

**GENETIC ANALYSIS IN FORAGE PEARL MILLET**  
**[*Pennisetum glaucum* (L.) R.Br.]**

**A Thesis submitted to the**

**MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI (M.S.)**

**By**

***RANGNATH SHIVRAM BAGUL***

**(Reg. No. 09/044)**

**In partial fulfilment of the requirements for the degree  
of**

***MASTER OF SCIENCE (AGRICULTURE)***

***in***

***AGRICULTURAL BOTANY***  
***(GENETICS AND PLANT BREEDING)***

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2011.**

***CANDIDATE'S DECLARATION***

***I hereby declare that this thesis or part  
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any other University  
or Institute for  
a Degree or  
Diploma.***

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## **CERTIFICATE**

This is to certify that the thesis entitled, “**GENETIC ANALYSIS IN FORAGE PEARL MILLET [*Pennisetum glaucum* (L.) R.Br.]**”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)**, embodies the results of a piece of *bona fide* research work carried out by **RANGNATH SHIVRAM BAGUL**, under my guidance and supervision and that no part of the thesis has been submitted to any other University for degree or diploma or publication.

The assistance and help rendered during the course of this investigation and sources of literature referred have been duly acknowledged.

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*Date :    /    /2011.*

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## LIST OF ABBREVIATIONS

%	Per cent
$\sigma^2A$	Additive variance
$\sigma^2D$	Dominance variance
$\sigma^2gca$	Variance due to general combining ability
$\sigma^2sca$	Variance due to specific combining ability
BP	Better parent
CD	Critical Differences
cm	Centimeter
Cov (F.S.)	Co-variance (full sib)
Cov (H.S.)	Co-variance (half-sib)
d.f.	Degrees of freedom
<i>et al.</i>	et all (and others)
g	Gram
gca	General combining ability
ha	Hectare
i.e.	That is
kg	Kilogram
MP	Mid parent
MSS	Mean sum of square
Mha	Million hectare
MS	Male sterile
q	Quintal
S.E.	Standard error
SS	Sum of square
sca	Specific combining ability
<i>viz.</i>	Videlicet (Namely)

## ABSTRACT

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**Research Guide** : **Prof. A. H. Sonone**  
**Department** : **Agricultural Botany**

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The present investigation entitled “Genetic Analysis in Forage Pearlmillet [*Pennisetum glaucum* (L.) R. Br.] was carried out with an aim to study the combining ability, gene action and heterosis for forage yield and its components. Three male sterile lines were crossed with ten testers in a line x tester fashion during summer, 2010. The resulting thirty hybrids along with thirteen parents were evaluated in a randomized block design with three replication at AICRP on Forage Crops, Mahatma Phule Krishi Vidyapeeth, Rahuri during Kharif, 2010.

Among the females 449A was found to be the best general combiner as it exhibited significant gca effect for four



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**R. S. Bagul**  
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characters *viz.*, number of tillers per plant, leaf length, GFY and DMY while, among male parents CO-8 was good general combiners for plant height, number of leaves per plant, number of tillers per plant, leaf length, GFY, DMY and CPY, CO-09 was found good general combiner for plant height, leaf length, GFY, DMY and CP% and Giant Bajra were promising good general combiners for number of leaves per plant, leaf length, leaf breadth CPY and CP %.

The combination 429A x Raj Bajra Chari for days to 50% flowering, 429A x DB-1 for plant height, 449A x DB-1 for number of leaves per plant, 425A x GFB-1 for number of tillers per plant, 429A x DB-2 for leaf length, 449A x Giant Bajra for leaf breadth, 425A x Raj Bajra Chari for GFY, 429A x GFB-1 for DMY, 425A x GFB-1 for DM % and 449A x DB-1 for CPY exhibited highly significant and maximum sca effects for the respective characters.

The variance of additive (A) component was higher than for that dominance (D), for days to 50% flowering, number of leaves per plant, leaf length, leaf breadth, L:S ratio and crude

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*Abstract Contd...**R. S. Bagul*

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protein content indicating preponderance of additive gene action in the inheritance of these trait. Non additive gene action was important for the traits *viz.*, plant height, number of tillers per plant, GFY, DMY, DM % and CPY.

The cross combination 449A x Raj Bajra Chari and 429A x PMFT-907 for days to 50 per cent flowering, 449A x PMFT-907 for plant height, 429A x GFB-1 for number of leaves, 425A x CO-08 for leaf breadth, 425A x Raj Bajra Chari for green forage yield, 449A x PNFT-907 for dry matter yield, 449A x CO-09 for dry matter percent, 425A x Raj Bajra Chari for crude protein yield and 449A x Bajra Biwal for crude protein percent exhibited maximum heterobeltosis.

Based on the results obtained in the present studies, it may be concluded that the best general combiners *viz.*, CO-8, CO-09 and Giant Bajra could be used in future breeding programmes for forage improvement in pearl millet.

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## 1. INTRODUCTION

Pearlmillet [*Pennisetum glaucum* (L.) R.Br.] commonly known as 'bajra' or 'bajri' in India, is one of the drought tolerant cereal food crops, belonging to the family Poaceae. It is mostly grown in arid and semi-arid parts of the world.

India is the largest producer of pearlmillet [*Pennisetum glaucum* (L.) R.Br.] both in terms of area (9.43 million ha) and production (8.01 million ton), with an average productivity of 850 kg/ha (Anonymous, 2010). This grain crop contributes significantly to food and nutritional security of the rural and urban poor people in drier areas where it is valued equally for both its grain and fodder. Although demand for pearl millet grain as human food in India is currently decreasing, it is emerging as forerunner in the form of alternative food, feed and industrial products. Being a C<sub>4</sub> species, it has tremendous potential for biomass production, most of which is accumulated in its vegetative parts (Appa Rao ,1999).

Pearlmillet is native of Africa where its wild forms are present. It is a major cereal crop being cultivated all over India, particularly in the states of Rajasthan, Gujarat, Maharashtra, Andhra Pradesh and Haryana. It is also greatly valued for its dry fodder in livestock based farming system. It is principle food crop and important source of diet for the majority of Indian and African people.

The whole grains are cooked like rice. It may also be popped or puffed. Its flour is used for preparing thin/thick porridge. Its grain are generally consumed as food by people and feed by cattle. It is being consumed in the form of unleavened flat bread called 'roti' or 'chapati', etc. This crop is suitable for green chop, dehydration, pelleting and production of quality silage. The fodder bajra is more palatable because it does not contain HCN as that of sorghum thus can be feed to cattle at any stage of the crop growth. Bajra grains are used for manufacture of beer and other alcoholic products. Pearlmillet flour may be used to prepare biscuits and tangris. Considering various uses of pearlmillet it is grown for food, feed, fodder and fuel and other purposes.

It is an erect annual plant growing 5 to 6 feet tall with varying number of tillers. It is highly cross pollinated due to protogynous flowering nature. It is diploid in nature ( $2n=2x=14$ ). Evidence of its secondary polyploidy nature is also available (Swaminathan and Nath, 1956). Pearlmillet is an allogamous crop belongs to the genus *Pennisetum*. Pearlmillet is an erect, tillering annual. Stem is round to oval green divided into nodes and internodes. Leaves are long scabrous, medium broad, linear, lanceolate, wavy margin, green or light green and usually sparsely hairy. The inflorescence is 20-25 cm long cylindrical compound terminal spike consists of central rachis on which fascicles are

closely packed. Each fascicle consists of one or more spikelets and a whorl of bristles. Generally spikelets contain two florets, the lower being staminate and the other bisexual. These flowers are partly enclosed by short outer glume, while inner glume is longer than it and covers nearly half of the spikelets. The lower floret is staminate often represented by sterile lemma enclosing three stamens and there are neither paleas nor lodicules. The upper flower is a perfect with lemma, palea, three stamens and an ovary with two styles on the top. The three stamens are with filament and versatile linear anthers. The ovary is monocarpellate, one celled, containing a single ovule. Seeds are whitish yellow, gray or dual light blue, oval (Chalam and Venkateswarulu, 1965).

Pearlmillet is highly heterozygous and heterogeneous being allogamous in nature. It has balanced genetic load and show considerable inbreeding depression (Harinarayana, 1980). Therefore, the varieties aimed to be developed in pearlmillet should have heterozygous nature to be heterotic and at the same time homogenous constitution to be synchroneous and uniformly productive. Therefore, breeding efforts are directed towards developing hybrids, synthetic and composite populations.

However, exploitation of heterosis at field level become feasible only an availability of male sterile lines. Discovery of cytoplasmic genetic male sterile line, Tift 23-A at Tifton, Georgia,

USA (Burton, 1951) opened new field for hybrid production in pearl millet. HB-1 was the first hybrid released in India in 1962 and since more than 60 hybrids have been developed and released for general cultivation by public and private sector.

At present in pearl millet breeding emphasis is given to develop diverse high yielding hybrids and varieties having multiple disease resistance. It is therefore necessary to develop new male sterile lines, restorers and inbreds having high combining ability, wide adaptability and disease resistance.

The improvement in pearl millet needs attention for the characters like early flowering, green forage yield, dry matter yield, crude protein yield, number of tillers/plant, number of leaves and disease and pest resistance.

The present scenario of livestock population in India at 485 million and total population expected to grow 1.23% in the coming years. India supports nearly 20 % of the world livestock. At present, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds (Handbook of Agriculture). Considering the present and projected livestock population in the country, the shortage of fodder may increase further if well planned improvement and management of fodder crops are not done. Pearl millet being important fodder crops of dry areas, improvement in it for fodder is the need of our.

Considering the importance of pearl millet as fodder crop, there is need to generate more information on heterosis, combining ability, nature of gene action among different sets of parents. The present investigation entitled “Genetic analysis in forage pearl millet [*Pennisetum glaucum* (L.) R.Br.]” was therefore undertaken with newly developed male sterile lines and restorers with following objectives.

1. To study the combining ability of parents and hybrids for forage yield and its components in forage pearl millet.
2. To study heterosis for forage yield and its component characters.

## 2. REVIEW OF LITERATURE

Since the occurrence of male sterility in pearl millet (Burton, 1958) many research workers engaged themselves in pearl millet improvement work for high yield, earliness and other desirable quantitative and qualitative characters. An attempt was therefore, made in this investigation to study the extent of heterosis, combining ability, heritability and gene action in pearl millet. The literature pertaining to the present investigation has been reviewed under the following sub-headings.

### 2.1 Combining ability

#### 2.1.1 GCA and SCA variance

#### 2.1.2 GCA and SCA effects

### 2.2 Gene action

### 2.3 Heterosis

## **2.1 Combining ability**

### **2.1.1 GCA and SCA variance**

In hybrid breeding programme, it is common practice to find out parents which are nicking well. Eventually, the lines, which produce better progenies on crossing, are of immense value to the plant breeder.

The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize. They defined the term general combining ability as an average performance of a line in hybrid combination and specific combining ability is used to designate those crosses in which certain combinations do relatively better or worse than that would be expected on the basis of the average performance of lines involved. General combining ability (gca) is relatively more important than the specific combining ability (sca) in previously unselected material. On the other hand specific combining ability (sca) assumes greater importance for the material which is previously selected for general combining ability (gca).

Allard (1960) defined general combining ability as the average performance of a strain in a series of crosses and specific combining ability as the deviation from the performance predicted on the basis of general combining ability.

According to Griffing (1956), the general combining ability is related to additive as well as additive x additive interaction, whereas specific combining ability is related to the dominance variance and all three type i.e. additive x additive, additive x dominance and dominance x dominance interactions.

Top cross test can be used for testing general combining ability and preliminary evaluation of inbreds. But single cross tests

are necessary for locating best specific combiners. Line x tester and diallel are single cross mating designs used for testing both gca and sca.

Bains *et al.* (1967) in a line x tester experiment reported that mean squares due to gca were important for days to 50 per cent flowering, number of productive tillers per plant, ear length, ear girth.

Tyagi *et al.* (1978) studied the combining ability in pearl millet. Estimates of both GCA and SCA variances were highly significant for plant height and number of productive tillers. However, the magnitude of GCA variance was more than that of SCA variance and high GCA: SCA ratio shows predominance of additive gene action for almost all characters.

Singh *et al.* (1980) studied combining ability for yield and its component in 36 hybrids of pearl millet involving nine parents. The GCA and SCA variances were highly significant for plant height and number of tillers. Comparatively additive gene effects were larger for plant height, number of ear bearing tillers, number of internodes per main shoot and grain yield per plant. For number of tillers per plant, ear length, ear girth and 100 grain weight, non additive gene effect were found playing a dominant role in the inheritance. They also reported that the presence of at

least one good general combiner is essential in a cross producing high SCA effects.

Prakash kumar *et al.* (1982) studied genetics of forage attributes in pearl millet, using 15 parent diallel cross in three environments. They reported that additive genetic component (D) as well as dominance variance (H1) was significant for all characters studied under different environment. However the magnitude of non additive genetic component was higher than corresponding additive component for Stover yield, plant height and number of tillers per plant.

