Original Research Article

Estimation of Heterosis and Inbreeding Depression for Yield Related and Quality Traits in Forage Sorghum [*Sorghum bicolor* L. (Moench)]

ABSTRACT

The present study was conducted at GBPUAT Pantnagar to study the heterosis and inbreeding depression for nine yield related and three quality traits which consisted of seventy F_1 crosses developed through line x tester mating design involving ten cytoplasmic male sterile (female) lines and seven pollinator (male) lines during *Kharif* 2018 and 70 F_2s developed by selfing of F_1 crosses during *Kharif*2019 in random block design (R.B.D.) with three replications. Observations were recorded on plant height, stem girth, number of leaves per plant, leaf length, leaf width, leaf area, leaf:stem ratio, total soluble solids, HCN content, green fodder yield per plot, dry fodder yield per plot, and protein percent. The observed F_1data was analyzed for mid parent heterosis, heterobeltiosis and standard heterosis whereas F_2data was analyzed for inbreeding depression.The large number of crosses exhibited heterosis and inbreeding depression in desired direction for all yield related and quality traits under study which indicated the presence of additive as well as non-additive gene actions. The crosses ICSA 271 x PC 5, ICSA 276 x CSV-15, 993100 A x 04K 668, 11 A_2 x 04 K 693, ICSA 469 x 04 K 668, ICSA 293 x 01 K 733, SPA_2 94012 x 04 K 700, ICSA 293 x CSV-15, SP 55609 A x UPMC-8, and 993100 A x 04 K 700 exhibited high mean performance for all the traits under study coupled with high heterosis in desired direction.

Keywords: Line x Tester, Checks, Heterosis, Inbreeding Depression, and Gene Action.

1. Introduction: Sorghum[*Sorghum bicolor* (L.) Moench], 2n=2x=20, a C_4 plant of family *Poaceae*, is a major food, feed and fodder crop globally. It is the fifth mostimportant crop after wheat, rice, maize and barley and is widely cultivated in the semi-arid regions of the world **(Anglani, 1998)**. It has extensive used as grain sorghum,forage sorghum, and sweet sorghum, providing feed, food, fodder,fiberand fuel. Nutritionally, among the *kharif* fodders, sorghum is a crop *par excellence* with starch (63-68%), high digestibility (50-60%),dry matter content (20-35%), sugars (8-17%), crude protein (7.5-10.0%), calcium (0.53%), phosphorus (0.24%), and crude fiber (30-32%) **(Sheoran*et al.*,2000)**. A major staple food of many countries in Asia and Africa, sorghum is now a major feed crop in the United States, Mexico, Australia, Argentina, and South Africa **(Miller and Kebede, 1984).** Globally, the sorghum is grown on an area of 41.14 million hectares with production of 58.72 million tons annually. In India, it is grown for food, feed and fodder purpose on an area of around 5.0 million hectares with 4.5 million tons of grain production per annum (**USDA Foreign Agriculture Service, 2019).** Five basic races of cultivated sorghum are recognized as *Bicolor, Caudatum, Guinea, Kafir,* and*Durra***(Harlan and de Wet, 1972).** Discovery of male sterility in sorghum due to interaction of milo cytoplasm with *kafir* genes **(Stephen, 1954)** opened avenues for utilization of male sterility for commercial exploitation of heterosis in sorghum through hybrid development. With the growing human population and increasing demands for meat and milk, there is need for more feed and fodder to feed increased population of livestock. Currently in India, on an average there is deficit of green and dry fodder to the extent of 40%, which may further increase in future because of increasing population, with the growing affluence and rising economies, are turning to non vegetarian diets and therefore, we need to increase the productivity of forage and fodder crops in a sustainable manner **(Anonymous, 2001).** Exploitation of heterosis is a quick and convenient way of combining desirable characters. It is important in sorghum, as it may be an indicative of producing transgressive segregants for many quantitative characters in advanced generations. Inbreeding depression is a component which could help in breeding programme by finding out the performance of the trait in segregating generation and its deviation from the first filial generation. Further high heterosis coupled with low inbreeding depression indicates additive genetic variance which can be fixed in the segregating generations. The objective of this study was to determine the heterosis and inbreeding depression of 70 F_1 and 70 F_2 crosses for fodder yield and quality traits by following a line x tester (L x T) mating design.

2. Material and Methods: The experimental materials for the present study consisted of seventy F_1 crosses developed through line x tester mating design involving ten diverse *Sorghum bicolor* type CMS lines (female) *viz.*, ICSA-467, 11A_2 , HB 94004 A, SPA_2 94012, ICSA-469, ICSA-271, 993100 A, ICSA-276, ICSA-293, SP55609 A and seven *Sorghum sudanense/Sorghum bicolor* type forage sorghum pollinator (male) lines *viz.*, CSV-15, PC-5, 04 K 693 (UPMC-512), 04 K 700 (SDSL 921001 x IS-3359), 01 K 733 (SDSL 92101 x SDSL 92111), UPMC-8, 04 K 668 (SDSL- 92134 x SDSL-92140). Resultant 70 hybrids along with 17 parents and four checks were planted during *Kharif*2018. The field experiment with 91 treatments (70 F_1s + 17 parents + 4 checks- (CSH-20MF, CSH-24MF, SSG 59-3 and CSH 13) were planted in random block design (R.B.D.) with three replications. Each treatment was accommodated in a plot size of 3 m^2 (4 rows of 3m length spaced at 25 cm). Observations were recorded on plant height, stem girth, number of leaves per plant, leaf length, leaf width, leaf area, leaf:stem ratio, total soluble solids, HCN content, green fodder yield per plot, dry fodder yield per plot, total soluble solids (TSS) and protein percent. The same practices were followed to raise F_2 generation of 70 F_1 crosses by selfing during *Kharif* 2019.

The mid parent heterosisandheterobeltiosiswere computed as suggested by **Fonesca and Patterson (1968)** for each character using the following formula:

$$\text{Mid parent heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{F_1}$ = Mean performance of F_1 hybrid

$\overline{P_1}$ = Mean performance of parent one

$\overline{P_2}$ = Mean performance of parent two

$\overline{MP}$ = Mean performance of mid parent

$\overline{BP}$ = Mean performance of better parent

The significance of heterosis was tested with‘t’ test.

The inbreeding depression (ID) between two generations *i.e.* F_1 and F_2 was calculated as the deviation of the mean performance from its previous generation mean.

$$\text{I.D. in } F_2 (\%) = \frac{\bar{F}_1 i - F_2 i}{\bar{F}_1 i} \times 100$$

Table 1:- Details of Parental Lines.

