1. INTRODUCTION

Agriculture continues to be the backbone of Indian economy. Agriculture sector employs 54.6% of the total workforce. The total Share of Agriculture & Allied Sectors (Including Agriculture, Livestock, forestry and fishery sub sectors) in terms of percentage of Gross Domestic Product was 13.9 percent during 2013-14.(Anonymous, 2014)[a]

Indian agricultural system is a model of sustainable agriculture, as it is predominantly a mixed crop-livestock farming system, with the livestock segment supplementing farm incomes by providing employment, draught animals, and manure. Livestock is an integral part of India’s agricultural economy and plays a multifaceted role in providing livelihood support to the rural population. Livestock sector apart from contributing to national economy in general and to agricultural economy in particular, also provides employment generation opportunities, asset creation, mechanism against crop failure and social and financial security. Livestock is the main source of animal protein for the population. It is estimated that about 70 million rural households own livestock of one species or the other. Women constitute about 70% of workforce engaged in livestock sector. The resource-poor small and marginal farmers and landless labourers own majority of the livestock resources. Hence sustainable development of the livestock sector would lead to more inclusive development and empowerment of women. (Anonymous, 2013)

India has the largest bovine population in the world. The bovine genetic resource of India is represented by 37 well recognized indigenous Breeds of cattle and 13 breeds of buffaloes. The 19th live stock census has been conducted through with reference date of October 15, 2012 and this census places total livestock population at 512.05 million. India rank first in respect to buffalo, second in cattle and goat and third in sheep population in world. (Anonymous, 2014)[b]

India ranks first in milk production, accounting for 17 percent of world production. During 2013-14, milk production peaked at 137.97 million tonnes, thus becoming an important secondary source of income for 70 million rural households engaged in dairying and for70 per cent of the workforce that comprised women.

. The livestock sector in India faces the following major challenges which need to be addressed enabling the sector to grow according to its potential. While the livestock population is increasing, the gap between the requirement and availability of feed and fodder is increasing primarily due to decreasing area under fodder cultivation and reduced availability of crop residues as fodder. There is continuous shrinkage of common property resources leading to over grazing in the existing grasslands. It is imperative to arrange sufficient good quality feed and fodder for efficient utilization of genetic potential of the various livestock species and for sustainable improvement in productivity.

A serious limitation in fully utilizing the production potential of improved animals is the non availability of quality forages. The importance of forage crops in livestock nutrition cannot be overlooked and every possible effort is needed to increase its availability in the country. In dairy sector, cost of feed alone accounts for about 60-65% of the total milk production charges. This can be brought down by 30-40% if quality roughages are available. Most farmers are unable to feed their animals properly with good quality roughages because of several constraints. Green forages are the cheapest source of roughages; however production of forages is still a sideline activity in India. For an average Indian farmer, forage crops come secondary and inputs such as fertilizers are applied to increase the yield of main crop and most often secondary crops are ignored. In such a situation, maximum productivity of forage crops cannot be achieved. A situation like this cannot be allowed to continue. Intensive efforts are needed to increase the supply of quality fodder so as to prevent the mass starvation of India's mammoth livestock population. (Thomas, 2008)

The National Livestock Policy 2013 aims at increasing availability of feed and fodder resources to meet the requirement of livestock to attain optimal productivity. It also mentions increasing livestock productivity and production in a sustainable manner, while protecting the environment, preserving animal bio-diversity, ensuring bio-security and farmer livelihood and states that efforts will be made to increase production of quality fodder seeds through necessary incentives, arranging foundation seeds of different high yielding fodder varieties and modern scientific farming procedures etc. while underlining that efforts will be made to increase area under fodder cultivation, especially through use of barren and fallow lands and silviculture through appropriate resources and technologies will be made available to ensure quality fodder seed production. It states that fodder cultivation in degraded land and forest land would be taken wherever possible with the help of farming community and round the year availability of quality fodder through promotion of hay; silage and fodder banks etc. will be emphasized.

A properly balanced dairy cattle ration should consist of both roughages and concentrates. Nutrient requirements for maintenance of cattle and buffaloes of about 450 kg weight is 8 to 9 kg dry matter, 250 g Digestible Crude Protein, 4 kg Total Digestible Nutrients, 31 g Calcium and 23 g Phosphorus (Anonymous, 1982).

Napier grass [*Pennisetum purpureum*. (K) Schum.] is a vigorous, hardy, high yielding perennial grass native to South Africa, which derives its name from Colonel Napier, who first drew the attention of the Rhodesian Department of Agriculture in 1909 to the fodder value of this grass. In its native habit it grows to a height of 3 to 3.6 meters and even elephants roaming inside the grass are hidden from the view, hence the grass is also known as “Elephant grass”. Napier grass was introduced in India during the year 1912.

Napier hybrid [*Pennisetum purpureum* (K) Schum.] is a perinnial crop derived from interspecific cross between bajra [*Pennisetum glaucum* (L) R.Br.] (2n=2x=14) and napier grass [*Pennisetum purpureum* (K) Schum] (2n=4x=28). The interspecific hybrid is a triploid with 2n=3x=21 chromosomes. Because of the dissimilar genomic constitution, the triploid hybrids are completely sterile. The triploid hybrids resulting from interspecific cross are usually highly variable because of the hetrozygosity of napier grass even though the pearl millet parent is an inbred (Hanna *et al.* 2004). The hybrids have extra vigour in overall morphological characters and green yield. (Hanna *et al*. 1984) The only way of propogation of the hybrid is through vegetative means.

With the popularization of interspecific hybrids the crop is increasing in significance as a fodder crop in India. The hybrid can be grown on a variety of soils, however sandy loam to clay soils are preferred. Deep fertile soils rich in organic matter and nutrients are ideal. It can tolerate Ph range of 5-8. The grass requires irrigation to express its full biological potential. Bajra x Napier grass hybrid is best suited for irrigated conditions. The interspecific hybrid between Napier and pearl millet is found to be more nutritious, succulent, palatable and responsive to nitrogenous fertilizers than Napier grass and is reported to have given 279,400 kg per hectare of fodder as compared to 135,300 kg by the latter. Also it has low oxalic acid content and reduced level of long coarse hairs than napier grass. Once established bajra x napier hybrid continiues to give fodder for a number of years, but as the productivity goes down it is more economical to replant it every 5-6 years. The grass is suitable for preparation of silage and hay making. (Das, 1997)

Hybrid napier is superior in quality than napier grass and contains 8.7 to 10.2 % CP and 28 to 30.5 % CF, 10 to11.5 % ash on approximate dry matter basis with Ca and P in proper balance (Faruquis *et al.*, 2009).

The real yield potential of crop can be exploited through hybrid/varieties improvement programme which needs the information regarding the range of existing genetic variability and relationship of economically important characters in genetic stock available with the breeder.

Association of one or more characters influenced by a large number of genes is elaborated statistically by correlations coefficients. Genotypic correlations coefficients provide a measure of genotypic conjugation between characters.

The method of partitioning the correlations into direct and indirect effects by path co-efficient analysis suggested by Wright (1921) provides useful information on the relative merit of the traits in the selection criterion.

The present investigation entitled “Variability and path coefficient analysis studies in bajra x napier hybrids” was undertaken with 29 new Bajra x Napier hybrids genotypes, along with 3 checks *viz*; NB-21, CO-3 and Phule Jaywant provided by the Research Officer, Grass Breeding Scheme, with objectives mentioned below.

1. To study the variability for forage yield and yield contributing characters of bajra x napier hybrids.

2. To study the magnitude and association of forage yield with yield contributing characters in bajra x napier hybrids

3. To study the cause and effect of yield contributing characters on forage yield in bajra x napier hybrids.

2. REVIEW OF LITERATURE

An attempt has been made to review the published literature on basic studies, variability, correlations and path coefficient analysis in Napier grass and its hybrid with Bajra. It is reviewed under three headings *viz.,* I) General II) Genetic variability and III) Correlations and path analysis.

I. General

Krishnaswamy and Raman (1953) studied morphological characters in two F_2 plants with 2n=22 and 2n=22+1, which were obtained in the progeny of the interspecific hybrid of *Pennisetum typhoides* x *P. purpureum* and compared with those of F_1. Comparative data with regard to the important morphological characters showed that the differences between F_2 and F_1 were not marked enough to correlate the genetical effects of the duplication, deletion and the fragment.

Lal *et al.* (1966) investigated oxalate status of pusa giant napier grass and its parents. Napier grass showed the highest oxalate content followed by pusa gaint napier and bajra. The water soluble oxalate content showed the same trend as the total oxalate. Considering the values of total and water soluble oxalate it appeared that oxalate level in pusa gaint napier is derived mainly form the napier grass parent. The age of pusa gaint napier appeared to exercise a profound influence on its oxalate status. There is a sharp fall both in the water soluble and total oxalate content from the tender (one month old) to the ripe (about 12 month) pusa gaint napier plants so much so that the water soluble oxalate content of the ripe plants has become quite negligible. It should thus, be possible to have plants of even lower oxalate content than those of pusa gaint napier depending on their age.

Gupta (1969) studied 200 germplsm lines of bajra representing Indian varieties, Indian inbreds, African varieties and American inbreds. Regression analyses from these studies were used to select bajra parents for crossing with napier grass. The resulting F_1 hybrids have shown great promise for both yield and quality of green fodder.

Kothandaraman and Dhanapalan (1973) studied 12 grasses including pusa giant napier for their nutritive value, and concluded that the chemical composition of fodder crops and grasses varied according to variety, soil and climatic conditions, stage of maturity, time of harvest, manuring etc.

Muldoon and Pearson (1979) studied interspecific hybrid between *Pennisetum americanum* and *Pennisetum purpureum* and concluded that the hybrid has advantages over napier grass in case of establishment, yields and quality.

Schank *et al.* (1993) evaluated 20 napier grass selection for bioconversion to methane. These studies included analysis of plant parts for lignin, crude protien and biochemical methane potential; overall objectives were to breed for higher quality and higher yielding napier grass types that can be raised from seed and to assess the large amount of genetic variability among accessions and hybrids and evaluate traits that can lead to low cost yield of convertible biomass for energy production.

Nagasuga *et al.* (1998) studied Napier grass (*Pennisetum purpureum* Schumach.) as a species with high productivity of biomass and high water use efficiency. In this study, the water transport and leaf photosynthesis of the species, using plants (var. Merkeron) grown in different environments, were discussed on the bases of photosynthetic and transpiratory responses measured directly after excisions of various parts of plants. During the measuring of rates of leaf photosynthesis (Pn) and transpiration (Tr), the excision of a lower part of the leaf blade allowed the rates to rise temporarily, and especially large increases were observed in leaves subjected to drought stresses. The rise of Pn depended on the increases in stomatal and mesophyll conductance. No responses in Pn and Tr were detected by excising any parts of plant below the sheath joint of the measuring leaf, but excision of the leaf sheath caused increases in both rates. Such parts as the leaf sheath joint seem to have a role in controlling or preventing water stream in a plant. Contrary to this, in shade-grown plants the rates increased by rhizome excision. Napier grass is considered to have a high sensitivity to water movement in a plant and a unique morphological mechanism to conserve the use of water.

Lira *et al.* (1999) evaluated seven elephant grass cultivars and seven pearl millet x elephant grass hybrids under grazing conditions. The results showed higher dry matter yield, forage height, stem diameter, leaf blade/stem ratio, leaf blade, dry matter yield for the cultivar group, compared with the hybrid group.

II. Genetic Variability

Gupta and Bharadwaj (1975) studied genetic variability and scope of selection in the clonal populations of 37 napier-bajara hybrids. The significant genotypic differences were observed for green fodder yield, plant height, tiller number, stem thickness and leaf number. The genetic variability was of considerably high magnitude in nine hybrid populations and the expected progress from selection was high in the case of eight hybrid populations. But selection would be worthwhile only in the populations of three hybrids, as they were the ones where a yield potential higher than that of the standard hybrid NB-21.

Das (1994) studied 22 genotypes of Napier grass and concluded that, number of tillers, leaf length and leaf area exhibited high coefficients of variability implying that selection for these characters might result in crop improvement.

Das (1994) conducted experiments involving 15 genotypes of *Pennisetum americanum*, 5 genotypes of *P. purpureum* and their 15 hybrids obtained by random crossing. Hybrids were evaluated for quality based on crude protein, Calcium, Phosphorous and oxalic acid contents. Analysis of variance showed significant differences between genotypes and hybrids for all 14 traits. In *P. americanum* high heritability and high genetic advance were recorded for crude protein and calcium content, while phosphorous and oxalic acid showed moderate heritability and genetic advance. In *P.purpureum*, high heritability and genetic advance were found for calcium content. The hybrid exhibited high heritability for both crude protein and calcium contents, but high heritability combined with high genetic advance was observed only for crude protien.