Navale *et al.* (1985) reported that magnitude of gca variance was larger for total and effective tillers, ear length and plant height. Whereas, sca variance was larger for grain yield and days to 50 per cent flowering.

Kunjir and Patil (1986) in a line x tester analysis found that gca variance was higher for yield component viz., days to 50 per cent flowering, productive tillers, plant height, ear girth and 500-grain weight, however, sca variance was significant for grain yield per plant.

Gopalan and Sree Rangasamy (1989) studied the combining ability of fodder attributes in pearl millet involving 25 inbreds lines were tested against 3 male sterile lines along with 75 hybrids (25 x 3) in four environments of two locations. The higher

magnitude of sca variances for plant height, number of tillers/plant, number of leaves, stem weight, leaf weight, green fodder yield, dry matter yield and crude protein content while gca variance was higher than sca variance for leaf length, leaf breadth and leaf weight . Among the male sterile line MS129D<sub>2</sub> A and testers FS120, IP2225, IP1689 reported good general combiner for fodder yield.

Pethani and Kapoor (1990) studied in a line x tester experiment under 3 environments reported that, sca variance were highly sensitive to environmental changes for bearing tillers, ear length, ear girth, however, gca variance was highly stable for ear length.

Yadav *et al.* (2002) observed parents and hybrids from a diallel cross (excluding reciprocal) of 7 male sterile lines were grown at Hissar during Kharif, 1988. Protein content was measured at 3 growth stages (panicle initiation, anthesis and maturity). Protein content of the leaf and stem decreased with increasing growth stage, being highest at panicle initiation and lowest at maturity. Gca and sca effects for protein content were significant.

Yadav *et al.* (1991) studied genetic analysis of protein content in leaf, stem and its mobilization to seed in pearl millet.

Patil *et al.*(1992) reported combining ability for green forage yield in six top yielding hybrids from a cross between 5

male sterile lines and 10 newly developed inbreds of pearl millet grown during Kharif, 1986. The best specific combination was 842A x Giant Bajra (SCA:15.16). Among parents 842A (12.14) and Giant Bajra (12.19) were best general combiners.

Pradhan and Dana (1992) assessed ten segregants of *pennisetum glaucum* cv. K-670 selected for fodder yield and regrowth ability for fodder yield and other components in a complete diallel cross. They noted that the GCA effects were high and great amount of significant heterosis for all characters.

Devanand and Das (1996) studied combining ability pearl millet. They reported predominance of gca variance for days to 50 % flowering, intermodal length, green fodder yield, dry matter yield, crude protein and oxalic acid content while predominance of sca variance for plant height, number of tillers/plant, stem girth, number of leaves , leaf area and calcium content.

Azhaguvel and Jayraman (1998) studied ninety pearl millet hybrids obtained by crossing, nine male sterile lines with ten pollinators in a line x tester mating design. These hybrids were grown during Kharif, 1997 and evaluated for forage yield component (plant, height, number of tillers, leaf length and leaf width). Male sterile line 851A was the best general combiner for forage yield.

Mohan *et al.* (1999) carried out (5x6) line x tester analysis for five important characters and showed that gca variance were highly significant for number of productive tillers ear girth, ear length and 1000-grain weight. Whereas, sca variance were significant for grain yield per plant.

Yash Pal *et al.* (2004) Studied on combining ability & heterosis for dry fodder yield and its contributing characters in pearl millet, using seven male sterile line and six testers. The GCA and SCA variances revealed that were highly significant for plant height, effective tiller, leaf area, dry fodder yield and biological yield. They observed HMS 6A (Line) good general combiner for all characters is essential in cross producing high SCA effects (HMS 6A x CSSC 46-2).

Ved Prakash and Singh (2004) .Genetic studies of fodder quality characters in Pearl Millet, having experimental material consisting of 9 x 9 diallel set excluding the reciprocals. The mean sum of squares of GCA and SCA were highly significant for protein content (%), Phosphorus content (%), Calcium content (%), Crude fibre content (%).

Bidinger and Yadav (2009) studied the relationship of heterosis for biomass and harvest index (HI) with heterosis for grain and stover yield in pearl millet hybrids. They concluded that

heterosis for biomass was the major determinant of grain and stover yield heterosis in pearl millet.

### **2.1.2 GCA and SCA effects**

Line x tester analysis proposed by Kempthorne (1957) is one such mating design, which provides information on general and specific combining ability of parents and at the same time it could be helpful for understanding the genetic nature of quantitatively inherited traits which helps to assertion the prepotency of parents.

Gupta and Singh (1973) reported H-18 and H-98 as the best combiners and L-111 x H-98 as the best combination with highest sca effects for yield and productive tillers per plant in pearl millet.

Singh *et al.* (1980) in a diallel observed that the combination of poor x poor combining parents produced good sca effects. They reported positive gca effects for plant height, number of productive tillers per plant, grain yield and negative gca effects for ear length, ear girth, 100-grain weight.

Subramanian and Rathinam (1980) in a diallel set observed that both gca and sca effects were highly significant for plant height and panicle length.

Chawla and Gupta (1983) in a diallel cross experiment were conducted that both gca and sca along with *per se* performance should be considered for selection of parents and high sca effects, *per se* performance and involvement of good combiner for selection of the best crosses.

Pethani and Kapoor (1984) in a line x tester analysis reported 5059A, H-49, H-112, H-138 as the best combiners and were the most suited parents for the improvement of different characters. High sca effects were observed in crosses having at least one good general combining parents and low x low combiners also yielded some crosses with high sca effects.

Mathur and Mathur (1986) studied combining ability for yield, protein, lysine and tryptophan in pearl millet, they reported differences were found for grain yield and protein in males and for protein and tryptophan in female. The variation due to male x female interaction was significant for all the characters.

Gopalan and Sree Rangasamy (1989) studied the combining ability of fodder attributes in pearl millet involving 25 inbred lines were tested against 3 male sterile lines along with 75 hybrids (25 x 3) in four environments of two locations. Among three lines MA 126 D<sub>2</sub>A recorded positive and significant GCA effects for number of leaves, leaf breadth, stem thickness, GFY, DMY and CPY.

Navale *et al.* (1991) in line x tester (14 x 18) analysis reported that high sca effect involved combinations with good x good, good x medium and poor x medium combining parents indicating presence of higher order interaction for grain yield and other characters.

Patil *et al.*(1992) reported combining ability for green forage yield in six top yielding hybrids from a cross between 5 male sterile lines and 10 newly developed inbreeds of pearl millet grown during Kharif, 1986. The best specific combination was 842A x Giant Bajra (SCA:15.16). Among parents 842A (12.14) and Giant Bajra (12.19) were best general combiners.

Kandaswami and Ramalingam (1995) in line x tester (9 x6) analysis reported that a cross 939A x PIB-2231P had the highest *per se* performance and maximum sca effects for grain yield.

Ramamoorthi and Jehangir (1995) estimated gca effects among parents and reported 732A and PT-1650 as the best general combiners for grain yield. Only seven crosses exhibited high sca effects for grain yield, four crosses for 100-grain weight and one for number of productive tillers per plant, respectively.

Sahane *et al.* (1996) in a full diallel set observed that, mean square due to gca, sca were highly significant for days to 50 per cent flowering, plant height, ear length, ear girth, while mean

square due to gca was significant for days to maturity and mean squares due to sca were significant for grain yield and dry fodder yield.

Yadav *et al.* (2002) studied on combining ability for forage attributes in 77 F1 hybrids developed by crossing seven male sterile lines with 11 testers (inbreeds) in line x testers fashion. Variances due to lines and their interaction were highly significant for plant height, dry matter yield and effective tillers. Parents 92777 A and 9311A among male sterile lines and ICR 161, 77/29-2, HP 8601 and HTP 91/32 among pollinator exhibited high gca effects for plant height , dry matter yield and effective tillers. Among crosses 93111A x HTP 91/32, 95555A x ICR 161 and 95555A x 77/29-2 exhibited high sca effects and per se performance.

Ved Prakash and Singh (2004) studied genetics of fodder quality characters in Pearlmillet. The GCA effects revealed that L 72 L 74 and UUI 1 for were highly significant for protein content (%) and SCA effects revealed that the best cross combination for protein content (%), was UUI IV M x JBF 822(1.65) L 72 x MBFH 1 (1.39) and L 72 x JBF 822 (1.19) in desirable direction effect .

Patel *et.al.* (2008) studied heterosis and combining ability for fodder yield and its component in 50 hybrids involving 5

lines and 10 testers in pearl millet. They recorded the significant relative heterosis and heterbeltois for days to 50% flowering, plant height, number of leaves and biological yield respectively and significant for standard heterosis for number of leaves and biological yield in desirable direction. The SCA effects revealed that the best cross combination for dry fodder yield was JMSA 101A x 217 SB in desirable direction effect for plant height, number of leaves, fresh weight and biological yield.

Patel *et al.* (2008) studied heterosis and combining ability for fodder yield and its component in pearl millet. The analysis of combining ability variances indicated that non additive gene action solely governed the trait namely days to 50% flowering, days to maturity, plant height, number of leaves, fresh weight, dry fodder yield, biological yield and harvest index.

Pachade (2006) studied heterosis, combining ability, gene action and heritability in 20 hybrids involving 2 lines and 10 testers in forage pearl millet. The gca and sca variances were significant for most of the characters. The sca variance was higher than gca variance for all characters studied except for leaf length.

Lakshmana *et al.* (2010) studied that the combining ability & heterosis involving diverse cytoplasmic male sterility system in pearl millet. The result revealed that the lines with A4 cytoplasm are significantly better general combiner for productive

tillers per plant than the lines with A1 and A5 cytoplasm. The mean as well as range and heterosis for days to flowering days to maturity, plant height, flag leaf area was limited in all three sources of cytoplasm.

## **2.2 Gene action**

Ahluwalia *et al.* (1962) observed non-additive gene action for number of tillers per plant, plant height and grain yield per plant.

Lal and Singh (1968) observed no dominance or complete additive gene action in the expression of number of tillers, peduncle length and spike thickness except for days to 50 per cent flowering showing non-additive gene action.

Indu and Gupta (1981) studied genetic evaluation of soluble v/s crude protein content in pearl millet of green fodder. They reported the gca variance and additive gene effect were predominant for both the soluble protein content and crude protein content of the stems.

Bhambre *et al.* (1983) noted predominant additive gene action for days to 50 per cent flowering, number of productive tillers, plant height and ear length. Dominant gene action was found in expressing grain yield and majority of yield component. Low heritability was reported for grain yield, whereas, medium

heritability was observed for ear length, 1000-grain weight and number of productive tillers per plant.

Navale *et al.* (1985) observed that sca variances were predominant for grain yield, total and productive tillers, ear length, plant height, 50 per cent flowering, indicating significance of non-additive gene action in the expression of these characters.

Das (1994) conducted an experiment involving 15 genotypes of *Pennisetum americanum*, 5 of *P. purpurenum* and their 15 hybrids obtained by random crossing were evaluated for quality based on crude protein, Ca, P and oxalic acid content. Analysis of variance showed significant differences between genotype and hybrid for all 4 traits. In *P. americanum* high heritability and high genetic advance were recorded. For CP and Ca contents, while P and OA showed moderate heritability and genetic advance.

Saraswati *et al.* (1996) indicated predominance of non-additive gene action for grain yield, days to 50 per cent flowering, plant height and number of productive tillers per plant

Karale *et al.* (1998) observed that the additive gene action for days to 50 per cent flowering, plant height, ear length, whereas non-additive gene action. Predominantly governed the

expression of yield, 1000- grain weight and number of productive tillers per plant.

Mohan *et al.* (1999) using line x tester in pearl millet revealed that additive gene action was important for number of productive tillers, ear length, ear girth, plant height, 1000-grain weight and non-additive gene action for grain yield per plant.

Rasal and Patil (2003) studied line x tester analysis in pearl millet, using five male sterile lines with eight diverse genotypes. They reported non-additive gene action for grain yield /plant and additive gene action for plant height, days to 50% flowering, tillers/plant, ear girth & ear length was observed good general combiner for plant height, ear girth and length and grain yield /plant and MS 88840 A was observed to be good general combiner for plant height, ear girth and length.

### **2.3 Heterosis**

The superiority of hybrids over their parents is termed as heterosis. Shull (1914) for the first time used the terms 'heterosis' and defined it as a phenomenon in which crossing of two genetically dissimilar gametes produced increased vigour over their parents.

Burton (1951) was the first to report heterosis in pearl millet. Heterosis in pearl millet for grain yield per plant over

their respective higher yielding parents was reported by Ahluwalia and Patnaik (1963) to the extent of 69.9 per cent.

Murty *et al.* (1967) observed substantial heterosis for earhead length and attributed it to be due to epistasis and non-additive components, while they reported significant negative heterosis for days to maturity character and did not observe significant positive heterosis for number of tillers.

Singh and Singh (1972) observed that the positive and significant heterosis for plant height, yield per plant, number of tillers and spike bearing tillers. In these characters heterosis was mainly due to dominance effects.