SI. No.	Genotype	Origin	Characteristics
Female lines			
1.	ICSA 467	ICRISAT	Tall, multicut, medium duration, tan type
2.	11 A_2	NRCS	Non-tillering, non milo, medium duration
3.	HB 94004 A	ICRISAT	Non-tillering, tan type and early duration
4.	SPA_2 94012	ICRISAT	Dwarf, tan type, single cut and late duration
5.	ICSA 469	ICRISAT	Tall, tan type, multicut, medium duration
6.	ICSA 271	ICRISAT	Tan type, non-tillering and medium duration
7.	993100 A	ICRISAT	Tan type, non-tillering and medium duration
8.	ICSA 276	ICRISAT	Tan type, non-tillering and medium duration
9.	ICSA 293	ICRISAT	Tan type, tillering
10.	SP 55609 A	ICRISAT	
Male lines (Testers)			
1.	CSV 15	DSR	Non-tillering, tan type
2.	PC 5	Pantnagar	Tall, tan, single cut and medium duration
3.	04 K 693	Pantnagar	Selection
4.	04 K 700	Zimbabwe	Selection
5.	01K 733	Zimbabwe	Selection
6.	UPMC 8	Pantnagar	Tall, tan type, multicut and medium duration
7.	04 K 668	Zimbabwe	Selection
Checks			
1.	CSH 13	DSR Hyderabad	Single cut
2.	CSH 20 MF	Pantnagar	Multicut
3.	CSH 24 MF	Pantnagar	Tillering, tan type and multicut
4.	SSG 59-3	HAU Hisar	multicut

* **04 K 693 – UPMC 512, 04 K 700 - SDSL 92101 x IS 3359, 01 K 733 – SDSL 92101 x SDSL 92111, 04 K 668 – SDSL 92134 x SDSL 92140**.

3. Result and Discussion:

3.1 Estimates ofmid parent heterosis, heterobeltiosis and standard heterosis for different yield related and quality traits:

3.1 Plant height: The range of heterosis for mid parent and better parent heterosis was -14.28 to 117.91 and 26.31 to 68.01 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24

MF was found -30.32 to 52.06, -29.38 t0 54.12, -49.71 to 9.74 and -33.51 to 45.10 respectively.Sixty eight crosses were had highly significant positive heterosis over mid parent except two crosses ICSA 467 X UPMC 8 and 11 A2 X CSV 15 while fifty crosses had highly significant positive heterosis over better parent and two crosses had significant positive heterosis *viz.* SPA_2 94012 X 01 K 733 and ICSA 271 X 01 K 733.Fifty crosses exhibited significant positive heterobeltiosiswhile twocrosseshad significant positive heterobeltiosis*viz.* SPA_2 94012 X 01 K 733 and ICSA 271 X 01 K733. Fifty four crosses had highly significant positive standard heterosis over CSH 20 MF, fifty crosses had highly significant positive standard heterosis over SSG 59-3, a single cross 993100 A X 04 K 700 had highly significant positive standard heterosis while two crosses ICSA 276 X CSV 15 and ICSA 293 X CSV 15 had significant positive standard heterosis over CSH 13 whereas forty two crosses had highly significant positive standard heterosis and single cross ICSA 293 X 04 K 700 had significant positive standard heterosis over CSH 24MF. The present findings were similar to the findings of **Desai *et al.* (1999), Shaug*et al.* (2000), Ravindrababu (2002), Sharma *et al.*(2003), Bhatt (2008), and Pandey** and**Shrotria (2012).**

3.2 Number of leaves perplant: The range of mid parent heterosis and better parent heterosis was observed -18.23 to23.03 and -22.59 to 20.35 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF were observed -14.78 to 23.77, -17.65 to 19.61, -31.52 to -0.54 and -24.90 to 9.07 respectively.Twelve crosses exhibited highly significant positive heterosis over mid parent and three crosses exhibited significant positive heterosis over mid parent viz. ICSA 467 X PC 5, HB 94004 A X 04 K 700, and ICSA 469 X UPMC8.Five crosses exhibited highly significant positive heterobeltiosis viz. HB 94004 A X 04 K 693,993100 A X CSV 15,ICSA 276 X 04 K 693,ICSA 276 X 04 K 700,SP 55609 A X CSV 15 while four crosses exhibited significant positive heterobeltiosis.Seven crosses exhibited highly significant positive standard heterosis over CSH 20 MFviz.HB 94004 A X 04 K 693,ICSA 271X 04 K 668,993100 A X CSV 15,ICSA 276 X CSV 15,ICSA 276 X 04 K 693,ICSA 276 X 04 K 700,SP 55609 A X CSV 15 while eleven crosses exhibited significant positive standard heterosis. Six crosses exhibited highly significant positive standard heterosis over SSG 59-3 viz. HB 94004 A X 04 K 693, ICSA 271X 04 K 668, 993100 A X CSV 15, ICSA 276 X CSV 15, ICSA 276 X 04 K 693, ICSA 276 X 04 K 700 and significant positive standard heterosis for only single cross SP 55609 A X CSV 15, none of the cross exhibited either highly significant positive or significant positive standard heterosis over CSH 13 and only single cross ICSA 276 X 04 K 700 had highly significant positive standard heterosis over CSH 24 MF. The present findings were similar to the The present findings were similar to the findings of **Desai (1999), Agrawal and Shrotria (2005),** and **Bhatt (2008).**

3.3 Leaflength:The range of mid parent heterosis and better parent heterosis was -7.24 to 19.61 and -18.33 to 16.55 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF were observed -17.96 to 12.46, -13.58 to 18.47, -17.02 to 13.76 and -28.61 to -2.13 respectively.Three crosses had highly significant positive relative heterosis viz. 11 A2 X CSV 15, ICSA 271X 04 K 668 and ICSA 276 X 01 K 733 while eight crosses had significant positive relativeheterosisandonly single cross 11 A_2 X CSV 15 had significant positive heterobeltiosis. Only single cross 11 A_2 X PC 5 had significant positive standard heterosisoverCSH20MF, SSG 59-3 and CSH 13 and four crosses had significant positive standard heterosis over SSG 59-3 viz. ICSA 467 X PC 5, 11 A_2 X CSV 15, HB 94004 A X PC 5 and SPA_2 94012 X PC 5. None of the crosses had either highly significant positive or significant positive heterosis over CSH 24 MF. The present findings were similar to the findings of **Desai (1999), Agrawal and Shrotria (2005),** and **Bhatt (2008).**