Poli *et al.* (1994) studied napier cultivars for different morphological traits. There were differences between cultivars in the leaf to stem ratio only at the beginning of plant development, at other times, leaf length and tiller number were not effective characters for distinguishing between cultivars.

Diz and Schank, (1995) studied heritability, genetic parameters, and response to selection in Pearl millet x Elephant grass hexaploid hybrids. Heritability estimates differed among the 11 traits and were very low to moderate. Despite moderate to very low heritabilities for seed characters, expected response to selection were high (17-43% increase) due to large phenotypic variation. They concluded that for improving seed yield per plant, selecting indirectly for days to flowering or other seed- related traits would be more efficient, for improving seed yield per plant, selecting indirectly for days to flowering or seed related traits would be more efficient and improvement through phenotypic selection should be satisfactory in several traits.

Sukanya (1995) evaluated 55 genotypes of napier grass (*Pennisetum purpureum* (K.) Schum) for diversity and genetic variability for green fodder yield and related characters like leaf length, leaf width, stem girth, number of leaves per tiller, plant height and found significant variability among genotypes for characters studied.

Suthamathi and Dorairaj (1997) evaluated 40 genotypes of napier grass of diverse origin to estimate genetic variability for sixteen characters. Leaf weight, green fodder yield per plant, stem weight, crude fat content, number of leaves and tillers per plant, plant height, crude protein content and stem diameter recorded high genotypic coefficient of variability, heritability and genetic advance.

Khan and Sukumar (2002) studied genetic variability and heritability for yield and yield components (plant height, leaf length, leaf width, stem thickness, number of tillers per plant, panicle length, crude protein and crude fibre) in 53 *P. purpureum* genotypes. The genotypic and phenotypic coefficients of variation did not significantly differ, indicating the lesser influence of the environment on the characters. High genotypic coefficient of variation was observed for panicle length, number of tiller per plant, leaf width, stem thickness and leaf length. Heritability estimates were generally high for majority of the characters. High heritability coupled high genetic advance was observed for panicle length, number of tillers per plant, and leaf width, suggesting that these characters should be considered in selection as these characters are expected to be controlled by additive genes.

Mahawar *et al.* (2003) studied variability in fodder bajra and found that difference in genotypic and phenotypic coefficients of variation was small, but the PCV in general higher than GCV for all the characters which indicated the favourable effect of environment on the character expression. The characters green fodder yield per plant and leaf to stem ratio exhibited high expected genetic advance (GA) indicating additive gene action thus suggested for direct phenotypic selection, whereas the characters like days to heading, plant height, tillers per plant and leaves per plant having moderate to low GA which indicated non-additive gene action and thus these characters can be improved through indirect selection.

Shinde (2005) reported high estimates of heritability (b.s.) accompanied by high genetic advance as percentage of mean for characters *viz.,* CPY, crude protein content, no. of leaves, L/S ratio, GFY, leaf area, number of tillers, DMY, plant height, leaf length and stem girth in B X N hybrids and suggested that selection of these traits will be more effective for desired improvement.

Kamble (2011) reported high heritability estimates for all the characters studied in napier grass. High estimates of heritability (b.s.) accompanied by high genetic advance as percentage of mean was reported for characters viz., number of tillers, dry matter yield and green forage yield, indicating presence of additive gene action in inheritance of these characters.

Chavan (2012) reported high heritability estimates for all the characters studied. High estimates of heritability (b.s.) accompanied by high genetic advance as percentage of mean was reported for characters *viz*; dry matter yield (kg/plant), green forage yield (kg/plant), leaf stem ratio, stomatal conductance, number of internodes per tiller. Thus selection for these traits was more effective for desired improvement.

Satpute *et al.* (2014) studied variability in 32 derivatives of Bajra x Napier hybrids for forage yield and its component characters viz., plant height, number of tillers per plant, number of leaves per tiller, number of internodes per tiller, leaf length, leaf width, L/S ratio, crude protein, oxalic acid content, dry matter yield and green forage yield. High genotypic coefficient of variation for dry matter per plant (33.50), moderate variability in plant height, number of tillers per plant and number of leaves per plant were observed. The estimates of heritability (b. s.) and GA as percentage of mean were high for characters viz., dry matter yield, green forage yield, number of tillers per plant, and L: S ratio, indicating influence of additive gene action on these characters, so selection of these characters be considered for crop improvement.

III. Correlations and path analysis

Katoch and Gupta (1976) studied component analysis for yield of green fodder in case of clonal populations of napier x bajra hybrids. Path coefficient analysis of the yield of 37 populations of *Pennisetum typhoides* and *P. purpureum* hybrids indicated that the number of tillers per plant is in general the most important component of yield. Number of leaves per plant and plant height were also important, while stem thickness was the least important. The character associations differed in each of the hybrid populations.

Sood and Singh (1982) computed correlation and path coefficients in thirty napier bajra hybrids. Dry matter yield per plant had a strong and positive genotypic association with average internode length, number of leaves per plant, leaf-stem ratio, in vitro dry matter digestibility and total digestible dry matter. Path coefficient analysis showed a positive and high direct effect of dry matter digestibility, leaf stem ratio and average internode length on dry matter yield, whereas the direct effect of the number of leaves was negative and high.

Das and Ratnam Nadar (1991) observed positive correlation of plant height, number of tillers and leaf length with green fodder yield in Napier grass.

Patil and Jadhav (1992) studied correlation and path analysis in pearl millet and napier grass hybrids. Correlation studies indicated positive significant association of length of tiller, length and breadth of leaves with green forage yield/plant. Path coefficient analysis also revealed higher and positive direct contribution of these characters to green forage yield/plant suggesting their importance in selection criterion for this crop. Number of tillers and L/S ratio was significantly correlated with green forage yield. However, the direct effect of L/S ratio on yield was positive. The indirect effects of length of leaves via all the characters studied except tiller girth and L/S ratio were positive with the highest estimate (1.048) via length of tiller.

Pradhan *et al.* (1993) studied correlation and path analysis of forage yield attributes of Bajra – Napier hybrids. Correlation analysis indicated that number of tillers per hill was the most important character positively influencing green fodder and dry matter yield.

Devarathinam and Dorairaj (1994) derived information on yield correlations from data on 12 yield components in 53 genotypes of napier grass. Green fodder yield was significantly and positively correlated with plant height, leaves per tiller, leaf weight, stem weight, dry matter and crude protein yield in Napier grass.

Thirumeni and Das (1994) carried out genotypic correlation and path analysis using data on green fodder yield and related traits in 15 forms of pearlmillet, 5 genotypes of napier grass and 15 interspecific hybrids from crosses between them. Results suggested that rapid improvement in green fodder yield could be achieved by using selection on high DMY in pearlmillet and napier grass and number of tillers per clump in the hybrids, since these were the traits shown by path analysis to have the maximum direct effect on green fodder yield in these different types.

Cheng Yukuei *et al.* (1995) observed positive correlation between forage yield and plant height as well as leaf width. In quality, there was a positive correlation between leaf: stem ratio and crude protein and a negative correlation between leaf: stem ratio and plant height.

Sukanya (1998) reported significant differences for green fodder yield and other associated traits. Green fodder yield showed significant and positive association with leaf length; leaf width, stem girth, number of leaves per tiller and plant height where as association with number of tillers per plant was negative. Path analysis of green fodder yield revealed high and positive and direct effects on number of leaves per tiller (0.940), leaf length (0.724), average inter-nodal length (0.509), leaf width (0.475) and number of tillers per plant. Hence from this study it can be concluded that in napier germplasm, selection of correlated leaf characters viz., number of leaves per tiller, leaf length and leaf width not only increases the green fodder yield but also improve quality.

Tessema-Zewdu *et al.* (2003) observed that the dry matter yield (DMY) of Napier grass was significantly affected by plant height at cutting, fertilizer application and their interaction. Plant height at cutting had a significant positive effect on number of leaves per tiller and per plant. The internodes and internode length per tiller, the number of tillers per plant and basal circumference were positively affected by both plant height at cutting and fertilizer application, but the effect of leaf: stem ratio on DMY was negative.

Daher *et al*. (2004) studied correlation and path analysis for dry matter production and related traits (plant height diameter of stem at the base and no of tillers) in *pennisetum purpureum* clones and found that the no. of tillers and diameter stem at the base had greater effects on dry matter production, the effects being directs and inverse respectively varing according to environment condition during growth.

Shinde (2005) in correlations studies of napier hybrids showed that green forage yield was significantly and positively associated with dry matter yield, crude protein yield, number of leaves, number of tillers and plant height. Path analysis revealed that characters *viz.*, DMY and plant height exhibited positive direct effects on GFY as well as they showed significant and positive correlation with GFY. Thus the relationship between these characters and GFY was true and positive.

Krishna and John (2007) studied correlation analysis in 14 bajra x napier (*Pennisetum typhoides* [*Pennisetum glaucum*] x *Pennisetum purpureum*) hybrid genotypes. Dry matter yield showed significant positive phenotypic and genotypic association with plant height, number of tillers per clump, leaf length, number of leaves per tiller, stem girth, crude protein content, crude fibre content, dry matter content, and green fodder yield both at phenotypic and genotypic levels. The genotypic correlations were higher than the corresponding phenotypic correlations. Plant height, number of tillers per clump, leaf length, number of leaves per tiller, stem girth and crude fibre content showed positive and highly significant association with green fodder. Dry matter yield showed a non-significant negative association with oxalate content, which is a desirable feature.

John (2008) studied character association and path coefficient analysis for green fodder yield and 8 other agro morphological traits in 37 Napier grass genotypes. Green fodder yield showed a significant and positive association at both genotypic and phenotypic levels for plant height and leaf width but number of tillers per plant and crude fibre content showed significant association at genotypic level only. Six characters showed a positive direct effect on green fodder yield, leaf width recorded the highest direct effect followed by plant height and crude protein content.

Shinde *et al.* (2009) studied correlation and path coefficients of forty derivatives of bajra x napier grass hybrids for green forage yield and twelve yield contributing characters. Green forage yield was significantly and positively associated with dry matter yield, crude protein yield, number of tillers and plant height. Path analysis revealed that characters viz., dry matter yield exhibited the highest positive direct effect on green forage yield followed by crude protein content, stem girth at IInd internode and plant height. Considering both, the correlation coefficients and path coefficients together, dry matter yield, plant height, and crude protein content emerged as important components of green forage yield which should be given due importance during indirect selection aimed at green forage yield improvement in bajra x napier hybrids.

Zhang *et al.* (2009) studied the relationship between yield and morphological traits in napier grass and found significantly positive correlations between yield and plant height, tillers/ plant and significantly negative correlations between yield and leaf length, leaf/stem ratio.

Hongru *et al.* (2009) studied variance analysis, correlation of biological characters including yield, leaf/stem ratio, plant height, tillering number, leaf length, leaf width, stem diameter of seventeen lines of *Pennisetum purpureum* and hybrid *Pennisetum*. The results showed that the differences were significant for the characters among these lines and cultivars. The dry yields of the second harvest were highly significant than that of the first harvest, whereas dry yields of one harvest per season were significantly higher than the sum of two harvest per season.

Jing-song *et al.* (2010) studied 86 vegetative lines derived from napier grass N-51 and found that significant positive correlation between yield and plant height. The partial correlation indicated that there was significantly positive correlation between the yield and tillering number.

Zhang *et al.* (2010) investigated 16 lines of elephant grass (*Pennisetum purpureum*) one purple elephant grass and hybrid *Pennisetum* (pearl millet x elephant grass) using correlation analysis. Plant height and tillers/plant were positive and significantly correlated with yield, while leaf length and leaf:stem ratio were negative and significantly correlated with dry matter yield. The factors with greatest effect on dry matter yield were plant height and leaf:stem ratio.

Chong-jian *et al*. (2011) studied path analysis between yield and morphological traits of hybrid giant napier. The results showed that the greatest direct and indirect effects on fresh yield of hybrid giant napier were its effectual stem numbers,node and tiller numbers.

Kamble (2011) in correlations studies of napier genotypes reported that green forage yield was significantly and positively associated with dry matter yield, number of tillers, plant height, leaf width, number of internodes, leaf length and number of leaves. Path analysis revealed that dry matter yield exhibited highest positive directs effects on green forage yield as well as it showed significant and positive correlation with green forage yield. Thus the relationship between dry matter yield and green forage yield was true and positive.

Chavan (2012) conducted correlation studies and found that green forage yield was significant and positively associated with dry matter yield (kg/plant), number of tillers per plant, number of leaves per tiller, average number of internode per tiller, plant height and leaf length. Path analysis in bajra x napier hybrids reveled that characters *viz*; rate of photosynthesis, average number of internodes per tiller, number of tillers per plant, dry matter yield exhibited positive direct effect on green fodder yield as well as they showed significant and positive correlation with green fodder yield. Thus the relationship between these characters and green fodder yield was true and positive.