Tyagi *et al.* (1975) observed limited heterosis for tillering in parents with high tillering, H-19 x H-403 appeared to be the best for earliness, ear length and grain yield and heterosis for grain yield over better parent was of 4.24 per cent.

Harinarayana (1980) concluded that crosses among geographically and genetically diverse parents unravel the concealed heterosis and productivity. He pointed that success of early released hybrids i.e. HB-1, HB-7, BK-560, BJ-104 itself proved importance of genetic diversity in the expressing of heterosis.

Mukherji *et al.* (1981) in a 8 x 8 complete diallel, involving five Indian and three exotic inbreds, reported crosses with significant and positive heterosis for ear length, ear girth and grain yield per plant. Arunachalam (1974) observed that crosses between high x low combiners provided not only genetic and geographic diversity but also combining ability divergence, which resulted in high frequency of heterotic crosses.

Hapse *et al.* (1986) observed heterobeltiosis to the tune of 192.68 per cent for number of productive tillers per plant and 13.49 per cent for ear girth. The cross MS-0554A x 1036 showed high heterosis for yield and its components.

Kulkarni *et al.* (1993) in a 8 x 8 full diallel of pearl millet noted that more than 50 per cent of the hybrid derived from Indian x Exotic were significantly heterotic for grain yield, productive tillers, days to 50 per cent flowering, grain weight. The frequency of significant Indian x Exotic or Exotic x Indian crosses was for greater than Indian x Indian or Exotic x Exotic crosses for mid-parental heterosis.

Chavan and Nerkar (1994) studied that the heterosis over better parental value for days to 50 per cent flowering (-16.44), days to maturity (-4.17), plant height (26.02%), number of productive tillers per plant (98.00%).

Patil *et al.* (1994) studied heterosis in pearl millet in line x tester, set of 30 hybrids involving 3 male sterile line and ten promising inbreds male parents. The hybrids MS 5054 A x CN-74-7 and MS 5141 A x CN-74-9 shown positive and significant heterosis for plant height.

Yash Pal *et al.* (2004) studied combining ability & heterosis for dry fodder yield and its contributing characters in pearl millet, using seven male sterile line and six testers. They reported significant heterobeltiosis for plant height, effective tiller, leaf area dry fodder yield and biological yield.

Pachade (2006) studied genetic analysis in forage bajra in line x tester , set of 20 hybrids involving two male sterile lines and ten testers. They reported significant heterobeltiosis for days to 50 % flowering, number of tillers, leaf length, leaf breadth, green forage yield, dry matter yield and crude protein percent.

Davda *et al.* (2008) high level of heterosis was observed for grain yield per plant, ear heads weight per plant, ear head length and number of effective tillers per plant, while moderate heterosis was found for 1000 seed weight and harvest index.

### 3. MATERIAL AND METHODS

The present investigation entitled “Genetic analysis in forage Bajra [*Penisetum glaucum* (L.) (R. Br.)]” was undertaken during *Kharif*, 2010 at AICRP on Forage Crops, MPKV, Rahuri. The details of material used and method adopted in conducting the experiment and the statistical procedures followed during the course of investigation are given as below.

#### 3.1 Material

Three male sterile lines (Female) received from AICRP on Pearl millet, Dhule and ten inbred restorers (Male) as obtained below constituted the parents which were intermated in line x tester mating design and the resulting thirty hybrids along with thirteen parents were evaluated in RBD with three replication.

SN	Parents	Salient features
<b>A.</b>	<b>Female (Male Sterile)</b>	
1	425A	Early, dwarf, profuse tillering, synchronous flowering , downy mildew resistant
2	429A	Early, dwarf, profuse tillering, synchronous flowering stay green, downy mildew resistant
3	449A	Early, dwarf, profuse tillering, more leaf stem ratio synchronous flowering ,downy resistant

<b>B.</b>	<b>Males (Inbreds/ OPV's)</b>	
1	CO-08	Late, Tall, profuse tillering, more number of leaves, high leaf length, high green forage yield, dry matter yield
2	CO-09	Early, Tall, profuse tillering, more leaf:stem ratio, high leaf length, high green forage yield, dry matter yield
3	Bajra Biwal	Early, Tall, profuse tillering, more number of leaves, high green forage yield, dry matter yield and crude protein percent.
4	Raj Bajra Chari	Early, Tall, profuse tillering, more number of leaves, high green forage yield, dry matter yield and crude protein percent.
5	DB-1	Late, Tall, profuse tillering, more number of leaves, high green forage yield, dry matter yield
6	DB-2	Early, medium tall, profuse tillering, high green forage yield, dry matter yield
7	GFB-1	Early, medium tall, profuse tillering, high green forage yield, dry matter yield
8	PMFT-907	Early, medium tall, profuse tillering, high palatasble green forage yield, dry matter yield
9	PMFT-905	Early, medium tall, profuse tillering, high green forage yield, dry matter yield
10	Giant Bajra	Tall, profuse tillering, broad leaves, high palatable, dark green colour, high protein content (9-11 %) at flowering, high green forage yield, dry matter yield.

## **3.2 Methods**

### **3.2.1 Experimental design**

To study heterosis and combining ability, the field testing of hybrids and parents was done during *Kharif*, 2010. All the thirty hybrids along with their thirteen parents were planted in randomized block design with three replications. Each genotype was entered as a separate treatment and was represented by two row of 4 m length spaced thirty cm apart.

### **3.2.2 Sowing and cultural practices**

The land was prepared by following one ploughing and two harrowings. It was leveled too. Basal fertilizer dose of 60 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> and 30 kg K<sub>2</sub>O per hectare was incorporated in the field. Top dressing with nitrogen was done after 30 days of sowing at the rate of 30 kg N/ha. The sowing was done on 5/7/2010 by hand sowing. Row to row and plant to plant spacing was 30 cm and 5 cm, respectively. All other cultural operations like weeding; hoeing and crop protection were carried out as per the requirements.

### **3.2.3 Observations recorded**

Five competitive plants were selected randomly from each treatment in each replication. They were labeled before flowering. The details of observations recorded as given below

### **3.2.3.1 Days to 50 per cent flowering**

The number of days taken from the date of sowing to the appearance of flower in 50 per cent of the plants in a plot was recorded as days to 50 per cent flowering.

### **3.2.3.2 Plant height (cm)**

The height of plant at 50 % flowering stage was measured from ground level to the tip of plant and recorded in centimeter.

### **3.2.3.3 Number of leaves/plant**

Total number of leaves of five observational plants was counted and average was worked out and expressed as number of leaves per plant.

### **3.2.3.4 Numbers of tillers/plant**

Total number of tillers of five observational plant were counted and average expressed was worked out and expressed as number of tillers per plant.

### **3.2.3.5 Leaf length (cm)**

Leaf length was measured from apex to base of leaf and recorded in centimeter. One leaf each from top, middle and base position of each observational plant tiller were selected for recording the observation and average, leaf length was worked out.

### **3.2.3.6 Leaf breadth (cm)**

Maximum leaf breadth was recorded in centimeters on the same leaves of which leaf length were measured. Average leaf breadth was worked out.

### **3.2.3.7 Leaf: Stem ratio (L/S)**

Leaf to stem ratio of five observational plants was recorded at harvest (50% flowering). Leaves along with sheath were separated from stem and both were weighed separately. The ratio L/S ratio was then calculated as:

$$\text{Leaf: Stem ratio} = \frac{\text{Weight of leaves in gm}}{\text{Weight of stems in gm}}$$

### **3.2.3.8 Green forage yield (q/ha)**

Weight green forage of entire net plot at harvest (50% flowering) was recorded. Green forage yield (q/ha) was worked out, by multiplying the net plot yield in kg with hector factor.

### **3.2.3.9 Dry matter (%)**

Composite sample of green forage (250 g) was taken at cut which was dried in hot air oven at 60°C temperature until constant dried weight was obtained. Dry matter (%) was then computed and recorded.

### **3.2.3.10 Dry matter yield (q/ha)**

Dry matter yield (q/ha) was worked out by multiplying the green forage yield (q/ha) with dry matter (%).

### **3.2.3.11 Crude protein content (%)**

Nitrogen percentage determined by Microkjeldahls method (Thimmaiah, 1999) per cent nitrogen was multiplied by conversion factor 6.25 to obtain per cent crude protein content (%).

### **3.2.3.12 Crude protein yield (q/ha)**

Crude protein yield (q/ha) was worked out by multiplying the dry matter yield (q/ha) with crude protein content.

## **3.3 Statistical procedure**

The mean values of observation plants for 12 different traits were used for statistical analysis. The following various statistical measures were worked out of the data on different quantitative traits as under.

### **3.3.1 Estimation of heterosis**

Heterosis (expressed in percentage) was estimated over mid-parent, better parent for all characters as described by Rai (1970). Following formulae were used to calculate heterosis.

$$\text{Mid parent (Relative heterosis)} = \frac{\bar{F}_1 - \bar{MP}}{MP} \times 100$$

$$\text{Better parent (Heterobeltiosis)} = \frac{\bar{F}_1 - \bar{BP}}{BP} \times 100$$

Where,

$F_1$  = Mean of  $F_1$  hybrid.

MP = Mid-parent value =  $P_1 + P_2 / 2$

BP = Mean of better parent value

**Test of significance:**

$$\text{L.S.D. (MP)} = \sqrt{\frac{3 Me}{2r}} \times t \text{ (at 5\% and 1\% level of error d.f.)}$$

**For testing heterosis over better parents :**

$$\text{L.S.D. (BP)} = \sqrt{\frac{2 Me}{r}} \times t \text{ (at 5\% and 1\% level of error d.f.)}$$

Where,

Me = Error mean sum of squares.

r = Number of replications.

Heterosis was considered significant when  $F_1 - MP$  or  $F_1 - BP$  was high than L.S.D. (least significant difference).

### 3.3.2 Analysis of variance for means

To test the significance of difference between treatments, the analysis of variance for randomized block design (RBD) was carried out by following Panse and Sukhatme (1967). The analysis of variance for all metric characters under study was done as follows.

#### Analysis of variance (ANOVA)

SN	Sources	D.F.	S.S.	M.S.S	Cal. F value
1.	Replication	(r-1)	RSS	$\frac{RSS}{(r-1)} = Mr$	Mr/Me
2.	Treatment	(t-1)	TrSS	$\frac{TSS}{(t-1)} = Mt$	Mt/Me
5.	Error	(r-1)(t-1)	ESS	$\frac{ESS}{(r-1)(t-1)} = Me$	-
6.	Total	(rt-1)	TSS	-	-

Where, r = Number of replication  
t = Number of treatment  
df = Degrees of freedom  
RSS = Replication sum of square  
TrSS = Treatment sum of square  
ESS = Error sum of square  
Me = Error mean sum of square

Standard error (SE), critical difference (CD) and coefficient of variation (CV) were calculated as follows.

$$SE (\pm) = \sqrt{Me/r}$$

$$CD = SE \times \sqrt{2} \times t \text{ (at error df)}$$

Where,

Me = Error mean square

t = Table 't' value of error degrees of freedom at 5 and 1 per cent level of significance.

### 3.3.3 Combining ability analysis

In order to test the combining ability effects of parents (gca) and crosses (sca) and to understand the nature of gene action, the combining ability variances were worked out by following line x tester analysis as suggested by Kempthorne (1957).

$$X_{ijk} = \mu + g_i + g_j + S_{ij} + e_{ijk}$$

Where,

$\mu$  = Population mean

$g_i$  = gca effect of the  $i^{\text{th}}$  male parent

$g_j$  = gca effect of the  $j^{\text{th}}$  female parent

$S_{ij}$  = sca effect of the  $(ij^{\text{th}})$  combination

$S_{ijk}$  = Random error associated with the  $X_{ijk}^{\text{th}}$  observation

$i$  = Number of male parents 1,2, ..., m

$j$  = Number of females parents 1, 2, ..., f

$k$  = Number of replications 1, 2, ..., r

In order to ascertain the heterosis, parents were also included in the same set and analysis of the data was done in the form of modified line x tester design as suggested by Arunachalam (1974).