3.4 Leafwidth: The range of mid parent heterosis and heterobeltiosis was -17.44 to 35.26 and -25.35 to30.73respectively.TherangeofstandardheterosisoverCSH20MF,SSG59-3,andCSH13CSH24MFwas-10.67 to 31.46, -4.22 to 40.96, -41.11 to -13.33 and -35.73 to -5.42 respectively.Thirty seven crosses had highly significant positive relative heterosis and significant positive relative heterosis for six crosses *viz.* ICSA 467 X 04 K 700,11A_2 X PC 5,SPA_2 94012 X CSV 15,SPA_2 94012 X 01 K 733, ICSA 469 X 04 K 700 and 993100 A X PC 5 over mid parent. Twenty five crosses had highly significant positive heterobeltiosis while two crosses viz. 993100 A X CSV 15 and ICSA 276 X 04 K 693 had significant positive heterobeltiosis. Twenty seven crosses had highly significant positive standard heterosis overCSH20 MF while nine crosses had significant positive standard heterosis viz. ICSA 467 X CSV 15, 11 A_2 X 01 K 733,HB 94004 A X 04 K 700,ICSA 469 X CSV 15,ICSA 276 X 04 K 693, ICSA 293 X PC 5, ICSA 293 X UPMC 8, SP 55609 A X 04 K 700 and SP 55609 A X 01 K 733 over CSH 20 MF. Fifty one crosses had highly significant positive standard heterosis over SSG 59-3 whilethreecrosses had significant positive standard heterosis viz. ICSA 467 X 04 K 700, ICSA 271 X UPMC 8 and ICSA 276 X 04 K 668 over SSG 59-3.None of the crosses had either highly significant positive or significant positive standard heterosis over CSH 13 and CSH 24 MF. The present findings were similar to the findings of **Desai (1999), Agrawal and Shrotria (2005),** and Bhatt **(2008).**

3.5 Leaf area (cm^2): The range of mid parent heterosis and better parent heterosis were found -21.14 to 58.13 and -28.71 to 42.05 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 24 MF and CSH 13 was -15.07 to 36.44, -6.54 to 50.14, -47.60 to -15.82 and -44.18 to 10.32 respectively.Forty one crosses had highly significant positive relative heterosis over mid parent andsinglecrossICSA 271 X UPMC 8had significant positive relative heterosis.Twenty nine crosses had highly significant positive heterosis over better parent while three crosses ICSA 467 X 01 K 733, $SPA_2$94012 X 04 K 668 and ICSA 293 X 04 K 668 exhibited significant positive heterobeltiosis. Twenty four crosses had highly significant positive standard heterosis over CSH 20 MFwhile three crosses SPA_2 94012 X CSV 15, ICSA 469 X CSV 15 and ICSA 271 X UPMC 8 had significant positive standard heterosis over CSH 20 MF.Forty three crosses had highly significant positive standard heterosis over SSG 59-3 while seven crosses had significant positive standard heterosis over SSG 59-3 viz. ICSA 467 X 01 K 733, HB 94004 A X PC 5, HB 94004 A X 04 K 693, HB 94004 A X UPMC 8, ICSA 276 X 04 K 668, ICSA 293 X CSV 15 and ICSA 293 X PC 5. None of the crosses had either highly significant or positive significant standard heterosis over CSH 13 and CSH 24 MF. The present findings were similar to the findings of **Desai (1999), Agrawal and Shrotria (2005),** and **Bhatt (2008).**

