PHENOTYPIC STABILITY AND ASSOCIATIONS OF MORPHO-PHYSIOLOGICAL CHARACTERS IN PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.]

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722,
DIST. AHMEDNAGAR, (M.S.) INDIA

in partial fulfilment of the requirement for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

CYTOGENETICS AND PLANT BREEDING

By

PRAMOD LAXMAN BADHE

DEPARTMENT OF AGRICULTURAL BOTANY,
POST GRADUATE INSTITUTE,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722
MAY, 1999.

DEDICATION

Affectionately dedicated

to

my father

Late Laxman V Badhe

... Pramod

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CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been previously
submitted by me or any
other person to any other
University or
Institute for
a degree or
diploma

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CERTIFICATE

This is to certify that, the thesis entitled, **"PHENOTYPIC ABILITY AND ASSOCIATION OF MORPHO-PHYSIOLOGICAL ARACTERS IN PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.]"**, mitted to the Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, huri - 413 722, Dist Ahmednagar, Maharashtra State, India, in partial fulfilment the requirement for the degree of **DOCTOR OF PHILOSOPHY** in **RICULTURAL BOTANY (CYTOGENETICS AND PLANT EEDING)**, embodies the results of a piece of *bona fide* research work carried by **SHRI. PRAMOD LAXMAN BADHE**, under my guidance and ervision and that no part of this thesis has been submitted for any other degree iploma

The assistance and help received during the course of this stigation have been duly acknowledged

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Place MPKV, Rahuri
Dated 5 / 5 /1999

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LIST OF ABBREVIATIONS

Symbol	Reference
AGR	Absolute growth rate between flowering and maturity
bi	Regression coefficient
cm	Centimeter (s)
D F	Degree of freedom
DMP I	Dry matter production at flowering
DMP II	Dry matter production at maturity
°C	Degree celsius
et al	and others
g	Gram (s)
G	Genotypic correlation coefficient
G x E	Genotype x environment
G M	Grand mean
h or hrs	Hour (s)
HUE	Heat unit efficiency
i e	That is
LAI	Leaf area index at flowering
no	Number
P	Phenotypic correlation coefficient
/	Per
%	Per cent
RHRB	Rahuri Bajra
RHRBI	Rahuri Bajra Inbred
RGR	Relative growth rate between flowering and maturity
SE	Standard error
S^2di	Mean square deviation
via	By way of , by means of
viz	Namely
vs	Verse

ABSTRACT

PHENOTYPIC STABILITY AND ASSOCIATION OF MORPHO-PHYSIOLOGICAL CHARACTERS IN PEARL MILLET [*Pennisetum glaucum* (L.) R. Br.]

By

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The investigation was undertaken during the period from 1995 to 1997 at Rahuri to study the phenotypic stability, heat unit requirement, heat unit efficiency, effect of photoperiod on flowering and association of grain yield with morpho-physiological characters Promising seven male sterile lines, five restorers, resultant 35 hybrids alongwith two checks were evaluated for seventeen morpho-physiological characters during *kharif* and summer under six different environments i e sowing in 2nd week of June (E1), 1st week of July (E2), 1st week of August (E3), 1st week of January (E4), 1st week of February (E5) and 1st week of March (E6)

Growth analysis studies revealed that the genotypic differences for grain yield were mainly due to differences in quicker leaf area development and its maintenance for longer period, DMP at flowering and maturity, AGR between flowering and maturity, lower stomatal densities, harvest index, effective tillers,

ear length, number of grains/cm^2 and 1000-grain weight. Physiological components *viz*, LAI, DMP, AGR, stomatal densities and harvest index were more important in this respect

Stability analysis indicated that both linear and non-linear components were observed to be important for LAI, and DMP at flowering, days to stigma emergence, plant height, fodder yield/plant, ear girth, number of grains/cm^2 and 1000-grain weight. The non-linear component was important for DMP at maturity, AGR and RGR between flowering and maturity, adaxial and abaxial stomatal densities, harvest index, number of effective tillers/plant, ear length and grain yield per plant.

Among the parents, female 9605 A had below average response for grain yield Most of the combinations involving male parents, 9611, 9612 and RHRBI 138 showed stability for grain yield

The hybrid combinations 9606A x 9611 and RHRB1A x RHRBI 178 possessed wider adaptability, while RHRB1A x RHRBI 138, RHRB2A x RHRBI 138, RHRB2A x 9612 and 9606A x RHRBI 178 exhibited suitability under favourable conditions for grain yield

None of the genotypes was found to be ideal with wider adaptability for all the characters The genotypes showing adaptability for grain yield and fodder yield also showed simultaneous stability for one or more yield components.

Considering the *per se* performance and stability in general, it can be concluded that female parents, 9605 A, 9606 A and 9607 A and male parents 9611, 9612 and RHRBI 138 are the most promising and deserve due consideration in future breeding programme The crosses obtained by using these parents would prove to be the potential combinations and need to be assessed further for their performance in future

Heat unit requirement studies indicated variation among genotypes in heat unit requirement for flowering and maturity during *kharif* and summer environments Number of genotypes showing consistent heat unit requirement from sowing to flowering and maturity during different two environments were identified RHRB 3A, RHRB 5A and RHRBI 458 were found to be the most thermosensitive genotypes, while, 9607 A and RHRBI 178 were observed to be less sensitive to temperature changes.

Efficiency of temperature utilization or heat use varies, depending upon the genotypes and also environments The parents, 9607 A, 9606 A, RHRB 2A, RHRBI 178, 9611 and 9612 have ability to produce hybrids possessing higher efficiency in conversion of absorbed heat into dry matter production and grain yield Heat unit efficiency can be used as a measure of crop efficiency under varying environments The parents with high heat unit requirement and heat unit efficiency produced hybrids with high heat unit efficiency

All the genotypes showed differential response to day length as they showed delay in flowering in all the environments over normal (E1) Average delay in flowering was more during summer day length environments than *kharif.* Hybrid involving RHRB 2A, 9605 A, 9612 and RHRBI 138 showed less delay in flowering The 9611 was found to be insensitive during *kharif* environmental day lengths

Effect of photoperiod on flowering showed differential photoperiod sensitivity in different environments Seed parents and the male parents showing more or less identical photoperiod sensitivity in same environments were identified The study suggested that parents having low photoperiod sensitivity could be used to develop photo-insensitive hybrids Photoperiod sensitivity/response can give an idea about planting schedules of seed parents in cross pollinated crop like pearl millet for synchronizing the flowering time for breeding and seed production programme

The genotypic and phenotypic correlation studies indicated that the grain yield showed a high and positive association with DMP at maturity, AGR between flowering and maturity and ear length, while moderate to high for ear girth All these characters were also positively correlated among themselves. Harvest index, fodder yield/plant, plant height and RGR between flowering and maturity showed significant and positive genotypic and phenotypic associations with grain yield in some of the environments

Path analysis revealed that the harvest index and DMP at maturity made appreciable positive and direct contribution to grain yield in most of the environments Harvest index, number of effective tillers/plant, RGR between flowering and maturity and abaxial stomatal density were found to be the most important components of grain yield in all the *kharif* environments. These characters contributed directly and indirectly through one another to their correlation with grain yield Similarly, harvest index, DMP at maturity, and fodder yield/plant were found to be important componentsof grain yield in most of the summer environments

From the studies on correlation, path and stability analysis together it can be inferred that DMP at maturity, harvest index, 1000-grain weight, ear length, ear girth, fodder yield per plant, AGR and RGR between flowering and maturity, abaxial stomatal density and number of effective tillers/plant are the important component of grain yield and whenever, there was stability for grain yield, there was simultaneous stability for one or more of these yield components

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INTRODUCTION

1. INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L) R Br] is a staple food of millions people in India and Africa. Being a drought tolerant crop, it is traditionally grown in the arid and semi-arid tropics under rainfed conditions during *kharif* It is also grown during summer season with limited irrigation in some part of the country for consumption and seed production. Pearl millet is generally grown in soils with depleted fertility which receive 150 to 750 mm of rainfall per year It has ability to withstand soil moisture stress and low soil fertility.

Pearl millet is the fourth most important cereal food crop in India, after rice, wheat and sorghum and is grown in the states of Rajasthan, Maharashtra, Gujarat, Punjab, Uttar Pradesh, Haryana, Tamil Nadu, Andhra Pradesh, Karnataka and some parts of Jammu and Kashmir In India, the total area under this crop was 11.11 million hectares with the production of 7 15 million tonnes The average per hectare yield was 707 kg. Following, Rajasthan, Maharashtra is the second largest *bajra* growing state, cultivating the crop on 16 71 lakh hectares of land and producing 11 26 lakh tonnes of grain production with an average productivity of 674 kg/ha (Anonymous, 1999). Inspite of having efficient C_4 photosynthetic mechanism, short growing season, capacity to overcome temperature fluctuations and adaptation to different day lengths, productivity of *bajra* is basically limited due to failure of development of suitable genotypes, having ability to withstand unpredictable environment and exploiting better source-sink capacity.

The harvest index reflects the sink capacity of a genotype. Improved harvest index represents the increased physiological capacity to mobilize photosynthate and translocate it to organs having economic value (Wallace *et al*, 1972). Since economic yield is only a fraction of dry matter produced, harvest index with higher total dry matter yield forms the useful measure of yield potential These parameters need to be given due consideration in breeding programmes

An ideal plant type in pearl millet should possess various desirable traits *viz*, bold grains and earliness (Singh and Govila, 1989), high tillering, high harvest index, large flag leaf area and more amount of chlorophyll 'b' (Phul *et al.*, 1974), high effective tillers, high dry fodder yield, late flowering, taller plant height, dense grains, high grain protein and early maturing types (Kumar and Dahiya, 1993) and accumulation of high dry matter and partition of the dry matter in higher proportion to the grain (Rao *et al.*, 1987) While, developing varieties for arid areas, high early seedling vigour must be incorporated for getting better crop establishment, growth and finally more product (Manga and Saxena, 1990). However, these characters themselves are the secondary effects of genes and greatly influenced by different physiological processes.

Rao *et al.* (1987) confirmed extensive varietal differences in physiological processes, determining the yield. Identification of various physiological components in different genotypes, to achieve physiological complementation and balance required for high yield is essential for rapid and predictable yield improvement Lawn and Imrie (1994) suggested the utilization of knowledge regarding physiological parameters to overcome the constraints in productivity, planning of research strategies and development of ideotypes suitable for target environments. This also offers an opportunity to identify traits conferring resistance to specific stresses.

The desirable plant type would be one which makes early growth at a faster rate and attains optimum leaf area index during vegetative phase with better partitioning of assimilates in sink during reproductive phase Because, vegetative growth prior to reproductive stage determines both sink capacity (potential number of seeds) and photosynthetic capacity for sustaining the growth and development of such economically important organs during reproductive growth stage

Plant breeders are aware of genotypic differences in adaptability, but it is still not possible to exploit them fully in breeding programme. The ultimate production capacity of the genotypes is determined by the yield and the association between various yield contributing traits. The significance of these traits and the simplicity with which they can be studied should not be underestimated for the fact that the traits are greatly influenced by the more complex physiological processes.

As pointed out by Wallace *et al.* (1972) breeding for higher yield would seem to identify physiological components causing varietal differences in economic yield and acquire understanding of their genetic control The evidence in other crops indicates that genetic variability exists for all such components Such genetically diverse parents should be selected for crosses It must be recognised that superior genotypes for complex physiological components and for economic yield may ultimately arise from transgressive segregation, sometimes in crosses, where both parents had poor performance. Selecting parents on the basis of complimentary of physiological components may simply improve the probability of finding superior segregates

Breeding genotypes with wider adaptability has been a major goal for the plant breeders A variety is desirable for commercial exploitation over wide range of environmental conditions, if adaptability in real sense is due to genetic make up. Eberhart and Russell (1966) suggested that with the stability parameters it has been possible to define adaptability of the genotypes for specific environmental conditions.

Lack of synchronization in flowering for hybrid seed production and breeding programme is a severe limitation to the choice of parental combination that can be used. Any physiological and morphological development occurring in plants is markedly influenced by temperature and day length Information on heat unit requirement is useful in estimating accurate flowering time regardless of planting dates

Early flowering is a desirable trait in pearl millet as it provides an opportunity for escape from terminal drought Mid-early pearl millet with a relatively low photoperiod sensitivity may be suitable for northern and peninsular Indian conditions (Talukdar *et al.*, 1993) The yield advantages of pearl millet hybrids are well known to farmers, but their seed production is often problematic if the two seed parents respond differently to the day length of the seed production environment.

Recently, number of new male sterile lines and restorers possessing bold grains, early maturity and downy mildew resistance have been developed at Bajra Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri However, in heterosis breeding, information on stability of newly developed parents and behaviour of hybrids under different environments and direct and indirect influence of various component characters on yield, which have less susceptibility to changing environmental conditions are quite important Study was thus formulated to interpret the importance of phenotypic stability and association of morpho-physiological characters in pearl millet with the following objectives.

1. To study phenotypic stability of different genotypes for important characters
2. To isolate genotypes suitable for different seasons under consideration.
3. To study the heat unit requirement for flowering and maturity and effect of day length on flowering
4. To study association of grain yield and important characters

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Present review is an attempt to bring together some of the recent findings on growth analysis, stability, heat unit requirement, effect of photoperiod on flowering, correlation, and path-coefficient analysis Very scanty literature is available on growth parameters, and genetics of morpho-physiological traits in pearl millet Therefore, in order to illustrate these aspects, very few but important relevant findings have been reviewed and quoted

2.1 Growth analysis

Growth and development are continuous processes leading to morphogenetic characteristics of plant species Both processes are controlled by genotype and environment. Growth is gain in dry matter, which includes differentiation One approach to the analysis of yield influencing factors and plant development as net photosynthate accumulation integrated over time is known as growth analysis This analysis came to be used extensively in the British Commonwealth Countries, including the classic work of Waston (1947, 1952) Growth analysis has been used by plant physiologists and agronomists in the United States (Radford, 1967) Only two measurements, made at frequent intervals are required for growth analysis i.e. leaf area and dry weight, while the other quantities in the analysis are derived by calculations.

2.1.1 Growth rates

Significant variation in RGR between HB-1 and its parents has been reported by Veersekharan and Rao (1971 b) The hybrid had high growth than its parents Very high growth rate was manifested 20 days after sowing. Ruwali *et al.* (1983a) reported high growth rate in HB-1 than its parents. However, in contrast to this, Vanangamudi *et al.* (1985) did not observe any significant differences for RGR and NAR between hybrid "X_5" and its parents "L 111 A" and "PT 1921"

The trend for the RGR was on the decline as the plant advanced towards maturity, while for CGR, the increase was noticed upto phase-II and followed the same pattern of RGR (Yadav and Nijhawan, 1993)

2.1.2 Leaf Area

Maximum production of dry matter (C max) corresponds to optimum value of LAI (LAI opt).

C max = Photosynthetic efficiency x LAI opt

With increase in leaf area and shading of lower leaves, photosynthetic efficiency of the canopy decreases and thus the LAI opt shifts upwards

Watson (1947) suggested that since dry matter increases due to photosynthesis and light interception, a better measure of "productive capital" would be leaf size and he proposed the use of leaf area index (LAI). Improvement in photosynthetic rate can be brought about by identifying or producing genotypes with improved canopy structure and activity of the photosynthetic apparatus, while assimilate partitioning can be brought about by manipulating the growth functions of organs and the interactions between them by means of the genetically controlled system for endogenous regulation of physiological processes (Kumakov, 1982).

Veersekharan and Rao (1971 b) and Ruwali *et al* (1983a) observed close association between leaf area and dry matter production. Mungse and Harinarayana (1985) observed that LAI in pearl millet increased slowly at first, followed by a period of rapid expansion attaining a highest value

(4 7) at the time of flowering and a decline towards maturity They have identified that the hybrid MBH-110 attains quick LAI during early growth period, which well reflects in its high dry matter production and grain yield

Genotypic differences for grain yield were mainly due to differences in early quick area development and its maintenance for longer period as reported by Mungse (1987) Yadav and Nijhawan (1993) observed the increased magnitude of leaf area and LAI values upto growth stage III The relative leaf growth rate decline toward maturity

2.1.3 Dry matter production

Donald (1962), Wallace and Munger (1966) and Singh and Stoskopf (1971) presented evidence that genetic improvement in economic yield of several crops is derived in part from higher percentage of biological yield being partitioned to plant organs constituting economic yield. The ratio of economic yield to biological yield is called the harvest index (HI) Improved harvest index represents increased physiological capacity (often termed sink power or sink capacity) to mobilize photosynthate and translocate it to organs having economic value Thus, the manner in which the net dry matter is produced and distributed among different parts of plant would determine the magnitude of economic yield

Mungse and Harinarayana (1985) in their dry matter partitioning studies observed large variation in dry matter production and distribution among the pearl millet genotypes The dry matter accumulation was rather slow during early growth stages and acquired peak after tillering stage They noticed that cultivars vary in their rate of dry matter production and relative distribution between vegetative and reproductive parts.

Rangasamy and Subbarayalu (1985) observed higher dry matter production and better partitioning in earheads of pearl millet cultivars, "MBH-110" and "PI 1921" Similar results in respect of "X_5" hybrid were reported by Vanangamudi *et al.* (1985)

It has been amply demonstrated by several research workers in different crops that dry matter production is proportionate to LAI development atleast in early growth stages. Crop growth is closely correlated with leaf area and therefore, the fundamental task in increasing yield is to ensure a quick development of a leaf area during early growth phase These and several other findings relating to crop architecture have been reviewed by Baker *et al* (1978).

Muchow (1989) studied the yield potential of high yielding F_1 hybrids of maize, sorghum and *Pennisetum americanum* and reported that grain yield of maize, was relatively stable across dates but varied with sowing date in sorghum and pearl millet High yield was associated with high biomass production both at maturity and during grain filling. They also noted that high biomass accumulation was associated with long growth duration, especially the duration of grain filling

Niwas and Sastri (1995) reported higher dry matter at vegetative (GS_1) and early reproductive (GS_2) stages might be due to greater absorbed PAR and greater diurnal temperature range leading to more per degree dry matter conservation in pearl millet.

2.1.4 Stomatal density

Shawesh *et al.* (1985) noticed higher average stomatal frequency in drought tolerant genotypes than that was recorded in susceptible genotypes in sorghum. They also observed higher number of stomata/mm^2 on abaxial surface Under non-stress soil moisture condition, stomatal frequencies were higher at the base of the leaf as compared to the abaxial leaf surfaces in both tolerant and susceptible genotypes They also reported that stomatal density was higher at the tip than the base on adaxial surface taken from the tolerant genotype under stress condition

Stomatal frequencies in flag leaf significantly higher than those of the lower three leaves of the same plant of pearl millet were reported by Das and Rajendrudu (1977) At the anthesis stage, flag leaf and upto 3rd leaf below, it did not differ in photosynthetic activity (Ruwali *et al.*, 1983 b).

Nerkar *et al.* (1981) reported that stomata were more frequent on abaxial than adaxial surface in *Vicia faba* They also reported that abaxial surface stomata were evidently more responsive to the environment than adaxial surface stomata when plants were well watered since, in the abaxial surface conductance was greater than might be expected on the basis of stomatal frequency and length measurement alone. Squire (1979) observed, that stomata of unirrigated pearl millet remain unaffected by large changes in the rate of transpiration

Henson *et al.* (1982) observed that stomatal behaviour of upper leaves of pearl millet at flowering largely operates to maximize assimilation rather than to minimize water loss. They further reported that the greater opening of adaxial than abaxial stomata under water stress may have been favoured by the upward folding of the leaf about the midrib (a characteristic of water stress in millet), suggesting, lower stress sensitivity of adaxial, compared with abaxial stomata

Henson *et al.* (1983) reported that water is conserved by mid-day stomatal closure during the vegetative phase of development, but after flowering, assimilation is maximized at the expense of increased water consumption, due to stomata remaining at least partly open However, Henson and Mahalakshmi (1985) suggested that the opening of flag leaf stomata was the outcome of an increase in panicle sink strength and when sink demand was reduced by panicle removal or eliminated by heat girdling, stomatal opening was reduced

Hofmann *et al* (1981) found highest stomatal density in hybrid No 4 as compared to its female parent and the hybrid maintaining a lower leaf temperature than either of its parents when grown under stressed and non-stressed soil moisture conditions.

Reddy (1987) observed highly significant difference in total stomatal number per plant in Foxtail millet at anthesis. They also reported that the genotype having low plant stomatal number and high dry matter accumulation would be more productive under rainfed or drought situation and also had a higher photosynthetic efficiency Similar, observations was also reported by Somashekarappa (1988) in finger millet.

Subramanian and Maheswari (1989) observed that transpiration efficiency of pearl millet was more responsive to increased atmospheric moisture and thus the physiological response explain better adaptation of pearl millet to drier region

Singh and Singh (1989) studied the effect of irrigation on stomatal pattern of sorghum, maize and pearl millet in summer season and observed that sorghum had highest stomatal frequency followed by pearl millet and maize. The stomatal frequency increased from base through middle to tip portions of leaf blades in all the crops. Abaxial leaf surface had more stomatal frequency than adaxial leaf surface. They also reported that stomatal frequency increased with the reduction in the number of irrigations, suggesting that the environmental and genetical factors play an important role in affecting the stomatal pattern in sorghum, maize and pearl millet grown in summer season

Jones *et al* (1995) reported that genotypic variation might exist within and between species due to sensitivity to declining soil moisture availability of stomatal response to light, as this could be an important factor in genotypic differences in drought tolerance, suggesting this might provide opportunities for screening different varieties for this adaptation to drought conditions

2.2 Stability

The study of stability gives an idea about the genotypic variation and the differential response of the genotypes to varying environments which helps to isolate widely adqpted genotypes and specific varieties for specific environments as well A phenotype is a result of interplay of genotype and environment The desirable genotypes may show low genotype x environment interaction for agriculturaly important characters and on the other hand, may be more flexible for other characters Such genotypes are said to be well buffered, as they can adjust their genotypic and phenotypic states in response to the changing environmental conditions This is also called genetic homeostasis (Lerner, 1954) The concept of regulatory mechanism offers variability in bonds and enables the organism to survive and be extremely useful under the set of environmental conditions

Various methods of estimating genotype x environment interactions include variance analysis and use of regression techniques (Finlay and Wilkinson, 1963 and Eberhart and Russell, 1966) particularly emphasized the need to consider the linear and non-linear components of genotypes and environment interactions for deriving the stability of genotype.