The sum of squares due to different factors were portioned, as shown in:

## ANOVA

S N	Sources of variation	DF	S.S.	M.S.S	Expected M.S.
1.	Replication	(r-1)	$\sum_{k=1}^r \frac{X^2_{..k}}{mf} - \frac{X^2_{...}}{mfr}$	-	-
2.	Males	(m-1)	$\sum_i \frac{X^2_{i..}}{fr} - \frac{X^2_{...}}{mfr}$	$M_1$	$\sigma^2 + r$ [Cov.(F.S.) – 2 Cov.(H.S.)] + rf Cov. H.S.)]
3.	Females	(f-1)	$\sum_j \frac{X^2_{.j.}}{mr} - \frac{X^2_{...}}{mfr}$	$M_2$	$\sigma^2 + r$ [Cov.(F.S.) – 2 Cov.(H.S.)] + mr Cov. H.S.)]
4.	Males x Females	$\frac{(m-1)}{f-1}$	$\sum_{ij} \frac{X^2_{ij.}}{r} - \sum_i \frac{X^2_{i..}}{fr}$ $\sum_j \frac{X^2_{.j.}}{mr} - \frac{X^2_{...}}{mfr}$	$M_3$	$\sigma^2 + r$ [Cov.(F.S.) – 2 Cov.(H.S.)]
5.	Error	$\frac{(r-1)}{(mf-1)}$	By subtraction	$M_4$	$\sigma^2_e$
6.	Total	(rfm-1)	$\sum_{k=1}^r \frac{X^2_{...}}{mfr}$	-	-

Where,

$m$  = Number of male parents  
 $f$  = Number of female parents  
 $r$  = Number of replications  
 $X...$  = Sum of all the  $(ij)^{th}$  hybrid combinations

$X_{..k}$	=	Sum of the $k^{\text{th}}$ replication
$X_{.j.}$	=	Sum of $j^{\text{th}}$ female parent over all males parents and replications
$X_{ij}$	=	Sum of the $(ij)^{\text{th}}$ hybrid combination over all replications
$X_{i..}$	=	Sum of the $i^{\text{th}}$ male parent over all female parents and replications
$X_{ijk}$	=	$(ij)^{\text{th}}$ observation in $k^{\text{th}}$ replication
$M_1$	=	Mean sum of squares of males
$M_2$	=	Mean sum of squares of females
$M_3$	=	Mean sum of squares of males x females interaction
$M_4$	=	Error mean sum of squares
Cov (HS)	=	Co-variance of half-sib
Cov (HS)	=	Co-variance of full-sib
$\sigma^2 e$	=	Environmental variance

$$\text{Cov. (H.S.)} = \frac{M_1 - M_3}{rm}$$

Females

$$\text{Cov. (H.S.)} = \frac{M_2 - M_3}{rf}$$

Males

$$\text{Cov. (H.S.)} = \frac{1}{r(2fm-f-m)} \frac{(f-1)(M-1) + (m-1)(M_2)}{f+m-2} - M_3$$

Average

$$\text{Cov. (F.S.)} = \frac{(M_1 - M_4) + (M-1) + (M_3 - M_4)}{3r} + \frac{\sigma^2 \text{Cov. (HS)} - r(f+m) + \text{Cov. (HS)}}{3r}$$

The mean sum of square due to females and males were tested against female x male interaction, while female x male interaction were tested against error variance. However, when females and males were non-significant they tested against error variance.

### **Estimation of general and specific combining ability effects:**

The combining ability effects were estimated as:

$$i) \quad \mu = \frac{X_{...}}{mfr}$$

Where,

$$X_{...} = \text{Grand total}$$

$$ii) \quad g_i = \frac{X_{i..}}{fr} - \frac{X_{...}}{mfr}$$

Where,

$$X_{i..} = \text{Total of the } i^{\text{th}} \text{ male parent over all females and replications}$$

$$iii) \quad g_j = \frac{X_{.j.}}{mr} - \frac{X_{...}}{mfr}$$

Where,

$$X_{.j.} = \text{Total of the } j^{\text{th}} \text{ female parent over all males and replications}$$

$$\text{iv) } S_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{mr} - \frac{X_{.j.}}{fr} + \frac{X_{...}}{mfr}$$

Where,

$X_{ij.}$  = (ij)<sup>th</sup> combination total over all replications

m = Number of male parents

f = Number of female parents

r = Number of replications

### Estimation of standard error (SE) for combining ability effects:

$$1. \quad \text{S.E. gca for lines} = \sqrt{\frac{M_4}{m \times r}}$$

$$2. \quad \text{S.E. gca for testers} = \sqrt{\frac{M_4}{r \times f}}$$

$$3. \quad \text{S.E. sca effects} = \sqrt{\frac{M_4}{r}}$$

Where,

$$M_4 = \sigma_e^2$$

### 3.3.4 Combining ability variance

From the expectations of mean square covariance of half-sibs [(Cov. H.S.)] and covariance of full-sibs [(Cov. (F.S.))] were obtained. Following are the formulae for gca and sca variance.

$$\begin{aligned}\sigma^2_{\text{gca}} &= \text{Cov. (H.S.)} \\ \sigma^2_{\text{sca}} &= [\text{Cov. (F.S.)} - 2 \text{Cov. (H.S.)}]\end{aligned}$$

Where,

$$\sigma^2_{\text{gca}} = \text{Variance due to gca.}$$

$$\sigma^2_{\text{sca}} = \text{Variance due to sca.}$$

#### Gene action :

Variance due to gca ( $\sigma^2_{\text{gca}}$ ) and due to sca ( $\sigma^2_{\text{sca}}$ ) were worked out for estimating the Cov. (H.S.) and Cov. (F.S.).

$$\begin{aligned}\sigma^2_{\text{gca}} &= [\text{Cov. (H.S.)}] \\ &= [1 + F/4]^2 \sigma^2_{\text{A}} \quad (F=0)\end{aligned}$$

$$\begin{aligned}\sigma^2_{\text{sca}} &= [\text{Cov. (F.S.)} - 2 \text{Cov. (H.S.)}] \\ &= [1 + F/2]^2 \sigma^2_{\text{D}} \quad (F=0)\end{aligned}$$

Where,

$$F = \text{Inbreeding co-efficient}$$

$$\sigma^2_{\text{A}} = \text{Additive genetic variance}$$

$$\sigma^2_{\text{D}} = \text{Dominance genetic variance}$$

## 4. EXPERIMENTAL RESULTS

In the present investigation three lines and ten testers were inter mated in a line x tester mating design during summer 2010. The resulting 30 hybrids and their 13 parents were evaluated in replicated field trial during *Kharif*, 2010. Observations on the twelve different characters viz. days to 50 per cent flowering, plant height, number of leaves per plant, number of tillers per plant, leaf length, leaf breadth, leaf:stem ratio, green fodder yield, dry matter yield, dry matter (%), crude protein yield (q/ha) and crude protein content (%) were recorded. The data obtained was analyzed by following modified line x tester analysis and the results obtained are described below.

### 4.1 Mean performance of parents and crosses

Data on mean performance of parents and hybrids are presented in Table 4.1.

#### 4.1.1 Days to 50 per cent flowering

Among the female parents, 429A was the earliest to flower (45 days) followed by 449A (50 days).

As regards the male parents, Bajra Biwal was earliest to flower (46.33 days) followed by PMFT-907 (46.67 days), while







Giant Bajra was late (59.00 days) to flower. Remaining male parents flowered in between 46.33 to 59.00 days.

Days to 50 per cent flowering in hybrids ranged between 38.67 to 50.33 days. Among the hybrids 429A x Raj Bajra Chari and 429A x PMFT-907 (38.67days) were the earliest to flower followed by 429A x GFB-1, 429A x PMFT-905 and 449A x Bajra Biwal (41.00 days). The hybrid combination 425 x Raj Bajra Chari (50.33days), 449AxDB-1 and 425A x CO-08(48.67 days) were late to flower.

It was interesting to note that all hybrids in which 429A was used as a female and hybrids in which PMFT-907 was used as a male were early to flower.

#### **4.1.2 Plant height (cm)**

Among female parents 425A (136.13cm) was the tallest. Likewise among males Giant Bajra (263.87 cm) was tallest.

The plant height in hybrids varied from 146.80 cm to 203.20 cm. The cross 425A x CO-08 (203.20 cm ) was tallest among the hybrids.

#### **4.1.3 Number of leaves per plant**

Variation in female parents for number of leaves ranged between 7.73 (429A) to 8.60 (425A).

Among male parents the number of leaves ranged between 8.33 (GFB-1) to 11.87 (Giant Bajra).

Among the hybrids the number of leaves ranged between 8.13 (449A x Bajra Biwal) to 10.47 (429A x CO-08).

#### **4.1.4 Number of tillers per plant**

High tillering is desirable character in forage as it directly contributes to fodder yield. The number of tillers per plant was less in female 425A (5.47) and more in 429A (5.60).

The number of tillers in testers parents ranged from 4.07 (CO-09) to 5.80 (GFB-1) .

The range of tillers among hybrids was from 3.00( 429A x CO-09) to 5.53(425A x GFB-1). The cross 425A x GFB-1 (5.53) and 425A x DB-2 (4.87) produced highest number of tillers, followed by 425A x CO-08 (4.53),425A x PMFT-905 (4.67) and 449A x DB-1 (4.47). Comparatively less number of tillers was observed in the cross 429A x CO-9 (3.00) and 425A x PMFT-907 (3.13).

#### **4.1.5 Leaf length (cm)**

Among the female lines, 449A (72.87 cm) recorded highest leaf length.

The male parents, Giant Bajra (99.40 cm) had maximum leaf length followed by CO-08 (97.73 cm). The male parent Raj Bajra Chari (70.27 cm) exhibited the lowest leaf length.

Among the hybrids 449A x CO-09 (81.93 cm) recorded maximum leaf length followed by 425A x Giant Bajra (81.33 .cm)

#### **4.1.6 Leaf breadth (cm)**

425A (3.87 cm) among lines and Giant Bajra (5.51 cm) among testers recorded highest leaf breadth.

Among hybrids the leaf breadth ranged between 2.93cm (429A x Bajra Biwal) to 4.43cm (449A x Giant Bajra). Highest leaf breadth was recorded in 449A x Giant Bajra (4.43 cm) followed by 425 A x CO-08 (4.33 cm) and 425A x CO-08 (4.33 cm).

#### **4.1.7 Leaf: Stem ratio**

The line in 449A (0.34) and testers CO-09 and Raj Bajra Chari (0.32) recorded highest L:S ratio.

In hybrids, L: S ratio ranged from 0.28 (429A x DB-2, 425A x Raj Bajra Chari) to 0.19 (429A x Bajra Biwal).

#### **4.1.8 Green forage yield (q/ha)**

In female parents maximum green forage recorded by 449A (420.33 q/ha) and minimum by 425A (259.24 q/ha).

Among male parents the highest green fodder yield exhibited by CO-08 (903.61 q/ha) followed by Giant Bajra (885.10 q/ha). Lowest green forage yield was recorded by PMFT-905 (522.17 q/ha).

Among hybrid maximum green forage yield was recorded by 449A x CO-08 (703.63 q/ha) followed by 449A x CO-09 (698.08 q/ha) and 425 A x CO-08 (686.97 q/ha). While minimum by 429A x Bajra Biwal (457.39 q/ha).

#### **4.1.9 Dry matter yield (q/ha)**

Among female parents, maximum dry matter yield was recorded by 449A (57.35 q/ha) and minimum in 425A (42.41 q/ha)

Maximum dry matter yield was recorded by CO-8 (192.55 q/ha) in male parents and lowest in PMFT-907 (78.14 q/ha).

Among hybrids, the maximum dry matter yield was recorded by 449A x CO-09 (141.49 q/ha) followed by 425A x CO-08 (130.98 q/ha) and 449A x CO-08 (127.79 q/ha).

#### **4.1.10 Dry matter (%)**

Among female parents, maximum dry matter percent was recorded by 429A (18.43) and minimum in 449 A (13.66 q/ha).

Among testers maximum dry matter percent was recorded by Giant Bajra (21.44) followed by CO-08 (21.31) and DB-2 (19.66)

Among hybrids, the maximum dry matter percent was recorded by 425A x GFB-1 (20.63) and lowest by 429A x GFB-1 (14.56)

#### **4.1.11 Crude protein yield (q/ha)**

Among female parents, maximum crude protein yield was recorded by 449A (4.76 q/ha) and minimum in 425A (3.69 q/ha).

Maximum crude protein yield was recorded by Giant Bajra (17.19 q/ha) in male parents and lowest in PMFT-907 (6.15 q/ha).

Among the hybrids, maximum crude protein yield was recorded by 425A x CO-08 (11.42 q/ha) and lowest by 425A x DB-1 (6.44 q/ha).

#### **4.1.12 Crude protein (%)**

Among the female parents 429A (8.90 %) and 449A (8.31 %) showed maximum and minimum crude protein content, respectively.

Among male parents Giant Bajra and DB-1 (9.19 %) recorded the highest crude protein per cent followed by Giant Bajra (9.04 %) and minimum crude protein per cent was found in DB-2 (5.69).

Among the hybrids, 425A x Giant Bajra (9.63 %) followed by 425A x Bajra Biwal (9.19%) and 425A x PMFT-905 (8.90 %) recorded highest crude protein content.

## **4.2 Analysis of variance**

The analysis of variance for twelve forage character was carried out and presented in Table 4.2. The mean squares due to treatment were significant for all the characters under study indicating significant differences among the genotypes used in the present investigation.



### **4.3 Combining ability**

#### **4.3.1 Analysis of variance of combining ability**

Analysis of variance of combining ability for the character under study has been given in Table 4.3. From the table it is observed that the mean sum of square of parents and crosses were significant for all characters indicating ample variability among parents and crosses. The mean sum of square due parents Vs crosses were significant for eight characters except plant height, no. of leaves, DM% and CPY indicating presence of heterosis for these traits. The mean sum of square due to lines were significant for days to 50 % flowering, leaf breadth, and CP%, while that due to testers were significant for eight characters. The mean sum of square due to interaction of line x testers was significant for all the traits except no. of tillers/plant and L:S ratio.