3.6 Stem girth(cm): The range of mid parent heterosis and better parent heterosis were found -30.12 to 28.47 and -42.96 to 25.71 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -16.43 to 34.82, -21.26 to 27.03, -48.19 to -16.41 and -53.05 to -24.26 respectively. Sixteen crosses had highly significant positive heterosis over mid parent whilefivecrosses had significant positive heterosis over mid parent viz. ICSA 469 X 04 K 700, ICSA 271 X UPMC 8,ICSA 293 X CSV 15,ICSA 293 X UPMC 8andSP 55609 A X CSV 15. TwocrossesICSA 271X 04 K 693andSP 55609 A X 04 K 693 exhibited highly significant positive heterosis over better parent and six crosses ICSA 467 X PC 5, ICSA 467 X 04 K 700, ICSA 271 X 04 K 700, SP 55609 A X CSV 15,SP 55609 A X 04 K 700 and SP 55609 A X 04 K 668 had significant positive heterosis over better parent. Eighteen crosses had highly significant positive standard heterosis over CSH 20 MF while four crosses ICSA 467 X 04 K 700, 993100 A X 04 K 493, 993100 A X 04 K 668 and SP 55609 A X 04 K 693 had significant positive standard heterosis over CSH 20MF. Ten crosses had highly significant positive standard heterosis over SSG 59-3 while two crosses ICSA 467 X PC 5 and ICSA 276 X 04 K 693 had significant positive standard heterosis over SSG59-3. None of the crosses had either highly significant positive or significant positive standard heterosis over CSH 13 and CSH 24 MF. **D**The present findings were similar to the findings of**Desai (1999), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.7 Total soluble solids: The range of mid parent heterosis and better parent heterosis were found -26.23 to 150 and -41.18 to 102.70** respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -34.78 to 63.04, 20-200, -48.19 to -16.41 and 87.27 to 368.16 respectively.Thirtysevencrosseshadhighlysignificantpositiveheterosisovermidparentwhile six crosses had significant positive heterosis over midparentviz.11 A_2 X 01 K 733,11A_2 X UPMC 8,HB 94004 A X 04 K668, SPA_2 94012 X PC 5, ICSA 469 X UPMC 8 and 993100 A X 04 K 493. Twenty crosses had highly significant positive heterosis over better parent while none of the cross had significant positive heterosis over better parent. Thirty six crosses had highly significant positive standard heterosis over CSH 20 MF while two crosses 11 A_2 X 04 K668 and ICSA 276 X PC 5 had significant positive standard heterosis over CSH 20 MF. Sixty nine out of seventy crosses had highly significant positive standard heterosis over SSG 59-3 except the cross 11 A_2 X 04 K 693. All seventy crosses had highly significant positive standard heterosis over SSG 59-3. Nineteen crosses had highly significant positive standard heterosis over CSH 13 while five crosses HB 94004 A X PC 5, SPA_2 94012 X 04 K 693, ICSA 469 X PC 5, 993100 A X 04 K 493 and SP 55609 A X UPMC 8had significant positive standard heterosis over CSH 13. All seventy crosses had highly significant positive standard heterosis over CSH 24 MF. The present findings were similar to the findings of **Desai (1999), Shaug (200), Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.8 Leaf:stemratio: The range of mid parent heterosis and better parent heterosis were found 43.62 to45.86 and -52.07 to 32.88 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -44.44 to 46.67, -40.24 to 41.94, -49.49 to 33.33 and -62.12 to -12.12 respectively. Seven crosses had highly significant positive heterosis over mid parent viz. ICSA 467 X PC 5, 11 A_2 X CSV 15, SP$A_2$94012 X PC 5, SP 55609 A X CSV 15, SP 55609 A X 04 K 693, SP 55609 A X 01 K 733 and SP 55609 A X UPMC 8 while three crosses SPA_2 94012 X 04 K 668, ICSA 271 X UPMC 8 and SP 55609 A X PC 5 had significant positive heterosis over mid parent.Three crosses SP 55609 A X 04 K 693, 11A_2 X CSV 15 and SP 55609 A X 01 K 733had highly significant positive heterosis over better parent while two crosses ICSA 467 X PC 5 and SP 55609 A X UPMC 8had significant positive heterosis over better parent. Two crosses ICSA 467 X PC 5 and HB 94004 A X PC 5had highly significant positive standard heterosis over CSH 20 MF while none of the other crosses had significant positive standard heterosis over CSH 20 MF. Two crosses ICSA 467 X PC 5 and 11A_2X CSV 15 had highly significant positive standard heterosis over CSH 13 while none of the other crosses had significant positive standard heterosis over CSH 13.None of the crosses had either highly significant positive or significant positive standard heterosis over CSH 24 MF. The present findings were similar to the findings of **Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.9 Hydrocyanic acid content(ppm): The range of mid parent heterosis and better parent heterosis were found -41.09 to37.69 and -46.6 to 25.74 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -20.22 to 62.07, -32.50 to 37.13, -46.72 to 8.23 and -24.42 to 53.54 respectively. Seventeen crosses had highly significant negative relative heterosis while three crosses exhibited significant negative viz. SPA$_2$ 94012 X PC 5, ICSA 469 X 04 K 693 and ICSA 293 X UPMC 8. Twenty one crosses exhibited highly significant negative heterobeltiosis whilesixcrosseshad significantnegativeheterobeltiosisviz.ICSA 467 X 04 K668,11A$_2$ X CSV 15,SPA$_2$ 94012 X PC 5, SPA$_2$94012 X 04 K 693, ICSA 293 X 01 K 733and ICSA 293 X UPMC 8. Only one cross HB 94004 A X 01 K 733 had significant negative standard heterosis over CSH 20 MF.Two crosses HB 94004 A X PC 5 and HB 94004 A X 01 K 733 had highly significant negative while fifteen crosses exhibited significant negative standard heterosis overSSG59-3. Forty eight crosses had highly significant negative standard heterosis over CSH 13whereas seven crosses exhibited significant negative standard heterosis over CSH 13 viz. ICSA 467 X CSV 15, SPA$_2$ 94012 X UPMC 8, 993100 A X 04 K 700, ICSA 293 X 04 K 693, ICSA 293 X 01 K 733, SP 55609 A X 04 K 700 and SP 55609 A X UPMC 8. A single cross HB 94004 A X 01 K 733 exhibited highly significant negative standard heterosis over CSH 24 MF. The present findings were similar to the findings of **Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.10 Green fodder yield(kg/plot): The range of mid parent heterosis and better parent heterosis were found -30.12 to28.47 and -42.96 to 25.71 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -16.43 to 34.82, -21.26 to 27.03, -48.19 to -16.41 and -53.05 to -24.26 respectively. Thirty six crosses exhibited highly significant positive relative heterosis and eight crosses had significant positive relative heterosis viz. SPA2 94012 X CSV 15, ICSA 469 X CSV 15,ICSA 469 X 01 K 733,ICSA 271 X UPMC 8,ICSA 276 X 04 K 668, ICSA 293 X 04 K 693, ICSA 293 X 04 K 668 and SP 55609 A X 04 K 668. Nineteen crosses exhibited highly significant positive heterobeltiosiswhereasfourcrosseshadsignificant positiveheterobeltiosisviz.SPA$_2$ 94012 X 04 K 693,SPA$_2$ 94012 X 04 K 668,ICSA 271 X 04 K 700 and ICSA 271X 04 K 668. Thirty one crosses exhibited highly significant positive standard heterosis over CSH 20 MF and three crosses had significant positive standard heterosis over CSH 20 MF viz., ICSA 293 X 04 K 693, SPA$_2$ 94012 X UPMC 8, and ICSA 469 X 04 K 700.Only two crosses had highly significant positive standard heterosis over SSG 59-3 viz. ICSA 271 X PC 5 and ICSA 276 X CSV 15. Only single cross ICSA 271 X PC 5 had highly significant positive standard heterosis over CSH 13 and only one cross 993100 A X 04 K 668 had significant positive standard heterosis over CSH 13.None of the cross exhibited either highly significant positive standard heterosis or significant positive standard over CSH 24 MF. The present findings were similar to the findings of **Desai (1999), Shaug (2000), Ravindrababu (2002), Grewal (2003),Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.11 Dry fodderyield: The range of mid parent heterosis and better parent heterosis were found -26.72 to134.82 and -40.55 to 103.04 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -25.78 to 128.26, -47.12 to 62.61, -65.36 to 6.52 and -75.86 to -25.76 respectively.