Obok *et al.* (2012) studied forage potentials of interspecific hybrids between elephant grass selections and cultivated pearl millet genotypes of Nigerian origins. Three harvests at six-weekly intervals were obtained from the plants cut at 30 cm above the ground level. ANOVA showed significant differences (p=0.05) between harvest intervals, plant height (cm) and dry matter content (%) of the hybrids except dry matter yields (g/m^2). Dry matter of the hybrids negatively correlated with plant height (r= -0.434). Dry matter yield had significant positive correlation with plant height (r=0.780).

Satpute (2012) conducted correlation studies in napier hybrids and found that green forage yield was significant and positively associated with dry matter yield (kg/plant), rate of photosynthesis, number of tillers per plant, plant height (cm), stomatal conductunce and average number of internodes per tiller. Path analysis in bajra x napier hybrids reveled that characters *viz*; rate of photosynthesis, average number of internodes per tiller, number of tillers per plant, dry matter yield exhibited positive direct effect on green fodder yield as well as they showed significant and positive correlation with green fodder yield. Thus the relationship between these characters and green fodder yield was true and positive.

Nyamabati *et al.* (2013) compared eight new cultivars of napier grass in the sub humid highlands of northwestern Kenya for two growing seasons. Agronomic measurements were made on DM yield, tiller number, length, diameter and angle, leaf length, width, hairiness and colour and disease incidence. There was positive and highly significant correlation (r = 0.65) between tiller thickness and tiller length.

3. MATERIAL AND METHODS

The present investigation entitled, "Variability and path coefficient analysis studies in bajra X napier hybrids" was conducted at Grass Breeding Scheme, MPKV, Rahuri, during June 2014 to February 2015. The details of the material used, methods adopted and statistical analysis followed during the investigation are described below.

3.1 Experimental material

The experimental material used for study consisted of thirty two hybrids of bajra x napier grass provided by the Research Officer, Grass Breeding Scheme, MPKV, Rahuri.

The list of genotypes is given in Table 1.

3.2 Experimental design

Thirty two bajra x napier grass hybrids were evaluated in a Randomized Block Design with two replications during June 2015 to February 2015. Each genotype was planted in two rows of 7.20 m length with spacing of 90 x 60 cm. The experiment was sown on 23 June 2014.

3.3 Cultural practices

After planting one irrigation was given and subsequent irrigations were given at an interval of 10-12 days. As a basal dose 150 kg of 'N' per ha, 50kg 'P' per ha and 40 kg 'K' per ha were applied, for top dressing 25 kg of 'N' per ha after every cut was applied. Other cultural practices like weeding were done manually as per requirement.

3.4 Observations recorded

Observations were recorded under three headings.

3.4.1 Field observations

3.4.2 Forage quality

3.4.3 Morphological characters

Observations on characters except GFY and DMY were recorded on five randomly selected plants in each experimental plot at the time of each cut and averages were worked out. Observations on GFY and DMY were recorded for a period of June 2014 to February 2015 (3 cuts in total) and expressed in kg / plant. First cut was taken 60 days after planting and subsequent cuts were taken at an interval of 50 days. In total observations for 3 cuts were recorded.

3.4.1.1 Plant height (cm)

Plant height of central or tallest tiller of five observational plants was measured in centimeter from ground level to top of the main axis and average plant height was worked out and expressed in centimeter.

3.4.1.2 Number of tillers/plant

Total number of tillers of five observational plants were counted and expressed as average number of tillers per plant.

3.4.1.3 Number of leaves/tiller

Total numbers of leaves of main tallest tiller of each five observational plants were counted and average was worked out and expressed as number of leaves per tiller.

3.4.1.4 Average number of internodes/tiller

Total average number of internodes of per tiller of five observational plants were counted, average were worked out and expressed as average number of internodes/ tiller.

3.4.1.5 Leaf length (cm)

One leaf each from top, middle and base position of five observational plants were selected, and the leaf length from top to base of the leaf was measured in centimeter. Average were worked out and expressed as leaf length.

3.4.1.6 Leaf width (cm)

Leaf width was measured in centimeter at the centre of leaf in all the leaves taken for estimation of leaf length. Average leaf width was worked out and expressed in centimeter.

3.4.1.7 L: S ratio

A 250 g sample of green fodder was taken at green stage of every cut. Leaves and stem were separated and weighted in (kg). The L: S ratio was then estimated as,

$$\text{L: S ratio} = \frac{\text{Av. weight of leaves (kg)}}{\text{Av. weight of stems (kg)}}$$

3.4.1.8 Green forage yield (kg/plant)

Weight of five randomly selected observational plants at green stage was recorded in Kg. after each cut and total of three cuts was made. Average GFY in kg per plant was worked out.

3.4.1.9 Dry matter yield (kg/plant)

Sample of size (100 g) of green fodder was taken at each cut which was dried in hot air oven at 60^0 C temperatures until constant dried. Weights of dried samples were recorded and dry matter percentage was worked out. The dry matter yield (kg/plant) was then estimated as,

DMY (kg/plant) = Av. GFY (kg/plant) X dry matter percentage

3.4.2 Forage quality

3.4.2.1 Crude protein (%)

Nitrogen percentage in dry fodder was determined by Microkjeldahl's method (Thimmaiah, 1999). Percent nitrogen was then multiplied by a conversion factor of 6.25 to obtain crude protein content.

3.4.2.2 Oxalic acid content (%)

Oxalic acid content was measured as per the procedure given in standard methods of biochemical analysis (Thimmaiah, 1999).

3.4.3 Morphological characters

a) Leaf colour (green /pale green)
b) Plant vigour- vegetative (good /medium /poor)
c) Growth habit (erect /semi erect)
d) Pigmentation on node (Absent / Present)
e) Hairiness - (stem / leaf sheath /leaf blade)
   (Absent /Present)
f) Leaf waxiness (Absent /Present)

Morphological data was recorded at third cut by visual appearance.

3.5 Statistical methodology

3.5.1 Assessment of variability

3.5.1.1 Analysis of variance

The average data on individual characters were subjected to the method of analysis of variance commonly applicable to the Randomized Block Design (Panse and Sukhatme, 1967).

The Genotypic mean squares (GMS) were tested for their significance against error mean square (EMS) by 'F' test for $n_1 = (g-1)$ and $n_2 = (r-1)(g-1)$ degrees of freedom.

Where,

g = Number of genotypes and

r = Number of replications

The characters showing significant treatment differences were only subjected to further analysis.

3.5.1.2 Estimation of Mean and range

The mean values for each character were worked out by dividing the total by corresponding number of observations.

$$\overline{X} = \frac{\sum_{i=l}^{n} xi}{n}$$

Where,

$\overline{X}$ = Mean of character

n = Number of observations

Σ = Total of all the observations for a character.

The lowest and highest values represent the rang

3.5.1.3 Estimation of components of variations

The genotypic and phenotypic variances were calculated by using respective mean squares from analysis of variance table (Johnson *et. al.*1955) as follows.

Environmental variance ($\sigma^2 e$) = EMS

$$\text{Genotypic variance } (\sigma^2 g) = \frac{GMS-EMS}{r}$$

Phenotypic variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

Where,

GMS = Genotypic mean sum of squares.

EMS = Error mean sum of squares.

r = Number of replications.

3.5.1.4 Estimation of coefficients of variation

The phenotypic and genotypic coefficient of variation were computed, as the ratio of corresponding standard deviation to the mean of the character, expressed as percentage, as per the formulae given by Burton (1952).

i) Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance and

$\bar{X}$ = Mean of character

ii) Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance and

$\bar{X}$ = Means of character

The high, medium and low GCV and PCV estimates were classified as:

Low = 0 to 10

Moderate = 10 to 20

High = 20 and above

3.4.1.5 Estimation of heritability

Heritability in broadsense for each character was estimated as suggested by Hanson *et al.* (1956)

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance and

$\sigma^2 p$ = Phenotypic variance

Heritability estimates were classified into the high, medium and low classes (Johnson *et al.*, 1955) as below

Low	=	less than 30
Medium	=	30 to 60
High	=	60 and above

3.5.1.6 Genetic advance

Genetic advance (at 5 % selection intensity) was estimated using the formula given by Allard (1960) as below.

$$GA = K \times \frac{\sigma^2 g}{\sigma^2 p} \times \sqrt{\sigma^2 p}$$

Where,

$\sigma^2 g$	=	Genotypic variance
$\sigma^2 p$	=	Phenotypic variance
k	=	Selection differential (at 5 % selection intensity, k = 2.06)
$\sqrt{\sigma^2 p}$	=	Phenotypic standard deviation

$$\text{GA as percentage of mean} = \frac{GA}{\bar{X}} \times 100$$

The high medium and low GA as per cent of mean estimates were classified as low, moderate and high (Johnson *et al*., 1955) as,

Low	=	0 to 10
Moderate	=	10 to 20
High	=	20 and above

3.5.2 Correlations

Analysis of covariance was carried out by taking two characters at a time. The genotypic and phenotypic co-variances were then calculated as per the formulae described by Singh and Chaudhari (1977) as below.

Environmental covariance (cov $e_{1.2}$) = EMP.

Genotypic covariance (cov. $g_{1.2}$) = GMP-EMP / r

Phenotypic covariance (cov $p_{1.2}$) = (cov. $g_{1.2}$) + (cov. $e_{1.2}$).

Where,

GMP = Genotypic mean sum of product

EMP = Error mean sum of product

r = Correlations coefficient

The appropriate variances and co-variances were used for calculating phenotypic and genotypic correlation coefficients (Johnson, *et al.* 1955).

i) The phenotypic correlation coefficients (rp) were calculated as:

$$rp_{1.2} = \frac{\text{Cov. } p_{1.2}}{\sqrt{(\sigma^2 p_1 \text{x } \sigma^2 p_2)}}$$

Where,

$rp_{1.2}$ = Phenotypic correlation coefficient between character 1 and 2

$\sigma^2 p_1$ = Phenotypic variance of first character

Cov. $p_{1.2}$ = Phenotypic co-variance between character 1 and 2

$\sigma^2 p_2$ = Phenotypic variance of second character

ii) The genotypic correlations coefficient (rg) was calculated as:

$$rg_{1.2} = \frac{Cov.\ g_{1.2}}{\sqrt{(\sigma^2 g_1 \times \sigma^2 g_2)}}$$

Where,

$rg_{1.2}$ = Genotypic correlation coefficient between character 1 and 2.

Cov. $g_{1.2}$ = Genotypic co-variance between character 1 and 2.

$\sigma^2 g_1$ and $\sigma^2 g_2$ = Genotypic variance of character 1 and 2 respectively.

The significance and phenotypic and genotypic correlation coefficients was tested against 'r' values given by Snedcor and Corhran (1967) at (n-2) degrees of freedom at 5 per cent and 1 per cent levels of significance.

$$t\ (cal) = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}}$$

Where,

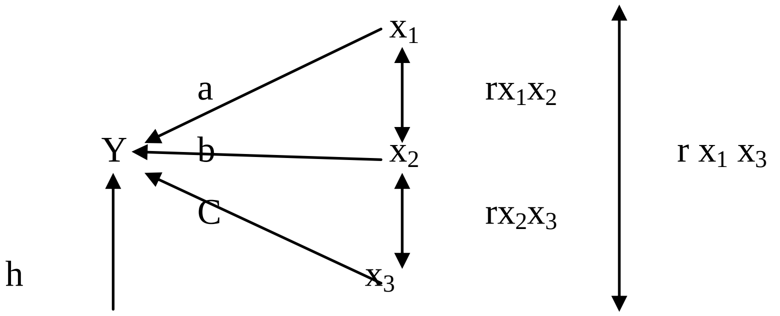
r = Correlations coefficient

n = Total no. of pairs of observations

3.4. 3 Path coefficient analysis

To establish a cause and effect relationship, the first step used was to partition the genotypic and phenotypic correlation coefficients into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959).

The second step in the path analysis is to prepare path diagram based on cause and effect relationship. In the present study, path diagram was prepared by taking yield as the effect i.e. functions of various components like X_1, X_2, X_3........... and these components showed following type of association with each other.



(Diagram)

In the path diagram the yield is the result of x_1, x_2, x_3 and some other undefined factors designated by R. The double arrow lines indicate mutual associations as measured by correlation coefficients. The single arrow represents direct effect as measured by path coefficient Pij. In the Figure a, b, c and h are the path coefficients due to respective variables.