2.2.1 Morpho-physiological characters

Bhamre (1986) reported that the variance due to varieties and environments were highly significant for leaf area of the main stem Mehndiratta and Phul (1985) reported that non-additive effect fluctuated more for flag leaf area at the three environments at a single location

Mungse (1987) noted the importance of linear component for LAI at flowering, AGR and RGR between flowering and maturity and non-linear component for LAI at maturity, DMP at flowering and maturity He also reported that the stability and high mean performance for grain yield was associated with simultaneous stability and high mean performance for physiological components *viz.*, DMP at maturity, AGR, RGR and NAR between flowering and maturity. Similarly, Rasal (1992) also reported greater magnitude of linear component for flag leaf area.

Singh and Hazra (1990) found genotype "Ex Borun Bulk"s to be most stable for dry matter production G x E interactions were significant for this indicating differential behaviour of genotypes under different agroclimatic conditions Similarly, Mohammad *et al.* (1993) also reported highly significant G x E interaction for green fodder yield and dry matter.

Bidinger *et al.* (1994) observed that top cross hybrids showed a consistent increase in biomass production across all test environments, including the harsh arid zone environments

The metabolism of crop plants depends to a greater extent on the diffusion of water vapour and of gases through stomatal pores The arrangement and frequency of stomata vary widely among plant species and varieties of the same plant species (Ciha and Brun, 1975). They also reported, environmental conditions under which plants are grown, have also been shown to influence stomatal frequency.

2.2.2 Harvest index and agronomic characters

Murty *et al.* (1967) and Mungse *et al.* (1982) observed prominent genotype x environment interaction for plant height and days to flower.

Kapoor *et al* (1982) evaluated hybrids and their parents at three environments for stability of harvest index and observed that gca and sca were significant under all the environments and MS 5141 A was the best general combiner, for this trait under all the environments showing its stability Similarly, Sagar *et al.* (1984) studied 12 parents and 66 hybrids under six environments for harvest index and revealed that g x e interaction was significant and linear as well as non-linear portions of interaction were equally important They noticed wide variability for harvest index among the hybrids. They identified four crosses with high harvest index, average response and comparatively greater stability.

Dass *et al.* (1983) observed that both linear and non-linear components contributed to total g x e interaction almost in equal proportion for fodder yield which, made it difficult to predict the performance of genotype. The parents were less responsive and more stable than their hybrids. Pethani and Kapoor (1985) also reported similar results for this trait except that non-linear component was greater than linear component. Chawla and Gupta (1983) observed significant g x e interaction for fodder yield and its components

Manga *et al.* (1986) studied phenotypic stability of synchrony of ear emergence among different genotypes. The genotype x year interactions for both linear and non-linear components were significant. The genotypes they studied were stable and average in performance and were found to be responsive

Pethani and Kapoor (1986) observed higher proportion of g x e (linear) in case of days to earing whereas non-linear portion for plant height in both parents (homozygous) and hybrids (heterozygous), 5054 A was good combiner for low non-linear responsiveness for ear length and days to emergence. Similarly, Tyagi (1987) also reported more linear component for days to first ear emergence whereas, Anarse (1995) observed major portion of linear component for fodder yield per plant and non-linear for plant height

Mungse (1987) reported importance of non-linear component for harvest index, whereas, both linear as well as nonlinear components were important for this trait (Rasal, 1992)

Das (1990) suggested significant linear component of G x E for days to 50 per cent flowering, plant height and green fodder yield. They also reported that flowering reflects on the genetic nature of a genotype and hence stability of this trait will be more useful. Suryavanshi *et al.* (1990) in their studies on flowering in some elite pearl millet male sterile lines and their maintainers during three seasons of the year, revealed that all the parental lines, flowered 8 to 18 days and 12 to 24 days earlier in *kharif* than in *rabi* and summer, respectively. Significance of linear and non-linear components of genotype-environment interaction, indicate the feasibility of the prediction of phenotypic performance for days to flowering and maturity

2.2.3 Grain yield and its components

Appadurai *et al* (1978) did not observe significant genotype x environment interaction for grain yield under nine environments, while Singh and Gupta (1968) reported significant such interaction for grain yield, larger portion of which was accounted for by the linear regression on environmental means and very small portion was accounted for by non-linear components.

Tyagi *et al* (1979) studied 169 entries under six environments and observed significant linear interactions for number of tillers, ear number, ear length and greater linear interaction for ear number and ear length They indicated that stable hybrids could be expected through the use of stable parents Chaudhari *et al* (1981) noticed that population were more stable phenotypically than hybrids They further concluded that stable population with high yielding ability would be more suitable than hybrids for unpredictable environments of arid zone

Singh *et al* (1982) observed that hybrids interacted more with environment than parents for grain yield, effective tillers and ear length, suggesting that hybrids were more sensitive to changes in environment and thus were unstable Similarly, Sagar (1983) reported significant g x e interaction for grain yield and its components

Kumar *et al.* (1982) noticed that mean squares due to linear and non-linear components, of g x e interaction were significant for 1000-grain weight, however, magnitude of linear component was larger as compared to non-linear component, indicating thereby possibility of predicting for this trait.

Virk *et al.* (1984) observed a large proportion of significant g x e interaction due to the non-linear component and mean grain yield was positively associated with regression coefficients and deviation mean squares, which were important in selecting stable genotypes

Pethani and Kapoor (1985) studied phenotypic stability for grain yield in three environments Variance due to genotypes and due to genotype x environment interactions was significant for grain yield in parents In general, they found that high yielding genotypes were the most responsive to favourable environments

Dass *et al* (1985) studied 82 genotypes in different environments and observed contribution of both linear and non-linear components to the total genotype x environment interactions and revealed that, parents were less responsive and stable than their F1s for grain yield

Bhamre (1986) reported that variances due to varieties and environments were highly significant for ear length, total and effective tillers Ear girth exhibited highly significant differences among varieties and varieties x environments interactions The variance due to environments for grain yield was highly significant making the differences among varieties It further revealed, significant differences due to pooled deviation (non-linear) and highly significant differences due to environment (linear) for above characters

Pethani and Kapoor (1986) reported higher proportion of g x e (linear) for ear length whereas, for ear bearing tillers, and ear weight non-linear portion was higher in parents and both the components were at par in hybrids

Tyagi (1987) noted that linear component was more than its non-linear counterpart for grain yield but for 500 grain weight the non-linear portion was more. Mungse (1987) observed importance of linear components for productive tillers/plant while that of nonlinear component for ear length, 1000-grain weight and grain yield/plant Similarly, Suryavanshi (1989) also reported importance of this component for productive tillers, ear length, ear girth, seeds per cm^2, seed yield per ear and 1000-grain weights. The both linear as well as non-linear components were important for yield/plant in studies conducted by Baviskar (1990). They also observed, linear component played significant role for productive tillers/plant and non-linear component was important for number of tillers/plant, ear length, ear girth and 1000-grain weight

Gupta and Ndoye (1991) studied stability for grain yield at four locations over four years They found that a large proportion of the interaction was accounted by the non-linear regression on the environmental means Although the linear component was significant its magnitude was considerably smaller than that of the non-linear component

Rasal (1992) observed that variance due to G x E (linear) was significant for number of productive tillers per plant, ear length and grain yield per plant He also reported that linear component of G x E interaction was of greater magnitude for these traits whereas, non-linear was greater in magnitude for ear girth, number of grains per cm^2 and 1000-grain weight

Ugale *et al.* (1993) evaluated twenty four genotypes of pearl millet at five locations in Maharashtra. They found that the Rahuri location was most favourable environment, while Chas was found to be the poorest All the genotypes showed considerable response to changes in the environments as was obvious from the significant values of bi

Highly significant g x e interactions were reported by Pethani (1993) and Ramamoorthi *et al.* (1996). They also reported that hybrids were more stable than parents Karale (1994) observed that the major portion of G x E interaction was linear in nature for number of productive tillers per plant and number of grains per cm^2. The non-linear component was greater in magnitude for ear length, ear girth, 1000-grain weight and grain yield per plant

Anarse (1995) observed that the major portion of G x E interaction was linear in nature for number of total tillers/plant, ear length and girth, 1000-grain weight and grain yield per plant. The non-linear component was greater in magnitude for number of effective tillers/plant and number of grains per cm^2

2.3 Heat unit requirement

Although many climatic factors influence plants, temperature is one of the primary factors affecting growth Any physiological and morphological developments occurring in plants are markedly influenced by temperature Practical application of the temperature effect on plants is the heat unit concept which is based on the idea that plants have a temperature requirement for their growth, development and maturity The heat unit system has been widely used as a guide in planting schedules for an orderly harvest of canning crops and multiple cropping systems for effective land use. It has been adopted to flowering time of parent varieties in cross pollinated crops for synchronizing the flowering time for breeding and seed production

Estimating the development of crops by the remainder index, which is the total summation of the degree-days above base temperature(The point of temperature above which it is accumulated for the summation is called the base temperature) to reach a particular stage of development, has been often successful (Iwata, 1984)

Heat unit requirement for pearl millet was worked out at ICRISAT during rainy and summer season (Anonymous, 1978) It was observed that the total heat unit required was 709 during rainy season as against 775 in summer season. The dry matter production was 650 and 575 g/m^2 during rainy and summer season, respectively

Ong (1983) observed in pearl millet that temperature influenced all aspects of early vegetative developments *viz.,* emergence of seedlings, the initiation, appearance and final number of leaves and tillers. He further stated that development processes could be described by a specific thermal time (total heat units)

Bishnoi *et al.* (1985) observed that heat unit requirement for emergence of leaves did not differ within varieties upto 4 or 5 leaf stage but the difference surfaced later on, towards emergence of last leaf They also reported that with consecutive delay in sowing from 18th July to the following dates, the heat unit requirement for ear emergence, seed setting and maturity increased.

Mungse (1987) observed variation among pearl millet genotypes in heat unit requirement for flowering and maturity during *kharif, rabi and* summer seasons He identifed genotypes which recorded consistent heat from sowing to flowering during *kharif* and summer and from sowing to maturity during *kharif* and *rabi*

Craufurd and Bidinger (1988 b) used the concept of thermal time and observed that the duration of the growth phase from panicle initiation to flowering (GS_2) and from flowering to maturity (GS_3) was 320 and 390 degree days (°C d), respectively. Maiti and Soto (1990) observed significant difference for thermal units accumulated during days to flowering and physiological maturity They also reported that no clear relationship was observed with respect of GS_1 but a decrease in thermal units tended to decrease the duration of GS_2 and GS_3. He suggested that thermal unit accumulated at GS_1, GS_2 and GS_3 contributed indirectly to potential grain yield.

Choi *et al* (1990) sown the pearl millet cv Australia on seven dates between 15th April and 15th July at Suwan and observed that days to heading decreased with late sowing date but growing degree days remained relatively constant (average 697°C)

Reddy and Visser (1993) compared two pearl millet photo-sensitive, late maturing genotypes and observed that the time to reach maturity in thermal time or days and the radiation accumulated during vegetative and total growth period were highly correlated among themselves in both cultivars

Jadhav *et al.* (1996) studied pearl millet crop for five years under three sowing dates at 15 days interval in *kharif* at Solapur and they reported that heat unit efficiency was higher in early sowing than late sown crop They also reported that seed yield had positive and significant association with heat unit efficiency, suggesting that heat unit efficiency can be used as a measure of crop efficiency for use under varying agroecological situations

2.4 Effect of photoperiod on flowering

Beside genetic control, the actual duration of growth stages largely depends on environmental conditions, of which photoperiod and temperature are most important Changing the relative duration of successive growth phases of any cereals offer scope for improvement. Pearl millet exhibit considerable genotypic variation in flowering response to photothermal regimes, particularly photoperiod (Begg and Burton, 1971; Ong and Everard 1979 and Alagarswamy and Bidinger, 1985). There was also a considerable variation in the growing season length across the major pearl millet growing areas in India The implications of these response to photoperiod and temperature for adaptation of genotypes to different sowing dates and latitudes.

Pearl millet is primarily a quantitative short day plant (Bidinger and Rai, 1989) Consequently, its flowering will be earlier in shorter than in longer day length. Traditional cultivars of pearl millet depend on strong sensitivity to photoperiod (day length) in order to regulate their flowering time to the environment of their origin Pearl millet being highly cross pollinated crop, the flowering behaviour of seed parent differs when they are sown at different locations (latitude) or seasons due to their variable response to day length and temperature Therefore, photoperiod sensitivity can be a major factor in hybrid seed production and breeding programme. It is essential that two parents of the hybrid must flower simultaneously in order to give maximum yield The photoperiod sensitivity (day length) can give an idea about planting schedules of parent varieties/hybrid in cross pollinated crops for synchronizing the flowering time for breeding and seed production.

Burton (1965) observed that photoperiodism was exhibited by 40 out of 290 pearl millet introductions from Nigeria and Upper Volta These 40 short day sensitive lines reached anthesis in November whether planted in May or August They also observed that hybrids obtained from crosses between day-neutral Tift-23 A and 40 short day sensitive lines exhibited heterosis, were intermediate in maturity, and flowered in late September. They suggested that such millet planted in late in season will be suited for commercial seed production by combine harvesting

Bhardwaj and Webster (1971) studied F_1 hybrids between photoperiod sensitive, Tift-23 A (day length neutral, short and early maturing) and non-sensitive, Maiwa (day length sensitive, tall and late maturing) They observed that genes for non-restoration of cytoplasmic male sterility are present in Nigerian Maiwa populations, and that adapted A and B lines resistant to downy mildew can be produced Also seems possible to develop high-yielding, day length neutral, and day length sensitive strains from the segregating generations of Tift 23 A x Maiwa crosses

Under three photoperiod and two temperature regime, Begg and Burton (1971) compared the growth of five genotypes and observed that all genotype behaved as facultative short day plants, flowering at all photoperiods, through much earlier with short days However, Hellmers and Burton (1972) also studied two inbred lines for time required for anthesis and head development under temperature are photoperiod regime, and observed that high day and night temperatures of 32 and 29°C, combined with long day (16 hrs) of light intensity favoured growth and early flowering could be induced with 8 hrs days. They also reported that short photoperiod can control the time to anthesis Plants appeared to be more responsive to 8 hrs short days than 11 hrs short days

Considerable reduction in the time to anthesis, without any adverse effect on head development was shown by all four hybrids when responded to 14 short days was noticed by Ong and Everard (1979). They also reported that BK 560 required atleast four short days for floral initiation and another four for subsequent development

Effect of day length on phenology and crop growth was carried out at ICRISAT during rainy season of 1981. (Anonymous, 1982) Delay in panicle initiation was of approximately 13 days in all cultivars and 21 days in tall hybrids and 15 days in dwarf hybrids under the extension of normal day length of 13 0-13 5 hrs to 16 0-16.5 hrs

Carberry and Campbell (1984) studied pearl millet hybrid BJ 104 with a range of population under three photoperiod and observed that as the photoperiod lengthened from 13 5 to 14.5 and 15.5 hrs, the time taken to panicle initiation of the main axis increased from 16 to 23 and 34 days after emergence, respectively.

Alagerswamy and Bidinger (1985) observed, delayed panicle initiation (PI) and flowering and increased leaf area index and assimilate production under extended day length Similarly, Mahalakshmi and Bidinger (1985) used extended day length and observed delay panicle initiation and flowering of crops exposed to single periods of mid-season drought for pearl millet They also suggested that photoperiodic control of floral initiation can provide an escape mechanism to avoid the coincidence of mild-season water stress with sensitive period of growth

Rao *et al.* (1986) evaluated 200 samples of pearl millet for morphological and agronomic characters under two seasons, and reported that during rainy season, most of accessions flowered very late (100 days), while in the post-rainy season, they flowered early 70 (days), indicating photoperiod sensitivity They reported, early and medium maturing types are less sensitive to day length However, Craufurd and Bidinger (1988 a) observed that the duration of GS_1 was increased from 20 to 30 days when studies two hybrids of pearl millet responded similarly to the short and long day length treatment.

Bidinger and Rai (1989) studied the photoperiodic sensitivity of parental lines of pearl millet and their F_1 hybrids. They define "photoperiodic sensitivity as delay in flowering in artificially extended day lengths of 14 5 or 15.5, over flowering under natural day length of 13 9 hrs" They reported that flowering time of hybrids was correlated to that of parental lines under normal and extended day lengths. The delay in mid parent flowering time was a very effective predictor of hybrid delay in flowering They suggested that a low of photoperiodic sensitivity is a requirement for broad adaptation in a short-day species and to produce hybrids with minimum sensitivity, both parents should have low photoperiodic response.

Maiti and Soto (1990) studied 15 pearl millet cultivars showing large genetic variability in growth parameters in different sowing environments and reported that a decline in both temperature and length of photoperiod over successive sowing date from July to September had a drastic effect on phenology and yield potentials They also observed that higher photoperiod (>13 hrs), higher temperature, and a significant difference between day and night temperature could be related for higher grain yield in July sowing as compared to other

Das (1994) studied thirty seven forage pearl millet genotypes for response to flowering time and observed that there was no marked variation in phenological pattern of development sown in September at temperatures ranging from 19 to 32°C and rainfall of 20 mm. However, there was a forward alterations in flowering time for the July and October sowing when temperature ranged from 21 to 31°C. On that basis they broadly grouped the varieties as highly and moderately temperature sensitive types. While, Reddy and Visser (1993) observed in their studies that, early and partially photosensitive cultivar HK B yielded more grain than late and photosensitive cultivar Somno.

Talukdar *et al.* (1993) evaluated seven pearl millet parents with good specific combining ability for grain yield and their 21 F_1 for time to 50 per cent flowering under normal and extended day lengths and observed that significant and negative GCA effects for ICMP 83401 and ICMP 451 under both summer normal day length (SNDL) and summer extended day length (SEDL) They also observed that the GCA estimates for photoperiod sensitivity for these two parents were also significant and negative, suggesting that these parents may be particularly useful in generating early flowering photoperiod insensitive progenies. They also noticed, strong positive correlation for time to 50 per cent flowering of the hybrid and parents in the SEDL, indicating that preliminary discrimination among lines on photoperiod sensitivity can be done using SEDL

A day length-insensitive pollinator was developed at ICRISAT by back-crossing photoperiod-insensitive, early flowering into the late, day length-sensitive male parent of an outstanding early dwarf hybrid The original hybrid was agronomically excellent, but it was very difficult to multiply seed due to a 2-3 week difference in flowering between the male (late) and female (early) parent, suggesting lack of flowering synchrony in seed production which is a severe limitation to the choice of parental combinations that can be used in hybrid breeding (Anonymous, 1996)

2.5. Correlations

The progress of selection is dependent upon the knowledge of inter-relationship existing between the economic trait and its components Phenotypic association between different pairs of traits might be genetically controlled (Pleiotropy or linkage), physiolologically regulated or influenced by the environment There may be direct influence of one variable on the other or correlated by common causes The direction and degree of association between two traits indicate how easy or difficult it would be to make selection for these trait simultaneously. A brief account of work done on association of characters in pearl millet is reviewed below :

2.5.1 Morpho-physiological character

As increase in dry matter is mostly determined by NAR and leaf area, differences in dry matter accumulation must arise from variation in leaf area In general, dry matter production does depend more on variation in leaf area than NAR

Significant positive correlation of leaf width with grain yield was observed by Burton (1951) Pokhriyal *et al* (1967) and Desale (1993) reported significant and positive correlation of leaf length and breadth with grain yield. Non-significant correlations between leaf number, leaf length and grain yield have been reported by Phul (1971). Substantial influence of flag leaf area and chlorophyll 'b' on grain yield was observed by Phul *et al.* (1974) They suggested that an efficient plant type should have high tillering capacity, high harvest index, large flag leaf and more amount of chlorophyll 'b'.

Pokhriyal *et al* (1976) reported a significant positive correlation between leaf area and grain yield and the yielding advantage of leaf area may be due to greater photosynthetic activity. Similarly, Egharevba *et al.* (1983) observed positive association of leaf area and plant height with grain yield, suggesting care must be exercised in introducing them as selection criteria because of some other undesirable effects. Rao *et al.* (1987) revealed that total dry matter and leaf area were positively correlated with grain yield

Thakur (1991) observed that green fodder yield and dry matter yield were positively associated with days to 50 per cent flowering, plant height, tiller number per plant, and leaf area.

Yadav and Nijhawan (1993) observed that total dry weight, RGR and CGR had positive and significant association with grain yield, suggesting that yield would be increased by selecting for a plant type having higher CGR, RGR and more dry matter at panicle initiation to 50 per cent bloom

Mungse (1987) revealed significant positive correlation between grain yield and DMP at flowering and maturity and RGR, AGR and NAR between flowering and maturity. They also observed, positive association of dry matter production with corresponding AGR and RGR

Patil (1994) reported that hybrid RHRBI 8609 was associated with high transpiration rate, high leaf area, LAI, high total dry matter per plant and high AGR and NAR between flowering and grain filling period. Similarly, Balakrishnan and Das (1995) observed positive correlation of leaf area with grain yield Seed size and genotypes were significantly influenced by dry matter production was noticed by Manga and Yadav (1995)

Das and Rajendrudu (1977) observed high correlation of the faster rates of carbon fixation and phosphate absorption with the greater frequencies of veins and stomata in the leaves Whereas Shashidhar *et al.* (1982) observed that there was a high positive correlation between total dry matter production and grain yield of finger millet. They also observed, significant variation in the stomatal frequency and also the plant stomatal number There was positive significant relationship between total stomatal number per plant and biological yield. Some genotypes produced high biological yield with low stomatal number per plant. Shirinkina (1990) found a high value of correlation (r = 0.69) between drought resistance and number of stomata on both sides of sorghum leaf

2.5.2 Harvest index and agronomic characters

Significant and positive correlation between harvest index and grain yield was reported by Phul *et al.* (1974), Kapoor *et al.* (1982), Mungse (1987) and Virk (1988) Positive correlation of days to flowering with grain yield was noticed by Gupta and Athwal (1966) and Gupta and Dhillon (1974). In contrast, Reddy and Sharma (1982), Manga *et al.* (1985), Rao *et al.* (1987), Sagar (1992), Reddi (1994) and Balakrishnan and Das (1995) observed negative correlation between these characters.