Thirty crosses had highly significant positive heterosis over mid parent and seven crosses exhibited significant positive heterosis over mid parent viz. HB 94004 A X PC 5, SPA$_2$ 94012 X 04 K 693,ICSA 469

X 04 K 700,ICSA 469 X 01 K 733,ICSA 469 X UPMC 8, ICSA 271X 04 K 693 and ICSA 271 X UPMC 8.Seventeen crosses had highly significant positive heterosis over better parent whereas three crosses HB 94004 A X 04 K 700, ICSA 276 X UPMC 8 and ICSA 293 X PC 5 had significant positive heterosis over betterparent. Twenty four crosses had highly significant positive standard heterosis over CSH 20 MF. Four crosses had highly significant positive standard heterosis over SSG 59-3 viz. ICSA 271 X PC 5, 993100 A X 04 K 668, ICSA 276 X CSV 15, ICSA 293 X 04 K 700 and SP 55609 A X 04 K 693 and only one cross ICSA 293 X CSV 15exhibited significant positive standard heterosis over SSG 59-3.Five crosses had highly significant positive standard heterosis over SSG 59-3 viz. ICSA 271 X PC 5, 993100 A X 04 K 668, ICSA 276 X CSV 15, ICSA 293 X 04 K 700 and SP 55609 A X 04 K 693. None of the cross exhibited either highly significant or significant standard heterosis over CSH 13 and CSH 24 MF.The present findings were similar to the findings of **Desai (1999), Shaug (2000), Ravindrababu (2002), Grewal (2003),Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.12 Protein per cent: The range of mid parent heterosis and better parent heterosis were found -16.70 to 25.76 and -20.65 to 24.03 respectively. The range of standard heterosis over CSH 20 MF, SSG 59-3, CSH 13 and CSH 24 MF was -16.43 to 34.82, -21.26 to 27.03, -48.19 to -16.41 and -53.05 to -24.26 respectively. Sixteen crosses had highly significant positive relative heterosis whereas only three crosses exhibited significant positive relative heterosis viz. $11A_2$ X CSV 15, ICSA 469 X 01 K 733 and ICSA 276 X PC 5. Eight crosses had highly significant positive heterobeltiosis viz. ICSA 467 X 01 K 733,ICSA 467 X UPMC 8,ICSA 467 X 04 K668,$11A_2$ X 04 K 700,$11A_2$ X 01 K 733,$11A_2$ X UPMC 8,HB 94004 A X PC 5 and HB 94004 A X 04 K 700 where as three crosses significant positive heterobeltiosis viz. ICSA 467 X 04 K 693, $11A_2$ X 04 K 693 and ICSA 469 X PC 5. None of the cross exhibited highly significant positive standard heterosis over CSH 20 MF while significant positive standard heterosis over CSH 20 MF was observed in two crosses 11 A_2 X UPMC 8 and ICSA 469 X PC 5. Only single cross ICSA 469 X PC 5 exhibited highly significant positive standard heterosis over SSG 59-3. Twenty three crosses highly significant positive standard heterosis over CSH 13 andelevencrosses had significant positive standard heterosis over CSH 13. Fourteen crosses exhibited highly significant positive standard heterosis over CSH 24MF. The present findings were similar to the findings of **Sharma *et al.* (2003), Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

In many crops where yield plateau has reached, among the conventional breeding approaches, heterosis is likely to play leading role in crop improvement programme for breaking yield stagnation and obtaining higher production. During the last 40-50 decades, the heterosis phenomenon has been proved to be most important genetic tool inenhancing grain and fodder yield in sorghum, pearl millet, maize and recently in self pollinated crop like rice. Moreover, hybrid vigour has not been fully exploited in self pollinated crops as compared cross pollinated as well as often cross pollinated crops where cost effective systems are available for producing the hybrid seed at commercial scale. As heterosis is generally expressed in the crosses of diverse parents and diversity of parents if combined with additive x additive interaction may give better recombinants in their cross combination with potential of giving high yielding genotypes in later generations of advancement.Sorghum has the unique advantages of being treated as pure autogamous crop under controlled pollination and pure allogamous with use of cytoplasmic genetic male sterility system.

3.2 Estimates of inbreeding depression: Study of inbreeding depression in $F_2$is a good indication of predicting performance of F_1hybrids. Further, inbreeding depression in F_2 generation may express the performance of different crosses.

3.2.1 Plant height: Highly significant negative inbreeding depression coefficient was observed in eight crosses 11 A_2 X 04 K 693, HB 94004 A X 01 K 733, ICSA 469 X 04 K 700, ICSA 271 X 04 K 668, 993100 A X 04 K 668, 993100 A X 04 K 693, ICSA 293 X 04 K 700, SP 55609 A X 04 K 668. The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.2 Number of leaves: The inbreeding depression coefficient was found highly significant positive in twenty eight crosses.Highly significant negative inbreeding depression coefficient was observed in thirty five crosses whereas in cross HB 94004 A X 01 K 733 exhibited significant negative inbreeding depression coefficient. The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.3 Leaf length: The inbreeding depression coefficient was found significant positive in four crosses ICSA 467 X 01 K 733, 11 A_2 X PC 5, ICSA 276 X 04 K 700 and SP 55609 A X 04 K 700.The magnitude of inbreeding depression coefficient was observed highly significant negative in crosses ICSA 271 X UPMC 8 and ICSA 293 X CSV 15.Significant negative inbreeding depression coefficient was observed in crosses ICSA 469 X 01 K 668, ICSA 276 X 04 K 693, HB 94004 A X CSV 15, ICSA 293 X 04 K 693.The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.4 Leaf width: The inbreeding depression coefficient was found highly significant positive in twenty seven crosses whereas the magnitude of inbreeding depression coefficient was observed highly significant negative in crosses forty crosses. The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.5 Leaf area: The magnitude of inbreeding depression coefficient was observed highly significant negative in crosses HB 94004 A X PC 5, HB 94004 A X 04 K 700, ICSA 469 X 04 K 668. The magnitude of inbreeding depression coefficient was observed significant negative in crosses HB 94004 A X 04 K 668,ICSA 469 X 01 K 733, ICSA 271 X UPMC 8. The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.6 Stem girth: The inbreeding depression coefficient was found highly significant positive in crosses thirty one crosses.The magnitude of inbreeding depression coefficient was observed highly significant negative in thirty seven crosses. The present findings were similar to the findings of **Agrawal and Shrotria (2005)**and **Pandey and Shrotria (2012).**

3.2.7 Total soluble solids: The inbreeding depression coefficient was found highly significant positive in twenty eight crosses whereas the magnitude of inbreeding depression coefficient was observed highly significant negative in thirty five crosses. The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.8 Leaf: Stem ratio: The inbreeding depression coefficient was found highly significant positive in fifty four crosses whereas the magnitude of inbreeding depression coefficient was observed highly significant negative in fifteen crosses ICSA 467 X 04 K 693, ICSA 467 X 04 K 700, ICSA 467 X 01 K 733, 11 A2 X PC 5, 11 A2 X 04 K 668, HB 94004 A X 04 K 668, SPA2 94012 X UPMC 8, ICSA 271 X PC 5, 993100 A X 04 K 668, ICSA 276 X CSV 15, ICSA 276 X PC 5, ICSA 276 X 04 K 693, ICSA 293 X UPMC 8, ICSA 293 X 04 K