#### **4.3.2 General combining ability effects**

Among female, lines 429 A was found to be good general combiner for traits *viz.*, days to 50 per cent flowering , leaf breadth and crude protein percent (%) (Table 4.4). The line 449 A was found to be good general combiner for the characters *viz.*, number of tillers/plant, leaf length, green forage yield and dry matter yield.





Among males, tester CO-08 was found to be the good general combiner for trait *viz.*, plant height, number of leaves per plant, no. tillers per plant, leaf length, leaf breadth, green forage yield, dry matter yield and crude protein yield. The tester CO-09 was good general combiner for plant height, leaf length, green forage yield, dry matter yield and dry matter content. PMFT-907 and Bajra Biwal were good general combiners for days to 50% flowering, whereas Giant Bajra and PMFT-905 were promising general combiners for crude protein content.

### **4.3.3 Specific combining ability effects**

Specific combining ability effects of different crosses for the character studied are presented in Table 4.5.

#### **4.3.3.1 Days to 50 per cent flowering**

The combination 429A x Raj Bajra Chari (-5.30\*\*) produced the highest significant sca effects and was followed by 425A x DB-1 (-3.19\*) for days to 50 per cent flowering.

#### **4.3.3.2 Plant height (cm)**

The cross 429A x DB-1 (18.38\*\*) recorded the highest significant sca effects and was followed by 449A x PMFT-907 (14.06\*\*), 425A x Giant Bajra (12.78\*\*) and 449A x Raj Bajra Chari (11.62\*) in desirable direction.





#### **4.3.3.3 Number of leaves per plant**

Among all the crosses only one hybrid combination 449A x DB-1 (0.72\*) showed significant sca effects in desirable direction for number of leaves per plant.

#### **4.3.3.4 Number of tillers per plant**

For this trait only one cross, exhibited sca effects in desirable direction, 425A x GFB-1 (0.81\*) showed significantly positive sca effect.

#### **4.3.3.5 Leaf length (cm)**

Three crosses exhibited significant sca effects in desirable direction. The combination 429A x DB-2 (7.50\*\*) recorded the highest sca effect followed by 425A x Raj Bajra Chari (5.64\*) and 449 A x CO-09 (4.81\*) in desirable direction for this trait.

#### **4.3.3.6 Leaf breadth**

For leaf breadth only one combination 449A x Giant Bajra (0.50\*) exhibited significant sca effects in desirable direction.

#### **4.3.3.7 L: S ratio:**

None of the hybrid recorded significant sca effects for L: S ratio.

#### **4.3.3.8 Green forage yield (q/ha)**

Out of 30 crosses studied, four crosses exhibited significantly positively sca effects. The combination 425A x Raj Bajra Chari recorded highest sca effect (91.05\*\*) and was followed by 429A x DB-2 (66.90\*\*) and 425A x Bajra Biwal (65.80\*\*) and 449A x DB-1 (46.60\*\*).

#### **4.3.3.9 Dry matter yield (q/ha)**

Out of 30 crosses studied, five crosses showed significant sca effects in desirable direction. The combination 429A x GFB-1 recorded the highest sca effect (18.55\*\*) followed by 449A x CO-09 (16.60\*\*), 449A x DB-1 (16.39\*\*), 425A x Raj Bajra Chari (15.91\*\*) and 429A x DB-2 (11.02\*).

#### **4.3.3.10 Dry matter (%)**

The combination 425A x GFB-1 recorded the highest sca effect of (2.37\*\*) followed by 429A x GFB-1 (1.68\*\*), 449A x DB-1 (1.31) and 449A x CO-09 (1.27\*\*) for dry matter percent in desirable direction.

#### **4.3.3.11 Crude protein yield (q/ha)**

Among all the crosses studied, two crosses showed significant sca effects in desirable direction. Among them the cross

449A x DB-1(1.34\*) recorded highest sca effects followed by 429A x DB-2 ( 1.24\*) for crude protein yield.

#### **4.3.3.12 Crude protein (%)**

None of the cross showed significant sca effect for crude protein percent in desirable direction.

### **4.4 Gene action**

The estimates of variances due to gca, sca, additive (A) and dominance (D) gene action are presented in Table 4.6.

The sca variance was greater than gca variance for all characters except for leaf breadth and crude protein percent. The variance of additive (A) component was higher than for that dominance (D), for days to 50% flowering, number of leaves per plant, leaf length, leaf breadth, L:S ratio and crude protein content indicating preponderance of additive gene action in the inheritance of these trait. For the remaining traits viz., plant height, number tillers per plant, green fodder yield, dry matter yield, dry matter content and crude protein yield non additive gene action was important.



## **4.5 Heterosis**

Heterosis expressed as percentage increase or decrease in F<sub>1</sub> over mid parent (MP) and better parent (BP) were calculated for the characters under study and are presented in the Table 4.7.

### **4.5.1 Days to 50 per cent flowering**

Earliness in flowering is desirable and hence cross combination indicating negative heterosis are of great value.

Heterosis for the character, days to 50% flowering ranged from -15.64 (429A x PMFT-907) to 6.34 (425A x Raj Bajra Chari) and from -14.07 (429A x Raj Bajra Chari) and (429A x PMFT-907) to 7.41 (429A x DB-2) per cent over mid parent and better parent, respectively.

Out of 30 crosses, 14 were significantly superior over better parents for days to 50 per cent flowering. Amongst them the combination 425A x PMFT-907, 425A x DB-1, 429A x CO-09, have exhibited negative heterosis over better parent.

### **4.5.2 Plant height (cm)**

Among the 30 crosses, not a single cross exhibits significant positive heterosis over better parent. Heterosis for this character ranged from -8.99 (429A x Giant Bajra) to 31.32 (449A x PMFT-907) and -34.99 (449A x Giant Bajra) to 11.16 (449A x PMFT-907) per cent over mid parent and better parent, respectively.









Amongst the combination 449A x PMFT-907 have exploited more per cent of heterosis.

#### **4.5.3. Number of leaves per plant**

The heterosis for this trait range between -19.66 (449A x Giant Bajra) to 17.60 (429A x GFB-1) and - 4.03 (449A x Giant Bajra) to 21.99 (429A x GFB-1) per cent over better parent and mid parent, respectively. Only one cross combination 429A x GFB-1 was significantly superior over better parent in desirable direction for number of leaves.

#### **4.5.4 Number of tillers per plant**

More number of tillers per plant is an important attribute hence positive heterosis for this trait is desirable. Heterobeltiosis for this traits was found ranging between -46.43 (429A x CO-09) to -5.68 (425A x GFB-1) per cent.

All the crosses exhibited negative heterosis over better parent and mid parent in undesirable direction.

#### **4.5.5 Leaf length (cm)**

The combination recorded minimum heterosis of -21.86 (429 A x Giant Bajra) over better parent. Whereas the combination produced maximum of 12.05 (425A Raj Bajra Chari) per cent heterosis, only one cross combination 425A x Raj Bajra Chari

showed higher heterobeltiosis among the genotypes in desirable direction.

#### **4.5.6 Leaf breadth (cm)**

The variation for heterobeltiosis and relative heterosis ranged from -40.31 (429A x Giant Bajra) to 12.07 (425A x CO-08) and -27.77 (429A x Giant Bajra) to 14.24 (425A x Co-08) for better parent and mid parent, respectively.

Cross combination 425A x CO-08 and 425A x CO-09 were significantly superior over both better parent and mid parent in desirable direction.

#### **4.5.7 L: S ratio**

For L: S ratio, the range of heterobeltiosis varied between -40.78 (449A x PMFT-907) to 16.95 (429A x PMFT-907) and -31.66 (449A x CO-09) to 19.70 (449A x CO-08) per cent over better parent and mid parent, respectively.

None of the cross combination was significantly superior over better parent and out of thirty crosses only eight crosses were significantly superior over mid parent in desirable direction for this trait.

#### **4.5.8 Green fodder yield (q/ha)**

Among the crosses studied for green fodder yield, the heterobeltiosis and mid parent heterosis ranged between  $-42.47$  (425A x Giant Bajra) to  $23.05$  (425A x Raj Bajra Chari) and  $-15.42$  (449 A x GFB-1) to  $65.69$  (425A x Raj Bajra Chari) respectively.

Out of thirty cross combinations, three crosses (425A x Raj Bajra, 425A x PMFT-907 and 449A x PMFT-907) were significantly superior over better parent.

#### **4.5.9 Dry matter yield (q/ha)**

In case of dry matter yield the range of heterobeltiosis and relative heterosis varied between  $-48.75$  (425A x Giant Bajra) to  $33.65$  (449A x PMFT-907) and to  $-25.81$  (449 x GFB-1) to  $73.08$  (425A x Raj Bajra Chari) respectively.

Out thirty only four crosses were significantly superior over both better and mid parent in desirable direction. The highest estimate of heterobeltiosis was recorded by the cross 449A x PMFT-907 (33.65%).

#### **4.5.10 Dry matter (%)**

The variation for heterobeltiosis and mid parent heterosis ranged from  $-22.45$  (429A x Giant Bajra) to  $25.48$

(425A x CO-09) and -16.60 (429A x Giant Bajra) to 36.03 (449A x CO-09), respectively.

Out of thirty only seven cross combinations were significantly superior over both better parent and mid parent in desirable direction.

#### **4.5.11 Crude protein yield (q/ha)**

Better parent and mid parent heterosis for crude protein yield ranged from -47.85 (429A x Giant Bajra) to 42.05 (425A x Raj Bajra Chari) and -17.67 (429A x Giant Bajra) to 81.62 (425A x Raj Bajra Chari) respectively. Only one cross 425A x Raj Bajra Chari showed significant positive heterosis over both better and mid parent in desirable direction for this trait.

#### **4.5.12 Crude protein (%)**

For the character crude protein content, the range of heterobeltiosis ranged between -26.30 (449A x DB-2) to 13.30 (449A x Bajra Biwal). The highest estimate of heterobeltiosis recorded by cross 449A x DB-2 (13.30 %) followed by 425A x Giant Bajra (6.45 %) and 425A x PMFT-905 (5.20 %).

## 5. DISCUSSION

Now a days heterosis breeding is being used to exploit the maximum productivity in many crop plants.

One of the major objectives in heterosis breeding is the choice of parents to be used in breeding programme among the promising genotypes. It is therefore necessary to select parents with good general combining ability for yield and its components. The combining ability analysis assesses the utility of the crosses and the parents.

Thus, a critical examination of the relative magnitude of gca and sca variances and gca and sca effects of the parents and crosses respectively help to plan suitable breeding methodology. But a high yielding genotype may or may not always transmit its superiority to its progenies. Therefore, the success of a breeding programme is determined by useful gene combination in the form of high combining inbreds.

In pearl millet (*Pennisetum glaucum* (L.) R. Br.) new field for genetic improvement was opened after the discovery of cytoplasmic genetic male sterile systems (Tift 23 A and Tift 18A) by Burton (1951). It is one of the most important cereal crop grown for food, feed and fodder purpose throughout the country as its

quick growing, short duration, drought tolerance. Besides its flower being a protogynous in nature makes pollination process easier. Success in crossing is also high. Besides, fertilization takes place within four hours after pollination and seed matured within 20-25 days after fertilization. This helps for making large numbers of crosses and also for raising sufficient  $F_1$  population and subsequent generations.

Keeping this in view, the efforts were made in present investigation to study the extent of heterosis, to identify the best general and specific combinations in forage pearl millet and to study the gene action for yield and yield contributing characters in crosses developed by intermating three male sterile lines and ten restores in a line x tester fashion. The results of present investigation are discussed below, under suitable headings.

## **5.1 Combining ability**

### **5.1.1 General combining ability effects**

The female parent 449A showed significant gca effects for four characters *viz.*, no. of tillers/plant, leaf length, green forage yield and dry matter yield and it was found good general combiner for these traits. Among female, lines 429 A was found to be good general combiner for traits *viz.*, days to 50 per cent flowering , leaf breadth and crude protein percent.

Among males, tester CO-08 was found to be the good general combiner for trait *viz.*, plant height, number of leaves per plant, no. tillers per plant, leaf length, leaf breadth, green forage yield, dry matter yield and crude protein yield. The tester CO-09 was good general combiner for plant height, leaf length, green forage yield, dry matter yield and dry matter content. PMFT-907 and Bajra Biwal were good general combiners for days to 50% flowering, whereas Giant Bajra and PMFT-905 were promising general combiners for crude protein content.

Gopalan and Shree Rangasamy (1989) studied the combining ability of fodder attributes in pearl millet. They reported among male sterile, the lines MA126D2A recorded positive and significant GCA effects for number of leaves, leaf breadth, stem thickness, GFY, DMY and CPY. Patil *et al.* (1992) studied heterosis for green forage yield in pearl millet. Among hybrids the best specific combination was 842A x Giant Bajra (SCA:15.16). Yadav *et al.* (2002) studied on combining ability for forage attributes in pearl millet. They reported among male sterile 92777A and 94111A high gca effect for plant height and number of effective tillers respectively. Among testers HP8603 and ICR161 for dry forage yield; G73-107 for effective tillers and HTP94/34, ICR161 and CSSC46-2 for plant height were good general

combiners. Ved Prakash and Singh (2004) studied genetic studies of fodder quality characters in Pearl Millet. They reported the line L74 and L72 were good general combiner for protein content. Lakshmana *et al.* (2010) studied combining ability and heterosis in pearl millet. They reported the line A4 cytoplasm were best general combiner for productive tillers per plant.