Significant positive correlation of plant height with grain yield was reported by several workers (Shankar *et al*, 1963, Gupta and Dhillon, 1974, Mukherji *et al.*, 1982, Reddy and Sharma, 1982, Raveendran and Appadurai, 1984, Jindal and Gill, 1984, *Rao et al.*, 1987, Virk, 1988; Borole and Patil, 1991, Desale, 1993, Karthigeyan *et al.*, 1995 and Balakrishnan and Das, 1995) However, Rangaswami and Rajbhooshnam (1936) observed negative correlation of this character with grain yield

Plant height was positively correlated with head length, (Singh *et al.*, 1980, Raveendran and Appadurai, 1984, Reddi, 1994; Desale, 1993, Anarse, 1995 and Poongadi and Palanisamy, 1995), tiller number and grain size (Gupta and Dhillon, 1974), ear girth and test weight (Singh *et al*, 1980, Desale, 1993 and Anarse, 1995), whereas the negative association of plant height with productive tillers per plant was noticed by Singh *et al* (1980)

Egharevba *et al.* (1983) also reported positive correlation between grain yield and plant height, they also suggested that tall plants were not necessarily more efficient than short plant in grain production as measured by harvest index.

Mangath (1986) observed fodder yield had positive correlation with plant height, and days to flower, Kamala *et al.* (1986) observed that days to 50 per cent flowering was significantly and positively correlated with panicle length and number of basal tillers. They also observed significant position correlation of plant height with number of seeds per head, 1000-grain weight and grain yield

Sagar (1992) reported that association of days to flowering and maturity was significantly negative with plant height, tiller number, harvest index, but significantly positive with dry fodder yield and negatively non-significant with grain yield, suggesting that breeding for earliness will not be antagonistic to grain yield improvement and plant height at stage-II could serve as useful indicator for screening the material However, Bidinger and Raju (1993) observed that fodder yield and plant height were strongly and positively associated with grain yield per plant

Navale *et al* (1995) observed positive significant correlation between days to 50 per cent flowering and grain numbers per cm^2 whereas, there was a significantly negative association of days to 50 per cent flowering with test weight and grain yield Dry fodder yield showed a positive correlation with grain yield per plant (Kumar and Dahiya, 1993).

2.5.3 Grain yield and its components

High positive correlation among grain yield and its components viz., number of tillers, ear length and girth, grain density and 1000-grain weight have been reported by Shankar *et al.* (1963); Gupta and Athwal (1966); Pokhriyal *et al* (1967 a), Phul (1971); Phul *et al.* (1974), Gupta and Dhillon (1974), Meenakshi Bai *et al.* (1977); Mukherji *et al.* (1982); Reddy and Sharma (1982), Vyas (1984), Jindal and Gill (1984) and Poongodi and Palanisamy (1995). Singh *et al* (1980) also reported negative association of grain yield with ear length

A number of selection indices have been suggested by several workers Earliness (Gupta and Athwal, 1966), surface area of the earhead and height of plant (Rangaswami and Rajbhooshnam, 1936), length and girth of spike and grain yield per plant (Shankar *et al*, 1963), tiller number and earliness were the important components of yield (Gupta and Nanda, 1971), high tillering, high harvest index, large flag leaf and higher amount of chlorophyll 'b' (Phul *et al.*, 1974) and yield per plant, plant height, tillers per plant and yield per plot (Reddy and Sharma, 1982)

Phul (1971) suggested that although grain yield in pearl millet is dependent on increased head weight and high tillering, emphasis should be given to the leaf and stem characters for efficient selection of high yielding genotypes. Murty and Tewari (1967) in their study of dwarfing genes on genetic diversity observed that association between different characters viz , plant height, tiller number, ear length and ear girth appeared to be different in dwarfs, medium dwarfs and extreme dwarfs.

Sangha and Singh (1973) did not observe any correlation of grain yield with tiller numbers, fodder yield, ear length, ear girth and 1000-grain weight

Raveendran and Appadurai (1984) observed that grain yield had significant positive correlation with number of productive tillers per plant, panicle length, panicle girth and number of grains per unit of panicle length They also observed significant negative association between number of grains per unit length of panicle and 1000-grain weight.

Kamala *et al.* (1986) revealed that yield was positively and significantly correlated with number of nodal tillers and panicle number/plant. Whereas, Singh and Govila (1989) reported that 1000-grain weight had high positive correlation with grain yield

Sagar (1992) observed that grain yield exhibited significant and positive association with plant height, effective tiller number, ear length, ear weight, dry fodder yield, harvest index and 500-grain weight The high magnitude of genotypic correlation of grain yield with a number of characters especially ear weight was almost reduced to one fourth suggesting, that selection of yield should be exercised both under stress and non-stress condition.

Bidinger *et al.* (1993) reported that greater panicle length and /or diameter are often associated with a loose arrangement of spikelets at the surface of the panicle, which may allow more space for grain growth There is no direct evidence that grain growth in pearl millet is affected by the space available for grain expansion, although an increase in the density of grains per unit of panicle surface area. Similarly, grain yield was positively and significantly correlated with ear thickness, while ear thickness had highly significant correlation with plant height, days to maturity and ear length was reported by Hepziba *et al.* (1993)

Patil (1994) indicated that the grain yield possessed a high and positive association with effective tillers per plant while moderate to high for earhead girth, earhead length and plant height. All these characters were also positively correlated among themselves. Karthigeyan *et al.* (1995) showed grain yield exhibited a strong positive association with earhead weight and plant height

2.6 Path coefficient analysis

Path-coefficient analysis has been used to partition correlation coefficient into direct and indirect effects on the basis of which selection indices may be formulated and applied in breeding programmes An account of investigations on path-coefficient analysis is summarized below

2.6.1 Morpho-physiological characters

Number of leaves, leaf length, leaf breadth and stem girth contributed directly as well as indirectly to grain yield in both homozygous and heterozygous population was reported by Phul (1971). Similarly, number of leaves contribute towards grain yield directly as well as indirectly also observed by Singh and Singh (1976), whereas, Hapse and Ugale (1988) noted negative direct effect of number of leaves and leaf width on grain yield. Substantial influence of flag leaf area and chlorophyll 'b' on grain yield were observed by

Phul *et al* (1974) and Virk (1988) Greatest positive influence of leaf area (0 7418) has been reported by Pokhriyal *et al.* (1976)

Tyagi *et al.* (1980) observed dry matter yield, and tiller number had direct effect on green fodder yield Rao *et al* (1987) also observed total dry matter and number of leaves had positive, whereas, total leaf area had negative direct effect on grain yield Thakur (1991) reported that leaf area contributed directly as well as indirectly for dry matter yield. Similarly, stem girth as one of the major dry matter yield contributing characters was noticed by Pradhan *et al.* (1993)

Desale (1993) observed direct effect of leaf length (fairly high magnitude), number of leaves (negatively highest) and stem girth and leaf width (very low magnitude) on grain yield Das and Balakrishnan (1994) observed, that leaf number had positive effect on grain yield They also noticed positive indirect effect of leaf area through leaf number However, Karthigeyan *et al* (1995) reported negative direct effect of this trait on grain yield

2.6.2 Harvest index and agronomic characters

Positive influence of plant height on grain yield was reported by Phul *et al.* (1974), Reddy and Sharma (1982), Mukherji *et al.* (1982), Rao *et al* (1987), Virk (1988), Baviskar (1990), Desale (1993), Poongadi and Palaniswamy (1995) and Karthigeyan *et al.* (1995) In constrast Pokhriyal *et al.* (1976), Singh *et al* (1980), Vyas (1984), Raveendran and Appadurai (1984), Jindal and Gill (1984), Hapase and Ugale (1988), Das and Balakrishnan (1994), Hepziba *et al.* (1993) and Savery and Prasad (1995) observed negative direct effect of this trait on grain yield Positive but in low magnitude direct effect was noticed by Gupta *et al*, (1976) and Manga *et al.*, (1985) for plant height

Days to flower had direct positive effect on grain yield as reported by several workers (Mukherji *et al.*, 1982; Reddy and Sharma, 1982, Jindla and Gill, 1984, Khairwal *et al.*, 1990 and Savery and Prasad, 1995) However, Pokhriyal *et al*, (1976), Phul *et al.* (1974), Vyas (1984); Manga *et al.* (1985); and Das and Balakrishnan (1994) exerted a negative effect of this character on grain yield, whereas, Dass *et al.* (1986) noted that days to flower did not contribute much either directly or indirectly on grain yield

Singh and Singh (1976) reported that days to flower showed direct positive contribution toward grain yield as well as indirect positive effect *via* total tillers and plant height The indirect effect *via* number of leaves however was negative. They also observed negative direct effect of plant height but, indirect effect *via* days to flower and total tiller were positive which nullified negative effect of this trait. Direct effect of harvest index on grain yield was noticed by Phul *et al.* (1974), Rao *et al.* (1987) and Virk (1988)

Tyagi *et al* (1980) observed that plant height and green fodder yield, had direct effect on dry matter yield Raveendran and Appadurai (1984) in their path relationship studies revealed that plant height had negative indirect influence on grain yield through panicle length and girth, number of grains per unit length of panicle and 1000-grain weight.

Manga and Saxena (1985) noted that yield/tiller had negative association with synchrony of ear emergence but had maximum positive direct effect on grain yield Hapse and Ugale (1988) revealed that though plant height had negative direct effect on grain yield it showed positive correlation which was attributed to positive indirect effects of plant height on ear girth, effective tillers and grain size.

Plant height influenced grain yield *via* biological yield was noticed by Khairwal *et al.* (1990) and Yadav *et al.* (1993) Similarly, this trait exerted indirect effect on grain yield *via* productive tillers (Hepziba *et al.*, 1993)

Kumar and Dahiya (1993) observed days to 50 per cent heading had direct and positive impact on grain yield. Similarly, the indirect effect of plant height *via* days to 50 per cent heading (0.542) was positive but again *via* days to maturity it was negative and very high (-0 968) They also observed that dry fodder yield showed positive indirect effect *via* days to heading and plant height

Navale *et al.* (1995) revealed that fodder yield possess high magnitude of direct effect with grain yield while plant height indirectly influenced the grain yield *via* ear girth. Similarly, positive direct effect of fodder yield on grain yield was also noticed by Savery and Prasad (1995), Anarse (1995) and Karthigeyan *et al.* (1995).

2.6.3 Grain yield and its components

Phul *et al.* (1974), Singh and Singh (1976), Gupta *et al.* (1976), Mukherji *et al* (1982), Reddy and Sharma (1982), Vyas (1984), Hepziba *et al* (1993) have reported positive influence of tiller number on grain yield

Pokhriyal *et al.* (1976) reported that although number of grains per unit area (seed set) and 1000-grain weight exerted a much direct influence upon grain yield, however, the influence of these characters was offset by the negative correlation existing between these two characters

Meenakshi Bai *et al.* (1977) revealed that girth of the panicle and grain yield per plant were grain yield contributing components whereas productive tillers and length of panicle appeared to contribute less to yield.

Singh *et al.* (1980) observed that productive tillers showed maximum direct effect on grain yield. Ear length had negative association with grain yield but its direct contribution was very high, though it was neutralized by high negative indirect effects *via* plant height and productive tillers per plant Whereas, Mukherji *et al.* (1982) noted negative direct effect of ear girth on grain yield.

Raveendran and Appadurai (1984) reported that number of grains per unit length of panicle, panicle length and productive tillers per plant registered high positive direct effect on grain yield. Jindal and Gill (1984) indicated that effective tillers and ear length showed high correlation with grain yield but had low indirect effects to account for grain yield.

Manga *et al.* (1985) observed that direct contribution of tillers per plant and ear weight and indirect contribution of ear length and girth through ear weight to grain yield Substantial direct as well as indirect influence of ear girth and length and grain density on grain yield was noticed by Dass *et al.* (1986) They suggested that more reliance be placed on ear girth alongwith grain density and days to flower in any programme of selection.

Unnikrishnan (1989) studied intra-population variability in two populations and revealed that in both populations tiller number played a highly significant role in making up the yield followed by 1000-grain weight, ear length and girth Baviskar (1990) reported that the direct effect of number of productive tillers per plant, ear length, ear girth and 1000-grain weight and their correlations with grain yield were quite appreciable in magnitude These characters also contributed substantially but indirectly through one another towards grain yield

Yadav *et al* (1993) observed that seed weight showed negligible direct effect on grain yield but influenced it through threshing percentage, suggesting the importance of this trait under moisture stress condition

Patil (1994) observed that effective tillers per plant, ear girth, ear length made appreciable positive and direct contribution to grain yield Also the 1000-grain weight had low small direct effects, their positive correlations with grain yield were contributed substantially and indirectly *via* ear girth and length Similarly, 500-grain weight had no significant influence on grain yield as noticed by Yadav *et al* (1994)

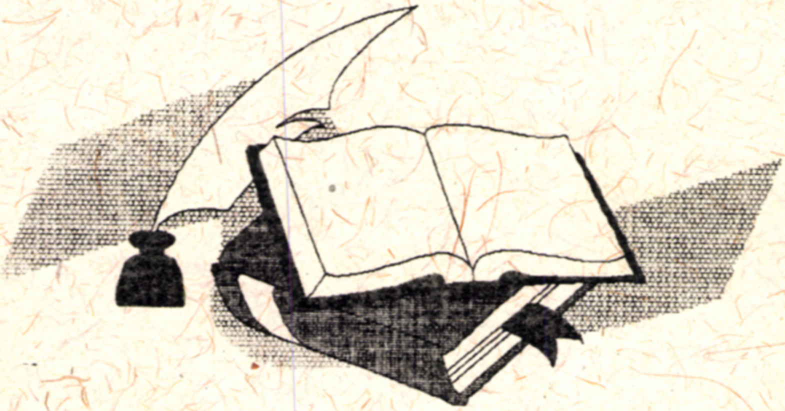
Grain yield had direct and positive effect with ear thickness, 100-seed weight, ear length and productive tillers as noticed by Hepziba *et al* (1993) Similarly, Navale *et al.* (1995) also reported that ear girth and length had high direct effect with grain yield

Diz *et al.* (1994) reported that all direct effects of the components viz , number of tillers per plant, panicle per tiller, seeds per panicle and 100-seed weight on seed yield per plant were positive. They also reported that phenotypic indirect effects were not as important as genetic indirect effects The components, seeds per plant and 100-seed weight made the greatest contribution to seed yield per plant both directly and indirectly.

Savery and Prasad (1995) observed that ear number, ear girth and length and grain weight had positive direct effect on grain yield The productive tillers and 100-grain weight had positive effect in the study conducted by Das and Balakrishnan (1994)

Reddi (1994) noticed that grain yield per main panicle and panicle number contributed high direct effects to grain yield. Whereas, Poongodi and Palanisamy (1995) reported that positive direct effect on grain per plant was exhibited by number of productive tillers, ear girth and length However, a very low negative contribution was shown by 1000-grain weight but it contributed indirectly *via* ear girth

Anarse (1995) reported that 1000-grain weight, ear girth, number of grains per cm^2 and total and effective tillers per plant contributed directly and positively to their correlations with grain yield uniformly in all the environments The direct and positive influence of the ear length was noted in three of the four environments These characters also contributed indirectly and positively through each other to their correlation with the grain yield.



MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present investigations entitled, "Phenotypic stability and association of morpho-physiological characters in pearl millet [*Pennisetum glaucum* (L) R Br] were conducted at the Post Graduate Research Farm, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *kharif* and summer seasons of 1996-97 Geographically, Rahuri is situated between 19°47' and 19° 57' North latitude and between 74°32' and 74°47' East longitude The altitude varies from 495 to 569 meter above the mean sea level

3.1 Soil and climate

In the present study all the six experiments were conducted on deep black soil Out of total precipitation of 779.8 mm received during *kharif* season for the period from 1st June to 31st October, 1996, 725 3 mm received during the crop growth period The maximum and minimum temperatures ranged from 25 1 to 35.4°C and 12 2 to 24 4°C respectively during growing season of *kharif*. The morning humidity ranged from 72 to 98 per cent and evening humidity was between 30 to 96 per cent. The open pan evaporation ranged from 0.2 to 10.8 mm. During the growing period of crop sunshine hours ranged from 0 00 to 11 2 hrs.

Temperatures during January and February, 1997 were very low (minimum 8 9°C) and maximum (28 9°C) which gradually increased during April and May, 1997 (minimum 17.5°C and maximum 36 9°C). Humidity (maximum) was high during January, 1997 (ranging between 74 to 96%) and was low during the month of May, 1997 (ranging between 59 to 86%). Open pan evaporation rate was low during January, 1997 (3.9 mm) which gradually increased during second fortnight of February, 1997 till maturity of crop (ranging 4 9 to 14 0 mm) Sunshine hours ranged from 5 4 to 11 7 hr during the growing period of summer experiment The weekly averages on rainfall, temperature, humidity, pan evaporation, sunshine hours and day length for period from June, 1996 to June 1997 are given in Appendix I

3.2 Material

The parental material selected for present study included seven male sterile lines and five restorers which were obtained from the Professor (Bajra Breeding), Mahatma Phule Krishi Vidyapeeth, Rahuri The F_1 seed of different hybrids was produced during summer season of 1996 by crossing each restorer with each male sterile line Enough crossed seed was produced in line x tester set The salient features of parents used are given below .

	Parents	Salient features
	Females	
1	RHRB 1A	Early, dwarf, compact earhead, good seed setting and good tillering, high yielding and downy mildew resistant
2	RHRB 2A	Early, dwarf, compact earhead, good seed setting, good tillering, high yielding, early vigour and downy mildew resistant
3	RHRB 3A	Early, bold grains, dwarf, non-lodging and downy mildew resistant
4	RHRB 5A	Compact earhead, good tillering, non-lodging and downy mildew resistant.
5	9605 A	Early, dwarf, longer and ticker earhead and good tillering
6	9606 A	Early, dwarf, longer and thicker earheads and good tillering
7	9607 A	Early, mid-tall, profuse tillering, more earhead girth and bolder grains

Males

1	RHRBI 138	Profuse tillering, longer and thicker ears, bolder grains, downy mildew resistant and has bristled ears
2	RHRBI 458	Early, profuse tillering, downy mildew resistant, bolder grains and bristled ears
3	RHRBI 178	Profuse tillering, thin straw, and medium dwarf.
4	9611	Longer and thicker earheads, downy mildew resistant, more tillers and bolder grains.
5	9612	Thicker and longrer earhead, downy mildew resistant, more tillers and bolder grains.

3.3 Layout

The resulting 35 hybrids alongwith twelve parents and two checks *viz.,* ICTP 8203 and MLBH 267 (49 genotypes) were sown in randomized block design with three replications under six environments (sowing dates) as below.

E1	Second week of June	E4	First week of January
E2	First week of July	E5	First week of February
E3	First week of August	E6.	First week of March

For phenotypic stability, heat unit requirement, heat unit efficiency and effect of photoperiod on flowering studies, all above mentioned 49 genotypes were considered, while for correlation and path analysis only parents were considered

The sowing was done during *kharif* on 15th June, 4th July and 4th August, 1996 whereas, it was sown on 7th January, 7th February and 7th March, 1997 in summer season Randomization of each entry was done separately for parents and hybrids in each group (Arunachalam, 1974) Each entry was sown in three rows each of three meter length spaced at 45 cm

Plants were spaced at 15 cm within a row A uniform layout of experiments was used in all the environments. Seeds were dibbled (4-5 seeds/hill) Thinning was done at 10-15 days after sowing. The material was adjusted in two tier to avoid soil heterogeneity. Guard rows were also provided to avoid border effects All the recommended cultural practices were followed to grow a good crop during all the six environments

3.4 Observations

Observation on individual plant for dry matter production at flowering and maturity whereas leaf area measured at flowering in each entry. Plant samples were dried in oven at 60°C temperature for 48 hours and weighed Leaf area was measured on Automatic leaf area meter (Model LI 3000A). Observation on days to stigma emergence were based on whole experimental population in the plot, while for remaining characters ten competitive plants from each entry were selected randomly excluding the border plants. For dry matter and leaf area studies, three plants per entry were uprooted and utilized for recording observations

Growth analysis formulae given by Waston (1958) and later on reviewed by Radford (1967) were employed to workout growth rates. From the values of dry weight and leaf area measurement per plant, different physiological attributes were derived for each entry. Observations were recorded for following characters

3.4.1 Morpho-physiological characters

i) Leaf Area Index (LAI)

Leaf area index at flowering was worked out on per plant basis by using formula.

$$\text{LAI} = \frac{\text{Leaf area/plant}}{\text{Unit ground area/plant}}$$

ii) Dry matter production (DMP) (g)

Total dry matter production per plant was recorded at flowering and maturity

Following physiological components were studied during flowering to maturity

iii) Absolute growth rate (AGR) (g/day)

Absolute growth rate is expressed as

$$\text{AGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 refer to dry matter weight per plant (g) at time t_1 and t_2 in days, respectively

iv) Relative growth rate (RGR) (g/g/day)

Relative growth rate was calculated as :

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

Where, $\text{Log}_e W_1$ and $\text{Log}_e W_2$ are the Naperian Log values of dry matter weights of plant at time t_1 and t_2, respectively.

v) Stomatal density (mm^2)

The stomatal density per unit leaf area was studied following leaf surface impression by using stickfast adhesive (colourless) at flowering Stomatal frequency was determined for adaxial (upper) and abaxial (lower) surfaces on 2nd leaf from top, which were freshly collected from selected plants during bright sunshine hours

The adhesive was smeared on the leaf surface and after 2-3 minutes, the solidified layer was pealed and mounted on slide with coverslip and observed using 10X objective and a 10X ocular (100X magnification) Stomatal frequencies were recorded from five, 0 423 mm^2 microscopic fields, then the mean of these five counts was converted into one mm^2. In selecting the area to count, care was taken to avoid having main veins in the microscopic field

3.4.2 Harvest index and agronomic characters

i) Harvest index (HI) (%)

$$HI = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Here biological yield did not include dry matter of root system.

ii) Days to stigma emergence

Number of days required for stigma emergence of the ears from sowing was recorded

iii) Plant height (cm)

Plant height was measured from soil surface to tip of ear of main shoot at maturity

iv) Fodder yield per plant (g)

The dry fodder yield per plant of sampled plants was recorded

3.4.3 Grain yield and its components

i) Number of effective tillers per plant

The number of grain bearing tillers on the sample plants.

ii) Ear length (cm)

The length of ear from base to tip on main shoot was measured.

iii) Ear girth (cm)

The maximum girth at the centre of the ear of the main shoot was measured

iv) Number of grains per cm^2

The grains in one centimeter square on the main ear were counted

v) 1000-grain weight (g)

1000-grains from the bulk of ten plants were counted and weighed

vi) Grain yield per plant (g)

Weight of grains of ten sampled plants was recorded from which average grain yield per plant was calculated

3.5 Determination of day length

Day length is a function of latitude of the place and day of the year, photoperiod at any location is decided by using different criterion such as duration from sunrise to sunset, duration from civil twilight in morning to civil twilight in evening, bright sunshine hours etc In the present investigaiton, the day length was determined by using Smithsonion Metrological handbook day length tables (List, 1958) which, includes two times the civil twilight (morning and evening) plus the actual day length itselt.