668 and SP 55609 A X 04 K 693.The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.9 Hydrocyanic acid content: The inbreeding depression coefficient was found highly significant positive in crosses ICSA 271 X 04 K 693, 993100 A X PC 5, 993100 A X 01 K 733 whereas significant positive in crossICSA 293 X 04 K 693.The magnitude of inbreeding depression coefficient was observed highly significant negative in eleven crosses viz. ICSA 467 X CSV 15, ICSA 467 X 01 K 733, ICSA 467 X UPMC 8, 11 A_2 X CSV 15, 11 A_2 X 04 K 693, HB 94004 A X 04 K 693, HB 94004 A X 01 K 733, HB 94004 A X 04 K 668, SPA_2 94012 X PC 5, SPA_2 94012 X 04 K 693, ICSA 271 X 01 K 733.The magnitude of inbreeding depression coefficient was observed significant negative in crosses SPA_2 94012 X 01 K 733,HB 94004 A X CSV 15 and ICSA 293 X CSV 15.The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.10 Green fodder yield per plot: The inbreeding depression coefficient was found highly significant positive in crosses fifty two crosses. The magnitude of inbreeding depression coefficient was observed highly significant negative in seventeen crosses ICSA 467 X PC 5, ICSA 467 X 04 K 693, 11 A2 X CSV 15 , 11 A2 X PC 5, 11 A2 X 01 K 733, HB 94004 A X 04 K 693, HB 94004 A X 01 K 733, SPA2 94012 X PC 5, ICSA 469 X PC 5, ICSA 469 X 04 K 700, ICSA 271 X 01 K 733, 993100 A X CSV 15, 993100 A X 04 K 693, ICSA 276 X 04 K 693, ICSA 276 X 04 K 700, SP 55609 A X CSV 15, SP 55609 A X 04 K 668.The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.11 Dry fodder yield per plot: The inbreeding depression coefficient was found highly significant positive in twenty crosses.The magnitude of inbreeding depression coefficient was observed highly significant negative in fifty crosses.The present findings were similar to the findings of **Agrawal and Shrotria (2005),Bhatt (2008),** and **Pandey and Shrotria (2012).**

3.2.12 Protein content: The inbreeding depression coefficient was found highly significant positive in thirty nine crosses.The magnitude of inbreeding depression coefficient was observed highly significant negative in twenty eight crosses.The present findings were similar to the findings of **Pandey and Shrotria (2012).**

4. Summary and Conclusion: The large number of crosses exhibited heterosis and inbreeding depression in desired direction for all yield related and quality traits under study which indicated the presence of additive as well as non-additive gene actions. The crosses ICSA 271 x PC 5, ICSA 276 x CSV-15, 993100 A x 04K 668, 11 A_2 x 04 K 693, ICSA 469 x 04 K 668, ICSA 293 x 01 K 733, SPA_2 94012 x 04 K 700, ICSA 293 x CSV-15, SP 55609 A x UPMC-8, and 993100 A x 04 K 700 exhibited high mean performance for all the traits under study coupled with high heterosis in desired direction. The magnitude of heterosis for forage yield and its component traits along with quality traits suggested enough diversity among the parental lines. Low and negative heterosis can be attributed to the presence of large epistatic gene effects and incomplete dominant gene action. High inbreeding depression was a reflection of high heterosis. Negative estimates of inbreeding depression may be attributed to the occurrence of transgressive segregants in the F_2 population. Both heterosis and inbreeding depression are the results of dominance type of gene action and heterosis is absent where the traits are governed only by additive gene action**(Hunter and Anderson, 1997).** For the crosses, showing negative and significant inbreeding depression there is a scope for selection of desirable plants in the F_2 population for improvement of these traits. Positive inbreeding depression of substantial magnitude for respective traits suggested the role of non additive gave action. It may be seen from the present study that the hybrid combinations that showed higher estimates of heterosis in general found to show substantial inbreeding depression.

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1.

2.

3.

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7. Tables: In next page

Table 2: Summary of heterotic effects for various characters in desired direction.

	Number of crosses showing significant heterosis in desired direction					
			SD			
Characters	**MP**	**BP**	**C-1**	**C-2**	**C-3**	**C-4**
Plant height	68	52	54	50	3	43
Number of leaves	15	9	18	7	0	1
Leaf length	11	1	1	5	1	0
Leaf width	43	28	36	54	0	0
Leaf area	42	44	27	50	0	0
Stem girth	21	8	22	12	0	0
TSS %	43	20	38	69	24	70
Leaf stem ratio	10	5	2	3	2	0
HCN content	20	27	1	17	54	1
Green fodder yield	44	23	35	2	1	0
Dry fodder yield	39	20	31	5	0	0
Protein per cent	19	11	2	1	23	19

C-1: CSH 20MF **C-2: SSG 59-3** **C-3: CSH13** **C-4: CSH 24 MF**

MP= Mid Parent Heterosis **BP= Better Parent Heterosis** **SD= Standard Heterosis**

Table 3: Mean performance of best hybrids and the extent of heterosis in its component traits.

Cross	Mean Performance	Estimate of heterosis											
		Plant height						Number of leaves					
	Green fodder yield (ton/ha)	MP	BP	SD				MP	BP	SD			
				C-1	C-2	C-3	C-4			C-1	C-2	C-3	C-4
ICSA 271 X PC 5	**42.5**	103.58**	65.39**	36.88 **	38.74 **	-1.21	30.62 **	-10.67 **	-13.74**	-8.99*	-12.04**	-26.86**	-19.80**
ICSA 276 X CSV 15	**34.2**	86.07**	57.67**	42.62 **	44.55 **	2.92 *	36.09 **	10.74 **	7.49*	16.52**	12.61**	-6.36*	2.68
993100 A X04 K668	**31.7**	74.85**	19.69**	26.27 **	27.98 **	-8.87 **	20.49 **	2.74	0	8.70*	5.04	-12.65**	-4.21
11 A2 X 04 K 693	**30.8**	12.97**	-5.09**	0.62	1.98	-27.39 **	-3.99 *	-6.50 *	-12.44**	0	-3.36	-19.64**	-11.88**
ICSA 469 X 04 K 668	**29.7**	38.75**	5.01**	10.78 **	12.29 **	-20.05 **	5.71 **	-12.26 **	-16.00**	-8.70*	-11.76**	-26.62**	-19.54**
ICSA 293 X 01K 733	**29.4**	42.37**	14.17**	21.15 **	22.80 **	-12.57 **	15.61 **	10.29 **	7.14*	8.70*	5.04	-12.65**	-4.21
SPA2 94012 X 04 K 700	**28.6**	53.87**	5.09**	5.73 **	7.17 **	-23.69 **	0.9	-1.57	-6.76	0	-3.36	-19.64**	-11.88**
ICSA 293 X CSV 15	**28.3**	84.36**	57.48**	42.45 **	44.38 **	2.80 *	35.93 **	-12.54 **	-12.78**	-11.01**	-14.01**	-28.49**	-21.58**
SP 55609 A X UPMC 8	**28.3**	1.76	1.63	-2.2	3.02	-1.07	-14.89 **	5.26	0.53	6.74	14.46**	-29.63**	-23.20**
993100 A X 04 K700	**27.8**	-2.35	-3.62	-9.98	-5.18	-8.95	-21.66 **	23.68**	16.23**	24.72**	33.73**	-17.78**	-10.27**

Continued……….