### **5.1.2 Specific combining ability effects**

Four crosses recorded significant sca effects in favorable direction were more for green forage yield followed by dry matter yield (5), days to 50 per cent flowering (2) and crude protein yield (2). The cross combination 429A x Raj Bajra Chari for days to 50 % flowering, 429A x DB-1 for plant height, 449A x DB-1 for number of leaves, 425A x GFB-1 for number of tillers, 429A x DB-2 for leaf length, 449A x Giant Bajra for leaf breadth, 425A x Raj Bajra Chari for green fodder yield, 429A x GFB-1 for dry matter, 425A x GFB-1 for dry matter percent and 449A DB-1 for crude protein yield exhibited highly significant and maximum sca effects

Yadav *et al.* (2002) studied combining ability for forage attributes in pearl millet. They reported the among the crosses 93111A x HTP 91/32, 95555A x ICR 161 and 95555A x 77/29-2 and 92777Ax HTP94/2 were high sca effect for dry fodder yield, the cross combination 93111AxH90/4-5, 94111AxCSSC46-2 and

95111Ax HTP94/34 for effective tillers, whereas for plant height 94111Ax8603,94111AxCSSC46-2 and 95555Ax77/29-2 were the top specific cross combinations. Patel *et.al.* (2008) studied heterosis and combining ability for fodder yield and its component in pearl millet. They reported high SCA effects the best cross combination JMSA 101A x 217 SB for dry fodder yield, plant height, number of leaves in desirable direction. Pachade (2006) studied heterosis, combining ability and gene action in forage pearl millet. They reported high sca effects for days to 50% flowering, plant height, number of leaves, leaf length, dry matter yield, green forage yield, and crude protein percent in desirable direction.

## **5.2 Gene action**

In the present studies, additive gene action was found to be predominant in the inheritance of the traits *viz.*, days to 50% flowering, number of leaves per plant, leaf length, leaf breadth, leaf:stem ratio and crude protein content thus selection for these traits would be effective. Karale *et al.* (1998) observed that the additive gene action for days to 50 per cent flowering, plant height, ear length, whereas non-additive gene action. Mohan *et al.* (1999) studied using line x tester in pearl millet. They reported additive gene action was important for number of productive tillers. Rasal and Patil (2003) studied line x tester analysis in pearl millet. They

reported additive gene action for days to 50% flowering, plant height and number of tillers/plant.

However non additive gene action was found for the characters *viz.*, plant height, number tillers per plant, green fodder yield, dry matter yield, dry matter content and crude protein yield. Therefore for improvement of these traits heterosis breeding would be beneficial in the present studies. Saraswati *et al.* (1996) reported the predominance of non-additive gene action for days to 50 per cent flowering, plant height and number of productive tillers per plant. Navale *et al.* (1985) studied combining ability of maintainers in pearl millet. They reported the significance of non-additive gene action for characters *viz.*, productive tillers, ear length, plant height, days to 50 per cent flowering.

### 5.3 Heterosis

Heterosis is the measure of superiority of hybrid over parental means. Heterosis may be either positive or negative. Depending on the magnitude of hybrid vigour, *per se* performance the best specific cross combination can be utilized for commercial exploitation of hybrid vigour.

Parent Vs crosses (P Vs C) interaction mean squares provide a measure of heterosis (Arunachalam, 1974). In the present investigation P Vs C interaction mean squares were significant for

all the traits studied except plant height, number of leaves per plant, leaf breadth and L:S ratio. But such comparison will test the difference between parental and hybrid group means. Hence analysis of heterosis based on single crosses of between two lines or two populations, which have no common origin has its importance (Falconer, 1985).

### **5.3.1 Magnitude and direction of heterosis**

It was observed from the data (Table 5.1) that, all the characters had significant heterosis over better parent in desirable direction except number of tillers and leaf:stem ratio.

In the present study the crosses, 429A x Raj Bajra Chari and 429A x PMFT-907 exhibited significant heterobeltiosis for days to 50 percent flowering. Tyagi *et al.* (1975), Kulkarni *et al.* (1993), Chavan and Nerkar (1994), Patil *et al.* (1994) and Pachade (2006) reported negative significant heterobeltiosis for days to 50 percent flowering.

For plant height only one cross *viz.*, 449A x PMFT -907 exhibited significant heterobeltiosis. Singh and Singh (1972),



Chavan and Nerkar (1994), Patil *et al.* (1994) and Patel *et al.* (2008) reported significant heterobeltiosis for plant height.

For number of leaves per plant only one cross *viz.*, 429A x GFB-1 exhibited significant heterobeltiosis. Patel *et al.* (2008) reported significant heterobeltiosis for this trait in desirable direction.

For number of tillers per plant none of the hybrids exhibited significant heterobeltiosis in favourable direction. However, Singh and Singh (1972), Tyagi *et al.* (1975), Hapse *et al.* (1986), Kulkarni *et al.* (1993), Chavan and Nerkar (1994), Pachade(2006) and Davada *et al.*(2008) reported significant heterobeltiosis for this trait .

The hybrid 425A x Raj Bajara Chari and 449A x CO-09 exhibited significant heterobeltiosis for leaf length. Pachade (2006) reported positive significant heterobeltiosis leaf length.

For leaf breadth *viz.*, 425AxCO-08 exhibited significant heterobeltiosis. Pachade (2006) reported positive significant heterobeltiosis leaf breadth.

For leaf stem ratio none of the hybrids exhibited significant heterobeltiosis in favourable direction.

For green forage yield the hybrids *viz.*, 425A x Raj Bajra, 425A x PMFT-907 and 449A x PMFT-907 Chari exhibited significant heterobeltiosis. Pachade (2006) and Patel *et al.* (2008) reported significant heterobeltiosis for green forage yield.

The hybrids *viz.*, 449AxPMFT-907,425A x Raj Bajra Chari and 425A x PMFT-907 exhibited significant heterobeltiosis for dry matter yield. Yash *et al* (2004) and Pachade (2006) reported significant heterobeltiosis for dry matter yield.

For dry matter percent the crosses *viz.*,449A x CO-09 and 449A x PMFT-907 exhibited significant heterobeltiosis.

For crude protein yield only one cross *viz.*, 425A x Raj Bajra exhibited significant heterobeltiosis in desirable direction.

The cross combination *viz.*, 449A x Bajra Biwal and 425A x Giant Bajra exhibited significant heterobeltiosis for crude protein percent. Pachade (2006) reported significant heterobeltiosis for crude protein percent.

The frequency of crosses showing the significant heterobeltiosis for days to 50 % flowering (46.67%) followed CP % (23.33%), dry matter yield (13.22 %), leaf breadth (9.99 %) GFY (9.99 %), leaf length (6.66%), DM % (6.66 %) plant height (3.33 %), number of leaves (3.33%) and crude protein yield (3.33%).

## 6. SUMMARY AND CONCLUSIONS

The present investigation entitled “Genetic Analysis in forage pearl millet [*Pennisetum glaucum* (L.) R.Br.] was carried out during *kharif*, 2010 at AICRP on Forage Crops, MPKV, Rahuri. Three male sterile lines namely 425A, 429A and 449A and ten testers namely Co-08, CO-09, Bajra Biwal, DB-1, DB-2, GFB-1, Raj Bajra Chari, PMFT-907, PMFT-905, Giant Bajra, were crossed during summer. The resulting thirty hybrids along with thirteen parents were evaluated in a randomized block design with three replication during *kharif*, 2010. In this investigation an attempt was made to study combining ability effects its variances, gene action and heterosis, in respect of forage yield and its components.

The mean squares due to treatment were significant for all the characters studied indicating ample variability among the genotypes studied. The mean sum of squares due to parent and crosses were significant indicating appreciable amount of variability in parents and crosses. The parents *vs* crosses interaction was significant for most of traits studied, indicating existence of good amount of heterotic effect in the hybrid studied. Significant heterobeltiotic crosses occurred most frequently for days to 50 per cent flowering, DM%, CP% DMY, GFY, leaf breadth.

Among the females 449A was the best combiner as it produced significantly desirable gca effects for four traits viz; number of tillers, leaf length, GFY and DMY. Among males, CO-8 was the best general combiner exhibiting gca effects in desirable direction for nine characters viz., days to 50% flowering, plant height, number of leaves, number of tillers, leaf length, leaf breadth, GFY, DMY and CPY. Giant Bajra was found to be good combiner for days to 50% flowering, number of leaves, leaf length, leaf breadth, CPY and CP.

The combination 429A x Raj Bajra Chari for days to 50 % flowering, 429A x DB-1 for plant height, 449A x DB-1 for number of leaves, 425A x GFB-1 for number of tillers, 429A x DB-2 for leaf length, 449A x Giant Bajra for leaf breadth, 425A x Raj Bajra Chari for green fodder yield, 429A x GFB-1 for dry matter yield, 425A x GFB-1 for dry matter percent and 449A x DB-1 for crude protein yield exhibited highly significant and maximum sca effects. In case of days to 50% per cent flowering two crosses showed significant sca effects.

The combination 449A x PMFT 907 produced the highest and significant heterobeltiosis (11.16 %) for plant height. Likewise 429A x PMFT 907 (14.07 %) for days 50% flowering, 429A x GFB-1 (17.60 %) for number of leaves, 425A x Raj Bajra

Chari (12.05 %) for leaf length, 425A x Raj Bajra Chari (23.05 %) for GFY, 449A x PMFT-907 (33.65 %) for DMY and 425A x Raj Bajra Chari (42.05 %) for crude protein yield showed significant heterobeltiosis in favorable direction.

On the basis of per se performance Co-08 (903.61 q/ha, 192.55 q/ha) among parents ranked first in respect of GFY and DMY followed by Giant Bajra (885.10 q/ha, 189.97q/ha). The cross 449A x CO-08 (703.63 q/ha) ranked first for GFY followed by 449A x CO-09 (698.08 q/ha) and 425A x CO-08 (686.97q/ha).

Considering the overall results obtained in the present studies the best general combiners *viz.*, CO-08, CO-09 and Giant Bajra should be used for further breeding programme for improvement in green forage yield and its components in forage Bajra.

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## 8. V I T A

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of

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in

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**2011.**

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**Table 4.1. Mean performance of parents and crosses for twelve characters in**

Parents/ Crosses	Days to 50% flowering	Plant height (cm)	No. of leaves/plant	No. of tillers /plant	Leaf length (cm)	Leaf breadth (cm)	L:S ratio	GFY (q/ha)	
1	2	3	4	5	6	7	8	9	
<b>Lines</b>									
425A	47.67	136.13	8.60	5.47	59.07	3.87	0.25	259.24	
429A	45.00	128.33	7.73	5.60	56.73	3.59	0.19	276.83	
449A	50.00	113.00	8.00	5.93	72.87	3.67	0.34	420.33	
<b>Mean</b>	<b>47.56</b>	<b>125.82</b>	<b>8.11</b>	<b>5.67</b>	<b>62.89</b>	<b>3.71</b>	<b>0.26</b>	<b>318.80</b>	
<b>Testers</b>									
CO-08	58.33	203.33	10.33	4.47	97.73	3.72	0.25	903.61	1
CO-09	50.00	182.47	9.33	4.07	74.07	4.16	0.32	733.26	1
Bajra Biwal	46.33	186.60	8.87	4.80	71.53	3.33	0.25	540.69	
DB-1	49.00	199.20	9.40	4.40	80.47	3.41	0.22	603.65	1
DB-2	61.67	235.60	10.40	4.33	92.80	4.57	0.29	705.49	1
GFB-1	48.33	176.07	8.33	5.87	75.67	2.80	0.29	792.52	1
Raj Bajra Chari	47.00	182.87	9.00	5.27	70.27	3.47	0.32	534.21	
PMFT-907	46.67	163.07	8.67	5.33	72.53	3.07	0.20	522.17	
PMFT-905	51.33	197.53	9.27	4.47	75.87	4.53	0.18	585.13	1
G.Bajra	59.00	263.87	11.87	4.67	99.40	5.51	0.24	885.10	1
<b>Mean</b>	<b>51.77</b>	<b>199.06</b>	<b>9.55</b>	<b>4.77</b>	<b>81.03</b>	<b>3.86</b>	<b>0.26</b>	<b>680.58</b>	<b>1</b>