Path coefficient were obtained by solving a set of simultaneous equations as given below,

$$r(x_1, y) = a + r(x_1, x_2)\, b + r(x_1, x_3)\, c$$

$$r(x_2, y) = r(x_2, x_1)\, a + b + r(x_2, x_3)\, c$$

$r(x_3, y) = r(x_3, x_1)\,a + r(x_3, x_2)\,b + c$

$r(R, y) = h.$

Where,

a	=	Direct effect of X_1 on yield
b	=	Direct effect of X_2 on yield
c	=	Direct effect of X_3 on yield
h	=	Direct effect of undefined factor (R)
$r(x_1y)$	=	Correlation between X_1 and yield
$r(x_2y)$	=	Correlation between X_2 and yield
$r(x_3y)$	=	Correlation between X_3 and yield
$r(Ry)$	=	Correlation between R and yield
$r(x_1x_2)\,b$	=	Indirect effect of X_1 on yield via x_2
$r(x_1x_3)\,c$	=	Indirect effect of X_1 on yield via x_3
$r(x_2x_3)\,c$	=	Indirect effect of X_2 on yield via x_3

Considering only the first three factors i.e. X_1, X_2 and X_3 the simultaneous equations given above can be presented in matrix notations as:

$$\begin{pmatrix} r\,x_1y \\ r\,x_2y \\ r\,x_3y \end{pmatrix} \begin{pmatrix} r\,x_1x_1 & r\,x_1\,x_2 & rx_1x_2 \\ r\,x_2x_1 & r\,x_2\,x_2 & rx_2x_3 \\ r\,x_3x_1 & r\,x_3\,x_2 & rx_3x_3 \end{pmatrix} \begin{pmatrix} a \\ b \\ c \end{pmatrix}$$

Matrix 'A' Matrix 'B' Matrix 'C'

$\therefore\ A = B.C$

$\therefore C = B^{-1} A$.

After having calculated the values of path coefficients, i.e. ‘C’ matrix, it is possible to obtain the path value for residual (R) in the following way.

$$R = \sqrt{1 - a^2 - b^2 - c^2 - 2r(x_1 x_2) ab - 2r(x_1 x_3) ac - 2r(x_2 x_3) bc}.$$

4. EXPERIMENTAL RESULTS

The results obtained on the present investigation entitled "Variability and path coefficient analysis studies in bajra x napier hybrids" have been presented in this chapter.

4.1 Genetic variability and heritability

4.1.1 Analysis of variance

The analysis of variance revealed significant genotypic differences for all the characters indicating presence of variability for the characters studied. (Table 2)

4.1.2 Mean performance and the range of variability

The mean values of genotypes for different characters studied are presented in Table 3, while estimates of range are given in Table 4.

4.1.2.1 Plant height (cm)

Wide range of variation in plant height between 124.70cm (RBN-2014-17) to 202.43cm (RBN-2014-21) was observed with overall mean performance of 162.94 cm. Two genotypes *viz.,* RBN-2014-21(202.43) and RBN-2014-23 (192.00) recorded significantly more plant height over the tallest check NB-21 (173.41).

4.1.2.2 Number of leaves/tiller

Variation in number of leaves ranging between 5.60 (RBN-2014-25) to 8.53 (RBN-2014-1) with mean performance of 6.71 was observed. Four genotypes RBN-2014-1(8.53), RBN-2014-23 (8.27), RBN-2014-2 (7.83) and RBN-2014-3(7.47) recorded significantly more number of leaves per tiller over the highest check NB-21 (6.33).

4.1.2.3 Number of Tillers/plant

Wide range of variation in Number of tillers/plant 39.76 (RBN-2014-23) to 81.13 (RBN-2014-25) was observed with overall mean performance of 62.39. None of the genotypes recorded significantly more number of tillers per plant over the best check Phule Jaywant (70.06).

4.1.2.4 Average Number of internodes/tiller

Average number of internodes ranging between 2.53 (RBN-2014-26) to 5.57 (RBN-2014-23) with mean performance of 3.52 was observed. Two genotypes *viz.,* RBN-2014-23 (5.57) and RBN-2014-8 (4.90) recorded significantly more average number of internodes per tiller over the best check NB-21 (3.83).

4.1.2.5 Leaf length (cm)

Variation in leaf length ranging between 61.83cm (RBN-2014-23) to 87.67cm (RBN-2014-21) with mean performance of 72.44cm was observed. None of the genotype recorded significantly more leaf length over the best check CO-3 (82.20).

4.1.2.6 Leaf width (cm)

Leaf width ranging between 1.80 cm (RBN-2014-24) to 2.46 cm (RBN-2014-3) was observed with overall mean performance of 2.13cm. None of the genotypes recorded significantly more leaf width (cm) over the best check CO-3 (2.52 cm).

4.1.2.7 L: S ratio

Variation in L: S ratio was recorded from 0.29 (RBN-2014-23) to 0.98 (RBN-2014-18) with overall mean performance of 0.60. None of the genotypes recorded significantly more L: S ratio over the best check CO-3 (0.98).

4.1.2.8 Dry matter yield (kg/plant)

Minimum value for dry matter yield recorded in RBN-2014-16 (1.62 kg/plant) and that of maximum in RBN-2014-11 (3.65 kg/plant) with overall mean performance of 2.20 kg/plant. Four genotypes *viz.*, RBN-2014-11 (3.65), RBN-2014-8 (3.20), RBN-2014-2 (2.99) and RBN-2014-2 (2.86) recorded significantly more dry matter yield (kg/plant) over the best check Phule Jaywant (2.07).

4.1.2.9 Crude protein (%)

Crude protein (%) ranging between 7.44 % (RBN-2014-1) to 12.69 % (RBN-2014-25) with overall mean performance of 10.43(%) was observed. The genotype RBN-2014-25 (12.69) recorded significantly more crude protein (%) over the best check Phule Jaywant (10.94).

4.1.2.10 Oxalic acid content (%)

Lowest value for oxalic acid content was recorded in RBN-2014-23 (1.81%) while highest in RBN-2014-15 (2.81 %) with mean performance of 2.18 %. None of the genotypes recorded significantly less oxalic acid (%) over the best check Phule Jaywant (2.06).

4.1.2.11 Green forage yield (kg/plant)

Lowest green forage yield observed in RBN-2014-29 (4.65 kg/plant) and highest in RBN-2014-11 (10.65 kg/plant) with mean performance 6.63 kg/plant. Four genotypes *viz.*, RBN-2014-11 (10.65), RBN-2014-2 (8.85), RBN-2014-28 (8.61) and RBN-2014-21 (8.21) recorded significantly higher green forage yield (kg/plant) over the best check Phule Jaywant (6.63kg/plant).

4.1.3 Estimates of components of variation

The estimates of genotypic variance, phenotypic variance, GCV, PCV, heritability (b.s.), genetic advance, expected genetic advance as % of mean genotypic and phenotypic variance for the different characters studied are presented in Table 4.

4.1.3.1 Genotypic variance and phenotypic variance.

Highest value of genotypic variance ($\sigma^2 g$) and phenotypic variance ($\sigma^2 p$) recorded for plant height (201.44 and 259.28 respectively), while that of lowest in case of leaf width i.e. (0.02 and 0.06 respectively).

4.1.3.2 Genotypic and phenotypic coefficient of variation

Genotypic coefficient of variation was highest for L: S ratio (24.01) and lowest for leaf width (6.36). Phenotypic coefficient of variation was highest for L: S ratio (27.62) lowest for plant height (9.88). In general, magnitude of PCV was observed to be higher than that of GCV.

High estimates of GCV and PCV were observed for L: S ratio (GCV=24.01, PCV=27.62). Average number of internode / tiller (PCV=23.73, GCV=19.50), dry matter yield (PCV=23.70, GCV=19.49) and green forage yield (PCV=21.89, GCV=18.72) showed high PCV and moderate GCV. Moderate estimates for GCV and PCV were observed for number of tillers/plant (GCV=15.98, PCV=19.06), crude protein (%) (GCV=11.81, PCV=14.33). Moderate estimates of PCV and low estimates of GCV were observed for characters like number of leaves (PCV=12.17, GCV=9.17), leaf length (PCV=11.22, GCV=9.65), leaf width (PCV=11.53, GCV=6.36) and oxalic acid (PCV=11.32, GCV=8.81). Low estimates for GCV and PCV were observed for plant height (GCV=8.71, PCV=9.88).

4.1.3.3 Heritability and Genetic advance

Maximum heritability (b.s.) was observed for plant height (77.70 %) and minimum for leaf width (30.40 %). High heritability (>60 %) was observed for all the characters except number of leaves/plant and leaf width which showed medium heritability (30-60%). High estimates of genetic advance as percentage of mean (>20%) were observed for characters like L: S ratio (42.99%), average number of internodes (33.05%), DMY (33.03%), GFY (32.97%), number of tillers (27.61%) and crude protein (20.07%), and Other characters showed moderate genetic advance as percentage of mean while leaf width (7.23%) showed low GA as percent of mean. Highest genetic advance as percentage of mean recorded for L: S ratio (42.99%) while lowest was for leaf width (7.23%).

4.2 Correlations studies

The genotypic and phenotypic correlations for eleven characters studied are present in Table 5 and 6 respectively. Only significant genotypic and phenotypic correlations either in positive or negative are described in this chapter.

4.2.1 Association of green forage yield with its components

It was revealed from Table 5 and 6 that green forage yield had significant positive correlations with plant height, leaf length and dry matter yield both at genotypic and phenotypic level. Green forage yield had significant positive correlations with number of tillers at genotypic level. Highest significant positive value of genotypic correlations of green forage yield was recorded with dry matter yield (0.900) followed by leaf length (0.511), plant height (0.450), and the lowest in case of average number of tiller/plant (0.264). At phenotypic level highest positive significant with dry matter yield (0.845) followed by leaf length (0.495) and plant height (0.400).

4.2.2 Inter relationship of yield components

4.2.2.1 Plant height (cm)

Plant height showed highly significant positive genotypic and phenotypic correlations with dry matter yield (0.489, 0.490), leaf length (0.480, 0.408), green forage yield (0.450, 0.400), average number internodes/tiller (0.402, 0.430) number of leaves/tiller (0.280, 0.351)while it showed highly significant negative genotypic and phenotypic correlations with number of tillers/plant (-0.546,-0.337) and L:S ratio (-0.558, -0.443) while with crude protein content (-0.263) at genotypic level only.

4.2.2.2 Number of leaves/tiller

Number of leaves showed significant positive correlations at genotypic and phenotypic level with average number of internodes/tiller (0.708, 0.653) while it showed significant negative correlations at genotypic and phenotypic level with leaf length (-0.555, -0.349) L:S ratio (-0.633, -0.341) and number of tillers/plant (-0.588,-0.294) while with crude protein content (-0.314) at genotypic level only.

4.2.2.3 Number of tillers/plant.

Number of tillers/plant showed significant positive genotypic and phenotypic correlations with L: S ratio (0.502, 0.342) crude protein (0.410, 0.310) and positive genotypic correlation with dry matter yield (0.322) and green forage yield (0.264) while it showed significant negative genotypic and phenotypic correlations with average number of internodes/tiller (-0.397,-0.332) and with leaf width (-0.287) at genotypic level only.

4.2.2.4 Average number of internodes/tiller

It showed significant positive genotypic correlations only with oxalic acid content (%) (0.272) while it showed significant negative genotypic and phenotypic correlations with leaf length (-0.525, -0.419), L: S ratio (-0.852, -0.579) and with leaf width (-0.460) and crude protein (-0.287) at genotypic level only.

4.2.2.5 Leaf length (cm)

Leaf length showed significant positive genotypic and phenotypic correlations with dry matter yield (0.423, 0.421) and green forage yield (0.511, 0.495) and L: S ratio (0.329) at genotypic level only while it showed negative genotypic correlations with oxalic acid content (-0.293).

4.2.2.6 Leaf width (cm)

Leaf width did not show significant positive correlations at genotypic and phenotypic levels with any other characters while it showed significant negative genotypic correlations with crude protein (-0.306), oxalic acid content (-0.304) and phenotypic correlation with L: S ratio (-0.959).

4.2.2.7 L: S ratio

It did not show significant positive or negative genotypic and phenotypic with any characters.

4.2.2.8 Dry matter yield (kg / plant)

DMY showed significant positive genotypic and phenotypic correlations with green forage yield at high level of magnitude (0.900, 0.845) while it did not show significant positive or negative correlation at genotypic or phenotypic levels with crude protein and oxalic acid content.

4.2.2.9 Crude protein (%)

Crude protein showed non-significant positive genotypic and phenotypic correlations with green forage yield.

4.2.2.10 Oxalic acid content (%)

It showed non-significant negative genotypic and phenotypic correlations with green forage yield.

4.3 Genotypic path-coefficient analysis

To find out direct and indirect contributions of each of the characters, path co-efficient analysis was carried out. The genotypic correlations coefficient being more important, were only partitioned into direct and indirect effects which are presented in Table 7.