3.6 Statistical procedures

3.6.1 Stability analysis

Eberhart and Russell (1966) proposed the use of the stability parameters to describe the performance of variety over an array of environments. They showed that the regression of each culture on an environmental index and the function on the squared deviation from this regression would provide useful estimates of cultivar's stability They provided a measure of partitioning the genotype x environment interaction of each entry into (i) the variation due to the response of the variety to varying environmental indices i e bi (sum of squares due to regression) and (ii) the unexplainable deviation from the regression on the environmental index i.e S^2di The parameters are defined with following modal.

$$Yij = \mu i + \beta i \, Ij + \delta ij$$

where, Yij = Mean of the i^{th} variety at j^{th} environment

($i = 1, 2 \ldots v$, $j = 1, 2 \quad n$)

μi = Mean of i^{th} variety over all environment.

βi = The regression coefficient that measures the response of i^{th} variety to varying environments i e $bi = \sum_{j} Yij \, Ij / \sum_{j} I^2 j$

Ij = The environmental index obtained as the mean of all varieties at the j^{th} environment minus the grand mean

i e $[Ij = (\sum_{i} Yij / v) - (\sum_{i}\sum_{j} Yij / vn)]$,

$\sum_{i} j = 0$

δij = The deviation from regression of the i^{th} variety at the j^{th} environment i.e $S^2di = [\sum_{j} \hat{\delta}^2 ij / (n-2)] - S^2e / r$

The methods of joint regression analysis of Eberhart and Russell (1966) is as follow.

Source	D.F	M S
Total	(nv-1)	
Varieties (V)	(v-1)	M_1
Environments (Env)	(n-1)	
V x Env	(n-1) (v -1)	
Env + (V x Env)	v (n-1)	
Env (linear)	1	
V x Env (linear)	(v-1)	MS_2
Pooled deviations	v (n-2)	MS_3
Variety 1	(n-2)	
Variety 2	(n-2)	
⋮	⋮	
Variety v	(n-2)	
Pooled error	n(r-1) (v-1)	

Varietal means and appropriate analysis of the variances were computed for all agronomic variables. The error mean squares for different environments were then pooled (on the assumption that error being homogeneous) to obtain the error mean squares S^2e for analysis of stability.

Variety x environment interaction mean squares and its components namely variety x environment (linear) and pooled deviation from regression mean squares, were tested against pooled error mean squares Wherever pooled deviation mean square was significant, varieties and V x E linear mean squares were tested against pooled deviations. The deviation from regression for each variety was tested by using the following formula .

$$F \approx \left(\sum_{j} \hat{\sigma}^2_{ij} / n-2 \right) / \text{pooled error.}$$

Stable genotype :

A genotype with unit regression coefficient (bi =1 or not significantly deviating from unity) and the deviation not significantly different from zero ($S^2di = 0$) is said to be stable one.

$$SE (b) = \frac{\sqrt{\text{M S due to pooled deviation}}}{\sqrt{\sum_{j} I^2_j}}$$

The significance of bi values was tested by 't' test

$$\text{Test of significance for regression coefficient (bi)} = \frac{bi - 1}{SE(bi)}$$

3.6.2 Heat unit requirement

The total heat units required from sowing to flowering and maturity was worked out by total summation of the degree-days above the base temperature with the help of formula suggested by Iwata (1984) Base emperature was taken as 17°C (Anonymous, 1978).

$$\text{Degree days (heat units)} = \sum_{i=1}^{n} \frac{(\text{minimum + maximum temperature °C})}{2} - \text{base temperature}$$

.6.3 Heat unit efficiency

The heat unit efficiency (HUE) was calculated for dry matter oduction and grain yield per plant as per the Rajput (1980)

i) Heat unit efficiency for dry matter (g) $$= \frac{\text{Dry matter production/plant (g)}}{\text{Growing degree days(heat units)}}$$

ii) Heat unit efficiency *for grain yield (g)* $$= \frac{\text{Grain yield /plant (g)}}{\text{Growing degree days (heat units)}}$$

3.6.4 *Effect of photoperiod*

I) The delay in flowering was worked out by days to stigma emergence (Flowering) in specific environment minus days to stigma emergence (Flowering) in normal environment (E1).

II) The photoperiod sensitivity was calculated as per cent delay in flowering under specific environment compared to the time of flowering in the normal environment with the help of formula suggested by Talukdar *et al.* (1993)

$$\text{Photoperiod sensitivity} = \frac{[\text{Time to flowering in specific environment} - \text{Time to flowering in normal environment (E1)}]}{\text{Time to flowering in normal environment (E1)}} \times 100$$

where,

Normal environment

E1 = 2nd week of June day length (13.36 h)

Specific environments

E2 = 1st week of July day length (13 26 h)

E3 = 1st week of August day length (13 15 h)

E4 = 1st week of January day length (12 16 h)

E5 = 1st week of February day length (12.20 h)

E6 = 1st week of March day length (13.08 h)

3.6.5 Correlation coefficient

In order to study the inter-relationship between the different characters, genotypic and phenotypic correlations were worked out following the co-variance analysis method Genotypic and phenotypic correlation coefficients were worked out following Johnson *et al.* (1955)

$$\text{Genotypic 'r'} = \frac{\sigma g_{12}}{\sqrt{(\sigma^2 g_1)(\sigma^2 g_2)}}$$

where,

σg_{12} = is the genetic co-variance between two traits

$\sigma^2 g_1$ = is the genetic variance of the first trait.

$\sigma^2 g_2$ = is the genetic variance of the second trait

$$\text{Phenotypic 'r'} = \frac{\sigma p_{12}}{\sqrt{(\sigma^2 p_1)(\sigma^2 p_2)}}$$

where,

σp_{12} = is the phenotypic co-variance between two traits

$\sigma^2 p_1$ = is the phenotypic variance of the first trait

$\sigma^2 p_2$ = is the phenotypic variance of the second trait

Significance of the various correlation coefficients was tested from the statistical table for correlation coefficients at 1 and 5 per cent level of significance (Snedecor and Cochran, 1967).

3.6.6 Path coefficients analysis

To establish a cause and effect relationship, the genotypic correlation coefficients were partitioned into direct and indirect effects for path analysis as suggested by Dewey and Lu (1959).

Path coefficients were obtained by solving a set of simultaneous equations as per Dewey and Lu (1959)

$rny = Pny + rn_2p + rn_3p +$

where, rny = represents correlation between one component and yield

Pny = represents path coefficient between that character and yield

rn_2p = represents correlation between that character and each of the yield components

The indirect effect of a particular character through other character was obtained by multiplication of direct paths and particular correlation coefficient between these characters separately.

Indirect effect = $rij \times pij$

where, i = 1 to 16 and j = 1 to 16

$pij = p_1y, p_2y \ . \ .. \ pny$

The residual factors, i.e. variation in yield unaccounted for by these associations was calculated by using the following formula .

Residual effect (X) = $1 - R^2$

where, $R^2 = p_1y\, r_1y + p_2y\, r_2y + . \ . \ pny\, rny.$

RESULTS

4. RESULTS

Results of the present investigation entitled, "Phenotypic stability and association of morpho-physiological characters in pearl millet [*Pennisetum glaucum* (L) R Br] are presented under following seven major heads

4.1 Mean performance
4.2 Stability analysis
4.3 Heat unit requirement
4.4 Heat unit efficiency
4.5 Effect of day length on flowering
4.6 Correlation
4.7 Genotypic path coefficient analysis

Standard initial abbreviations as described in "Material and Methods" for different growth parameters have been used in the text of this and subsequent chapters. Mean DMP I and DMP II indicate the mean dry matter production per plant at flowering and maturity, respectively

Yield is a complex entity expressed as the product of various component characters Therefore, to understand the genetic mechanism of yield inheritance, it is better to study the inheritance of the components rather than yield itself It is difficult to group the various component characters in separate groups as all of them are interlinked with each other through the common biochemical and physiological processes. However, for the sake of convenience, the results under each major head are presented in three broad groups of characteristics *viz.,* morpho-physiological characters, harvest index and agronomic characters, grain yield and its components The symbols used for hybrids have been given in Appendix II

4.1 Mean performance of genotypes

Mean performance of parents and hybrids for seventeen characters studied are given in Table 1

4.1.1 Morpho-physiological characters

i) Leaf area index

The mean values of parents for LAI ranged from 4 02 to 8 27 in E1, 2.71 to 5 86 in E2, 0.73 to 4 20 in E3, 2 48 to 7 64 in E4, 2 90 to 7 94 in E5 and 2 48 to 7 74 in E6 Over environments, the LAI was ranged from 3 02 to 6 41 The leaf area index recorded in hybrids was ranged from 3 20 to 8.47, 3.34 to 6 38, 2 35 to 5 24, 3 14 to 9.74, 2.82 to 8.80, 2 57 to 7 57 and 3 37 to 6 94 in E1, E2, E3, E4, E5, E6 and over environments, respectively.

Among the male sterile lines the highest value of LAI was exhibited by 9607A in E1 (7.08), E3 (3 11), E5 (4 90), E6 (4.68) and over environment (4 59) The highest LAI however was recorded in case of RHRB 5A (3 65) in E2 and 9605A (5.38) in E4 Among the inbreds, 9611 had the highest leaf area index in E1(8 27), E4 (7 64) and E6 (7 74) In E2, E3 and over environments, RHRBI 138 showed highest value of LAI i e 5 86, 4 20 and 6 41 respectively The inbred RHRBI 458 exhibited the higher LAI (7 94) in E5 environment

As regards to hybrids the highest value of LAI was recorded in case of VII x 1 (8 47) in E1, IV x 2 (6 38) in E2, VI x 5 in E3 (5 24), and E4 (9 74), IV x 4 (8 80) in E5 and I x 4 in E6 (7 57) and over environments (6.94).

1 Mean performance of parents and hybrids for 17 characters in different environments

ents	LAI							DMP-I per plant (g)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
es														
RB 1A	4 99	3 50	1 77	2 48	2 90	2 48	3 02	39 60	30 80	17 56	31 93	22 93	18 06	26 81
RB 2A	4 02	3 23	1 05	4 08	3 50	3 67	3 25	34 06	28 16	13 30	34 73	25 63	25 03	26 82
RB 3A	5 06	2 71	1 33	4 69	4 35	2 86	3 49	35 10	21 16	11 30	44 36	33 06	20 86	27 64
RB 5A	6 58	3 65	0 73	4 47	3 70	3 97	3 85	43 53	34 86	7 73	44 93	32 93	17 53	30 25
5 A	5 65	3 09	3 08	5 38	4 53	3 85	4 26	50 36	36 93	31 83	48 23	40 76	31 66	40 01
6A	4 78	3 56	2 63	3 67	3 56	3 16	3 55	36 20	26 56	14 86	36 33	29 46	32 13	29 26
07 A	7 08	3 22	3 11	4 58	4 90	4 68	4 59	50 36	35 70	28 70	35 93	35 50	40 60	37 80
	5 45	3 27	1 95	4 19	3 92	3 52	3 72	41 35	30 60	17 89	39 49	31 47	26 55	31 22
BI 138	7 94	5 86	4 20	7 38	6 43	6 68	6 41	66 96	67 16	33 10	85 23	55 26	52 53	60 04
BI 458	7 38	5 77	2 68	5 78	7 94	5 96	5 91	61 60	48 26	25 23	55 93	55 73	47 70	49 07
BI 178	4 96	2 82	2 67	4 42	3 89	2 65	3 56	42 36	27 76	19 16	42 90	34 26	16 23	30 45
1	8 27	4 40	1 98	7 64	7 62	7 74	6 27	63 26	33 96	20 20	65 10	58 53	53 50	49 09
2	7 62	5 83	1 79	5 81	4 58	5 58	5 19	45 33	39 33	17 23	50 40	29 06	39 46	36 80
	7 23	4 93	2 66	6 20	6 09	5 72	5 46	55 90	43 29	22 98	59 91	46 57	41 88	45 09
ds														
x 1	5 91	5 23	3 58	6 09	6 87	4 72	5 40	46 53	48 60	35 30	66 46	63 43	40 66	50 16
x 2	5 21	6 01	2 85	4 36	5 14	5 45	4 83	45 46	49 03	30 53	55 96	41 96	44 56	44 58
x 3	3 37	4 16	2 59	3 81	2 82	3 50	3 37	33 26	31 43	27 46	34 86	20 86	23 16	28 51
x 4	6 70	5 69	3 59	9 71	8 39	7 57	6 94	50 00	45 96	31 46	89 43	73 40	57 80	58 01
x 5	4 42	4 67	2 51	6 31	4 07	4 72	4 44	39 30	43 30	23 03	55 36	33 43	37 86	38 71
x 1	4 80	4 56	2 85	4 85	4 54	4 15	4 29	49 70	32 96	30 50	47 90	45 20	29 90	39 86
x 2	5 33	4 65	3 15	6 67	5 25	4 17	4 86	43 20	44 96	36 26	63 10	38 06	30 26	42 63
x 3	4 62	4 05	2 54	3 35	3 20	2 57	3 38	46 33	33 56	25 80	34 20	31 96	19 06	31 82
x 4	5 49	4 68	3 29	7 01	5 50	6 25	5 36	41 13	44 76	34 70	70 96	49 00	47 60	48 02
x 5	5 41	3 34	3 27	6 09	4 29	4 82	4 53	43 00	32 96	27 36	51 86	31 76	41 33	38 05
x 1	6 10	4 04	3 80	7 57	5 11	6 68	5 55	46 26	34 03	35 83	73 00	40 50	55 10	47 45
x 2	4 79	4 45	3 30	5 11	5 27	5 44	4 72	42 30	40 63	30 40	45 23	38 33	40 53	39 57
x 3	5 59	3 63	2 35	3 62	4 59	2 77	3 75	53 13	25 16	19 96	33 33	33 80	20 53	30 98
x 4	5 74	5 69	4 25	8 28	7 58	7 19	6 45	48 93	45 16	42 76	72 73	63 56	60 23	35 56
x 5	5 98	4 68	4 03	6 93	6 60	6 32	5 75	40 40	33 60	32 56	54 03	55 06	43 16	43 13
x 1	7 47	6 20	3 98	5 72	5 29	4 24	5 48	63 30	58 43	40 40	75 63	47 00	32 93	52 95
x 2	7 33	6 38	4 34	5 94	6 65	5 76	6 06	73 43	53 20	42 43	61 73	55 60	48 33	55 78
x 3	4 98	3 88	3 00	4 58	3 05	3 72	3 86	39 30	36 50	22 70	40 73	23 00	23 86	31 01
x 4	6 39	6 07	3 79	6 99	8 80	6 34	6 39	55 03	49 16	44 10	72 83	73 53	49 43	57 35
x 5	8 03	4 98	2 65	7 87	7 45	4 86	5 94	75 83	39 96	30 40	64 43	64 20	33 33	51 36
x 1	5 23	4 62	3 96	4 49	5 19	4 09	4 59	45 06	43 03	40 16	40 83	39 63	39 66	41 40
x 2	6 69	6 15	3 47	5 78	5 44	4 32	5 30	56 70	53 23	35 16	52 83	51 10	34 56	47 26
x 3	3 20	4 28	3 28	3 75	4 23	3 39	3 68	29 13	27 93	32 80	38 16	32 50	31 16	31 95
x 4	6 96	3 91	4 21	4 52	5 89	4 99	5 08	48 30	35 10	42 23	46 90	57 93	37 96	44 73
x 5	5 96	5 34	3 73	5 02	5 14	4 68	4 97	45 60	39 36	33 56	44 16	39 50	25 53	37 95
x 1	5 11	4 70	3 79	7 08	4 20	4 71	4 93	46 43	41 43	43 43	72 06	55 23	36 80	49 23
x 2	5 19	6 03	4 06	6 72	5 52	5 98	5 58	46 93	53 60	39 36	52 70	59 16	41 56	48 88
x 3	6 23	3 59	3 73	3 14	3 19	2 59	3 74	49 26	31 40	35 46	30 63	26 70	21 93	32 56
x 4	5 02	4 65	4 40	8 41	6 87	6 24	5 93	44 46	38 46	36 50	77 60	48 96	48 36	49 06
x 5	6 41	4 85	5 24	9 74	7 12	4 98	6 38	39 53	40 63	52 46	70 86	56 06	35 63	49 20
x 1	8 47	5 69	5 13	7 62	6 74	4 93	6 42	73 76	51 20	42 90	60 36	62 13	35 20	54 26
x 2	6 55	4 91	4 91	7 70	5 71	5 04	5 80	50 23	48 16	47 20	64 16	45 83	42 23	49 63
x 3	5 55	4 35	3 73	3 54	3 68	3 85	4 11	46 40	31 20	30 46	34 30	27 70	29 90	33 32
x 4	6 31	5 36	4 72	8 79	6 83	6 69	6 44	44 30	40 50	38 90	96 16	58 56	49 96	54 73
x 5	5 77	5 38	4 73	8 16	5 38	5 91	5 89	41 43	39 90	46 66	61 36	46 03	43 70	46 50
	5 78	4 88	3 68	6 15	5 47	4 96	5 15	48 10	41 10	35 55	57 34	46 59	38 11	43 89
s														
3203	5 21	3 75	2 54	4 24	6 31	4 65	4 51	37 13	39 23	28 43	43 20	59 83	38 53	41 06
267	7 21	5 32	2 88	9 28	9 16	9 60	7 34	52 46	41 43	25 00	100 86	49 96	56 43	54 36
Mean	5 90	4 64	3 29	5 91	5 41	4 92	5 01	47 79	39 79	31 38	55 65	44 77	37 22	42 77
	0 35	0 24	0 19	0 36	0 21	0 33	0 07	2 93	1 93	1 84	3 31	2 06	2 61	0 59
t 5%	0 97	0 68	0 53	1 02	0 58	0 92	0 13	8 24	5 43	5 18	9 31	5 78	7 34	1 16