**Table 4.1. Contd...**

1	2	3	4	5	6	7	8	9	
<b>Hybrids</b>									
425A x CO-08	48.67	203.20	10.07	4.53	77.33	4.33	0.24	686.97	1
425A x CO-09	47.00	192.07	9.53	3.20	73.80	4.21	0.24	618.46	1
425A x Bajra Biwal	42.00	181.20	8.73	3.20	70.33	3.51	0.21	586.98	1
425 A x DB-1	45.67	177.47	9.00	3.37	68.13	3.29	0.23	499.95	
425A x DB-2	47.33	174.13	9.40	4.87	73.00	4.11	0.25	513.84	
425A X GFB-1	47.33	185.93	8.80	5.53	73.20	3.48	0.26	459.21	
425A x Raj Bajra Chari	50.33	175.47	9.53	4.40	78.73	3.88	0.28	657.35	1
425A x PMFT- 907	41.67	173.27	9.33	3.13	68.47	3.41	0.23	596.25	
425A x PMFT- 905	41.67	175.53	10.20	4.67	65.47	3.99	0.20	546.25	
425A x G.Bajra	48.33	200.00	9.93	3.60	81.33	4.08	0.24	509.21	
429A x CO-08	48.00	185.33	10.47	4.53	77.93	4.16	0.26	601.80	1
429A x CO-09	43.00	186.87	9.73	3.00	70.13	3.67	0.23	559.21	1
429A x Bajra Biwal	39.67	170.33	8.47	4.00	61.93	2.93	0.19	457.36	
429 A x DB-1	47.67	206.40	9.80	3.70	73.27	3.35	0.24	522.17	
429A x DB-2	48.33	172.80	9.20	4.00	80.80	3.75	0.28	592.53	1
429A X GFB-1	41.00	177.80	9.80	4.00	68.07	3.07	0.25	514.77	1
429A x Raj Bajra Chari	38.67	167.67	9.20	3.20	63.60	3.27	0.22	453.66	

**Table 4.1. Contd...**

<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>
<b>Hybrids</b>								
429A x PMFT-907	38.67	146.80	8.33	3.27	58.20	3.18	0.23	509.21
429A x PMFT-905	41.00	167.20	9.80	3.73	66.00	3.65	0.21	496.25
429A x G.Bajra	47.33	178.47	9.87	3.60	77.67	3.29	0.23	601.61
449A x CO-08	47.33	186.33	9.13	3.93	77.53	3.55	0.26	703.63
449A x CO-09	46.33	177.80	8.87	4.13	81.93	3.55	0.23	698.08
449A x Bajra Biwal	41.00	168.00	8.13	3.87	63.60	3.01	0.22	509.21
449 A x DB-1	49.67	192.13	10.13	4.47	76.73	3.75	0.26	625.87
449A x DB-2	46.00	185.13	9.40	4.73	73.67	3.48	0.27	570.31
449A X GFB-1	42.67	171.07	8.53	4.40	71.13	3.19	0.27	512.91
449A x Raj Bajra Chari	47.33	189.13	9.27	4.07	74.87	3.97	0.25	577.89
449A x PMFT-907	41.67	181.27	8.93	3.93	71.00	3.55	0.20	592.54
449A x PMFT-905	43.00	178.00	9.27	3.80	72.13	3.70	0.24	490.70
449A x G.Bajra	46.00	171.53	9.53	4.40	78.60	4.43	0.23	659.38
Hybrid Mean	44.81	179.94	9.35	3.98	72.29	3.63	0.24	564.12
Mean	46.62	180.61	9.31	4.28	73.67	3.69	0.24	574.09
<b>SE ±</b>	<b>1.07</b>	<b>4.18</b>	<b>0.32</b>	<b>0.39</b>	<b>2.23</b>	<b>0.22</b>	<b>0.02</b>	<b>20.87</b>
<b>CD (5%)</b>	<b>3.02</b>	<b>11.75</b>	<b>0.91</b>	<b>1.11</b>	<b>6.28</b>	<b>0.61</b>	<b>0.05</b>	<b>58.70</b>
<b>CD (1%)</b>	<b>3.99</b>	<b>4.01</b>	<b>5.99</b>	<b>15.93</b>	<b>5.25</b>	<b>10.24</b>	<b>13.36</b>	<b>6.30</b>

**Table 4.2. Analysis of variance (MSS) for twelve characters in forage Pearl**

Source of variation	D.F.	Days to 50% flow.	Plant height (cm)	No. of leaves /plant	No. of tillers /plant	Leaf length (cm)	Leaf breadth (cm)	L/S ratio	GFY (q/ha)
Replication	2	12.43	84.63	0.55	1.43	4.49	0.10	0.0001	572.80
Treatment	42	72.96**	1783.25**	1.79**	1.74**	236.93**	0.81**	0.003**	47632.32**
Error	84	3.46	52.39	0.31	0.46	14.98	0.14	0.001	1307.13

\*, \*\* = Significant at 5% and 1% level, respectively.

**Table 4.3. Analysis of variance of combining ability(MSS) for twelve characters**

Source of variation	D.F	Days to 50% flow.	Plant Height (cm)	No. of Leaves/plant	No. of Tillers /plant	Leaf length (cm)	Leaf breadth (cm)	L:S ratio	GFY (q/ha)
Replications	2	12.43*	84.63	0.55	1.43	4.49	0.10	0.0001	572.81
Treatments	42	72.96**	1783.25**	1.79**	1.74**	236.93**	0.81**	0.004**	47632.32**
Parents	12	86.97**	5181.92**	3.76**	1.19**	512.31**	1.56**	0.008**	126570.11**
Parents vs Crosses	1	974.24**	133.44	0.47	27.14**	565.65**	1.06**	0.008**	29585.72**
Crosses	29	36.08**	433.79**	1.02**	1.09**	111.65**	0.48**	0.002	15590.70**
Line	2	55.21*	463.55	1.16	1.78	153.39	1.19*	0.000	30201.88
Tester	9	73.16**	591.82	1.87*	1.58	209.38**	0.79*	0.004**	24310.67*
Line x Tester	18	15.42**	351.47**	0.58*	0.77	58.14**	0.25*	0.001	9607.25**
Error	84	3.47	52.39	0.31	0.46	14.98	0.14	0.001	1307.13

\*, \*\* = Significant at 5% and 1% level, respectively.

**Table 4.4. Estimates of general combining ability effects for twelve character**

Parents	Days to 50% flow.	Plant height (cm)	No. of leaves/plant	No. of tillers/plant	Leaf length (cm)	Leaf breadth (cm)	L:S ratio	GFY (q/ha)	DMY (q/ha)
<b>Lines</b>									
425A	1.89**	3.88**	0.11	0.07	0.69	0.20**	-0.001	3.33	-0.54
429A	-1.48**	-3.98**	0.12	-0.27**	-2.53**	0.19*	-0.003	-33.26**	-6.05**
449A	0.29	0.10	-0.23*	0.20*	1.83*	-0.01	0.004	29.93**	6.59**
<b>S.E. ±</b>	<b>0.39</b>	<b>1.39</b>	<b>0.10</b>	<b>0.10</b>	<b>0.74</b>	<b>0.07</b>	<b>0.006</b>	<b>7.25</b>	<b>1.59</b>
<b>CD (5%)</b>	<b>0.78</b>	<b>2.77</b>	<b>0.21</b>	<b>0.20</b>	<b>1.48</b>	<b>0.15</b>	<b>0.012</b>	<b>14.52</b>	<b>3.19</b>
<b>CD (1%)</b>	<b>1.03</b>	<b>3.69</b>	<b>0.28</b>	<b>0.26</b>	<b>1.97</b>	<b>0.20</b>	<b>0.016</b>	<b>19.32</b>	<b>4.24</b>
<b>Testers</b>									
CO-08	3.19**	11.68**	0.54**	0.36*	5.31**	0.39**	0.014	100.02**	20.00**
CO-09	0.63	5.63*	0.03	-0.53**	3.00*	0.19	-0.006	61.13**	15.94**
Bajra Biwal	-3.92**	-6.77**	-0.90**	-0.29	-7.00**	-0.48**	-0.032**	-46.27**	-9.67**
DB-1	2.86**	12.06**	0.30	-0.13	0.42	-0.16	0.005	-14.79	0.53
DB-2	2.41**	-2.59	-0.01	0.56**	3.54*	0.15	0.030**	-5.22	-6.52*
GFB-1	-1.14	-1.68	-0.30	0.67**	-1.49	-0.38**	0.021	-68.49**	-11.49**
Raj Bajra Chari	0.63	-2.52	-0.01	-0.09	0.11	0.08	0.012	-1.15	-0.13
PMFT-907	-4.14**	-12.83**	-0.48*	-0.53**	-6.40**	-0.25	-0.018	1.88	-5.80
PMFT-905	-2.92**	-6.37**	0.41*	0.09	-4.42**	0.16	-0.022*	-53.06**	-7.05**
G.Bajra	2.41**	3.39	0.43*	-0.11	6.91**	0.31*	-0.005	25.95	4.19
<b>S.E. ±</b>	<b>0.71</b>	<b>2.53</b>	<b>0.19</b>	<b>0.18</b>	<b>1.35</b>	<b>0.14</b>	<b>0.011</b>	<b>13.24</b>	<b>2.91</b>
<b>CD (5%)</b>	<b>1.42</b>	<b>5.07</b>	<b>0.39</b>	<b>0.36</b>	<b>2.70</b>	<b>0.27</b>	<b>0.022</b>	<b>26.51</b>	<b>5.82</b>
<b>CD (1%)</b>	<b>1.89</b>	<b>6.74</b>	<b>0.51</b>	<b>0.48</b>	<b>3.60</b>	<b>0.36</b>	<b>0.030</b>	<b>35.27</b>	<b>7.74</b>

\*, \*\* = Significant at 5% and 1% level, respectively.

**Table 4.5. Estimates of specific combining ability effects for twelve characters**

Cross	Days to 50% flow.	Plant height (cm)	No. of leaves/plant	No. of tillers /plant	Leaf length (cm)	Leaf breadth (cm)	L:S ratio	GFY (q/ha)
425A x CO-08	-0.52	7.70	0.071	0.126	-0.96	0.115	-0.015	19.51
425A x CO-09	0.37	2.61	0.049	-0.319	-2.18	0.199	0.008	-10.12
425A x Bajra Biwal	-0.08	4.14	0.182	-0.563	4.35	0.155	0.001	65.80**
425 A x DB-1	-3.19*	-18.42**	-0.751*	-0.552	-5.27*	-0.378	-0.016	-52.71*
425A x DB-2	-1.08	-7.10	-0.040	0.259	-3.52	0.124	-0.014	-48.38*
425A X GFB-1	2.48*	3.78	-0.351	0.814*	1.71	0.033	0.001	-39.75
425A x Raj Bajra Chari	3.70**	-5.84	0.093	0.437	5.64*	-0.032	0.034	91.05**
425A x PMFT-907	-0.19	2.27	0.360	-0.386	1.88	-0.170	0.010	26.92
425A x PMFT -905	-1.41	-1.93	0.338	0.526	-3.09	0.008	-0.015	31.86
425A x G.Bajra	-0.08	12.78**	0.049	-0.341	1.44	-0.054	0.007	-84.19**
429A x CO-08	1.48	-2.31	0.458	0.472	2.86	0.339	0.013	-29.07
429A x CO-09	-0.97	5.27	0.236	-0.172	-2.63	0.050	0.003	-32.78
429A x Bajra Biwal	0.26	1.13	-0.098	0.583	-0.83	-0.028	-0.014	-27.23
429 A x DB-1	1.48	18.38**	0.036	0.128	3.08	0.086	0.002	6.10
429A x DB-2	2.59*	-0.58	-0.253	-0.261	7.50**	0.168	0.017	66.90**
429A X GFB-1	-1.19	3.51	0.636	-0.372	-0.21	0.017	-0.010	52.40

**Table 4.5. Contd....**

Crosses	Days to 50% flow.	Plant height (cm)	No. of leaves/plant	No. of tillers /plant	Leaf length (cm)	Leaf breadth (cm)	L:S ratio	GFY (q/ha)
429A x Raj Bajra Chari	-5.30**	-5.78	-0.253	-0.417	-6.27**	-0.241	-0.025	-76.04**
429A x PMFT-907	-0.52	-16.33**	-0.653	0.094	-5.16**	-0.006	0.012	-23.52
429A x PMFT-905	0.59	-2.40	-0.076	-0.061	0.66	0.066	0.000	18.45
429A x G.Bajra	1.59	-0.89	-0.031	0.006	0.99	-0.450	0.002	44.80
449A x CO-08	-0.96	-5.38	-0.529	-0.598	-1.90	-0.454	0.002	9.56
449A x CO-09	0.60	-7.87	-0.284	0.491	4.81*	-0.249	-0.011	42.90
449A x Bajra Biwal	-0.18	-5.27	-0.084	-0.020	-3.52	-0.127	0.012	-38.58
449 A x DB-1	1.71	0.04	0.716*	0.424	2.19	0.293	0.015	46.60*
449A x DB-2	-1.51	7.68	0.293	0.002	-3.99	-0.292	-0.003	-18.52
449A X GFB-1	-1.29	-7.30	-0.284	-0.442	-1.50	-0.049	0.009	-12.65
449A x Raj Bajra Chari	1.60	11.62*	0.160	-0.020	0.63	0.273	-0.009	-15.01
449A x PMFT-907	0.71	14.06**	0.293	0.291	3.28	0.175	-0.022	-3.40
449A x PMFT-905	0.82	4.33	-0.262	-0.464	2.43	-0.074	0.016	-50.30*
449A x G.Bajra	-1.51	-11.90**	-0.008	0.336	-2.43	0.504*	-0.009	39.38
<b>S.E. ±</b>	<b>1.23</b>	<b>4.38</b>	<b>0.33</b>	<b>0.31</b>	<b>2.34</b>	<b>0.24</b>	<b>0.02</b>	<b>22.94</b>
<b>CD (5%)</b>	<b>2.46</b>	<b>8.78</b>	<b>0.67</b>	<b>0.63</b>	<b>4.68</b>	<b>0.47</b>	<b>0.04</b>	<b>45.91</b>
<b>CD (1%)</b>	<b>3.27</b>	<b>11.68</b>	<b>0.89</b>	<b>0.84</b>	<b>6.23</b>	<b>0.63</b>	<b>0.05</b>	<b>61.09</b>

\*, \*\* = Significant at 5% and 1% level, respectively.