Dry matter yeild exhibited highest positive direct effect (1.759) on GFY followed by oxalic acid content % (0.178), on the other hand average number of internodes/tiller (-2.151), L: S ratio (-1.323) showed highest negative direct effects on GFY followed by characters *viz.*, leaf length (-0.670), number of tillers/plant (-0.646), leaf width (-0.318), plant height (-0.254), number of leaves/tiller (-0.039) and crude protein (-0.106).

4.3.1 Green forage yield Vs Plant height (cm)

Plant height showed negative direct effects of magnitude (-0.254) on green forage yield, while it showed positive indirect effects through number of tillers/plant (0.353), L: S ratio (0.739), dry matter yield (0.860), and crude protein % (0.028). It showed negative indirect effects through number of leaves/tiller (-0.011), average number of internodes/tiller (-0.867), leaf length (-0.322), leaf width (-0.028), oxalic acid content (-0.050) leading to significant positive total genotypic correlations of magnitude (0.450).

4.3.2 Green forage yield Vs Number of leaves/tiller

Number of leaves showed negative direct effects of magnitude (-0.039). It had positive indirect effects through number of tillers/plant (0.381), leaf length (0.372), leaf width (0.001), L: S ratio (0.838), dry matter yield (0.177), crude protein (0.033) and negative indirect effects through plant height (-0.071) followed by average number of internodes/tiller (-1.525) and oxalic acid content (-0.012) leading to non-significant positive genotypic correlations of magnitude (0.154).

4.3.3 Green forage yield Vs Number of tillers/plant

Number of tillers/plant exhibited negative direct effect of magnitude (-0.646) while positive indirect effect through average number of internodes/tiller (0.855), dry matter yield (0.584), plant height (0.139), leaf width (0.091), number of leaves/tiller (0.023), oxalic acid content (0.007) and negative indirect effect through L:S ratio (-0.665), leaf length (-0.081), and crude protein (-0.044) leading to significant positive total genotypic correlations of value (0.264).

4.3.4 Green forage yield Vs Average number of internodes/tiller

Average number of internodes/tiller showed negative direct effects of magnitude (-2.152) on green forage yield while it showed positive indirect effects through L:S ratio (1.129), leaf length (0.352), number of tillers/plant (0.257), dry matter yield (0.162), leaf width (0.147), oxalic acid content (0.048) and crude protein (0.030) and negative indirect effect through plant height (-0.102) and number of leaves/tiller (-0.028) leading to negative non significant genotypic correlations of magnitude (-0.156).

4.3.5 Green forage yield Vs Leaf length (cm)

Leaf length showed negative direct effects of magnitude (-0.670) on green forage yield. It showed positive indirect effects through average number of internodes/tiller (1.131), dry matter yield (0.745), number of leaves/tiller (0.022), crude protein (0.007) and negative indirect effect through L: S ratio (-0.436), plant height (-0.122), number of tillers/plant (-0.079), oxalic acid content (-0.052), and leaf width (-0.035) leading to significant positive total genotypic correlations of magnitude (0.511).

4.3.6 Green forage yield Vs Leaf width (cm)

Leaf width showed negative direct effects of magnitude (-0.318), while it showed positive indirect effects through average number of internodes/plant (0.992), number of tillers /plant (0.186) and crude protein (0.033) and negative indirect effects through dry matter yield (-0.402), L:S ratio (-0.295), leaf length (-0.074), oxalic acid content (-0.054) and plant height (-0.022) leading to non significant positive genotypic correlations of magnitude (0.044).

4.3.7 Green forage yield Vs L: S ratio

L:S ratio showed negative direct effects of magnitude (-1.323), while showing positive indirect effects through average number of internodes/tiller (1.835), dry matter yield (0.143), plant height (0.141), number of tillers/plant (0.025), oxalic acid content (0.010) and negative indirect effect through number of tillers/plant (-0.325), leaf length (-0.221), leaf width (-0.071), crude protein (-0.023) leading to positive total genotypic correlations of non significant magnitude (0.192) with GFY.

4.3.8 Green forage yield Vs Dry matter yield (kg/plant)

Dry matter yield showed positive direct effects of magnitude (1.759) on green forage yield, while it showed positive indirect effects through leaf width (0.073), crude protein (0.001) and negative indirect effects through leaf length (-0.283), number of tillers/plant (-0.215), average number of internodes/tiller (-0.198), plant height (-0.124), L: S ratio (-0.108), number of leaves/tiller (-0.004) and oxalic acid content (0.001) leading to total significant positive correlations of magnitude 0.900.

4.3.9 Green forage yield Vs Crude protein (%)

Crude protein (%) showed negative direct effects of magnitude (-0.106), while it showed positive indirect effects through average number of internodes/tiller (0.617), leaf width (0.097), plant height (0.066), leaf length (0.043), number of leaves/tiller (0.012), and negative indirect effects through L:S ratio (-0.286), number of tillers/plant (-0.265), oxalic acid content (-0.024) and dry matter yield (-0.013) leading to total genotypic correlations of non significant and positive value (0.142).

4.3.10 Green forage yield Vs Oxalic acid content (%)

It showed positive direct effects of magnitude (0.178), while positive indirect effects through leaf length (0.197), leaf width (0.097) plant height (0.071), crude protein (0.014), number of leaves/tiller (0.003), and negative indirect effects through average number of internodes/tiller (-0.587), number of tillers/plant (-0.026), L: S ratio (-0.071) and dry matter yield (0.001) leading to non significant negative genotypic correlations of magnitude (-0.125) with GFY.

4.4 Morphological characterization

The 32 genotypes characterized morphologically are given in Table 8. On the basis of visual observations they are grouped in six categories.

4.4.1 Leaf colour

Based on leaf colour, the 32 genotypes were grouped into three categories namely dark green, green and pale green of which 7 were dark green, 19 were green and 6 were pale green coloured types.

4.4.2 Plant vigour

Based on plant vigour, the 32 genotypes were grouped in to three categories namely 15 good, 13 medium and 3 poor types.

4.4.3 Growth habit

Based on growth habit, the 32 genotypes were grouped in two categories namely erect and semi-erect of which 30 were erect and 2 were semierect.

4.4.4 Pigmentation on node

Based on pigmentation on node the 32 genotypes were grouped in to two categories namely pigmentation absent or present. 26 genotypes did not show pigmention on node while 6 genotypes had pink or purple pigmentation.

4.4.5 Hairiness

Based on hairiness of the leaf the 32 genotypes were grouped in to three categories i.e hairs on stem, leaf sheath and leaf blade either absent or present of which 2 had hairs on stem, 15 on leaf sheath, 1 on leaf blade.

4.4.6 Leaf waxiness

Based on the leaf waxiness the genotypes were grouped in to two categories namely waxiness present (20 genotypes) and absent (12 genotypes).

5. DISCUSSION

Plant breeding deals with the management and utilization of genetic variability. It is therefore necessary to classify and utilize this variability systematically for genetic upgradation of biological population. Similarly, the assessment of the magnitude and direction of association between different yield contributing characters especially with yield is useful in selecting desired genotypes on the basis of their phenotypic values. Hence, it is important to study the cause and effects relationship between yield and its component characters.

In present investigation, 29 Bajra x Napier grass hybrids developed at Grass Breeding Scheme, MPKV, Rahuri along with three checks were evaluated for variability, correlations and path coefficient analysis. Association between different characters and direct and indirect effects of the component characters on green forage yield were studied.

The results obtained on these aspects are presented in previous chapter and discussed in this chapter under appropriate headings.

5.1 Variability and genetic parameters

There can be little doubt that the existence of genetic variability is advantageous to the evolutionary survival of a species. Yield improvement in any crop can be brought about through plant breeding but necessary variability upon which selection is to be practiced must be available in the genetic material. Therefore, before embarking on any plant breeding programme, a plant breeder must survey and assess variability present, with respect to yield and its attributes. The variability for a given agronomic or yield component character can be estimated through variance, co-efficient of variability (GCV, PCV), heritability and genetic advance.

5.1.1 Range of variability

Wide range of variability was observed for characters *viz.*, plant height, number of tillers/plant, leaf length, L: S ratio, crude protein (%), average number of internodes/tiller, DMY and GFY.

Suthamathi and Dorairaj (1997) also reported wide variability for character GFY and plant height and low for oxalic acid content and L: S ratio.

Low range of variability was noticed for characters *viz.*, number of leaves/tiller, leaf width (cm), and oxalic acid content (%).

5.1.2 Genotypic and phenotypic coefficient of variation

The estimates of GCV and PCV for all the characters studied showed little difference, PCV being slightly greater than the GCV, thus indicating that the variability existing in these characters was mainly due to genetic factors.

The estimates of genotypic as well as phenotypic coefficients of variances were the highest for L: S ratio followed by average number of internodes/tiller, dry matter yield (kg/plant) and green forage yield (kg/plant).

Moderate estimates of GCV and PCV observed for number of tillers/plant and crude protein (%). Low estimates was observed in case of plant height (cm), number of leaves/tiller, leaf length (cm), leaf width (cm), and oxalic acid content (%).

Wide range of variation (GCV and PCV) observed for the characters would offer scope of selection of superior genotypes for these traits.

Satpute *et al.* (2014) also reported high genotypic coefficient of variation for dry matter (kg/ plant) whereas, Suthamathi and Dorairaj (1997) reported high estimates of GCV and PCV for leaf weight, GFY, plant height (cm) and crude protein (%). Khan and Sukumar (2002) reported high GCV for number of tillers/plant, leaf width (cm) and leaf length (cm).

5.1.3 Heritability and genetic advance

Genotypic coefficient of variation alone does not indicate the proportion of total heritable variation. The heritability estimates are better indicator in this respect. The broad sense heritability includes the contribution of additive gene effects, dominance and non-allelic due to epistasis. Johonson *et al.* (1955) pointed out that in a selection programme, heritability values as well as estimates of genetic advance are more useful than heritability alone.

In the present investigation, number of tillers/plant, number of internodes/tiller, L: S ratio, dry matter yield, crude protein (%) and green forage yield showed high estimates of heritability (b.s.) accompanied by high genetic advance as percentage of mean indicating that these traits could be prominently governed by additive gene action and selection of these traits could be more effective for desired genetic improvement.

High heritability along with high genetic advance was also reported by Suthamathi and Dorairaj (1997) for number of tillers/plant, crude protein (%) and GFY, Khan and Sukumar (2002) for number of tillers/plant, Mahawar *et. al.* (2003) for L:S ratio and GFY in fodder bajra, Shinde (2005) for L:S ratio, number of tillers/plant, and crude protein (%), L:S ratio, DMY and GFY in bajra x napier hybrids, Kamble (2011) for number of tillers/plant, DMY and GFY in Napier grass, Chavan (2012) for number of internodes/tiller, DMY, GFY, L:S ratio and Satpute (2012) for dry matter yield, green forage yield, number of tillers per plant, and L: S ratio.

In the present investigation, high heritability of plant height, leaf length and oxalic acid was not associated with high genetic advance as percentage of mean indicating that these characters are controlled by non-additive gene action and hence these characters can be improved through indirect selection.

Das (1994) reported moderate heritability and genetic advance for oxalic acid content. Satpute (2012) in his investigation reported that high heritability for oxalic acid content, leaf length was not associated with high genetic advance as percentage of mean.

Thus considering the estimates of genetic parameters like genotypic coefficient of variation, heritability and genetic advance as a percentage of mean, characters like number of tillers/plant, L:S ratio, crude protein, dry matter yield, green forage yield, are the most important characters in bajra x napier hybrids.

5.2 Correlations studies

The associations between two traits that can be directly observed are the phenotypic correlation. Thus does not give a true genetic picture of the relationship as it indicates effects of both heredity as well as environment inheritances.

The genotypic correlation coefficients provide an estimate of an inherent association between genes controlling any two characters i. e. when two characters are invariably and linearly associated, the underlined genetic mechanism causing such association may be due to complete linkage between the two characters or due to pleiotropic correlation is of greater significance and can be effectively utilized in formulating an effective selection scheme. It may also help to identify the characters that prove to be of little or no importance in the selection programme.

It was revealed from the present study that the genotypic correlations coefficients between most of the characters were higher in magnitude than the phenotypic correlations coefficients indicating strong inheriting association between various characters studied and that the genotypic expression of the correlations was comparatively less influenced by the environmental deviation.

5.2.1 Association of green forage yield with its components

It is revealed from present investigation that green forage yield had significantly and positive correlation with dry matter yield (0.900) followed by leaf length (0.511), plant height (0.450) and number of tillers/plant (0.264), GFY did not show significant negative association with any of the character under study.