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nents	DMP-II per plant (g)							AGR (g/day)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
les														
RB 1A	106 43	80 03	29 93	108 83	84 90	52 43	77 09	1 91	1 42	0 39	2 20	1 94	1 15	1 49
RB 2A	88 70	74 40	29 36	102 76	73 73	60 53	71 58	1 56	1 32	0 50	1 94	1 50	1 18	1 33
IRB 3A	111 00	73 00	29 83	74 86	66 96	55 96	68 60	2 17	1 48	0 58	0 87	1 06	1 17	1 22
RB 5A	109 40	80 10	24 53	94 66	72 13	60 96	73 63	1 88	1 29	0 53	1 42	1 23	1 45	1 29
)5 A	139 43	118 53	57 33	156 86	168 10	100 23	123 41	2 54	2 33	0 80	3 10	3 98	2 29	2 50
D6A	107 70	105 90	40 10	99 43	73 60	58 43	80 86	2 04	2 27	0 79	1 80	1 38	0 88	1 52
)07 A	160 70	128 70	65 40	153 16	123 13	105 93	122 83	3 15	2 66	1 15	3 35	2 74	2 18	2 53
	117 62	94 38	39 50	112 94	94 65	70 63	88 28	2 18	1 82	0 68	2 10	1 97	1 47	1 69
BI 138	137 76	121 93	51 63	134 66	99 76	84 63	105 06	1 95	1 57	0 58	1 41	1 39	1 07	1 32
BI 458	135 06	109 00	44 76	95 66	93 56	84 53	93 75	2 10	1 74	0 61	1 14	1 18	1 23	1 33
BI 178	112 63	99 20	49 66	144 36	101 90	99 43	101 20	2 01	2 02	0 95	2 90	2 15	2 77	2 13
1	130 53	105 13	49 10	164 60	110 73	78 93	106 50	1 92	2 04	0 90	2 84	1 63	0 85	1 69
2	125 10	85 00	32 43	100 73	56 16	71 93	78 56	2 28	1 30	0 48	1 44	0 85	1 08	1 23
	128 22	104 05	45 52	128 00	92 41	83 89	97 01	2 05	1 73	0 70	1 95	1 44	1 40	1 54
ls														
x 1	168 53	119 70	62 76	125 03	137 50	95 73	118 21	3 49	2 03	0 86	1 65	2 31	1 84	2 02
x 2	160 00	112 40	69 50	87 00	102 90	103 10	105 81	3 27	1 81	1 22	0 89	1 90	1 95	1 84
x 3	146 73	114 46	59 46	143 83	110 50	90 38	110 89	3 24	2 37	1 00	3 11	2 80	2 17	2 45
x 4	173 20	133 96	79 06	148 33	112 86	120 16	127 93	3 52	2 51	1 49	1 68	1 24	2 08	2 08
x 5	134 06	118 60	59 16	114 53	131 06	81 90	106 55	2 71	2 15	1 12	1 69	3 05	1 47	2 03
x 1	162 70	119 46	62 00	143 36	107 70	104 56	116 63	3 23	2 47	0 89	2 73	1 95	2 49	2 29
x 2	151 10	114 23	56 70	166 63	127 76	87 33	117 29	3 08	1 98	0 64	2 96	2 80	1 90	2 22
x 3	123 90	106 03	45 56	87 70	103 26	87 03	92 25	2 22	2 07	0 62	1 53	2 23	2 27	1 82
x 4	151 36	123 10	61 66	164 40	114 00	91 56	117 68	3 15	2 24	0 84	2 67	2 03	1 47	2 06
x 5	150 36	109 46	59 76	144 26	106 36	83 40	109 03	3 09	2 19	1 01	2 64	2 33	1 40	2 10
x 1	165 53	124 60	68 66	129 43	89 50	115 13	115 42	3 41	2 59	1 03	1 61	1 53	2 00	2 02
x 2	153 06	118 83	66 03	130 60	89 10	85 06	107 11	3 16	2 23	1 11	2 44	1 59	1 48	2 00
x 3	123 50	107 96	55 80	135 46	157 80	81 80	110 38	2 01	2 37	1 12	2 92	3 87	2 04	2 38
x 4	171 10	131 86	65 63	170 66	142 03	104 53	130 97	3 49	2 48	0 72	2 80	2 45	1 48	2 23
x 5	170 50	108 76	59 60	159 96	111 86	100 66	118 56	3 72	2 15	0 85	3 03	1 78	1 92	2 23
x 1	168 33	141 63	61 63	129 56	97 00	94 23	115 40	3 00	2 38	0 66	1 54	1 56	2 04	1 86
x 2	160 26	134 00	63 50	135 70	93 03	93 23	113 28	2 54	2 31	0 66	2 11	1 17	1 50	1 71
x 3	152 43	103 93	50 96	170 86	90 93	74 10	107 20	3 23	1 93	0 88	3 72	2 12	1 67	2 25
x 4	178 13	127 06	72 33	158 76	112 16	90 06	123 08	3 52	2 26	0 88	2 46	1 21	1 35	1 94
x 5	153 06	145 20	62 90	115 46	105 23	76 23	109 68	2 21	3 01	1 02	1 46	1 28	1 43	1 73
1	145 23	128 36	82 43	144 80	144 06	91 46	122 72	2 95	2 44	1 32	2 97	3 26	1 73	2 44
2	159 23	135 00	91 70	113 03	121 60	101 06	120 27	2 94	2 34	1 77	1 73	2 20	2 22	2 19
3	125 93	113 60	66 23	113 63	97 53	84 56	100 25	2 77	2 45	1 05	2 11	2 03	1 78	2 02
4	188 40	132 20	85 76	132 33	105 96	96 26	123 48	4 00	2 77	1 36	2 44	1 50	1 94	2 33
5	160 80	124 16	84 23	181 43	100 40	76 23	121 21	3 29	2 52	1 58	3 92	1 90	1 69	2 48
1	173 26	130 76	76 30	156 60	108 96	105 50	125 23	3 62	2 55	1 03	2 42	1 68	2 29	2 26
2	183 00	139 03	83 36	109 56	115 60	100 73	121 88	3 89	2 44	1 38	1 62	1 76	1 97	2 17
3	156 20	107 96	63 90	113 50	134 00	72 70	108 04	3 06	2 18	0 89	2 63	3 35	1 69	2 30
4	163 13	131 63	96 43	161 96	147 90	119 06	136 68	3 39	2 66	1 87	2 41	3 09	2 36	2 63
5	151 50	136 76	89 33	155 46	110 00	102 70	124 29	3 20	2 75	1 15	2 42	1 69	2 24	2 23
1	176 93	143 36	83 33	102 06	102 76	101 73	118 36	2 95	2 63	1 26	1 19	1 27	2 22	1 92
2	186 26	127 60	94 20	123 20	120 16	115 13	127 76	3 89	2 27	1 47	1 69	2 32	2 43	2 34
3	143 16	114 70	74 76	135 73	92 40	101 03	110 30	2 77	2 39	1 38	2 90	2 02	2 37	2 30
4	210 26	137 40	73 33	153 80	111 20	96 03	130 34	4 74	2 77	1 08	1 65	1 64	1 54	2 23
5	138 93	130 73	73 30	161 43	126 93	111 36	123 78	2 79	2 60	0 83	2 86	2 53	2 26	2 30
	159 45	124 24	70 32	137 72	113 77	95 30	116 79	3 19	2 38	1 09	2 30	2 10	1 90	2 15
03	132 60	130 00	69 63	138 56	119 66	106 33	116 13	2 73	2 59	1 29	2 72	1 87	2 26	2 24
67	166 63	137 43	56 40	180 90	124 96	92 76	126 51	3 26	2 74	0 98	2 29	2 34	1 21	2 13
lean	149 88	118 30	63 09	134 08	109 21	90 76	110 88	2 91	2 25	0 99	2 23	2 01	1 78	2 02
	7 50	5 59	3 43	6 82	3 23	5 45	1 31	0 17	0 13	0 08	0 16	0 07	0 14	0 03
%	21 09	15 70	9 64	19 19	9 09	15 32	2 57	0 47	0 37	0 23	0 44	0 20	0 38	0 06

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atments	RGR (g/g/day) (10⁻²)							Adaxial stomatal density (mm²)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
ales														
HRB 1A	2 82	2 73	1 66	3 52	4 09	3 59	3 06	74 21	79 52	78 73	128 30	98 99	99 31	93 18
HRB 2A	2 75	2 77	2 51	3 10	3 31	2 95	2 89	76 82	81 73	106 34	117 24	98 99	95 12	96 04
HRB 3A	3 20	3 54	3 03	1 49	2 20	3 26	2 80	103 67	88 67	82 34	100 29	100 61	89 47	94 17
HRB 5A	2 63	2 37	3 61	2 14	2 46	4 16	2 89	78 61	108 71	90 56	117 56	102 22	93 34	98 50
605 A	2 89	3 33	1 83	3 40	4 43	3 88	3 29	87 39	83 78	84 41	104 00	88 98	99 40	91 33
606A	3 12	3 94	3 03	2 82	2 86	2 01	2 96	93 74	73 37	73 68	92 86	101 90	94 15	88 28
9607 A	3 32	3 66	2 57	4 15	3 89	3 19	3 46	76 49	88 67	71 95	92 20	100 44	92 37	87 02
n	2 97	3 19	2 61	2 94	3 32	3 29	3 05	84 42	86 35	84 00	107 49	98 88	94 74	92 64
es														
RBI 138	1 95	1 70	1 40	1 34	1 84	1 57	1 63	74 87	70 52	64 37	87 69	107 07	105 94	85 07
RBI 458	2 24	2 33	1 79	1 53	1 62	1 91	1 90	65 59	66 27	50 81	78 97	85 75	75 90	70 55
RBI 178	2 79	3 62	3 03	3 48	3 42	6 04	3 73	73 89	73 84	77 63	65 40	94 63	84 94	78 39
511	2 07	3 23	2 78	2 65	1 99	1 29	2 33	50 45	68 16	60 27	78 16	82 52	76 02	69 26
512	2 89	2 20	1 98	1 97	2 06	2 00	2 18	78 61	81 73	78 42	114 49	107 23	91 08	91 93
n	2 39	2 62	2 20	2 19	2 18	2 56	2 35	68 68	72 10	66 30	84 94	95 44	86 78	79 04
rids														
I x 1	3 68	2 57	1 80	1 77	2 42	2 86	2 51	80 56	91 20	73 69	86 40	78 32	91 24	83 57
I x 2	3 59	2 37	2 57	1 26	2 81	2 79	2 56	94 07	103 35	71 63	128 06	95 44	92 83	97 56
I x 3	4 27	3 71	2 41	4 03	5 24	4 46	4 02	76 98	94 51	78 30	97 54	75 90	104 64	87 98
I x 4	3 56	3 05	2 89	1 46	1 36	2 46	2 46	71 12	71 63	69 42	101 09	85 10	95 28	82 27
I x 5	3 50	2 87	2 95	2 08	4 27	2 58	3 04	92 93	110 61	85 01	97 54	108 84	108 36	100 55
II x 1	3 41	3 69	1 93	3 13	2 72	4 16	3 17	70 80	76 05	73 84	99 64	83 98	109 97	85 71
II x 2	3 58	2 66	1 43	2 78	3 80	3 53	2 96	89 84	91 98	77 79	79 29	96 73	103 09	89 79
II x 3	2 85	3 29	1 79	2 71	3 67	5 08	3 23	89 84	79 99	79 36	116 27	80 58	86 72	88 79
II x 4	3 73	2 89	1 79	2 40	2 64	2 17	2 60	97 00	86 15	77 63	113 36	98 51	98 35	95 16
II x 5	3 60	3 43	2 44	2 92	3 77	2 33	3 08	97 16	87 88	78 57	94 96	84 46	113 53	92 76
III x 1	3 65	3 71	2 03	1 64	2 48	2 47	2 66	70 31	95 61	76 05	89 63	104 16	93 50	88 21
III x 2	3 67	3 06	2 44	3 04	2 65	2 48	2 88	72 75	85 20	69 58	81 71	99 15	110 46	86 48
III x 3	2 39	4 15	3 25	4 01	4 82	4 63	3 87	76 66	89 62	65 95	95 44	82 04	110 30	86 67
III x 4	3 57	3 06	1 35	2 44	2 51	1 84	2 46	61 51	83 15	72 27	86 88	90 11	88 49	80 40
III x 5	4 11	3 35	1 88	3 09	2 22	2 84	2 91	107 09	76 05	80 15	92 85	104 00	101 74	93 65
IV x 1	2 79	2 53	1 32	1 53	2 26	3 50	2 32	87 77	91 20	80 94	97 86	102 87	89 95	91 76
IV x 2	2 32	2 65	1 26	2 22	1 60	2 19	2 03	91 79	83 94	79 83	116 92	105 13	93 83	95 24
IV x 3	3 86	2 98	2 56	4 09	4 31	3 80	3 59	96 35	84 09	72 74	90 44	86 39	108 03	89 67
IV x 4	3 35	2 78	1 55	2 23	1 33	2 00	2 20	69 82	68 63	71 64	98 18	82 69	89 30	80 04
IV x 5	2 01	3 67	2 27	1 68	1 54	2 76	2 32	69 65	90 09	79 06	118 21	114 17	90 43	93 60
V x 1	3 35	3 14	2 23	3 61	4 04	2 76	3 18	70 30	83 62	82 84	86 24	94 95	104 80	87 12
V x 2	2 93	2 66	2 98	2 17	2 71	3 56	2 83	68 35	91 83	76 84	83 49	85 77	82 88	81 53
V x 3	4 18	4 02	2 21	3 10	3 45	3 44	3 39	87 40	85 04	78 89	87 36	95 12	124 67	93 08
V x 4	3 88	3 79	2 22	2 96	1 89	3 11	2 97	84 14	85 83	73 68	87 04	100 28	94 79	87 63
V x 5	3 62	3 36	2 88	4 05	2 92	3 65	3 41	96 39	90 73	71 32	92 53	116 76	116 76	97 41
VI x 1	3 78	3 29	1 79	2 23	2 13	3 54	2 79	105 46	86 46	70 37	85 75	96 08	91 40	89 25
VI x 2	3 89	2 72	2 35	2 10	2 11	2 96	2 68	82 03	76 68	64 53	88 33	83 01	92 05	81 10
VI x 3	3 33	3 56	1 85	3 74	5 05	3 99	3 58	77 63	95 61	73 53	98 99	70 57	114 49	88 47
VI x 4	3 72	3 52	3 10	2 11	3 46	3 00	3 15	78 77	88 99	66 74	95 28	99 80	77 51	84 51
VI x 5	3 84	3 46	1 67	2 24	2 11	3 51	2 80	88 21	92 62	75 97	121 12	95 92	108 20	97 01
VII x 1	2 51	2 95	2 07	1 51	1 58	3 54	2 35	69 01	73 21	65 64	88 02	84 62	87 36	77 97
VII x 2	3 74	2 80	2 14	1 86	3 01	3 33	2 81	71 61	92 93	65 01	92 37	80 90	81 55	80 73
VII x 3	3 19	3 72	2 81	3 94	3 78	4 09	3 58	83 49	90 41	80 94	93 67	90 91	80 42	86 64
VII x 4	4 08	3 49	1 98	1 34	2 00	2 20	2 51	63 80	78 10	75 26	100 93	80 74	81 23	80 01
II x 5	3 46	3 37	1 42	2 78	3 17	3 12	2 88	87 41	77 31	64 85	112 23	95 60	85 91	87 22
n	3 46	3 27	2 16	2 58	2 91	3 16	2 91	82 23	86 58	74 28	97 02	92 10	97 26	88 24
cks														
8203	3 65	3 41	2 78	3 33	2 16	3 38	3 11	72 42	74 00	83 62	104 00	94 93	125 15	92 35
H 267	3 32	3 42	2 55	1 67	2 87	1 65	2 57	85 12	85 36	77 95	87 53	97 70	78 48	85 35
d Mean	3 28	3 15	2 25	2 59	2 88	3 09	2 87	81 02	84 78	75 12	97 23	93 58	96 01	87 97
±	0 14	0 12	0 14	0 12	0 10	0 18	0 03	2 45	2 45	2 77	4 03	4 36	4 07	0 81
at 5%	0 38	0 35	0 39	0 35	0 29	0 51	0 06	6 89	6 90	7 80	11 35	12 26	11 46	1 59

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ıtments	Abaxıal stomatal densıty (mm²)							Days to stıgma emergence						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
ıales														
κHRB 1A	84 80	100 19	107 60	154 71	139 53	126 45	118 88	44 66	44 66	42 66	68 33	57 00	47 00	50 72
ʀHRB 2A	86 42	91 20	117 54	154 54	128 71	130 97	118 23	44 33	44 33	45 00	73 33	56 00	46 33	51 55
RHRB 3A	117 35	105 08	95 77	133 87	158 10	113 69	120 64	42 66	44 00	46 00	79 33	61 00	51 66	54 11
ʀHRB 5A	87 07	119 44	97 67	143 89	141 10	146 63	122 64	44 66	47 33	48 00	77 66	61 66	50 00	54 88
9605 A	102 86	105 08	109 97	147 92	139 53	134 36	123 29	43 00	42 00	43 00	67 33	56 66	47 00	49 83
9606A	111 65	91 04	92 26	144 85	140 66	134 04	119 08	45 00	43 33	44 66	68 00	57 00	48 00	51 00
9607 A	87 89	97 82	78 10	113 04	115 14	124 67	102 78	42 33	41 33	42 66	66 00	56 00	46 33	49 11
an	96 86	101 41	99 84	141 83	137 54	130 12	117 93	43 80	43 85	44 56	71 42	57 96	48 04	51 60
les														
HRBI 138	87 24	83 62	76 84	131 29	136 62	123 54	106 52	50 33	48 00	50 66	80 66	65 33	57 66	58 77
HRBI 458	88 86	90 09	87 25	119 18	140 89	108 69	105 83	52 00	50 33	53 33	81 66	65 33	58 66	60 22
HRBI 178	92 61	92 30	97 20	99 32	123 19	107 88	102 08	41 33	43 33	43 33	69 66	56 00	45 00	49 77
)611	53 22	84 25	62 63	98 19	100 62	95 60	82 42	53 66	48 33	48 33	82 66	69 33	60 33	60 44
)612	99 44	104 29	105 87	148 57	131 78	117 73	117 94	53 33	52 00	50 66	79 66	64 66	54 66	59 16
ɜn	84 27	90 91	85 96	119 31	126 62	110 69	102 96	50 13	48 39	49 26	78 86	64 13	55 26	57 67
brıds														
I x 1	94 72	108 24	86 15	126 39	99 48	114 17	104 86	45 33	44 33	42 66	68 66	56 33	47 33	50 72
I x 2	116 04	127 65	91 20	148 57	125 48	127 58	122 75	47 66	47 33	46 33	78 33	63 33	51 66	55 77
I x 3	95 21	116 92	97 66	123 70	104 00	130 00	111 25	37 66	39 00	42 00	62 66	53 66	43 00	46 33
I x 4	92 44	94 19	100 67	117 08	111 43	110 94	104 46	46 33	47 00	44 00	79 00	65 33	51 00	55 44
I x 5	104 00	123 86	93 52	139 53	150 44	128 71	123 34	44 00	44 66	44 00	71 00	59 33	47 00	51 66
II x 1	85 77	92 46	95 14	107 23	99 15	140 33	103 35	43 66	42 00	43 33	66 33	55 33	44 66	49 22
II x 2	101 88	121 33	100 19	117 40	139 53	122 58	117 15	47 00	45 00	45 33	68 66	57 00	48 00	51 83
II x 3	106 12	96 09	94 51	124 67	121 12	134 20	112 78	36 33	37 66	38 33	60 00	52 66	39 66	44 11
II x 4	110 21	99 25	80 94	131 45	126 29	114 18	110 38	46 33	45 00	45 00	75 00	59 33	50 33	53 50
II x 5	122 39	106 18	110 45	120 15	106 90	132 74	116 47	45 66	43 66	42 66	67 00	55 66	45 66	50 05
III x 1	78 61	111 55	77 79	123 54	119 66	116 11	104 54	43 66	44 33	43 33	71 33	58 66	49 33	51 77
III x 2	84 63	101 61	82 99	109 16	124 67	138 56	106 94	46 66	45 00	47 33	67 66	58 00	48 00	52 11
III x 3	86 91	101 45	78 42	111 27	108 84	130 16	102 84	37 33	38 00	41 33	66 66	53 33	45 00	46 94
III x 4	67 38	92 14	79 84	121 28	107 07	114 50	97 03	47 33	46 33	45 33	72 33	61 66	51 00	54 00
III x 5	124 67	87 73	92 60	120 95	136 62	136 62	116 53	43 66	44 00	44 66	73 00	60 00	49 00	52 38
IV x 1	96 51	106 19	93 57	123 64	125 80	119 83	110 92	50 33	49 33	47 66	78 33	63 00	54 00	57 11
IV x 2	101 72	94 04	87 73	148 57	125 64	133 23	115 15	50 33	50 33	49 00	79 00	63 00	54 00	57 61
IV x 3	113 60	100 03	88 35	114 01	118 86	156 16	115 17	45 00	44 33	41 66	71 00	55 66	47 66	50 88
IV x 4	85 45	92 77	96 24	120 80	117 24	109 33	103 64	51 00	48 00	46 33	79 66	65 66	53 00	57 27
IV x 5	85 45	107 20	97 82	152 45	156 32	129 03	121 38	50 33	47 33	47 33	74 33	62 00	50 33	55 27
V x 1	91 80	108 55	115 02	121 76	119 99	143 41	116 75	43 66	42 66	43 66	64 66	57 33	47 33	49 88
V x 2	76 33	105 40	83 94	106 26	122 89	120 42	102 55	46 00	46 33	47 00	72 33	60 33	49 66	53 61
V x 3	104 48	103 50	96 56	107 07	125 87	155 52	115 50	38 33	41 00	40 66	62 33	53 33	44 66	46 72
V x 4	101 38	104 45	91 83	107 23	112 72	102 22	103 30	47 00	45 66	44 33	69 66	60 33	51 00	53 00
V x 5	*123 86*	*114 23*	*94 98*	*117 56*	*134 68*	*145 34*	*121 77*	45 66	44 33	44 00	70 00	59 33	47 66	51 83
VI x 1	130 53	102 71	88 20	103 84	135 81	118 85	113 32	47 00	45 66	46 66	71 66	60 33	49 66	53 50
VI x 2	102 86	95 46	97 97	126 61	117 24	112 24	108 73	47 66	45 00	47 33	71 00	61 00	50 66	57 77
VI x 3	92 14	111 24	82 36	144 53	92 37	138 72	110 23	40 00	39 66	41 66	63 66	54 66	46 00	47 61
VI x 4	93 09	106 03	77 78	117 56	109 01	96 90	100 06	45 66	43 33	46 00	77 33	62 66	54 00	54 83
VI x 5	94 56	116 12	79 84	156 16	118 78	124 34	114 97	46 00	46 66	44 66	74 00	61 00	50 00	53 72
VII x 1	94 07	91 67	85 05	116 27	107 55	105 45	100 01	45 33	45 66	45 00	73 00	58 00	50 33	52 88
VII x 2	82 52	107 13	77 15	145 18	112 07	111 75	105 97	46 33	45 33	47 33	73 66	60 66	52 00	54 22
VII x 3	91 30	101 45	88 83	118 05	115 98	110 94	104 42	37 33	40 33	42 00	63 00	54 33	45 33	47 05
VII x 4	77 63	95 93	94 83	108 69	98 18	89 79	94 17	47 00	48 00	46 33	75 33	64 00	52 33	55 50
/II x 5	101 72	88 83	78 10	153 58	123 06	122 25	111 25	46 33	45 33	46 33	71 66	60 00	50 00	53 27
ı	97 49	103 82	90 23	124 35	120 15	129 92	111 00	44 99	44 50	44 58	70 94	59 03	48 85	52 26
cks														
ˀ 8203	94 24	92 28	102 24	117 02	120 79	146 63	112 20	43 00	41 33	43 66	69 00	57 00	47 33	50 22
H 267	102 04	96 40	85 51	115 95	117 24	114 01	105 19	48 33	48 00	47 66	78 00	65 33	55 66	57 16
ıd Mean	96 09	101 77	91 32	126 01	122 54	123 72	110 23	45 38	44 81	45 11	71 93	59 48	49 50	52 66
ᴇ	2 46	2 52	3 08	4 37	4 23	4 07	0 84	0 45	0 47	0 38	0 84	0 60	0 55	0 13
at 5%	6 92	7 09	8 66	12 31	11 91	11 45	1 64	1 27	1 33	1 06	2 36	1 69	1 55	0 26