**Table 4.6. Components of genetic variance for twelve different characters in**

<b>Components</b>	<b>Days to 50% flow.</b>	<b>Plant height (cm)</b>	<b>No. of leaves /plant</b>	<b>No. of tillers /plant</b>	<b>Leaf length (cm)</b>	<b>Leaf breadth (cm)</b>	<b>L:S ratio</b>	<b>GFY (q/ha)</b>
$\delta^2_{gca}$	3.06	24.10	0.0604	0.0709	8.46	0.0422	0.0000	1316.81
$\delta^2_{sca}$	3.63	97.93	0.0797	0.1562	13.90	0.0281	-0.0001	2676.28
$\delta^2_A$	6.12	48.20	0.1209	0.1418	16.92	0.0844	0.0001	2633.63
$\delta^2_D$	3.63	97.93	0.0797	0.1562	13.91	0.0281	-0.0001	2676.28
<b>A:D ratio</b>	1.68	0.49	1.5174	0.9081	1.22	2.9997	-1.1791	0.98

**Table 4.7. Per cent heterosis over mid parent, better parent for twelve characters in for**

SN	Crosses	Days to 50% flow.		Plant height (cm)		No. of leaves /plant		No. of tillers /plant	
		MP	BP	MP	BP	MP	BP	MP	BP
1	425A x CO-08	-8.18**	2.10	19.72**	-0.07	6.34	-2.58	-8.72	-17.07*
2	425A x CO-09	-3.75	-1.40	20.57**	5.26	6.32	2.14	-32.87**	-41.46**
3	425A x Bajra Biwal	-10.64**	-9.35*	12.29**	-2.89	0.00	-1.50	-37.66**	-41.46**
4	425 A x DB-1	-5.52	-4.20	5.84	-10.91**	0.00	-4.26	-31.76**	-38.41**
5	425A x DB-2	-13.41**	-0.70	-6.31*	-26.09**	-1.05	-9.62*	-0.68	-10.98
6	425A X GFB-1	-1.39	-0.70	19.11**	5.6	3.94	2.33	-2.35	-5.68
7	425A x Raj Bajra Chari	6.34	5.59	10.01**	-4.05	8.33	5.93	-18.01*	-19.51*
8	425A x PMFT-907	-11.66**	-10.71	15.82**	6.26	8.11	7.69	-41.98**	-42.68**
9	425A x PMFT-905	-15.82**	-12.59**	5.21	-11.14**	14.18**	10.07	-6.04	-14.63
10	425A x G.Bajra	-9.38*	1.40	0.00	-24.20**	-2.93	-16.29**	-28.95**	-34.15**
11	429A x CO-08	-7.10*	6.67	11.76**	-8.85**	15.87**	1.29	-9.93	-19.05*
12	429A x CO-09	-9.47**	-4.44	20.25**	2.41	14.06**	4.29	-37.93**	-46.43**
13	429A x Bajra Biwal	-13.14**	-11.85**	8.17*	-8.72*	2.01	-4.51	-23.08**	-28.57**
14	429 A x DB-1	1.42	-2.72	26.03**	3.61	14.40**	4.26	-26.00**	-33.93**
15	429A x DB-2	-9.38**	7.41	-5.04	-26.66**	1.47	-11.54*	-19.46*	-28.57**
16	429A X GFB-1	-12.14**	-8.89*	16.82**	0.98	21.99**	17.60**	-30.23**	-31.82**
17	429A x Raj Bajra Chari	-15.94**	-14.07**	7.75*	-8.31*	9.96*	2.22	-41.10**	-42.86**
18	429A x PMFT-907	-15.64**	-14.07**	0.75	-9.98*	1.63	-3.85	-40.24**	-41.67**

**Table 4.7 Contd...**

SN	Crosses	Days to 50% flow.		Plant height (cm)		No. of leaves /plant		No. of tillers /plant	
		MP	BP	MP	BP	MP	BP	MP	BP
19	429A x PMFT-905	-14.88**	-8.89*	2.62	-15.36**	15.29**	5.76	-25.83**	-33.33**
20	429A x G.Bajra	-8.97**	5.19	-8.99**	-32.36**	0.68	-16.85**	-29.87**	-35.71**
21	449A x CO-08	-12.62**	5.33	17.81**	-8.36**	-0.36	-11.61*	-24.36**	-33.71**
22	449A x CO-09	-7.33*	-7.33*	20.35**	-2.56	2.31	-5.00	-17.33*	-30.34**
23	449A x Bajra Biwal	-14.88**	-11.51**	12.15**	-9.97**	-3.56	-8.27	-27.95**	-34.83**
24	449 A x DB-1	0.34	-0.67	23.08**	-3.55	16.48**	7.80	-13.55	-24.72**
25	449A x DB-2	-17.61**	-8.00*	6.22*	-21.42**	2.17	-9.62*	-7.79	-20.22**
26	449A X GFB-1	-13.22**	-11.72**	18.36**	-2.84	4.49	2.40	-25.42**	-25.84**
27	449A x Raj Bajra Chari	-2.41	0.71	27.85**	3.43	9.02	2.96	-27.38**	-31.46**
28	449A x PMFT-907	-13.79**	-10.71**	31.32**	11.16**	7.20	3.08	-30.18**	-33.71**
29	449A x PMFT-905	-15.13**	-14.00**	14.64**	-9.89**	7.34	0.00	-26.92**	-35.96**
30	449A x G.Bajra	-15.60**	-8.00*	-8.97**	-34.99**	-4.03	-19.66**	-16.98*	-25.84**
	<b>LSD (5%)</b>	<b>3.01</b>	<b>3.48</b>	<b>10.75</b>	<b>12.41</b>	<b>0.82</b>	<b>0.94</b>	<b>0.77</b>	<b>0.89</b>
	<b>LSD (1%)</b>	<b>4.01</b>	<b>4.62</b>	<b>14.30</b>	<b>16.51</b>	<b>1.09</b>	<b>1.26</b>	<b>1.02</b>	<b>1.18</b>

**Table 4.7 Contd...**

	Crosses	L:S ratio		GFY (q/ha)		DMY (q/ha)		DM (%)	
		MP	BP	MP	BP	MP	BP	MP	BP
1	425A x CO-08	-4.70**	-5.33	18.15**	-23.98**	11.49*	-31.98**	1.01	-10.70**
2	425A x CO-09	-15.29**	-25.00**	24.63**	-15.66**	40.26**	-4.77	12.10**	11.40**
3	425A x Bajra Biwal	-16.78**	-17.33	46.76**	8.56	50.16**	9.76	2.85	0.88
4	425 A x DB-1	-2.86**	-8.11	15.88*	-17.18**	7.35	-26.13**	-4.92	-10.84**
5	425A x DB-2	-5.00**	-11.63	6.53	-27.17**	-4.26	-37.50**	-5.71	-13.60**
6	425A X GFB-1	-3.70**	-11.36	-12.68*	-42.06**	1.60	-34.22**	19.53**	13.69**
7	425A x Raj Bajra Chari	0.00	-11.46	65.69**	23.05**	73.08**	25.80**	5.63	2.17
8	425A x PMFT-907	3.76**	-6.76	52.61**	14.19*	56.72**	20.89*	1.02	-3.30
9	425A x PMFT-905	-6.25**	-18.92	29.39**	-6.65	26.69**	-13.26*	1.30	-7.10*
10	425A x G.Bajra	-1.37**	-2.70	-11.00*	-42.47**	-16.21**	-48.75**	1.10	-10.85**
11	429A x CO-08	19.70**	5.33	1.96	-33.40**	-11.13*	-43.75**	-9.63**	-15.74**
12	429A x CO-09	-8.50**	-27.08**	10.72	-23.74**	18.51*	-15.15*	3.84	-2.53
13	429A x Bajra Biwal	-13.64**	-24.00*	11.89	-15.41*	16.23	-9.48	2.43	-1.48
14	429 A x DB-1	18.70**	10.61	18.61**	-13.50*	21.46**	-11.69	2.62	1.89
15	429A x DB-2	18.88**	-1.16	20.64**	-16.01**	6.15	-27.34**	-10.74**	-13.53**
16	429A X GFB-1	2.07**	-15.91	-3.72	-35.05**	6.01	-28.13**	9.83**	8.97*
17	429A x Raj Bajra Chari	-12.42**	-30.21**	11.87	-15.08*	19.47*	-7.56	6.03	3.40
18	429A x PMFT-907	18.97**	16.95	27.46**	-2.48	40.41**	16.2	5.91	-4.03

**Table 4.7 Contd...**

	Crosses	L:S ratio		GFY (q/ha)		DMY (q/ha)		DM (%)	
		MP	BP	MP	BP	MP	BP	MP	BP
19	429A x PMFT-905	15.32**	12.28	15.14*	-15.19**	5.35	-23.84**	-7.39*	-10.21**
20	429A x G.Bajra	8.53**	-2.78	3.55	-32.03**	-14.78**	-45.91**	-16.60**	-22.45**
21	449A x CO-08	-12.36**	-24.27**	6.29	-22.13**	2.27	-33.64**	3.96	-14.70**
22	449A x CO-09	-31.66**	-33.98**	21.03**	-4.80	60.91**	19.39**	36.03**	25.48**
23	449A x Bajra Biwal	-24.72**	-34.95**	5.97	-5.82	26.34**	2.63	20.41**	8.52*
24	449 A x DB-1	-6.51**	-23.30**	22.24**	3.68	48.01**	11.66	24.26**	7.52*
25	449A x DB-2	-14.29**	-21.36**	1.32	-19.16**	1.98	-27.93**	5.74	-10.39**
26	449A X GFB-1	-14.14**	-20.39*	-15.42**	-35.28**	-25.81**	-48.11**	-8.42**	-19.73**
27	449A x Raj Bajra Chari	-25.63**	-28.16**	21.08**	8.18	36.14**	9.83	14.06**	1.50
28	449A x PMFT-907	-24.69**	-40.78**	25.74**	13.48*	54.15**	33.65**	23.20**	17.81**
29	449A x PMFT-905	-9.55**	-31.07**	-2.39	-16.14**	14.84*	-13.90*	21.14**	2.73
30	449A x G.Bajra	-21.14**	-33.01**	1.02	-25.50**	-3.33	-37.07**	5.70	-13.48**
	<b>LSD (5%)</b>	<b>0.05</b>	<b>0.05</b>	<b>56.23</b>	<b>64.93</b>	<b>12.35</b>	<b>14.26</b>	<b>1.14</b>	<b>1.32</b>
	<b>LSD (1%)</b>	<b>0.06</b>	<b>0.07</b>	<b>74.82</b>	<b>86.39</b>	<b>116.43</b>	<b>18.97</b>	<b>1.52</b>	<b>1.76</b>

\*, \*\* = Significant at 5% and 1% level, respectively.

**Table 5.1. Range of heterosis, significant heterotic crosses and best heterotic crosses for in forage Pearlmillet**

Sr. No.	Characters	Heterosis per cent over better parent	
		Range	Number of significant crosses (%)
1.	Days to 50% flow.	-14.07 to 7.41	14 (46.67)
2.	Plant height (cm)	-34.99 to 11.16	1 (33.33)
3.	No. of leaves /plant	-19.66 to 17.60	1 (3.33)
4.	No. of tillers /plant	-46.43 to -5.68	0 (00.00)
5.	Leaf length (cm)	-21.86 to 12.05	2 (6.66)
6.	Leaf breadth (cm)	-40.31 to 12.07	3(9.99)
7.	L:S ratio	-40.78 to 16.95	0 (00.00)
8.	GFY (q/ha	-42.47 to 23.05	3 (9.99)
9.	DMY (q/ha)	-48.75 to 33.65	4 (13.22)
10.	DM%	-22.45 to 25.48	7 (23.33)
11	CPY (q/ha)	-47.85 to 42.05	1 ( 3.33)
12.	CP (%)	-26.30 to 13.30	7 (23.33)