_n	86.96	60.61	76.92	40.80	47.88	72.98	32.91	22.36	37.44	0.00	0.00	0.00

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استخدام تحليل السلالات في الكشاف لتقدير القدرة علي التألف في السورجم

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الهدف الرئيسي من هذه الدراسة هو تقدير القدرة علي التألف بالاضافة الي تقدير المكونات الوراثية وطبيعة فعل الجين لصفات المحصول ومكوناته في السورجم وذلك للحصول علي تراكيب وراثية متفوقة محصوليا . اجريت هذه الدراسة في محطة البحوث الزراعية بسخا مواسم 2007 و 2008 و 2009 . تعتبر القدرة علي التألف عامل مهم جدا من خلاله يمكن اختيار الاباء وتحديد طريقة وبرنامج التربية الذي يمكن عن طريقه التقدم بمحصول وانتاجية السورجم . استخدمت في هذه الدراسة عدد اربعة سلالات استخدمت كامهات وسلالتين استخدمتا كاباء وتم الحصول علي ثمانية هجن بطريقة السلالات في الكشافات وتم تقييم هذه الهجن واظهرت النتائج المتحصل عليها من خلال تحليل التباين ان هناك اختلافات عالية المعنوية لكل الصفات تحت الدراسة مما يوضح وجود اختلافات وراثية بين المواد الوراثية المستخدمة في هذه الدراسة . من نتائج القدرة العامة والخاصة علي التألف لبعض السلالات وكذلك للكشافات لمعظم الصفات تحت الدراسة تشير النتائج ان هناك سلالات ذات قدرة عالية علي التالف وممتازة وانها ذات قدرة علي توريث هذه الصفات . بالنسبة لمساهمة السلالات والكشافات وكذلك الهجن يتضح من القيم الناتجة ان مدي مساهمة الكشافات كانت اعلي من السلالات وكذلك الهجن فيما عدا صفتي نسبة الورق للسيقان جاف واخضر كانت مساهمة السلالات والهجن اعلي. اظهرت النتائج ايضا ان قيم التباين الاضافي كانت اعلي من قيم التباين السيادي لكل الصفات تحت الدراسة تقريبا وان التباين الاضافي كان له السبق ويلعب الدور الاكبر في توريث هذه الصفات وان كانت قيم التباين السيادي قريبة من التباين الاضافي في الغالب ومن هذا يتضح ان استخدام برنامج تهجين مع الانتخاب هام جدا . ومن النتائج يتضح ايضا ان قيم معامل التوؤيث بالمدي الواسع كانت اعلي من قيم معامل التوريث بالمدي الضيق لكل الصفات تحت الدراسة .

قام بتحكيم البحث

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Table 1: The analysis of variances and mean squares for green and dry forage yield obtained from the combined data over two years 2008 and 2009

S.V.	d.f. Comb.	Fresh forage yield				Dry forage yield			
		1st cut	2nd cut	3rd cut	Total fresh yield	1st cut	2nd cut	3rd cut	Total dry yield
Replicates	4	101.18	61.27	28.27	488.6	1.413	1.227	0.925	10.091
Years	1	48.00	5..33	184.083	285.188	0.032	0.205	2.205	4.479
Crosses	7	31.714**	34.47**	19.33**	153.045**	0.752**	0.893**	0.766**	6.718**
Testers	1	126.75**	120.33**	85.33**	540.02**	3.554**	4.174**	3.645**	34.07**
Lines	3	2.50	18.00**	7.83**	54.13**	0.051	0.22	0.276*	0.828
L. × T.	3	29.250**	22.333**	8.83**	122.96**	0.518**	6.472*	0.29*	3.488**
C. × YEAR	7	27.429**	6.76	5.655**	30.09**	0.509**	0.152	0.174*	1.522**
T. × YEAR.	1	36.75**	5.33	2.083	1.688	0.273	0.112	0.056	0.384
L. × YEAR	3	22.5**	4.00	1.917	34.24*	0.461**	0.064	0.043	1.00
L. × T. × YEA	3	29.25**	10.00*	10.583	35.41*	0.637	0.253	0.343**	2.423**
Error	28	2.116	3.485	1.628	7.604	0.076	0.139	0.064	

***, ** Significant and highly significant at 0.05 and 0.01 probability levels, respectively.**

Table 2: The analysis of variances and mean squares for other traits for all genotypes obtained from the combined data over two years 2008 and 2009

S.V.	d.f. Comb.	Stem diameter			Plant height			Green leaf/stem ratio			Dry leaf/stem ratio		
		1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Replicates	4	0.006	0.007	0.006	351.43	249.77	233.33	17.13	16.638	2.644	24.442	26.98	59.10
Years	1	0.424**	0.166	0.301**	768.0	1102.08	111.02	66.035	208.33*	103.84**	51.668	129.035	229.6
Crosses	7	0.079**	0.081**	0.69**	98.89**	425.19**	420.52**	44.111**	47.428**	39.46**	44.947**	65.899	31.44**
Testers	1	0.373**	0.347**	0.261**	396.7*	1344.08**	2041.0**	64.635*	72.030**	27.00	11.213**	50.635**	5.88
Lines	3	0.043**	0.037**	0.035**	31.250	261.83**	150.85**	60.982**	52.082**	67.635**	50.314**	25.222*	17.476**
L. × T.	3	0.015**	0.035**	0.034**	67.75**	282.25**	150.0**	20.394	34.572**	15.441**	50.828**	111.664**	53.927***
C. × YEAR	7	0.022**	0.014**	0.006	159.85**	94.655	118.44**	35.809**	17.761**	15.487**	11.201	1.432	0.945
T. × YEAR.	1	0.003	0.023*	0.013*	147.0*	133.3	35.0	14.852	18.253	0.241	0.053	1.725	0.75
L. × YEAR	3	0.029**	0.016*	0.002	122.5**	55.5*	19.68	74.13**	31.542**	5.636	6.77	0.975	0.79
L ×T. × YEA	3	0.020**	0.009	0.007	201.5**	120.833**	245.02	4.477	3.816	30.420**	19.407	1.792	0.492
Error	28	0.002	0.003	0.005	14.72	19.128	16.690	7.472	5.838	4.004	7.606	6.84	2.21

***, ** Significant and highly significant at 0.05 and 0.01 probability levels, respectively.**