1. Contd

nents	Plant height (cm)							Fodder yield per plant (g)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
les														
RB 1A	147 80	149 23	92 56	115 10	99 36	107 30	118 56	46 96	28 96	13 67	47 00	30 73	21 23	31 42
RB 2A	168 83	173 20	97 16	121 00	103 70	105 76	128 27	37 53	27 53	11 60	36 03	26 46	22 93	27 01
IRB 3A	139 16	134 30	82 33	106 53	93 63	107 53	110 58	57 60	30 53	10 47	52 73	35 03	26 33	35 45
RB 5A	165 26	141 60	77 00	123 60	96 50	110 50	119 07	72 00	44 00	13 17	41 53	35 93	24 46	38 51
5 A	176 00	188 86	140 90	141 30	133 00	140 26	153 38	74 73	50 00	25 00	68 03	58 50	37 83	52 35
06A	172 20	174 60	104 26	114 60	115 50	121 90	133 84	49 80	43 33	16 83	29 96	26 70	19 73	31 06
07 A	175 30	187 13	126 80	135 53	135 73	140 00	150 08	90 00	55 83	34 87	74 43	45 26	40 33	56 78
	163 50	164 13	103 00	122 52	111 06	119 03	130 54	61 23	40 03	17 93	49 95	36 94	27 55	38 94
s														
RBI 138	218 13	235 10	165 30	196 70	181 90	198 60	199 28	85 20	58 83	31 57	66 83	57 26	49 73	58 23
RBI 458	208 86	218 93	159 30	175 20	168 23	172 80	183 88	69 30	45 66	29 50	46 33	52 03	41 33	47 36
RBI 178	169 20	177 73	143 96	142 93	142 53	141 46	154 13	65 10	46 40	29 00	60 23	40 90	42 30	47 32
1	176 73	179 90	131 00	146 13	133 40	152 63	153 30	70 96	56 50	24 07	65 26	53 80	46 80	52 90
2	180 23	178 90	120 56	128 23	125 16	136 23	144 80	70 80	40 56	15 23	35 36	30 76	29 50	37 03
	190 63	198 11	144 02	159 23	150 24	160 34	167 09	72 27	49 59	25 87	54 80	46 95	41 93	48 56
ds														
x 1	204 06	220 63	179 06	182 53	174 46	164 40	187 52	95 46	56 50	31 46	73 83	59 16	41 60	59 67
x 2	206 90	222 56	172 70	190 16	187 03	185 90	194 21	88 40	55 83	35 40	57 40	48 36	45 60	55 16
x 3	182 13	192 30	147 73	149 23	140 33	139 96	158 61	79 56	46 73	29 83	53 36	36 70	32 06	46 37
x 4	206 26	206 80	167 43	190 20	168 43	167 16	184 38	93 60	68 16	42 86	95 10	66 83	55 53	70 35
x 5	182 50	188 00	152 20	150 86	151 17	148 53	162 30	64 26	43 67	29 93	52 16	43 96	40 80	45 80
x 1	202 30	208 90	166 00	168 86	168 83	153 33	178 53	77 70	49 17	29 06	64 86	42 90	34 83	49 75
x 2	207 86	221 86	165 20	169 53	171 53	155 96	181 99	75 60	46 40	28 83	62 16	51 16	30 53	49 11
x 3	182 40	189 96	141 03	133 60	142 13	129 93	153 17	64 20	41 73	20 93	38 73	37 86	29 70	38 86
x 4	197 10	210 60	161 36	175 26	163 43	152 90	176 77	74 76	53 23	30 93	87 96	49 60	39 93	56 07
x 5	187 20	198 73	153 70	150 86	141 10	139 16	161 79	73 13	37 17	28 10	56 56	36 40	28 83	43 36
x 1	195 76	213 16	177 26	185 40	173 90	168 53	185 67	90 90	59 50	34 13	70 80	49 56	48 20	58 85
x 2	209 70	207 20	170 63	167 90	172 23	171 73	183 23	85 06	51 90	32 90	73 26	52 63	37 50	55 54
x 3	174 30	172 86	146 36	162 86	142 46	136 03	155 81	66 33	45 53	28 36	72 20	47 50	31 00	48 48
x 4	184 03	183 53	150 26	168 90	157 23	154 66	166 43	80 40	58 57	35 20	73 76	68 10	41 83	59 64
x 5	172 86	179 56	140 80	158 93	135 76	142 06	155 00	82 66	43 40	25 26	58 50	43 60	32 33	47 62
x 1	221 96	224 53	162 56	172 40	159 46	168 70	184 94	108 26	72 40	29 73	56 03	40 30	38 86	57 68
x 2	211 46	220 93	167 20	184 16	166 66	176 76	187 86	104 16	66 60	35 06	68 10	55 33	46 23	62 58
x 3	191 73	199 36	150 13	159 26	153 26	139 93	165 61	89 23	47 50	25 60	54 73	39 46	28 50	47 50
x 4	197 40	201 40	161 83	185 10	163 60	163 76	178 85	114 30	58 40	32 06	83 86	57 76	47 90	65 71
x 5	204 03	211 36	162 43	173 80	154 20	145 76	175 26	77 60	70 83	33 53	53 33	47 80	39 33	53 73
x 1	201 10	216 00	176 40	169 80	178 43	176 53	186 37	75 56	52 56	40 73	74 13	61 63	39 30	57 32
x 2	217 40	235 60	187 06	190 56	176 56	175 03	197 05	89 96	55 16	42 00	65 00	53 66	46 30	58 68
x 3	188 86	191 86	165 03	144 86	153 73	139 50	163 97	67 60	53 03	33 43	52 16	49 13	30 90	47 71
x 4	200 66	214 10	173 43	173 36	167 36	156 03	180 82	114 93	62 33	35 10	68 76	55 30	41 56	63 00
x 5	185 36	198 40	167 76	157 86	153 83	148 33	168 59	82 56	52 23	33 63	58 10	43 13	26 53	49 36
x 1	208 50	223 96	178 30	186 20	168 03	164 20	188 20	87 60	53 06	39 70	73 16	49 10	43 06	57 61
x 2	200 70	225 06	175 40	159 20	165 16	172 43	182 99	103 80	64 33	44 26	47 90	56 60	40 90	59 63
x 3	177 40	191 83	150 50	139 60	149 46	127 13	155 98	79 33	41 50	28 63	47 23	51 30	25 23	45 53
x 4	195 26	197 80	162 00	165 90	155 26	150 43	171 19	81 76	54 06	34 93	70 33	56 90	44 76	57 12
x 5	189 20	188 10	164 96	163 30	154 86	145 26	167 61	76 20	55 50	40 36	59 70	46 06	34 73	52 09
x 1	220 90	230 13	189 63	184 53	184 90	176 33	197 73	114 00	67 90	41 03	49 46	57 03	42 16	61 93
x 2	215 23	228 13	180 43	182 76	177 30	176 00	193 31	100 23	60 90	46 30	61 16	69 36	48 80	64 46
x 3	183 73	181 53	164 96	144 26	148 23	139 36	160 35	64 56	48 26	39 23	54 46	41 86	34 23	47 10
x 4	207 43	196 20	152 46	180 36	160 53	160 83	176 30	146 70	68 50	36 06	84 66	57 53	44 70	73 02
x 5	194 60	193 46	160 80	158 70	150 63	156 26	169 07	74 13	59 66	34 86	55 66	50 33	40 53	52 53
	197 34	204 77	164 10	167 99	160 88	156 29	175 35	86 99	54 93	33 98	63 67	50 68	38 71	54 83
s														
203	200 53	213 16	146 43	166 00	176 36	186 90	181 56	98 40	55 50	34 40	66 96	58 90	52 53	56 11
267	184 20	202 26	150 86	141 13	134 93	157 23	161 77	92 40	57 56	28 00	57 43	42 63	45 46	53 91
Mean	191 62	198 77	152 69	160 01	152 46	152 02	167 91	81 54	52 32	30 75	60 75	48 34	37 86	51 92
	2 95	2 97	2 61	2 84	2 40	2 24	0 63	3 98	2 66	2 05	2 76	2 24	1 86	0 63
5%	8 30	8 34	7 35	8 00	6 77	6 29	1 24	11 21	7 49	5 77	7 77	6 29	5 22	1 24

1 Contd

ents	Harvest index (%)							Number of effective tillers per plant						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
es														
'B 1A	35 83	40 39	27 09	28 40	31 75	37 92	33 56	3 10	3 26	1 30	3 66	3 06	2 03	2 73
'B 2A	41 42	45 19	18 95	36 36	37 72	35 13	35 79	3 00	3 06	1 30	3 23	3 36	2 16	2 68
RB 3A	34 34	38 61	20 67	23 66	24 39	25 87	27 92	2 46	2 83	1 23	2 33	2 10	1 23	2 03
B 5A	26 42	31 14	27 55	25 19	39 22	32 49	30 33	2 56	2 63	1 10	1 80	1 70	1 26	1 84
A	35 71	35 75	33 29	23 98	24 55	33 34	31 10	2 30	2 40	1 26	2 96	2 20	1 43	2 09
6A	34 60	36 91	32 09	26 98	36 37	34 06	33 50	2 03	2 23	1 26	1 46	1 50	1 10	1 60
07 A	36 20	35 69	30 83	21 98	31 33	30 98	31 17	2 86	2 40	1 56	2 56	2 10	1 26	2 12
	34 93	37 66	27 21	26 65	32 19	32 83	31 91	2 61	2 68	1 28	2 57	2 28	1 49	2 15
BI 138	23 72	22 66	21 80	15 13	24 73	19 60	21 27	2 10	2 53	1 56	1 70	1 50	1 13	1 75
BI 458	30 98	23 61	14 82	28 31	31 15	23 91	25 46	2 33	1 86	1 06	1 43	1 33	1 23	1 54
BI 178	28 57	29 73	28 30	25 25	29 49	24 02	27 56	3 53	3 60	1 93	4 73	3 16	2 36	3 22
	32 60	30 85	24 47	25 04	28 43	25 54	27 82	2 73	2 76	1 26	2 26	1 56	1 40	2 00
'	31 25	39 28	20 28	35 40	40 43	40 18	34 47	2 53	2 60	1 06	2 23	1 86	1 16	1 91
	29 42	29 23	21 93	25 83	30 85	26 65	27 31	2 64	2 67	1 37	2 47	1 88	1 45	2 08
s														
1	33 75	46 20	32 12	32 46	31 47	36 43	35 40	2 23	1 96	1 63	2 30	1 46	1 43	1 83
k 2	35 66	39 79	35 13	40 44	30 47	28 70	35 03	1 90	1 80	1 53	1 46	1 23	1 10	1 50
k 3	37 40	45 63	34 61	27 54	30 95	38 20	35 72	3 26	3 46	2 13	3 50	2 66	2 13	2 86
k 4	43 75	39 91	39 28	33 10	36 07	38 47	38 43	2 56	2 26	1 86	2 40	1 56	1 30	1 99
k 5	39 63	49 74	38 93	47 66	36 67	47 25	43 31	2 56	2 46	1 96	4 06	2 30	1 90	2 54
x 1	39 56	44 95	33 77	36 31	39 41	34 94	38 16	2 43	2 26	1 86	3 26	1 66	1 76	2 21
x 2	34 00	43 23	33 05	33 04	35 35	32 07	35 12	2 36	2 73	1 53	2 63	1 90	1 50	2 11
x 3	34 52	45 99	30 38	38 98	40 50	43 61	39 00	2 93	3 33	2 16	3 36	2 83	2 56	2 86
x 4	33 84	43 99	38 65	37 47	41 44	37 40	38 80	2 63	2 63	1 83	2 16	1 80	1 36	2 07
x 5	40 45	49 89	35 35	37 44	37 48	36 71	39 55	2 63	2 23	2 00	3 96	2 76	1 66	2 54
x 1	34 20	40 93	39 68	31 89	38 87	32 37	36 32	2 06	1 86	1 50	1 86	1 36	1 33	1 66
x 2	34 27	36 89	34 15	23 47	33 55	32 81	32 52	1 60	1 93	1 20	2 00	1 56	1 13	1 57
x 3	34 01	42 61	35 69	34 44	24 99	35 67	34 57	3 13	3 03	2 00	2 50	2 63	1 50	2 46
x 4	39 24	46 71	40 02	27 85	37 69	33 25	37 46	2 20	2 40	1 73	1 96	1 80	1 26	1 89
x 5	38 95	44 70	34 87	37 04	51 49	40 69	41 29	2 63	2 60	1 36	2 53	1 90	1 63	2 11
x 1	34 53	42 33	35 67	27 94	36 49	27 22	34 03	1 93	2 36	1 33	1 50	1 40	1 10	1 60
x 2	28 42	32 26	26 01	29 11	42 25	31 30	31 56	1 73	1 86	1 26	1 60	1 16	1 06	1 45
x 3	31 69	35 83	37 75	24 73	36 21	36 04	33 71	2 40	2 60	1 80	2 33	1 76	1 66	2 09
x 4	35 07	39 55	38 07	26 92	42 09	36 86	36 42	2 03	2 20	1 46	1 60	1 30	1 10	1 61
x 5	37 12	44 95	27 54	44 64	40 75	46 86	40 31	2 40	2 56	1 36	1 80	1 73	1 43	1 88
1	33 30	38 66	35 76	28 01	31 83	33 10	33 44	2 03	1 96	1 43	1 86	1 36	1 06	1 62
2	34 47	38 64	33 95	34 86	29 80	30 01	33 62	1 73	1 96	1 53	1 30	1 10	1 00	1 43
3	33 71	40 92	29 36	30 64	38 65	32 59	34 31	2 90	2 70	2 06	2 46	2 10	1 36	2 26
4	38 58	42 60	34 11	29 82	43 37	33 26	36 95	2 33	2 00	1 60	1 60	1 30	1 20	1 67
5	43 47	46 93	36 49	36 16	41 44	42 93	41 24	2 76	2 56	2 03	1 93	1 40	1 30	2 00
1	34 90	39 09	34 90	35 13	35 14	29 44	34 76	1 70	2 20	1 60	1 86	1 60	1 13	1 68
2	34 39	37 08	31 17	32 94	38 20	35 49	34 88	2 00	1 70	1 26	1 33	1 23	1 16	1 45
3	35 20	45 48	28 06	36 61	32 68	42 16	36 70	2 96	2 53	1 86	3 20	2 53	1 43	2 42
4	35 86	43 24	32 05	33 52	32 66	33 78	35 18	2 43	2 23	1 60	1 96	1 30	1 16	1 78
5	41 46	42 76	36 93	37 39	40 02	34 55	38 85	1 83	2 70	1 53	2 16	1 63	1 53	1 90
1	39 10	42 82	36 02	34 32	39 29	30 74	37 05	1 90	1 76	1 33	1 20	1 40	1 13	1 45
2	37 94	41 50	30 81	30 26	33 23	24 70	33 07	1 70	1 76	1 46	1 40	1 20	1 06	1 43
3	37 65	43 20	35 01	30 19	35 47	36 38	36 62	3 25	3 30	2 10	2 86	1 60	1 66	2 46
4	34 24	40 02	38 67	30 15	33 62	36 08	35 46	2 20	1 90	1 20	1 60	1 06	1 00	1 49
5	38 77	42 06	34 50	33 97	41 71	42 30	38 88	2 66	2 46	1 43	2 30	1 73	1 36	1 99
	36 37	42 32	34 53	33 33	36 89	35 55	36 50	2 34	2 34	1 64	2 22	1 69	1 38	1 94
03	33 13	36 48	32 88	31 60	34 93	35 39	34 07	2 40	2 46	1 53	1 76	1 36	1 06	1 76
67	36 01	42 99	30 43	33 86	39 84	37 32	36 74	3 20	3 30	1 70	3 33	2 10	1 56	2 53
ean	35 39	40 21	32 08	31 58	35 62	34 29	34 86	2 43	2 46	1 56	2 31	1 80	1 40	1 99
	1 48	1 54	1 75	1 51	1 33	1 54	0 36	0 19	0 22	0 10	0 20	0 10	0 10	0 04
%	4 17	4 33	4 93	4 24	3 74	4 34	0 71	0 53	0 61	0 29	0 55	0 28	0 28	0 07

e 1 Contd

ments	Ear length (cm)							Ear girth (cm)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
ales														
IRB 1A	14 48	15 24	10 22	12 55	12 73	13 28	13 08	10 04	9 48	8 32	9 15	8 70	8 69	9 06
IRB 2A	17 66	16 79	10 93	14 05	13 91	15 11	14 74	10 83	10 47	8 45	9 87	9 78	9 42	9 80
HRB 3A	17 77	16 69	9 62	13 22	13 13	13 84	14 04	10 15	10 40	8 28	9 63	8 84	9 59	9 48
IRB 5A	14 82	14 12	9 30	11 58	12 40	12 38	12 43	9 92	9 35	7 52	9 07	8 22	8 48	8 76
05 A	20 49	21 49	16 87	16 72	17 99	19 31	18 81	12 02	12 14	10 69	10 79	10 79	11 01	11 24
06A	17 01	17 24	13 03	12 81	13 62	13 39	14 52	11 90	11 78	10 59	10 41	10 02	10 40	10 85
607 A	23 85	23 16	20 05	20 84	21 51	24 00	22 23	11 83	11 38	10 91	11 20	10 92	11 29	11 25
	18 01	17 81	12 86	14 53	15 04	15 90	15 69	10 95	10 71	9 25	10 01	9 61	9 84	10 06
s														
RBI 138	21 55	22 62	15 15	17 23	19 73	20 71	19 50	12 13	11 74	9 82	9 96	10 42	10 57	10 77
RBI 458	19 50	18 42	13 25	16 50	20 05	21 08	18 13	12 50	12 28	11 08	11 72	12 17	12 21	11 99
RBI 178	17 28	16 75	13 24	14 16	15 12	16 33	15 48	8 90	8 08	8 25	8 80	8 47	8 84	8 56
1	19 14	19 75	16 69	15 97	17 26	17 57	17 73	11 84	10 80	9 40	10 24	9 74	10 11	10 35
2	17 50	16 85	11 43	15 85	16 45	17 47	15 92	11 68	10 70	9 03	10 41	9 89	9 67	10 23
	18 99	18 87	13 95	15 94	17 72	18 63	17 35	11 41	10 72	9 51	10 22	10 14	10 28	10 38
ds														
x 1	20 07	20 37	17 82	18 08	18 40	20 99	19 29	12 06	11 63	10 62	11 21	10 47	10 32	11 05
x 2	21 38	21 01	15 67	18 45	20 45	20 48	19 57	12 09	11 60	10 84	11 24	11 03	11 36	11 36
x 3	19 56	17 88	14 99	15 19	16 07	17 96	16 94	9 93	9 73	8 67	9 57	8 92	9 31	9 35
x 4	22 13	20 86	17 94	16 65	17 57	19 64	19 13	11 86	11 29	10 51	11 49	10 25	11 06	11 07
x 5	19 07	18 40	15 96	17 23	17 49	18 87	17 84	10 65	10 77	9 73	10 95	9 88	9 88	10 31
x 1	22 44	20 74	19 28	19 72	18 69	21 86	20 45	12 13	11 58	11 09	11 37	10 47	10 59	11 20
x 2	22 30	21 94	17 65	18 98	20 26	21 93	20 51	11 91	11 67	11 08	11 95	11 43	11 17	11 53
x 3	19 28	18 15	14 82	15 60	16 22	17 13	16 87	9 57	9 88	8 63	9 12	8 99	8 74	9 15
x 4	20 87	20 33	15 34	15 72	17 42	19 77	18 24	11 35	11 27	10 18	10 96	10 44	10 95	10 86
x 5	21 46	19 59	14 27	17 78	17 43	19 52	18 34	10 96	11 16	10 24	11 16	9 80	9 78	10 51
x 1	23 69	22 42	18 67	17 72	19 23	21 81	20 59	11 60	11 33	10 47	10 56	10 49	10 80	10 87
x 2	23 84	23 20	17 01	20 06	20 32	22 84	21 21	11 69	11 10	10 93	11 94	11 33	11 13	11 35
x 3	19 99	17 39	12 18	16 41	17 64	18 84	17 07	9 42	8 97	8 91	10 19	9 76	9 75	9 50
x 4	22 56	21 71	16 70	16 87	18 73	19 96	19 42	11 83	11 35	11 02	10 98	10 91	11 24	11 22
x 5	21 64	20 83	16 43	18 31	18 98	20 67	19 47	11 38	11 49	10 13	10 95	10 28	10 58	10 80
x 1	20 69	19 31	15 87	16 68	17 52	18 07	18 02	11 85	11 21	10 34	10 17	9 93	10 27	10 63
x 2	20 57	21 21	15 76	17 88	18 86	19 19	18 91	12 30	11 73	10 54	11 11	10 70	11 36	11 29
x 3	20 09	17 92	14 66	14 44	16 76	16 93	16 80	9 73	9 58	8 54	8 85	9 39	9 19	9 21
x 4	21 16	19 19	14 92	16 04	17 50	19 12	17 99	11 73	10 90	9 90	10 47	10 20	10 67	10 64
x 5	20 65	20 43	15 27	15 85	17 38	18 57	18 02	11 28	10 95	9 26	10 24	10 02	10 01	10 29
x 1	23 11	20 69	18 42	19 20	20 85	20 42	20 45	11 98	11 28	10 80	11 70	11 38	10 83	11 33
x 2	25 16	25 29	20 34	22 29	20 94	22 98	22 83	12 75	12 05	11 93	12 90	11 89	12 38	12 31
x 3	22 38	19 80	16 98	15 69	18 94	18 80	18 76	10 07	10 30	9 87	10 10	10 15	10 16	10 11
x 4	23 24	22 01	19 72	18 86	18 47	21 16	20 58	12 62	11 51	11 03	11 22	10 92	11 15	11 41
x 5	22 02	20 87	18 31	18 58	19 18	19 87	19 81	12 11	11 29	11 13	11 22	11 04	11 00	11 30
x 1	22 25	22 63	18 10	19 77	20 48	20 89	20 68	12 56	12 69	11 75	11 80	11 47	11 77	11 99
x 2	24 06	23 29	17 51	19 85	21 31	23 31	21 55	13 35	13 04	12 68	13 05	12 44	13 08	12 94
x 3	20 03	18 30	14 05	15 40	17 24	16 33	16 89	10 68	10 66	9 52	10 37	10 36	10 07	10 28
x 4	22 23	20 83	18 42	18 03	19 21	20 21	19 82	12 35	11 79	10 96	12 08	11 22	11 80	11 70
x 5	21 08	21 01	17 57	19 38	19 39	20 50	19 82	12 07	11 84	11 21	11 47	11 20	11 37	11 53
x 1	27 15	26 42	23 58	21 73	23 84	24 50	24 54	12 19	12 17	11 60	11 76	11 26	11 04	11 67
x 2	28 14	25 20	23 68	24 41	25 16	26 90	25 58	13 20	12 99	12 15	12 72	12 15	12 08	12 55
x 3	21 11	20 87	17 84	18 41	17 87	21 23	19 55	10 62	10 16	9 94	10 79	10 09	10 51	10 35
x 4	26 76	24 31	18 93	19 71	20 78	22 63	22 18	12 71	11 91	10 75	12 24	11 48	11 82	11 82
x 5	22 43	23 50	15 83	20 53	20 52	24 61	21 24	12 02	11 64	10 70	11 33	11 13	11 08	11 32
	22 13	21 08	17 16	18 16	19 06	20 53	19 68	11 61	11 26	10 50	11 12	10 65	10 81	10 99
s														
203	23 51	21 15	15 83	19 85	21 26	22 16	20 63	11 16	11 00	9 66	11 30	11 51	11 41	11 01
267	22 26	21 43	16 69	19 34	19 22	19 75	19 78	11 65	11 19	9 56	10 82	9 72	10 81	10 62
Mean	21 25	20 40	16 18	17 47	18 39	19 69	18 89	11 49	11 12	10 18	10 87	10 45	10 63	10 78
	0 50	0 35	0 56	0 45	0 42	0 44	0 11	0 22	0 16	0 25	0 21	0 17	0 16	0 05
5%	1 41	0 99	1 57	1 26	1 19	1 23	0 21	0 61	0 44	0 69	0 59	0 47	0 45	0 09