Cross	Mean Performance	Estimate of heterosis											
		Leaf length						Leaf width					
	Green fodder yield (ton/ha)	MP	BP	SD				MP	BP	SD			
				C-1	C-2	C-3	C-4			C-1	C-2	C-3	C-4
ICSA 271 X PC 5	**42.5**	10.8	-8.82	4.01	9.57	5.21	-9.49	28.97**	23.95**	16.29**	24.70**	-23.33**	-16.33**
ICSA 276 X CSV 15	**34.2**	8.03	0.08	-6.37	-1.37	-5.29	-18.52 **	21.94	18.23**	20.22**	28.92**	-20.74**	-13.50**
993100 A X04 K668	**31.7**	-3.63	-5.93	-10.14	-5.34	-9.11	-21.80 **	2.72	-1.05	6.18	13.86**	-30.00**	-23.61**
11 A2 X 04 K 693	**30.8**	3.71	3.3	-2.83	2.36	-1.71	-15.44 **	-11.22**	-18.31**	-2.25	4.82	-35.56**	-29.67**
ICSA 469 X 04 K 668	**29.7**	2.58	-5.23	-9.47	-4.64	-8.43	-21.22 **	-2.08	-9.18**	5.62	13.25**	-30.37**	-24.01**
ICSA 293 X 01K 733	**29.4**	12.71*	11.03	-0.67	4.64	0.48	-13.56 *	20.71**	12.71**	14.61**	22.89**	-24.44**	-17.54**
SPA2 94012 X 04 K 700	**28.6**	0.53	0.46	-6.17	-1.16	-5.09	-18.35 **	2.75	0	-5.62	1.2	-37.78**	-32.09**

ICSA 293 X CSV 15	**28.3**	-5.88	-9.29	-15.13 *	-10.6	-14.16 *	-26.15 **	12.82**	9.39**	11.24**	19.28**	-26.67**	-19.97**
SP 55609 A X UPMC 8	**28.3**	1.76	1.63	-2.2	3.02	-1.07	-14.89 **	5.26	0.53	6.74	14.46**	-29.63**	-23.20**
993100 A X 04 K700	**27.8**	-2.35	-3.62	-9.98	-5.18	-8.95	-21.66 **	23.68**	16.23**	24.72**	33.73**	-17.78**	-10.27**

Continued………..

Cross	**Mean Performance**	**Estimate of heterosis**											
	Green fodder yield (ton/ha)	**Leaf area**						**Stem girth**					
		MP	**BP**	**SD**				**MP**	**BP**	**SD**			
				C-1	**C-2**	**C-3**	**C-4**			**C-1**	**C-2**	**C-3**	**C-4**
ICSA 271 X PC 5	**42.5**	49.68**	28.16**	23.09 **	35.46 **	-19.09 **	-24.05 **	12.29**	5.51	11.98**	5.51	-30.57**	-37.09**
ICSA 276 X CSV 15	**34.2**	38.84**	32.67**	16.36 **	28.05 **	-23.52 **	-28.21 **	14.14**	3.53	22.56**	15.49**	-24.01**	-31.14**
993100 A X04 K668	**31.7**	-11.03**	-21.34**	-1.43	8.47	-35.21 **	-39.18 **	-8.00*	-14.07**	10.58*	4.2	-31.43**	-37.87**
11 A_2 X 04 K 693	**30.8**	-10.28**	-20.96**	-4.65	4.92	-37.33 **	-41.17 **	-25.53**	-38.94**	-6.96	-12.34**	-42.31**	-47.73**
ICSA 469 X 04 K 668	**29.7**	2.79	-1.38	-5.07	4.47	-37.60 **	-41.43 **	-27.06**	-30.96**	-13.65**	-18.64**	-46.46**	-51.49**
ICSA 293 X 01K 733	**29.4**	33.00**	30.85**	17.08 **	28.84 **	-23.04 **	-27.76 **	28.30**	22.78**	23.12**	16.01**	-23.66**	-30.83**
SPA_2 94012 X 04 K 700	**28.6**	-0.16	-2.31	-14.86 **	-6.31	-44.04 **	-47.47 **	-13.41**	-21.53**	-5.57	-11.02**	-41.45**	-46.95**
ICSA 293 X CSV 15	**28.3**	15.99**	15.26**	1.08	11.24 *	-33.56 **	-37.63 **	9.33*	6.65	2.79	-3.15	-36.27**	-42.25**
SP 55609 A X UPMC 8	**28.3**	11.90**	8.03	5.02	15.57 **	-30.97 **	-35.20 **	3.88	3.74	0.56	-5.25	-37.65**	-43.51**
993100 A X 04 K700	**27.8**	8.99*	-7.60*	15.78 **	27.40 **	-23.90 **	-28.56 **	19.07**	4.76	34.82**	27.03**	-16.41**	-24.26**

Continued………..