These results are in agreement with findings reported by several scientists. Das and Ratnam Nadar (1991) observed positive correlation of plant height, number of tillers/plant and leaf length with GFY. Patil and Jadhav (1992) observed significant positive correlation of leaf length and number of tillers with GFY. Devarathinam and Dorairaj (1994) observed significant positive correlation of plant height, and DMY with GFY in napier grass. Sukanya (1998) observed significant positive correlation of leaf length leaf width, number of leaves/tiller and plant height with GFY. Shinde *et al.* (2009) observed significant positive correlation of DMY, plant height and number of tillers/plant with GFY. Zhang *et al.* (2009) observed significant positive correlation of plant height, tillers/plant with

GFY. Kamble (2011) observed significant positive correlation of DMY, number of tillers/plant, with GFY. Chavan (2012) reported that DMY, plant height, number of tillers/plant and leaf length was significantly and positively correlated with GFY. Satpute (2012) reported that green forage yield was significantly and positively correlated with dry matter yield and plant height and number of tillers/plant.

5.2.2 Inter relationship among yield contributing characters

5.2.2.1 Plant height (cm)

It showed significant positive genotypic correlations with number of leaves/tiller, average number of internodes/tiller, leaf length, DMY and GFY and significant negative correlations with number of tillers/plant, L: S ratio, crude protein (%) and oxalic acid content. Shinde *et al.* (2009) noticed significant and positive genotypic correlations of plant height with GFY in bajra-napier hybrid whereas, Sukanya (1998) also noticed similar results in napier grass. Satpute (2012) noticed significant positive genotypic correlations of plant height with GFY, DMY number of leaves/tiller and average number of internodes/tiller.

5.2.2.2 Number of leaves/tiller

It exhibited significant positive genotypic correlations with average number of internodes/tiller and significant negative correlation with number of tillers, leaf length, L: S ratio and crude protein (%). This result is in confirmation with the findings of Kamble (2011) in napier grass and Satpute (2012) who also noticed strong and positive association of average number of internodes/tiller with number of leaves/tiller in bajra-napier grass hybrids.

5.2.2.3 Number of tillers/plant

It showed significant positive genotypic correlations with L:S ratio, DMY, crude protein(%), GFY, while it showed significant and negative genotypic correlations with average number of internodes/tiller and leaf width. Shinde *et al.* (2009) observed significant and positive association of number of tillers with dry matter yield and green forage yield in bajra-napier hybrids. Kamble (2011) also noticed similar results in napier grass. Satpute (2012) found significant positive genotypic correlations of tillers with DMY, GFY and significant and negative genotypic correlations with leaf width.

5.2.2.4 Average number of internodes/tiller

It exhibited significant positive genotypic correlations with oxalic acid (%) and significant negative with leaf length, leaf width, L: S ratio and crude protein. On contrary Kamble (2011) reported significant positive association of internodes with GFY, DMY and leaf length in napier grass. However, Satpute (2012) observed significant negative correlation of internodes with leaf length in bajra x napier hybrids.

5.2.2.5 Leaf length (cm)

It showed significant positive correlations with L: S ratio, DMY and GFY and significant negative correlations with oxalic acid content. Kamble (2011) also observed strong and positive association of leaf length with GFY and DMY in napier grass and Satpute (2012) in bajra x napier hybrids for DMY and GFY.

5.2.2.6 Leaf width (cm)

It showed significant negative genotypic correlations with crude protein and oxalic acid. Kamble (2011) noticed significant positive correlation of leaf width with GFY, DMY and plant height. Satpute (2012) noticed significant negative correlation of leaf width with crude protein content.

5.2.2.7 L: S ratio

It did not show significant positive and negative genotypic correlations with DMY, crude protein, oxalic acid and GFY. The finding is in conformation with Satpute (2012) in bajra x napier hybrids.

5.2.2.8 Dry matter yield (kg/plant)

It showed significant positive correlations with GFY. Sood and Singh (1982) observed strong and positive association of DMY with number of leaves/tiller, average number of internodes/tiller in napier-bajra hybrids. Das and Ratnam Nadar (1991) also reported significant positive correlation of DMY with GFY which is in confirmation with the findings of present study. Confirmatory results were also by Thirumeni and Das (1994), Krishna and John (2007) Kamble (2011) in napier grass and Satpute (2012).

5.2.2.9 Crude protein (%)

It showed non-significant genotypic correlations with oxalic acid and GFY. The study is in conformation with Kamble (2011) in napier grass and also Satpute (2012) in bajra x napier.

5.2.2.10 Oxalic acid content (%)

It showed non-significant genotypic correlations with green forage yield. Kamble (2011) in napier grass and Satpute (2012) in bajra x napier hybrids also reported similar findings.

5.3 Path coefficient analysis

Direct effect of any component character on yield gives an idea about the reliability of indirect selections to be made through those characters to bring about improvement in seed yield. If the correlation coefficient between a causal factor and the effect is equal to its direct effect, then correlation explains the true relationship and a selection for that trait will be effective. If the final correlation coefficient is positive, but the direct effect is negative or negligible, in such relations the indirect causal factors are to be considered simultaneously for selection. When correlation coefficient is negative but the direct effect is positive and high, a restricted simultaneous selection model is to be followed i.e. restrictions are to be imposed to multiply the undesirable indirect effects in order to make use of direct effects (Singh and Kakar, 1977). The residual effect determines how best the causal factors accounts for the variability of the dependent factor, the green forage yield per plant in this case.Character wise path analysis is discussed as under.

5.3.1 Green forage yield Vs Plant height (cm)

Plant height showed negative direct effects on green forage yield but its association with green forage yield was observed to be strong and positive which may be due its high and positive indirect effects via DMY, L: S ratio, and number of tillers/plant. Contradictory John (2008) noticed high direct effects of plant height accompanied by its strong positive association with green forage yield. Kamble (2011) in napier grass and Satpute (2012) in bajra x napier hybrids also observed negative direct effects of plant height on green forage yield but its association with green forage yield was observed to be strong and positive.

5.3.2 Green forage yield Vs Number of leaves/tiller

It exhibited low negative direct effects accompanied by non significant positive correlations with green forage yield which, may be due to its high positive indirect effects via tillers, leaf length L: S ratio and DMY. Sukanya (1998) noticed high and positive direct effects of number of leaves/tiller and significant positive association with green forage yield in napier, which is contradictory with the present investigation. Satpute (2012) noticed negative direct effect of leaves with green forage yield which is in conformation of the present study.

5.3.3 Green forage yield Vs Number of tillers/plant

The trait showed negative direct effects on green forage yield while showing significant positive correlations with green forage yield. This may be due its high positive indirect effects via dry matter yield average number of internodes and plant height. Thirumeni and Das (1994) noticed strong positive direct effects of number of tillers/plant on green forage yield and it was significant positively correlated with green forage yield in bajra-napier hybrids. Sukanya (1998) noticed low and positive direct effects of number of tillers/plant accompanied by significant negative correlations with green forage yield, in napier grass. Chavan (2012) in napier grass and Satpute (2012) in bajra x napier hybrids noticed positive direct effects which is contradictory with the present findings

5.3.4 Green forage yield Vs Average number of internodes/tiller

It exhibited high negetive direct effects and non significant negative correlations with green forage yield. Sukanya (1998) and Satpute (2012) found positive direct effect of average number of internodes/tiller on green forage yield which is not in conformation with this study.

5.3.5 Green forage yield Vs Leaf length (cm)

It showed negative direct effects accompanied by significant positive correlations with green forage yield. This may be due to the high indirect effect in average number of internodes/tiller and dry matter yield. Satpute (2012) observed low negative direct effects accompanied by non significant positive correlations with green forage yield which is contradictory with this study.

5.3.6 Green forage yield Vs Leaf width (cm)

It exhibited negetive direct effects on green forage yield accompanied by non-significant negative association with green forage yield. Sukanya (1998) and John (2008) reported positive direct effects of leaf width on green forage yield in napier grass and Satpute (2012) in bajra-napier hybrids which is not in conformation with this study.

5.3.7 Green forage yield Vs L: S ratio

It exhibited high negative direct effects and non-significant positive correlations with green forage yield. Satpute (2012) reported negligible negative direct effects and non-significant negative correlations with GFY.

5.3.8 Green forage yield Vs Dry matter yield (kg/plant)

It showed the highest positive direct effects on green forage yield and highly significant positive correlations with green forage yield.

This result is in confirmation with the findings of Thirumeni and Das (1994) in napier, Shinde (2005), Shinde (2009) and Satpute (2012) in bajra- napier hybrids who also noticed high positive direct effects of DMY on green forage yield and strong positive association among them.

5.3.9 Green forage yield Vs Crude protein (%)

It showed negative direct effect on green forage yield but its association with green forage yield was non-significant positive. John (2008) and Shinde (2009) noticed positive direct effects on green forage yield of crude protein; while Satpute (2012) observed direct negative effects on green forage yield but its association with green forage yield was non-significant negative.

5.3.10 Green forage yield Vs Oxalic acid content (%)

It showed positive direct effects and negative non significant correlations on with green forage yield. Satpute (2012) had reported negative direct effects and non significant correlations with green forage yield.

6. SUMMARY AND CONCLUSIONS

The present investigation entitled as, "Variability and path coefficient analysis studies in bajra X napier hybrids" was conducted during June 2014 to Feb. 2015 to study,

1. The variability for forage yield and yield contributing characters of bajra x napier hybrids.
2. The magnitude and association of forage yield with yield contributing characters in bajra x napier hybrids.
3. The cause and effect of yield contributing characters on forage yield in bajra x napier hybrids.

Twenty nine genotypes of bajra x napier hybrids with three checks were evaluated in Randomized Block Design with two replications, Eleven characters *viz.,* plant height, number of leaves/tiller, number of tillers/plant, average number of internodes/tiller, leaf length, Leaf width, L: S ratio, crude protein, oxalic acid content, dry matter yield and Green forage yield were studied.

6.1 Summary

Variability and genetic parameter

Range of variability, genotypic and phenotypic variances, genotypic and phenotypic coefficients of variation, heritability percentage and genetic advance, GA as % of mean were worked out.

Treatment differences were found to be significant for all characters studied. Wide range of variability was observed for characters *viz.,* plant height, number of tillers/plant, average number of internodes/tiller, L: S ratio, DMY and GFY.

The estimates of GCV, PCV, heritability (bs) and GA as percentage of mean were high for characters *viz.,* number of tillers/plant, number of internodes/tiller, L: S ratio, dry matter yield, crude protein (%) and green forage yield.

Correlations

Correlations studies at genotypic level were made to resolve the direction and magnitude of association of the characters *viz.,* dry matter yield (0.900), leaf length (0.511), plant height (0.450) and number of leaves/tiller (0.264) with green forage yield.

Path coefficient analysis

High direct effects along with significant and positive correlation with green forage yield were observed for dry matter yield. The characters *viz.,* average number of internodes/tiller, number of tillers/plant and dry matter yield also indirectly contributed to the green forage yield.

6.2 Conclusion

Genetic variability

The mean sum of squares due to genotypes was highly significant for all the characters indicating sufficient amount of genetic variation among the genotypes under study.

Three traits namely L: S ratio, average number of internodes/tiller, dry matter yield (kg/plant) had high GCV and PCV. Hence it is concluded that there is ample scope for selection for these characters.

High estimates of heritability accompanied by high estimates of genetic advance as percentage of mean were observed for characters like number of tillers/plant, number of internodes/tiller, L: S ratio, dry matter yield, crude protein (%) and green forage yield indicating that these traits are predominately governed by additive gene action and selection for these characters will be effective.

Correlations

The characters like dry matter yield, leaf length, plant height and number tiller/plant showed significant positive genotypic correlations with green forage yield indicating their importance for indirect green fodder improvement programme.

Path coefficient analysis

Dry matter yield exhibited high positive direct and indirect effect and significant positive genotypic correlation with green yield. The characters *viz.*, Average number of internodes, number of tillers also exhibited high indirect effects. Thus emphasis should be given on these characters for green forage improvement in the present bajra x napier hybrids.

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*** Indicates original was not seen**

8. VITA

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A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

Title of Thesis : "Variability and path coefficient analysis studies in bajra x napier hybrids"

Major Field : Genetics and Plant Breeding

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ABSTRACT

"VARIABILITY AND PATH COEFFICIENT ANALYSIS STUDIES IN BAJRA X NAPIER HYBRIDS"

By

SHINDE ROHIT BALASAHEB
A Candidate for the degree
Of
MASTER OF SCIENCE (AGRICULTURE)

In
Agricultural Botany
(Genetics and Plant breeding)

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722
2015

Research Guide	**: Prof. P. P. Surana.**
Department	**: Agricultural Botany**
Major Field	**: Genetics and Plant Breeding**

The investigation on "Variability and path coefficient analysis studies in bajra x napier hybrids" was undertaken with the objectives to estimate variability among different bajra x napier hybrids; to study character association among green forge yield and its components and to find out direct and indirect effects of different component characters on green forage yield.