1 Contd

nents	Number of grains per cm^2							1000-grain weight (g)						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
les														
RB 1A	18 96	20 46	18 26	17 80	16 46	20 36	18 72	12 10	12 45	8 30	11 62	11 62	10 57	11 11
RB 2A	16 73	19 16	16 70	18 36	16 46	19 93	17 89	11 73	11 85	7 18	12 09	10 95	8 85	10 44
IRB 3A	17 86	17 70	17 00	14 96	14 73	15 86	16 35	11 66	11 64	9 26	14 23	13 30	11 38	11 91
RB 5A	22 06	22 90	19 13	21 80	21 63	24 03	21 92	12 22	13 12	9 29	12 64	11 83	9 68	11 46
5 A	21 13	19 10	21 80	17 23	17 30	17 86	19 07	12 21	11 92	10 85	12 36	12 54	11 32	11 86
6A	22 50	20 83	20 46	20 00	19 66	20 40	20 64	11 85	11 68	8 65	12 16	13 25	11 10	11 45
07 A	15 93	17 40	16 73	13 46	13 80	15 06	15 40	12 80	15 18	10 88	12 50	14 39	13 66	13 50
	19 31	19 65	18 58	17 66	17 15	19 07	18 57	12 08	12 54	9 43	12 51	12 55	10 94	11 67
BI 138	16 16	15 40	15 00	14 03	13 86	14 90	14 89	12 93	13 64	10 86	13 16	12 54	11 88	12 50
BI 458	15 70	15 36	14 46	13 76	12 90	13 86	14 34	13 54	13 01	8 01	11 86	12 47	11 38	12 13
BI 178	18 46	15 90	17 20	16 13	15 36	15 86	16 48	11 17	11 32	8 93	10 94	9 86	10 56	10 31
1	16 83	18 66	17 53	16 96	17 06	15 33	17 06	11 66	13 50	5 73	12 33	11 97	11 88	11 71
2	25 16	22 86	21 33	19 80	17 07	20 93	21 19	11 32	12 32	12 09	12 05	11 19	9 96	10 43
	18 46	17 64	17 10	16 14	15 25	16 18	16 79	12 12	12 75	9 12	12 06	11 60	11 13	11 42
ls														
x 1	17 96	16 40	17 00	16 76	15 33	17 06	16 75	15 09	16 74	10 44	14 72	14 41	13 27	14 11
x 2	17 83	16 33	17 66	15 96	14 86	17 00	16 61	14 22	16 38	11 08	14 28	13 52	12 16	13 61
x 3	17 26	16 76	19 00	16 53	15 23	16 60	16 90	11 38	12 85	10 64	12 00	11 56	10 74	11 53
x 4	19 10	19 90	17 76	20 63	20 10	19 13	19 43	14 22	16 37	11 09	13 63	11 10	11 54	12 99
x 5	21 63	21 36	20 50	18 63	18 00	19 26	19 90	12 33	14 29	10 57	12 94	11 95	11 44	12 25
x 1	17 23	15 83	15 76	14 63	14 76	15 90	15 68	14 08	15 25	8 54	13 00	12 95	12 03	12 64
x 2	15 36	16 96	16 63	15 33	14 96	15 46	15 78	14 69	13 93	9 14	12 66	13 16	13 17	12 79
x 3	17 36	16 90	18 36	16 70	15 23	16 13	16 78	11 01	11 70	8 93	10 70	10 97	10 47	10 63
x 4	17 10	18 33	20 43	22 43	17 80	18 46	19 09	14 26	14 50	11 41	12 74	12 04	11 87	12 80
x 5	18 23	19 33	18 63	16 80	16 63	19 20	18 13	12 45	12 92	11 45	11 32	11 28	11 20	11 77
x 1	16 26	15 50	17 03	16 36	16 23	16 13	16 25	14 46	19 01	10 78	14 92	14 53	14 37	14 68
x 2	15 63	16 46	16 03	13 50	12 73	13 83	14 70	16 64	15 80	13 14	13 47	14 75	14 58	14 73
x 3	17 66	16 70	17 73	15 03	14 33	17 46	16 48	10 85	12 13	11 03	13 33	11 80	12 96	12 02
x 4	19 53	19 86	17 76	18 66	15 90	17 73	18 24	13 86	14 12	12 01	14 11	13 40	12 89	13 40
x 5	18 90	19 10	18 36	18 30	15 46	19 70	18 30	12 50	14 44	11 82	13 47	13 14	12 16	12 92
x 1	18 13	20 90	19 63	19 36	19 66	20 80	19 75	14 96	13 96	11 88	11 84	11 88	10 80	12 55
x 2	17 43	16 90	18 63	16 53	16 20	17 93	17 27	15 50	15 33	10 54	13 10	13 39	12 70	13 43
x 3	17 33	20 16	19 66	19 10	18 50	19 46	19 03	11 61	13 13	8 46	11 14	11 15	11 06	11 09
x 4	22 53	22 03	22 10	20 06	22 06	22 16	21 82	13 64	14 53	12 16	12 46	11 66	11 44	12 65
x 5	22 10	22 53	23 36	22 66	19 96	22 43	22 17	13 29	14 34	10 49	12 34	12 08	11 06	12 27
x 1	15 83	17 46	18 06	15 16	16 53	17 56	16 77	17 33	16 29	11 00	13 68	13 80	12 27	14 06
x 2	17 10	16 90	16 60	15 03	15 10	15 43	16 02	14 70	13 70	10 37	14 95	12 91	12 48	13 18
x 3	18 03	18 83	18 80	16 83	17 36	17 03	17 81	11 18	12 54	9 38	10 91	11 98	11 51	11 25
x 4	18 33	22 33	19 73	18 86	19 90	20 16	19 88	15 25	13 86	11 05	13 56	13 37	11 23	13 05
x 5	22 76	21 16	21 80	20 66	20 06	21 00	21 24	12 17	14 82	8 93	11 72	12 04	11 45	11 85
x 1	17 53	17 10	16 36	16 86	17 30	17 06	17 03	15 26	14 98	10 90	13 93	13 05	12 24	13 39
x 2	17 10	14 83	16 10	14 56	13 96	15 13	15 28	15 89	14 70	13 31	15 29	14 06	14 90	14 69
x 3	21 10	19 10	21 76	15 63	16 46	19 26	18 88	10 97	11 68	8 54	11 12	11 34	10 52	10 69
x 4	19 50	20 16	20 26	19 33	19 60	19 46	19 72	12 68	13 08	10 89	13 56	12 29	11 67	12 36
x 5	22 10	21 66	23 33	20 10	20 53	22 23	21 66	11 96	14 21	12 50	13 52	12 35	11 00	12 59
x 1	16 96	16 10	15 70	15 53	15 06	16 56	15 98	14 62	17 05	12 45	14 30	14 05	12 64	14 18
x 2	15 40	14 56	15 26	14 06	13 13	13 26	14 28	16 00	15 12	11 90	13 96	13 46	13 11	13 92
x 3	16 96	16 63	17 83	15 40	16 26	16 43	16 58	11 97	13 04	10 57	12 58	12 06	12 71	12 15
x 4	19 13	18 70	18 23	18 80	17 00	18 83	18 45	15 78	15 06	12 85	12 93	13 71	11 92	13 71
5	22 00	19 70	21 66	18 96	19 46	18 20	20 00	12 88	14 18	9 68	12 45	12 70	12 14	12 34
	18 41	18 38	18 67	17 42	16 90	17 99	17 97	13 71	14 46	10 85	13 05	12 68	12 11	12 81
03	16 26	17 70	17 63	16 70	16 70	17 70	17 11	14 80	15 18	12 09	14 66	15 02	14 76	14 42
67	24 73	21 20	20 53	18 53	19 80	20 83	20 93	11 36	12 10	8 58	11 36	10 84	10 68	10 82
lean	18 63	18 53	18 52	17 33	16 82	18 01	17 97	13 28	13 98	10 42	12 87	12 56	11 86	12 49
	0 45	0 40	0 43	0 63	0 42	0 44	0 11	0 45	0 49	0 52	0 40	0 35	0 41	0 10
5%	1 26	1 11	1 20	1 76	1 19	1 23	0 21	1 27	1 37	1 47	1 12	1 00	1 15	0 21

Table 1 Contd .

Treatments	Grain yield per plant (g)						
	E1	E2	E3	E4	E5	E6	Pooled
Females							
I RHRB 1A	37 92	32 36	8 05	30 17	27 02	19 88	25 90
II RHRB 2A	36 62	33 50	5 53	37 37	27 84	23 02	27 31
III RHRB 3A	38 31	28 33	6 17	17 77	16 34	14 42	20 22
IV RHRB 5A	29 12	24 99	6 73	23 75	28 31	19 82	22 12
V 9605 A	49 73	42 21	18 55	37 53	41 28	33 32	37 10
VI 9606A	37 24	38 94	12 91	27 09	26 79	19 93	27 15
VII 9607 A	58 21	45 72	19 61	33 64	38 61	32 73	38 09
Mean	41 02	35 15	11 08	29 62	29 46	23 30	28 27
Males							
1 RHRBI 138	32 71	27 75	11 27	20 13	24 70	16 43	22 16
2 RHRBI 458	41 38	25 80	6 65	27 16	29 09	20 23	25 05
3 RHRBI 178	32 23	29 42	14 16	36 42	30 09	23 81	27 69
4 9611	42 43	32 54	12 01	41 15	31 52	20 10	29 95
5 9612	39 03	33 21	6 53	35 69	22 73	24 39	26 93
Mean	37 56	29 74	10 12	32 11	27 63	20 99	26 35
Hybrids							
I x 1	56 86	55 25	20 13	39 89	43 20	34 83	41 69
I x 2	57 10	44 75	24 55	35 21	31 17	29 24	37 00
I x 3	54 55	52 30	20 56	39 24	34 21	33 77	39 10
I x 4	75 81	53 40	30 95	49 11	40 80	46 24	49 38
I x 5	53 69	59 03	22 93	54 58	48 09	46 18	47 41
II x 1	64 33	53 70	19 84	52 04	42 44	36 32	44 78
II x 2	51 37	49 18	18 74	54 57	45 16	27 64	41 11
II x 3	42 91	48 79	13 87	34 20	41 83	37 91	36 58
II x 4	51 16	54 07	23 72	61 70	47 24	34 20	45 35
II x 5	61 16	54 52	21 11	53 77	39 58	30 53	43 45
III x 1	56 69	50 87	27 20	40 73	34 78	37 03	41 21
III x 2	52 35	43 63	22 56	30 76	29 95	27 87	34 51
III x 3	42 01	45 91	19 94	46 74	49 44	29 04	37 18
III x 4	67 19	61 67	26 32	47 57	53 56	34 72	48 50
III x 5	66 37	48 39	21 00	59 02	55 79	40 83	48 56
IV x 1	58 07	59 92	21 99	36 25	35 25	25 86	39 65
IV x 2	45 47	43 29	16 54	39 28	39 32	28 98	35 48
IV x 3	48 14	37 01	19 11	42 39	32 94	26 76	34 39
IV x 4	62 11	50 13	27 59	42 67	48 60	33 02	44 00
IV x 5	56 67	64 80	17 19	51 61	42 88	37 87	45 17
V x 1	48 41	49 67	29 69	40 30	45 92	30 13	40 68
V x 2	54 42	52 20	30 96	39 08	36 32	30 21	40 53
V x 3	42 55	47 20	19 40	34 38	37 69	27 54	34 79
V x 4	72 38	56 46	29 13	39 26	45 91	32 22	45 89
V x 5	69 88	59 91	30 74	65 50	41 62	32 80	50 07
VI x 1	60 63	51 20	27 95	54 86	38 14	31 09	43 98
VI x 2	63 07	51 50	25 86	36 01	44 09	35 65	42 70
VI x 3	55 06	49 08	17 83	41 59	43 86	30 71	39 69
VI x 4	58 45	56 88	30 98	54 32	48 41	40 17	48 20
VI x 5	62 57	58 22	33 06	58 05	44 05	35 23	48 53
VII x 1	69 35	61 46	29 52	35 03	40 38	31 31	44 51
VII x 2	70 65	52 85	29 18	37 30	39 73	28 39	43 02
VII x 3	53 56	49 59	25 95	40 80	32 80	36 69	39 90
VII x 4	72 03	55 02	28 39	46 29	37 27	34 60	45 60
VII x 5	53 87	54 83	25 31	54 80	52 90	45 27	47 83
Mean	58 03	52 48	24 28	45 40	41 58	33 74	42 58
Checks							
ICTP 8203	43 96	47 31	22 98	43 84	41 86	37 61	39 39
MLBH 267	60 07	58 92	17 20	61 29	49 00	34 42	46 70
Grand Mean	53 26	47 71	20 78	42 08	38 58	31 04	38 90
S E ±	2 99	2 65	1 74	2 17	1 71	1 90	0 53
C D at 5%	8 43	7 47	4 89	6 10	4 81	5 34	1 04

ii) Dry matter production-I

From the data presented in Table 1, it could be seen that the ranges of parents for DMP I in E1, E2, E3, E4, E5 and E6 environments were from 34.06 to 66 96, 21 16 to 67 16, 7 73 to 33 10, 31 93 to 85 23, 22 93 to 58.53 and 17 53 to 53 50 g per plant, respectively. The average range was 26 81 to 60 04 g The hybrids had such range from 29 13 to 75.83, 25 16 to 58 43, 19 96 to 52 46, 30 63 to 96 16, 20.86 to 73.53 and 19.06 to 60.23 g per plant in E1, E2, E3, E4, E5 and E6 environments, respectively. The range over environments was between 28 51 to 58.01 g per plant.

The female parent, 9605A produced higher dry matter production at flowering in E1 (50.63 g), E2 (36 93 g), E3 (31 83 g), E4 (48 23), E5 (40 76 g) and over environments (40 01 g), while 9607A produced higher DMP I (40 60 g) in E6 Among the males, RHRBI 138 had highest dry matter production at flowering in E1 (66.96 g), E2 (67.16 g), E3 (33.10 g), E4 (85 23 g) and over environments (60.04 g). In E5 and E6 9611 produced highest dry matter at flowering with 58 53 and 53 50 g of values, respectively

Among hybrids, the combinations IV x 5 in E1 (75 83 g), IV x 1 in E2 (58 43 g), VI x 5 in E3 (52.46 g), VII x 4 in E4 (96 16 g), IV x 4 in E5 (75.53 g), III x 4 in E6 (60.23 g) and I x 4 over environments (58.01 g) produced highest dry matter

iii) Dry matter production-II

Dry matter production at maturity was ranged from 88 70 to 160 70, 73.00 to 128 70, 24.53 to 51 63, 74.86 to 164.60, 66 96 to 168 10, 52.43 to 100 23 and 68 60 to 123 41 g per plant in E1, E2, E3, E4, E5, E6 and over environments, respectively. In case of hybrids, such a range in E1 was from 123.50 to 210 26 g, in E2 103.93 to 145 20 g, in E3 45 56 to 96 43 g, in

E4 87 00 to 181 43 g, in E5 89 10 to 157 80 g, in E6 72 70 to 120 16 g and 92.25 to 136 68 g over environments.

The highest dry matter i.e 160 70, 128 70 and 65.40 g per plant was produced by the female 9607A in E1, E2 and E3 respectively, while, 9605A had highest such values for DMP II in E4 (156 86 g), E5 (168.10 g), E6 (100 23 g) and over environments (123.41 g) Male parent RHRBI 138 exhibited the highest value in E1 (137 76 g), E2 (121 93 g) and E3 (51 63 g) and 9611 in E4 (164 60 g), E5 (110 73 g) and over environments (106 50 g) In E6, the male RHRBI 178 produced the highest dry matter (99 43 g)at maturity

If the hybrids were considered it was found that, the combination VII x 4 produced highest value (210 26 g) of DMP II in E1, IV x 5 in E2 (145 20 g), VI x 4 in E3 (96 43 g) and over environments (136 68 g), V x 5 in E4 (181 43 g), III x 3 in E5 (157 80 g) and I x 4 in E6 (120 16 g).

iv) Absolute growth rate

The values of absolute growth rate, for parents were ranged from 1 88 to 3 15, 1 29 to 2 66, 0 39 to 1 15, 0.87 to 3 35, 0.85 to 2.74, 0 88 to 2 77 and 1 22 to 2 53 g/day in E1, E2, E3, E4, E5, E6 and over environments, respectively For hybrids, such a range was from 2.01 to 4 74 (E1), 1 81 to 3 01 (E2), 0 62 to 1 87 (E3), 0.89 to 3.92 (E4), 1 17 to 3.87 (E5) and 1.40 to 2 43 g/day (E6) and 1 71 to 2 63 g/day (over environments)

The values of AGR were highest in case of 9607A in E1 (3.15), E2 (2.66), E3 (1 15), E4 (3 35), E5 (2 74), E6 (2 18) and over environments (2 53 g/day) Among the male parents 9612 had the highest value of AGR in E1 (2.28 g/day), while, 9611 in E2 (2 04 g/day) and RHRBI 178 had highest such value in E3 (0 95), E4 (2 90), E5 (2 15), E6 (2.77) and over environments (2 13 g/day), respectively

Among the hybrids, VII x 4 displayed highest value of AGR in E1 (4 74 g/day) The hybrid combination IV x 5 in E2, VI x 4 in E3 and over environments, V x 5 in E4, III x 3 in E5, and VII x 2 in E6 exhibited highest AGR with 3.01, 1 87, 2 63, 3 92, 3.87 and 2 43 g/day value, respectively.

v) Relative growth rate

Mean for RGR of parents ranged from 0 0195 to 0.0332, 0 0170 to 0.0394, 0 0140 to 0 0361, 0.0134 to 0 0415, 0 0162 to 0.0443, 0.0129 to 0.0604 and 0.0163 to 0 0373 g/g/day in E1, E2, E3, E4, E5, E6 and over environments, respectively The such means for hybrids were ranged from 0 0201 to 0.0427(E1), 0 0237 to 0 0415 (E2), 0.0126 to 0 0325 (E3), 0 0126 to 0 0409 (E4), 0 0133 to 0 0524 (E5), 0.0184 to 0 0508 (E6) and 0 0203 to 0 0402 g/g/day (over environements)

Among the male sterile lines 9607A had the highest RGR values in E1 (0 0332 g/g/day), E4 (0.0415 g/g/day) and over environments (0 0346 g/g/day), 9606A in E2 (0 0394 g/g/day), while RHRB 5A in E3 (0 0361g/g/day) and E6 (0 0416 g/g/day) recorded the highest RGR values. The female 9605A had highest such value in E5 (0.0443 g/g/day). The pollinator 9612 in E1 (0 0289) and RHRBI 178 in E2, E3, E4, E5, E6 and over environments (0 0362, 0.0303, 0 0348, 0.0342, 0.0604 and 0.0373 g/g/day, respectively) recorded highest RGR values.

The hybrids exhibiting highest RGR values were I x 3 in E1 (0.0427), E5 (0 0524) and over environments (0.0402), III x 3 in E2 (0 0415) and E3 (0 0325), IV x 3 in E4 (0.0409) and II x 3 in E6 (0 0508 g/g/day)

i) Adaxial stomatal density

The adaxial stomatal density recorded in parents was ranged rom 50 45 to 103 67, 66 27 to 108 71, 50.81 to 106 34, 65.40 to 128.30, 82 52 o 107 07 and 75.90 to 105.94 mm^2 in E1, E2, E3, E4, E5 and E6 nvironments, respectively. The average was ranged from 69 26 to 98 50 m^2 In case of hybrids the range was from 61 51 to 107 09 mm^2 in E1, 68 63 o 110 61 in E2, 64 53 to 85.01 in E3, 79 29 to 128 06 in E4, 70 57 to 116 76 in 5 and 77.51 to 124 67 in E6 environments. The range over environments as between 77 97 to 100.55 mm^2

The female parents RHRB 1A (74 21 mm^2), 9606 A (73 37 mm^2), 607 A (71.95 and 92 21 mm^2) , 9605 A (88.98 mm^2) and RHRB 3A (89.47 nm^2) recorded lowest adaxial stomatal density in E1, E2, E3, E4, E5 and E6 espectively, while lowest stomatal density on pooled basis was noted in case f 9607 A (87.02 mm^2). Among the males, 9611 had lowest adaxial stomatal ensity in E1 (50 45 mm^2), E5 (82.52 mm^2) and over environments (69.26 nm^2), while, RHRBI 458 expressed lowest such values in E2 (66.27 mm^2), E3 50.81 mm^2) and E6 (75.90 mm^2) In E4, RHRBI 178 showed lowest adaxial tomatal density (65.40 mm^2).