Cross	**Mean Performance**	**Estimate of heterosis**											
	Green fodder yield (ton/ha)	**TSS %**						**Leaf stem ratio**					
		MP	**BP**	**SD**				**MP**	**BP**	**SD**			
				C-1	**C-2**	**C-3**	**C-4**			**C-1**	**C-2**	**C-3**	**C-4**
ICSA 271 X PC 5	**42.5**	-2.22	-22.81**	-4.35	76.00**	-16.76*	174.66**	-7.29	-12.75*	-1.11	-4.3	-10.1	-32.58**
ICSA 276 X CSV 15	**34.2**	-26.23**	-28.57**	-2.17	80.00**	-14.87*	180.90**	-43.62**	-44.21**	-41.11**	-43.01**	-46.46**	-59.85**
993100 A X04 K668	**31.7**	2.27	-19.64**	-2.17	80.00**	-14.87*	180.90**	-25.00**	-35.96**	-36.67**	-38.71**	-42.42**	-56.82**
11 A_2 X 04 K 693	**30.8**	-15.49	-41.18**	-34.78**	20	-43.25**	87.27**	10.86*	-14.16**	7.78	4.3	-2.02	-26.52**
ICSA 469 X 04 K 668	**29.7**	79.22**	53.33**	50.00**	176.00**	30.53**	330.71**	-15.98**	-33.02**	-21.11**	-23.66**	-28.28**	-46.21**
ICSA 293 X 01K 733	**29.4**	73.49**	33.33**	56.52**	188.00**	36.21**	349.44**	-22.65**	-42.15**	-22.22**	-24.73**	-29.29**	-46.97**
SPA_2 94012 X 04 K 700	**28.6**	73.13**	56.76**	26.09**	132.00**	9.72	262.05**	-7.98	-16.67**	-16.67**	-19.35**	-24.24**	-43.18**

ICSA 293 X CSV 15	**28.3**	6.52	-22.22**	6.52	96.00**	-7.3	205.87**	-36.45**	-43.80**	-24.44**	-26.88**	-31.31**	-48.48**
SP 55609 A X UPMC 8	**28.3**	38.64	7.02	32.61**	144.00**	15.40*	280.77**	18.67**	15.58*	-1.11	-4.3	-10.1	-32.58**
993100 A X 04 K700	**27.8**	35.48**	12.5	36.96**	152.00**	19.18**	293.26**	-36.31**	-36.67**	-36.67**	-38.71**	-42.42**	-56.82**

Continued………..

Cross	**Mean Performance**	**Estimate of heterosis**											
	Green fodder yield (ton/ha)	**HCN content**						**Green fodder yield**					
		MP	**BP**	**SD**				**MP**	**BP**	**SD**			
				C-1	**C-2**	**C-3**	**C-4**			**C-1**	**C-2**	**C-3**	**C-4**
ICSA 271 X PC 5	**42.5**	5.56	-8.67	53.42**	29.81**	2.45	45.34**	128.36**	93.67**	128.36**	45.71**	51.79**	-23.16**
ICSA 276 X CSV 15	**34.2**	30.03**	11.53	40.96**	19.27*	-5.87	33.54**	78.26**	66.22**	83.58**	17.14**	22.02**	-38.23**
993100 A X04 K668	**31.7**	-4.45	-13.92*	21.71*	2.98	-18.72**	15.31	100.00**	70.15**	70.15**	8.57	13.10*	-42.75**
11 A_2 X 04 K 693	**30.8**	8.47	-1.4	30.92**	10.78	-12.57	24.03*	88.14**	54.17**	65.67**	5.71	10.12	-44.25**
ICSA 469 X 04 K 668	**29.7**	-27.47**	-32.28**	-4.25	-18.98*	-36.06**	-9.29	72.58**	59.70**	59.70**	1.9	6.15	-46.26**
ICSA 293 X 01K 733	**29.4**	-7.56	-16.28*	25.08*	5.84	-16.47*	18.50*	31.68**	8.16	58.21**	0.95	5.16	-46.77**
SPA_2 94012 X 04 K 700	**28.6**	-4.39	-4.87	22.89*	3.98	-17.94**	16.42	82.30**	45.07**	53.73**	-1.9	2.18	-48.27**
ICSA 293 X CSV 15	**28.3**	3.18	-9.92	9.19	-7.61	-27.08**	3.45	48.91**	37.84**	52.24**	-2.86	1.19	-48.77**
SP 55609 A X UPMC 8	**28.3**	10.14	-3.13	25.11*	5.86	-16.45*	18.53*	64.52**	32.47**	52.24**	-2.86	1.19	-48.77**
993100 A X 04 K700	**27.8**	3.37	-2.5	24.70*	5.51	-16.73*	18.14	69.49**	40.85**	49.25**	-4.76	-0.79	-49.78**

Continued………..

Cross	**Mean Performance**	**Estimate of heterosis**											
	Green fodder yield (ton/ha)	**Dry fodder yield**						**Protein per cent**					
		MP	**BP**	**SD**				**MP**	**BP**	**SD**			
				C-1	**C-2**	**C-3**	**C-4**			**C-1**	**C-2**	**C-3**	**C-4**
ICSA 271 X PC 5	**42.5**	134.82**	103.04**	128.26**	62.61**	6.52	-25.76**	-2.79	-11.75**	-14.21**	-13.03**	4.04	-3
ICSA 276 X CSV 15	**34.2**	66.11**	48.76**	85.71**	32.30**	-13.33*	-39.60**	-6.05	-10.10*	-14.84**	-13.68**	3.27	-3.72
993100 A X04 K668	**31.7**	128.83**	93.60**	97.20**	40.49**	-7.97	-35.86**	1.58	-1.69	-11.80**	-10.60*	6.95	-0.29
11 A_2 X 04 K 693	**30.8**	66.82**	32.00**	63.98**	16.81	-23.48**	-46.67**	13.16**	12.26*	0.76	2.14	22.19**	13.92**
ICSA 469 X 04 K 668	**29.7**	66.78**	54.57**	57.45**	12.17	-26.52**	-48.79**	-13.79**	-20.65**	-20.78**	-19.70**	-3.94	-10.44*

ICSA 293 X 01K 733	**29.4**	35.04**	11.21	63.35**	16.37	-23.77**	-46.87**	-1.67	-12.77**	-15.64**	-14.49**	2.3	-4.62
SPA2 94012 X 04 K 700	**28.6**	81.97**	45.78**	66.15**	18.36*	-22.46**	-45.96**	1.42	-1.31	-11.00*	-9.79*	7.92	0.62
ICSA 293 X CSV 15	**28.3**	53.11**	34.83**	68.32**	19.91*	-21.45**	-45.25**	4.78	3.71	0.3	1.67	21.63**	13.39**
SP 55609 A X UPMC 8	**28.3**	84.08**	41.49**	65.22**	17.7	-22.90**	-46.26**	-14.08**	-15.22**	-25.80**	-24.79**	-10.02	-16.11**
993100 A X 04 K700	**27.8**	67.00**	35.15**	54.04**	9.73	-28.12**	-49.90**	4.9	4.63	-5.65	-4.36	14.42**	6.67