A set of 32 bajra x napier hybrids was evaluated in Randomized Block Design with two replications at Grass Breeding Scheme, MPKV, Rahuri under irrigated condition during the period June 2014 to February 2015.

Abstract contd…….Mr. Shinde.R.B.

The observations were recorded on green forage yield and yield contributing characters *viz.*, plant height (cm), number of leaves/tiller, number of tillers/plant, leaf length (cm), leaf width (cm), L/S ratio, crude protein (%), oxalic acid content (%), dry matter yield (kg/plant).

Considerable amount of variation was found in material under study. High heritability estimates (b.s) were observed for all the characters studied. High estimates of heritability (b.s.) accompanied by high genetic advance as percentage of mean was reported for characters viz., number of tillers/plant, number of internodes/tiller, L: S ratio, dry matter yield, crude protein (%) and green forage yield. Thus, selection of these traits will be more effective for desired improvement.

Correlations studies showed that green forage yield was significantly and positively associated with characters like dry matter yield, leaf length, plant height and number of leaves/tiller indicating their importance for indirect green fodder improvement programme.

Path analysis revealed that Dry matter yield exhibited positive direct effect and indirect effect on green forage yield as well as it showed significant and positive correlation with green forage yield. The characters *viz.,* Average number of internodes, number of tillers also showed high indirect effects. Thus, emphasis should be given on these characters for improvement of green forage yield of bajra x napier hybrids.

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VARIABILITY AND PATH COEFFICIENT ANALYSIS STUDIES IN BAJRA X NAPIER HYBRIDS

By

Mr. Shinde Rohit Balasaheb

Reg.No. R 013/021

A thesis submitted to the

Mahatma Phule Krishi Vidyapeeth, Rahuri- 413 722

Dist. Ahmednagar, Maharashtra state, India

In partial fulfillment of the requirements for the Degree

Of

MASTER OF SCIENCE (Agriculture)

In

AGRICULTURAL BOTANY

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DEPARTMENT OF AGRICULTURAL BOTANY,

POST GRADUATE INSTITUTE,

MAHATMA PHULE KRISHI VIDYAPEETH,
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CANDIDATE'S DECLARATION

I hereby declare that this thesis or part there of

has not been submitted by me or any other

person to any other University

or Institute for Degree

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C E R T I F I C A T E

This is to certify that the thesis entitled, **Variability and path coefficient analysis studies in bajra x napier hybrids** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra State, India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING**, embodies the results of a piece of *bona fide* research work carried out by **Mr. SHINDE ROHIT BALASAHEB** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

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Date: Research Guide

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Date:

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My friends, teachers, seniors, juniors and the years during my stay at College of Agriculture, Baramati strike a deep emotional chord in my life. I would like to thank them for the memories that they have given me for the rest of my life. Finally, I bow down before my family members – *Babaji, Ajji, Bapu, Tatya, Mummy, Kaki, Didi, Bhaiya and Bablu.* They have constantly supported me during the ups and downs of my life.

Place: MPKV, Rahuri.

Date : (R.B.Shinde)

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LIST OF ABBREVIATIONS

b.s.	:	Broadsense heritability
C.D.	:	Critical difference
cm	:	Centimeter
D.F.	:	Degrees of freedom
DMY	:	Dry matter yield
EMP	:	Environment mean sum of products
et al.	:	And others (et alia)
g	:	Gramme (s)
G.A.	:	Genetic advance
GCV	:	Genotypic coefficient of variation
GFY	:	Green forage yield
GM	:	General mean
ha	:	Hectare
i.e.	:	That is (id est)
K	:	Potassium
Kg/pl.	:	Kilograms per plant
MSS	:	Mean sum of squares
N	:	Nitrogen
P	:	Phosphorus
PCV	:	Phenotypic coefficient of variation
Cov.	:	Covariance
RBD	:	Randomized Block Design
S.E.	:	Standard error
S.S.	:	Sum of square
Viz.,	:	Namely
%	:	Per cent
σ	:	Variance

Table 1: List of 32 genotypes

Sr. no.	Genotypes	Pedigree	Sr. no.	Genotypes	Pedigree
1	RBN-2014-1	ICMV-05222 X FD 463	17	RBN-2014-17	GB X GBN-2001-10-2
2	RBN-2014-2	ICMV-05222 X FD 463	18	RBN-2014-18	GB X GBN-2001-10-2
3	RBN-2014-3	ICMV-054444 X FD 476	19	RBN-2014-19	GB X GBN-2001-10-2
4	RBN-2014-4	ICMV-055555 X FD 482	20	RBN-2014-20	GB X GBN-2001-10-2
5	RBN-2014-5	ICMV-05777 X FD 444	21	RBN-2014-21	GB X FD-468-2
6	RBN-2014-6	ICMV-05777 X FD 444	22	RBN-2014-22	GB X FD-472-2-1
7	RBN-2014-7	ICMV-05777 X FD 444	23	RBN-2014-23	GB X FD-472-2-1
8	RBN-2014-8	APFB-2 X FD-439	24	RBN-2014-24	GB X FD-476-2
9	RBN-2014-9	APFB-2 X FD-451	25	RBN-2014-25	GB X FD-476-3
10	RBN-2014-10	APFB-2 X FD-462	26	RBN-2014-26	GBX FD-476-3
11	RBN-2014-11	APFB-2 X FD-479	27	RBN-2014-27	GB X FD-477-1-1
12	RBN-2014-12	RBB-2X FD-450	28	RBN-2014-28	GBX FD-483-1
13	RBN-2014-13	BAIF Bajra X FD-477	29	RBN-2014-29	GBX TUCN-011-2
14	RBN-2014-14	GB X GBN-2001-4-2	30	CO-3 (NC)	
15	RBN-2014-15	GB X GBN2001-4-2	31	NB-21 (NC)	
16	RBN-2014-16	GB X GBN2001-10-1	32	Phule Jaywant©	

Table 2 : Analysis of variance for green forage yield and yield contributing characters in bajra x napier hybrids

Source of Variation	DF	Plant height (cm)	No. of leaves/ tiller	No of tillers/ plant	Av. No of Inter-nodes/ tiller	Leaf length (cm)	Leaf width (cm)	L/s ratio	Dry matter yield (kg/plant)	Crude protein (%)	Oxalic acid content (%)	Green forage yield (kg/plant)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Replication	1	434.618**	9.211**	196.420*	0.002	14.109	0.004	0.011	0.041	2.701	0.037	0.427
Treatment	31	460.736**	1.049**	240.985**	1.170**	115.040**	0.079**	0.049**	0.456**	3.757**	0.098**	3.649**
Error	31	57.838	0.289	42.025	0.226	17.291	0.042	0.006	0.088	0.715	0.024	0.567

Indicates Significant at 5% level of Significance** * Indicates Significant at 1% level Significance**

Table 3: Mean Performance of 32 genotypes of bajra X napier hybrids

Sr. no	Genotypes/hybrids	Plant height (cm)	No. of leaves /tiller	No. of tillers /plant	Av. No. of internodes /tiller	Leaf length (cm)	Leaf width (cm)	L/S ratio	Dry matter yield (kg/plant)	Crude protein (%)	Oxalic Acid content (%)	Green forage yield (kg/plant)
1	RBN-2014- 1	167.23	8.53*	55.37	4.70	69.10	2.07	0.50	2.33	7.44	2.18	7.23
2	RBN-2014- 2	179.73	7.83*	61.37	3.93	80.53	2.36	0.61	2.99*	7.88	2.25	8.85*
3	RBN-2014- 3	164.70	7.47*	53.63	4.13	66.90	2.46	0.50	1.90	9.19	1.88	5.28
4	RBN-2014- 4	160.43	7.06	61.63	2.77	74.37	2.25	0.68	2.23	9.63	2.21	7.45
5	RBN-2014- 5	156.56	5.73	63.30	3.53	77.17	1.93	0.59	1.95	7.44	2.13	5.26
6	RBN-2014- 6	171.23	6.40	53.73	3.10	79.67	2.26	0.76	2.44	11.81	2.19	7.49
7	RBN-2014- 7	162.83	6.50	75.70	3.73	69.73	1.85	0.77	2.86*	12.25	2.44	7.46
8	RBN-2014- 8	177.16	7.36	74.17	4.90*	62.90	2.24	0.43	3.20*	10.06	2.44	7.47
9	RBN-2014- 9	158.06	6.40	71.83	4.37	66.83	1.89	0.48	2.36	10.50	2.63	5.72
10	RBN-2014- 10	151.50	6.77	68.37	3.97	67.03	2.20	0.57	1.80	10.94	2.13	5.07
11	RBN-2014- 11	167.30	6.40	71.97	2.73	86.60	2.03	0.91	3.65*	10.50	2.00	10.65*
12	RBN-2014- 12	159.83	6.87	58.77	2.80	67.40	2.22	0.61	1.63	10.50	1.94	5.31
13	RBN-2014- 13	163.46	7.03	41.13	3.83	68.13	2.24	0.56	2.11	9.19	2.50	6.36
14	RBN-2014- 14	169.43	6.97	60.70	4.53	71.53	2.08	0.49	2.25	11.38	2.44	7.15
15	RBN-2014- 15	139.93	6.60	62.13	3.37	63.03	2.19	0.68	1.72	10.50	2.81	5.55
16	RBN-2014- 16	151.66	6.80	50.53	3.77	69.50	1.99	0.48	1.62	9.63	2.19	5.01
17	RBN-2014- 17	124.70	6.57	78.03	2.97	62.17	2.00	0.65	1.76	11.38	2.13	5.42
18	RBN-2014- 18	135.06	7.00	73.47	2.97	63.80	1.92	0.93	2.02	12.25	2.19	7.19
19	RBN-2014- 19	149.26	7.10	62.33	3.13	63.47	2.23	0.69	1.85	11.81	2.00	6.53
20	RBN-2014- 20	159.33	7.00	70.03	3.07	68.83	2.41	0.58	2.29	11.38	1.88	7.67
21	RBN-2014- 21	202.43*	7.03	50.73	3.33	87.67	2.27	0.44	2.48	10.50	2.04	8.21*
22	RBN-2014- 22	176.26	6.80	52.77	3.17	82.90	2.42	0.50	2.50	11.81	2.13	7.24
23	RBN-2014- 23	192.00*	8.27*	39.77	5.57*	61.83	1.89	0.29	2.29	10.94	1.81	6.90
24	RBN-2014- 22	161.43	6.96	64.13	4.00	70.30	1.80	0.56	1.79	11.81	2.31	5.40
25	RBN-2014- 25	164.25	5.60	81.13	2.98	83.93	1.90	0.60	2.46	12.69*	2.00	7.50
26	RBN-2014- 26	158.60	5.73	78.00	2.53	77.47	2.08	0.54	2.14	10.94	2.00	6.45
27	RBN-2014- 27	177.56	6.43	60.63	4.01	74.10	2.36	0.45	1.95	9.63	2.13	5.57
28	RBN-2014- 28	167.70	6.16	69.53	2.87	78.33	2.23	0.56	2.41	10.06	2.06	8.61*
29	RBN-2014- 29	156.37	6.03	44.27	3.07	68.53	2.26	0.60	1.39	10.94	2.25	4.65

***Represents characters showing significantly higher values than the best performing check.**

Sr. no	Genotypes	Plant height (cm)	No. of leaves /tiller	No. of tillers /plant	Av. No. of internodes /tiller	Leaf length (cm)	Leaf width (cm)	L/S ratio	Dry matter yield (kg/plant)	Crude protein (%)	Oxalic Acid content (%)	Green forage yield (kg/plant)
30	**C0-3 (Check))**	148.96	5.10	67.67	2.08	**82.20**	**2.52**	**0.98**	1.94	9.63	2.13	5.82
31	**NB-21 (Check**	**173.41**	**6.33**	49.86	**3.83**	72.10	1.89	0.55	2.06	8.31	2.31	5.35
32	**Phule Jaywant (Check)**	165.86	6.13	**70.06**	2.90	80.10	1.97	0.88	**2.07**	**10.94**	**2.06**	**6.33**
	Mean	162.94	6.71	62.39	3.52	72.44	2.13	0.60	2.20	10.43	2.18	6.63
	S.E.	5.37	0.38	4.58	0.33	2.94	0.14	0.05	0.21	0.59	0.10	0.53
	C.D.at 5%	15.51	1.09	13.22	0.97	8.48	0.41	0.16	0.60	1.72	0.31	1.53
	C.V.	4.66	8.00	10.39	13.53	5.74	9.61	13.65	13.48	8.10	7.10	11.36

Values in bold represent the best performing check for the concerned character

Table 4: Parameters of genetic variability for green forage yield and yield contributing characters in bajra x napier hybrids

Sr. No.	Characters	Range	General mean	Genotypic variance (σ^2_g)	Phenotypic variance (σ^2_p)	Environmental variance (σ^2_e)	GCV (%)	PCV (%)	ECV (%)	Heritability (b.s.) (%)	GA	G.A. as % of mean
1.	Plant height (cm)	124.70-202.43	162.94	201.44	259.28	57.84	8.71	9.98	4.66	77.70	25.77	15.81
2.	No. of leaves/tiller	5.60-8.53	6.71	0.38	0.66	0.28	9.17	12.17	8.00	56.80	0.95	14.23
3.	No. of tillers/plant	39.76-81.13	62.39	99.48	141.50	42.02	15.98	19.06	10.39	70.30	17.22	27.61
4.	Av. No. of Internodes/tiller	2.53-5.57	3.52	0.47	0.69	0.22	19.50	23.73	13.53	67.50	1.16	33.05
5.	Leaf length (cm)	61.83-87.67	72.44	48.87	66.16	17.29	9.65	11.22	5.74	73.90	12.37	17.08
6.	Leaf width (cm)	1.80-2.46	2.13	0.02	0.06	0.04	6.36	11.53	9.62	30.40	0.15	7.23
7.	L:S ratio	0.29-0.93	0.60	0.02	0.03	0.01	24.01	27.62	13.65	75.60	0.26	42.99
8.	Dry matter yield(kg/plant)	1.62-3.65	2.20	0.18	0.27	0.09	19.49	23.70	13.48	67.60	0.72	33.03
9.	Crude protein (%)	7.44-12.69	10.43	1.52	2.23	0.71	11.81	14.33	8.10	68.00	2.09	20.07
10.	Oxalic acid content (%)	1.81-2.81	2.18	0.04	0.06	0.02	8.81	11.32	7.10	60.60	0.30	14.14
11.	Green forage yield (kg/plant)	4.65-10.65	6.63	1.54	2.11	0.57	18.72	21.89	11.36	73.10	2.18	32.97

Table 5: Genotypic correlation coefficients of green forage yield with yield contributing character in Bajra x Napier hybrids

Sr. No	Characters	Plant height (cm)	No. of leaves /tiller	No. of tillers /plant	Av. No. of internodes/ tiller	Leaf length (cm)	Leaf width (cm)	L/S ratio	Dry matter yield (kg/plant)	Crude protein (%)	Oxalic acid content (%)	Green forage yield (kg/plant)
1	**Plant height (cm)**	**1.000**	0.280*	-0.546**	0.402**	0.480**	0.088	-0.558**	0.489**	-0.263*	-0.278*	0.450**
2	**No. of leaves/tiller**		**1.000**	-0.588**	0.708**	-0.555**	-0.002	-0.633**	0.100	-0.314*	-0.069	0.154
3	**No. of tillers/plant**			**1.000**	-0.397**	0.121	-0.287*	0.502**	0.332**	0.410**	0.041	0.264*
4	**Av. No. of internodes /tiller**				**1.000**	-0.525**	-0.460**	-0.852**	0.092	-0.287*	0.272*	-0.155
5	**leaf length(cm)**					**1.000**	0.110	0.329*	0.423**	-0.064	-0.293*	0.511**
6	**leaf width(cm)**						**1.000**	0.222	-0.228	-0.306*	-0.304*	0.043
7	**L/S ratio**							**1.000**	0.081	0.216	0.053	0.191
8	**Dry matter yield (kg/pl.)**								**1.000**	-0.007	-0.004	0.900**
9	**Crude protein (%)**									**1.000**	-0.135	0.141
10	**Oxalic acid content (%)**										**1.000**	-0.125
11	**Green forage yield (kg/pl.)**											**1.000**

Indicates significant at 5% level of significance** * Indicates significance at 1% level of significance**

Table 6: Phenotypic correlation coefficients of green forage yield with yield contributing character in bajra x napier hybrids

Sr. No	Characters	Plant height (cm)	No. of leaves /tiller	No. of tillers /plant	Av. No. of internodes/ tiller	Leaf length (cm)	Leaf width (cm)	L/S ratio	Dry matter yield (kg/plant)	Crude protein (%)	Oxalic acid content (%)	Green forage yield (kg/plant)
1	**Plant height (cm)**	**1.000**	0.351**	-0.337**	0.430**	0.408**	0.178	-0.443**	0.490**	-0.143	-0.148	0.400**
2	**No. of leaves/tiller**		**1.000**	-0.294*	0.653**	-0.349**	0.061	-0.341**	0.212	-0.150	-0.030	0.228
3	**No. of tillers/plant**			**1.000**	-0.332**	0.076	-0.208	0.342**	0.245	0.310*	-0.004	0.198
4	**Av. No. of internodes /tiller**				**1.000**	-0.419**	-0.158	-0.579**	0.170	-0.226	0.209	-0.062
5	**leaf length(cm)**					**1.000**	0.226	0.203	0.421**	-0.068	-0.236	0.495**
6	**leaf width(cm)**						**1.000**	-0.959**	0.080	-0.141	-0.136	0.105
7	**L/S ratio**							**1.000**	0.073	0.195	0.006	0.191
8	**Dry matter yield (kg/pl.)**								**1.000**	-0.014	0.034	0.845**
9	**Crude protein (%)**									**1.000**	-0.045	0.069
10	**Oxalic acid content (%)**										**1.000**	-0.188
11	**Green forage yield (kg/pl.)**											**1.000**

Indicates significance at 5% level of significance** * Indicates significance at 1% level of significance**

Table 7: Genotypic direct and indirect effect of yield components on green forage yield in 32 bajra X napier hybrids

Sr. No	Characters	Plant height (cm)	No. of leaves /tiller	No. of tillers /plant	Av. No. of internodes /tiller	Leaf length (cm)	Leaf width (cm)	L/S ratio	Dry matter yield (kg/Plant)	Crude protein (%)	Oxalic acid content (%)	Genotypic Correlation with GFY
1	Plant height(cm)	**-0.254**	-0.011	0.353	-0.867	-0.328	-0.028	0.739	0.860	0.028	-0.050	0.450**
2	No. of leaves/tiller	-0.071	**-0.039**	0.381	-1.525	0.372	0.001	0.838	0.177	0.034	-0.012	0.154
3	No. of tillers/plant	0.139	0.023	**-0.646**	0.855	-0.081	0.091	-0.665	0.584	-0.044	0.007	0.264*
4	Av. No. of internodes /tiller	-0.102	-0.028	0.257	**-2.152**	0.352	0.147	1.129	0.162	0.031	0.049	- 0.156
5	leaf length(cm)	-0.122	0.022	-0.079	1.131	**-0.670**	-0.035	-0.436	0.745	0.007	-0.052	0.511**
6	leaf width(cm)	-0.022	0.001	0.186	0.992	-0.074	**-0.318**	-0.295	-0.402	0.033	-0.054	0.044
7	L/S ratio	0.141	0.025	-0.325	1.835	-0.221	-0.071	**-1.323**	0.143	-0.023	0.010	0.192
8	Dry matter yield(kg/plant)	-0.124	-0.004	-0.215	-0.198	-0.283	0.073	-0.108	**1.759**	0.000	-0.000	0.900**
9	Crude protein (%)	0.066	0.012	-0.265	0.617	0.043	0.097	-0.286	-0.013	**-0.106**	-0.024	0.142
10	Oxalic acid content (%)	0.071	0.003	-0.026	-0.587	0.197	0.097	-0.071	-0.001	0.014	**0.178**	-0.125

Diagonal values in bold font represents direct effects and others indirect effects. R= 0.13

Table 8: Morphological characterization

Sr. No.	Description	Total No.	Genotypes
A)	**Leaf colour**		
a)	Dark green	7	RBN-2014-3, RBN-2014-7, RBN-2014-14, RBN-2014-16, RBN-2014-17, RBN-2014-23, RBN-2014-27.
b)	Green	19	RBN-2014-1, RBN-2014-2,RBN-2014-4, RBN-2014-5, RBN-2014-6,RBN-2014-8, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-15, RBN-2014-18,RBN-2014-19,RBN-2O14-20,RBN-2014-24,RBN-2014-26, RBN-2014-28, RBN-2014-29.
c)	Pale green	6	RBN-2014-21, RBN-2014-22, RBN-2014-25, CO-3(NC), NB-21(NC), P. Jaywant©.
B)	**Plant vigour-vegetative**		
a)	Good	15	RBN-2014-1, RBN-2014-2, RBN-2014-6, RNB-2014-7, RBN-2014-8, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-14, RBN-2014-15, RBN-2014-16, RBN-2014-17, CO-3(NC), NB-21(NC), P. Jaywant©.
b)	Medium	13	RBN-2014-3, RBN-2014-4, RBN-2014-5, RBN-2014-9, RBN-2014-10, RBN-2014-18, RBN-2014-19, RBN-2014-21, RBN-2014-23, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28.
c)	Poor	3	RBN-2014-20, RBN-2014-22, RBN-2014-25.
C)	**Growth habit**		
a)	Erect	30	RBN-2014-1, RBN-2014-2, RBN-2014-3, RNB-2014-4, RBN-2014-5,

			RBN-2014-6, RNB-2014-8, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-14, RBN-2014-15, RBN-2014-16, RBN-2014-17, RNB-2014-19,RBN-2O14-20, RBN-2014-21, RBN-2014-22, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28, RBN-2014-29, CO-3(NC), NB-21(NC), P. Jaywant©.
b)	Semi erect	2	RBN-2014-7, RBN-2014-18.
D)	**Pigmentation on node**		
a)	Present	6	Pink- RBN-2014-15, RBN-2014-17, RBN-2014-18, RBN-2014-26, RBN-2014-28. Purple- RBN-2014-24.
b)	Absent	26	RBN-2014-1, RBN-2014-2, RBN-2014-3, RBN-2014-4, RBN-2014-5, RBN-2014-6, RNB-2014-7, RBN-2014-8, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-14, RBN-2014-16,RBN-2014-19,RBN-2O14-20, RBN-2014-21, RBN-2014-22, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-27, CO-3(NC),NB-21(NC), P. Jaywant©
E)	**Hairiness**		
a)	Stem		
	Present	2	RBN-2014-5, RBN-2014-8,
	Absent	30	RBN-2014-1, RBN-2014-2, RBN-2014-3, RBN-2014-4,RBN-2014-6, RNB-2014-7, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-14, RBN-2014-15, RBN-2014-16, RBN-2014-17, RBN-2014-18,RBN-2014-

			19,RBN-2O14-20, RBN-2014-21, RBN-2014-22, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28, RBN-2014-29, CO-3(NC),NB-21(NC), P. Jaywant©.
b)	Leaf sheath		
	Present	15	RBN-2014-1, RBN-2014-2, RBN-2014-3, RBN-2014-5, RBN-2014-6, RNB-2014-7, RBN-2014-8, RBN-2014-13, RBN-2014-14, RBN-2014-15, RBN-2014-16, RBN-2014-22, CO-3(NC), NB-21(NC), P. Jaywant©.
	Absent	17	RBN-2014-4, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-17, RBN-2014-18,RBN-2014-19,RBN-2O14-20, RBN-2014-21, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28, RBN-2014-29.
c)	Leaf blade		
	Present	1	RBN-2014-8.
	Absent	31	RBN-2014-1, RBN-2014-2, RBN-2014-3, RBN-2014-4, RBN-2014-5, RBN-2014-6, RNB-2014-7, RBN-2014-9, RBN-2014-10, RBN-2014-11, RBN-2014-12, RBN-2014-13, RBN-2014-14, RBN-2014-15, RBN-2014-16, RBN-2014-17, RBN-2014-18,RBN-2014-19,RBN-2O14-20, RBN-2014-21, RBN-2014-22, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28, RBN-2014-29, CO-3(NC),NB-21(NC), P. Jaywant©.
F)	**Leaf waxiness**		
a)	Absent	12	RBN-2014-9, RBN-2014-10, RBN-

			2014-11, RBN-2014-14, RBN-2014-15, RBN-2014-16.
b)	Present	20	RBN-2014-1, RBN-2014-2, RBN-2014-3, RBN-2014-4, RBN-2014-5, RBN-2014-6, RNB-2014-7, RBN-2014-8, RBN-2014-12, RBN-2014-13, RBN-2014-17, RBN-2014-18,RBN-2014-19,RBN-2O14-20, RBN-2014-21, RBN-2014-22, RBN-2014-23, RBN-2014-24, RBN-2014-25, RBN-2014-26, RBN-2014-27, RBN-2014-28, RBN-2014-29, CO-3(NC), NB-21(NC), P. Jaywant©