The lowest adaxial stomatal density in hybrids were noted in III x 4 1.51 mm^2) in E1, IV x 4 (68.63 mm^2) in E2, VI x 2 (64.53 mm^2) in E3, II x 2 79 29 mm^2) in E4, VI x 3 (70.57 mm^2) in E5, VI x 4 (77 51 mm^2) in E6 and VII x (77.97 mm^2) over environments

ii) Abaxial stomatal density

The number of stomata per mm^2 observed on abaxial surface resented in Table 1 showes that parents had such number of stomata ranging om 53 22 to 117 35 in E1, 83 62 to 119.44 in E2, 62 63 to 117.54 in E3, 98.19 to 154 71 in E4, 100 62 to 158 10 in E5, 95.60 to 146.63 in E6 and 82.42 to 123 29 mm^2 if all the environments were considered together. In respect of hybrids stomata on abaxial surface were ranged from 67 38 to 130 53 (E1), 87 73 to 127.65(E2), 77.15 to 115 02(E3), 103 84 to 156.16 (E4), 92.37 to 156 32(E5), 89 79 to 156 16(E6) and 94 17 to 123.34 mm^2 (over environments)

Among the male sterile lines, the lowest abaxial stomatal density was noticed in RHRB 1A in E1 (84.80 mm^2), 9606 A in E2 (91 04), 9607 A in E3 (78.10), E4 (113.04), E5 (115 14) and over environment (102.78 mm^2), and RHRB 3A in E6 (113.69 mm^2) Among the male parents the lowest abaxial stomatal density i e 53 22, 62.63, 98 19, 100 62, 95.60 and 82.42 mm^2 was recorded in 9611 in E1, E3, E4, E5, E6 and over environment respectively However, in E2, RHRBI 138 showed lowest such value (83.62 mm^2).

Among the hybrids, the combinations, III x 4 (67.38) in E1, III x 5 (87.73) in E2, VII x 2 (77 15) in E3, VI x 1 (103.84) in E4, VI x 3 (92.37) in E5 and VII x 4 (89 79) in E6 and over environments (94.17) recorded lowest abaxial stomatal density per mm^2.

4.1.2 Harvest index and agronomic characters

i) Days to stigma emergence

The mean days to stigma emergence in parents ranged from 41.33 to 53 66, 41.33 to 52.00, 42 66 to 53 33, 66 00 to 82.66, 56.00 to 69 33 and 45 00 to 60.33, in E1, E2, E3, E4, E5 and E6 environments respectively. The such means in hybrids ranged from 36 33 to 51.00(E1), 37 66 to 50 33 (E2), 38 33 to 49.00 (E3), 60 00 to 79.66(E4), 52 66 to 65 33(E5) and 39 66 to 54 00 days (E6) in different environments. Considering the overall mean performance, it can be seen that the parents flowered between 49.11 to 60.44 days and the hybrids between 44 11 to 57.77 days

Among the females 9607 A was earliest to flower in all the environments with a mean number days of 42 33(E1), 41 33 (E2), 42 66(E3), 66 00(E4), 56 00(E5), 46 33(E6) and 49 11 (over environments) In different environments RHRB 2A was earliest to flower in E5 (56.00) and in E6 (46.33 days) and RHRB 1A in E3 which tooks 42.66 days for stigma emergence The male parent RHRBI 178 was early in all the environments which took on an average 41 33, 43 33, 43 33, 69 66, 56.00, 45.00 and 49 77 days for stigma emergence in E1, E2, E3, E4, E5, E6 and over environments, respectively.

The hybrid II x 3 was earliest which required average 36.33(E1), 37 66(E2), 38 33(E3), 60.00(E4), 52.66(E5), 39 66(E6) and 44.11 (over environments) days for stigma emergence

ii) Plant height

From the data presented in Table 1, it could be seen that the range of parents for plant height in E1, E2, E3, E4, E5 and E6 environments was from 139 16 to 218 13, 134 30 to 235 10, 77.00 to 165 30, 106 53 to 196.70, 93 63 to 181 90 and 105 76 to 198.60 cm, respectively. The average plant height over environments was ranged from 110.58 to 199 28 cm The range of plant height of hybrids was from 172 86 to 221 96(E1), 172 86 to 235.60 (E2), 140.80 to 189 63(E3), 133.60 to 190.56(E4), 135.76 to 187 03(E5) and 127 13 to 185 90 cm (E6) in different environments The range over environments was between 153.17 to 197 73 cm

Among the male sterile lines 9605 A was the tallest in E1 (176 00 cm), E2 (188.86 cm), E3 (140.90 cm), E4(141.30 cm), E6 (140.26 cm) and over environments (153 38 cm). The male sterile 9607 A was tallest in E5

(135.73 cm). As regards the male parents, RHRBI 138 was the tallest (218.13, 235.10, 165 30, 196.70, 181 90, 198.60 and 199.28 cm) in all the respective and over environments, respectively.

Among the hybrids, IV x 1 was the tallest in E1 (221.96 cm), V x 2 in E2 (235 60 cm) and E4 (190.56 cm), VII x 1 in E3 (189 63 cm) and over environments (197.73 cm). The combination, I x 2 however, showed, highest mean values in E5 (187.03 cm) and in E6 (185 90 cm).

iii) Fodder yield per plant :

Fodder yield per plant of the parents were ranged from 37.53 to 90.00 in E1, 27 53 to 58 83 in E2, 10.47 to 34 87 in E3, 29 96 to 74.43 in E4, 26.46 to 58 50 in E5, 19 73 to 49.73 in E6 and 27 01 to 58.23 g over environments In case of hybrids its range was from 64.20 to 146.70(E1), 37 17 to 72 40 (E2), 20 93 to 46.30 (E3), 38.73 to 95.10 (E4), 36.40 to 69.36(E5), 25 23 to 55.53 (E6) and 43.36 to 73 02 (over environment), in different environments.

The highest fodder yield was produced by the female 9607 A in E1 (90 00 g), E2 (55 83 g), E3 (34 87 g), E4 (74 43 g), E6 (40.33 g) and over environments (56 78 g). In E5, 9605 A produced the highest fodder yield (58.50 g). *Male parent RHRBI 138 exhibited highest fodder yield in E1* (85.20 g), E2 (58 83 g), E3 (31.57 g), E4 (66.83 g), E5 (57 26 g), E6 (49.73 g) and over environments (58 23 g).

Among hybrids, the combinations VII x 4 in E1 (146.70 g) and over environments (73 02 g), IV x 1 in E2 (72.40 g), VII x 2 in E3 (46 30 g) and in E5 (69 36 g) and I x 4 in E4 (95.10 g) and in E6 (55.53 g) produced the highest fodder yield

iv) Harvest index :

The data on harvest index presented in Table 1 showed that the range of harvest index in case of parents was from 26.42 to 41.42, 22 66 to 45 19, 14.82 to 33 29, 15.13 to 36 36, 24.39 to 40.43, 19 60 to 40 18 and 21.27 to 35 79 in E1, E2, E3, E4, E5, E6 and over environments, respectively. The range of harvest index in hybrids was from 28 42 to 43 75 in E1, 32 26 to 49 89 in E2, 26 01 to 40.02 in E3, 23.47 to 47.66 in E4, 24.99 to 51 49 in E5, 24.70 to 47.25 in E6 and overall environments it was between 31.56 to 43.31

The male sterile line RHRB 2A exhibited highest harvest index in E1 (41.42), E2 (45 19), E4 (36.36), and over environments (35.79) In E3, 9605 A (33 29) showed the highest harvest index However, RHRB 5A and RHRB 1A exhibited highest harvest index in E5 (39.22) and in E6 (37 92), respectively. The inbred 9611 recorded highest harvest index in E1 (32 60), while 9612 displayed the highest harvest index in E2 (39.28), E4 (35 40), E5 (40.43), E6 (40 18) and over environments (34 47). In E3 RHRBI 178 had the highest harvest index (28.30).

The hybrids I x 4 (43.75) in E1, II x 5 (49.89) in E2, III x 4 (40 02) in E3, I x 5 (47 66) in E4, (47 25) in E6 and (43 31) over environments and III x 5 (51 49) in E5 showed higher harvest index.

4.1.3 Grain yield and its components

i) Number of effective tillers per plant :

The number of effective tillers produced by parents ranged from 2.03 to 3.53 in E1, 1 86 to 3 60 in E2, 1.06 to 1 93 in E3, 1 43 to 4.73 in E4, 1 33 to 3 16 in E5, 1.10 to 2.36 in E6 and 1 54 to 3 22 over environments The effective tillers recorded in case of hybrids ranged from 1.60 to 3 26, 1.70 to

3.46, 1.20 to 2.16, 1.20 to 4.06, 1.06 to 2.83, 1.00 to 2.56 and 1.43 to 2.86 per plant in E1, E2, E3, E4, E5, E6 and over environments, respectively.

The highest number of effective tillers per plant among the females were displayed by RHRB 1A in E1 (3.10), E2 (3.26), E4 (3.66) and over environments (2.73). However, 9607 A exhibited the highest number of effective tiller per plant in E3 (1.56) and RHRB 2A in E5 (3.36) and in E6 (2.16). The male parent, RHRBI 178 showed the highest number of effective tillers, *viz.*, 3.53 (E1), 3.60 (E2), 1.93 (E3), 4.73 (E4), 3.16 (E5), 2.36 (E6) and 3.22 per plant (over environments)

Among the hybrids, the combinations, I x 3 in E1 (3.26), in E2 (3.46) and over environments (2.86) and II x 3 in E3 (2.16), in E5 (2.83), in E6 (2.56) and also over environments (2.86) exhibited highest values. In E4, the hybrid I x 5 (4.06) was found to be the best in respect of effective tillers/plant.

ii) Ear length :

The average ear length in respect of parents was measured from 14.48 to 23.85, 14.12 to 23.16, 9.30 to 20.05, 11.58 to 20.84, 12.40 to 21.51, 12.38 to 24.00 and 12.43 to 22.23 cm in E1, E2, E3, E4, E5, E6 and over environments, respectively. The hybrids produced panicles length measuring from 19.07 to 28.14 in E1, 17.39 to 26.42 in E2, 12.18 to 23.68 in E3, 14.44 to 24.41 in E4, 16.07 to 25.16 in E5, 17.13 to 26.90 in E6 and 16.94 to 25.58 cm over environments.

The longest panicles among the male sterile lines was exhibited by 9607 A in all the environments and also over environments *viz.*, 23.85(E1), 23.16(E2), 20.05(E3), 20.84(E4), 21.51(E5), 24.00(E6) and 22.23 cm (over environments), respectively. When the pollinators were considered, RHRBI 138 produced the longest panicles in E1 (21.55 cm), E2 (22.62 cm), E4 (17.23

cm)and over the environments (19 50 cm) which was followed by 9611 in E3 (16 69 cm) and RHRBI 458 in E5 (20 05 cm) and in E6 (21.08 cm).

As regards hybrids, the combination, VII x 2 in E1 (28 14 cm), E3 (23 68 cm), E4 (24 41 cm), E5 (25 16 cm), E6 (26.90 cm) and over environments (25 58 cm), while VII x 1 in E2 (26 42 cm) showed highest panicle length

iii) Ear girth

The ear girth, recroded on parents was measured from 8.90 to 12 50 cm in E1, 8 08 to 12.28 in E2, 7 52 to 11 08 in E3, 8 80 to 11 72 in E4, 8.22 to 12.17 in E5, 8.48 to 12 21 in E6 and 8.56 to 11.99 over environments. The hybrids produced panicles having girth ranging from 9.42 to 13.35, 8.97 to 13 04, 8 54 to 12 68, 8.85 to 13.05, 8.92 to 12.44, 8.74 to 13.08 and 9,.15 to 12 94 cm in respective and over environment, respectively.

The average value of ear girth among the female parents was found to be the highest in case of 9605 A (12.02 cm) in E1, and (12 14 cm) in E2 and 9607 A in E3 (10.91), E4(11.20), E5(10 92), E6(11.29) and over environemnts (11 25 cm) The male parent, RHRBI 458 exhibited thickest ears i.e 12 50(E1), 12.28 (E2), 11.08(E3), 11.72(E4), 12.17(E5), 12 21(E6) and 11.99 cm (over environments) in different environments.

The combination, VI x 2 exhibited the highest ear girth among the hybrids in E1 (13.35 cm), E2 (13.04 cm), E3 (12.68 cm), E4 (13 05 cm), E5 (12.44 cm), E6 (13 08 cm) and also when the mean values were pooled over environments (12 94 cm).

iv) Number of grains per cm^2

For number of grains per cm^2, the parents under study exhibited range from 15.70 to 22.50, 15.36 to 22.90, 14.46 to 21.80, 13.76 to 21.80, 12 90 to 21 63, 13.86 to 24.03 and 14.34 to 21.92 in E1, E2, E3, E4, E5, E6 and over environments, respectively The such a range for hybrids in E1 was from 15 36 to 22 76, in E2 14 56 to 22 53, in E3 15.26 to 23 36, in E4 13 50 to 22 66, in E5 12 73 to 22 06, in E6 13.26 to 22 43 and over environment 14.28 to 22 17

As regards mean performance among the female parents, 9606 A exhibited the highest number of grains per cm^2 in E1 (22.50). However, the female parents RHRB 5A displayed the highest number of grains per cm^2 in E2 (22.90), E4 (21 80), E5 (21.63), E6(24.03) and over environments (21 92) and 9605 A in E3(21 80) The male parent 9612 expressed the highest number of grains per cm^2 in all the environments with values of 25.16, 22.86, 21.33, 19.80, 17.07, 20 93 per cm^2 and over environments (21.19) / cm^2, respectively

The hybrid, V x 5 in E1 (22 76) and IV x 5 in E2 (22.53), E3 (23 36), E4 (22.66), E6 (22 43) and over environments (22.17) exhibited the highest number of grains per cm^2. The hybrid IV x 4 in E5 (22.06) expressed highest number of grains per cm^2

v) 1000-grain weight

In respect of this character, the parents were ranged between 11 17 and 13 54 g in E1, 11.32 and 15.18 g in E2, 5 73 and 12.09 g in E3, 10 94 and 14 23 g in E4, 9.86 and 14.39 g in E5, 8.85 and 13.66 g in E6 and 10 31 and 13 50 g, over environments Such a range for this character in case of hybrids was between 10 85 and 17.33(E1), 11.68 and 19.01(E2), 8.46 and 13 31(E3), 10 70 and 15.29(E4), 10.97 and 14.75 (E5), 10 47 and 14.90(E6), 10.63 and 14.69 g (over environments).

Highest grain weight was noticed in the female parent 9607 A in E1 (12.80 g), E2 (15.18 g), E3 (10.88 g), E5 (14.39 g), E6 (13.66 g) and over environments (13 50 g) and RHRB 3 A in E4 (14.23 g) The male parent

RHRBI 458 (13 54 g) in E1, RHRBI 138 (13 64, 13 16, 12.54 and 12 50 g) in E2, E4, E5 and over environment respectively, 9612 (12.09 g) in E3 and 9611 (11 88 g) in E6 produced highest grain weight.

Among the hybrids, V x 1 in E1 (17 33 g), III x 1 in E2 (19.01 g), VI x 2 in E3 (13 31 g), E4 (15 29 g), E6 (14.90 g) and over environments (14.69 g) and III x 2 in E5 (14 75 g) produced highest grain weight

vi) Grain yield per plant

The grain yield per plant in case of parents ranged from 29.12 to 58 21 g in E1, 24.99 to 45 72, in E2, 5.53 to 19 61 g in E3, 17.77 to 41.15 g in E4, 16 34 to 41.28 g in E5, 14.42 to 33.32 g in E6 and 20.22 to 38.09 g when the overall mean performance was considered The hybrids produced grain yields (Table 1) ranging from 42.01 to 75.81, 37.01 to 64.80, 13 87 to 33 06, 30 70 to 65.50, 29 95 to 55 79, 25.86 to 46.24 and 34 39 to 50.07 g per plant in E1, E2, E3, E4, E5, E6 and over environments, respectively.

Among the male sterile lines,9607 A produced highest grain yield weighing 58.21, 45 72, 19.61 and 38.09 g/plant in E1, E2, E3 and over environments, respectively In E4 (37.53 g), E5 (41.28 g) and E6 (33.32 g), 9605 A was the highest yielding male sterile line. Among the inbreds, 9611 in E1 (42 43 g), E4 (41 15 g), E5 (31.52 g) and over environments (29 95 g), 9612 in E2 (33.21 g) and in E6 (24.39 g) and RHRBI 178 in E3 (14.16 g) produced the highest grain yield per plant.

The hybrid combination I x 4 produced highest grain yield in E1 (75.81 g) and E6 (46 24 g). The hybrids IV x 5 (64.80 g), VI x 5 (33 06 g), V x 5 (65.50, 50.07 g), and III x 5 (55 79 g) produced the highest grain yields in E2, E3, E4, over environments and E5, respectively. If the overall performance of the hybrid was considered, it was observed that the hybrid, V x 5 (50 07 g) ranked first which was followed by I x 4 (49 38 g), III x 5 (48 56 g), VI x 5 (48 53 g), III x 4 (48 50 g) and VI x 4 (48 20 g) in respect of grain yield/plant.

4.2 Stability analysis

4.2.1 Analysis of variance (individual)

The mean sum of squares for individual environment of all genotypes are presented in Table 2 The variance due to genotypes was found to be highly significant for all the characters in all the environments.

4.2.2 Analysis of variance (pooled)

The analysis of variance representing the mean sum of squares due to different sources of variance is presented in Table 3. Pooled analysis of variance over six environments showed that, genotypic variance when tested against G x E and pooled deviation, were highly significant for all the characters studied. Environmental variances were highly significant for all the characters The data also indicated the significance of G x E interaction for all the characters when tested against pooled error. Environmental (linear) effects were significant for all the characters. However, genotype x environment (linear) effects were significant for LAI, DMP I, days to stigma emergence, plant height, fodder yield per plant, ear girth, number of grains per cm^2 and 1000 grain weight Pooled deviation was significant for all the characters when tested against pooled error

Linear components G x E interaction were of greater magnitude than non linear components for LAI, DMP I, abaxial stomatal density, days to stigma emergence, plant height, fodder yield per plant, number of effective tillers per plant, ear length, ear girth, number of grains per cm^2, 1000 grain weight and grain yield per plant Non linear components were of greater magnitude than linear component for DMP II, AGR, RGR, adaxial stomatal density and harvest index

Table 2. **Mean sum of squares for all genotypes for morpho-physiological, agronomic characters and grain yield components**

SN	Characters	E1	E2	E3	E4	E5	E6
	Leaf area index	4 38**	2 97**	3 09**	10 60**	7 85**	6 95**
	Dry matter production I /plant (g)	320 41**	255 74**	301 42**	921 58**	574 47**	401 23**
	Dry matter production II /plant (g)	1831 94**	955 62**	910 85**	2159 14**	1547 71**	805 13**
	Absolute growth rate (g/day)	1 35**	0 52**	0 34**	1 60**	1 55**	0 66**
	Relative growth rate (g/g/day) (10^{-4})	1 05**	0 82**	1 02**	2 26**	3 03**	2 70**
	Adaxial stomatal density (mm^2)	442 80**	284 83**	217.05**	571 33**	318 14**	449 40**
	Abaxial stomatal density (mm^2)	662 26**	316 89**	369 18**	817 31**	688 07**	682 52**
	Days to stigma emergence	47 19**	29 26**	23 72**	95 91**	46 04**	48 57**
	Plant height (cm)	988 52**	1567 77**	2010 21**	1527 91**	1586 42**	1363 87**
0	Fodder yield/plant (g)	1106 95**	323 27**	215 29**	568 77**	314 83**	223 12**
1	Harvest index (%)	47 06**	100 91**	100 02**	107 34**	91 46**	102 07**
2	No of effective tillers/plant	0 67**	0 71**	0 28**	1 99**	0 98**	0 39**
3	Ear length (cm)	22 87**	20 61**	28 27**	20 42**	20 33**	27 49**
4	Ear girth (cm)	3 16**	2 93**	3 86**	3 07**	2 85**	3 04**
5	No of grains/cm^2	18 85**	16 14**	14 47**	16 96**	16 52**	18 33**
6	1000-grain weight (g)	8 80**	8 30**	7 92**	4 15**	4 41**	4 89**
7	Grain yield/plant (g)	411 02**	324 69**	174 62**	359 52**	214 30**	159 97**

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* significant at P = 0 01

Table 3 Analysis of variance (m s s) for stability parameters for morpho-physiological, agronomic characters and grain yield components

Source	D F	LAI	DMP I	DMP II	AGR	RGR (10^{-4})	Adaxial stomatal density	Abaxial stomatal density	Days to stigma emergence	Plant height	Fodder yield/ plant	Harvest index	No of effective tillers/ plant	Ear length	Ear girth	No of grains/ cm^2	1000 grain weight	Grain yield/ plant
Genotypes	48	GE P.D ++** 7 39	++** 548 59	++** 1630 24	++** 0 84	++** 1 56	++** 276 51	++** 449 06	++** 81 72	++** 2679 44	++** 580 92	++** 103 43	++** 1 16	++** 42 31	++** 5 68	++** 28 10	++** 8 77	++** 395 30
Environment	5	G.E ++ 47 71	++ 3571 31	++ 47107 30	++ 19 82	++ 7 51	++ 3988 55	++ 11878 35	++ 5874 53	++ 22531 1	++ 15815 29	++ 473 21	++ 10 35	++ 177 67	++ 10 91	++ 27 11	++ 75 10	++ 6705 20
G x E	240	PE @@ 0 91	@@ 75 27	@@ 221 30	@@ 0 23	@@ 0 42	@@ 96 93	@@ 145 92	@@ 3 04	@@ 67 07	@@ 67 3	@@ 15 91	@@ 0 10	@@ 0 87	@@ 0 13	@@ 1 13	@@ 0 79	@@ 30 54
E + (GxE)	245	1 87	146 62	1178 16	0 63	0 56	176 35	385 36	122 86	525 52	388 69	25 24	0 31	4 48	0 35	1 66	2 31	166 77
Environment (L)	1	PD ** 238 53	** 17856 53	** 235536 5	** 99 08	** 37 53	** 19942 62	** 59391 93	** 29372 66	** 112653 9	** 79076 37	** 2365 99	** 51 77	** 888 39	** 54 53	** 135 52	** 375 5	** 33525 95
G x E (L)	48	PD * 1 18	* 101 70	186 26	0 16	0 30	70 18	154 26	** 8 03	* 85 86	** 145 46	8 79	0 11	0 99	** 0 21	** 1 76	** 1 32	30 84
Pooled deviation	196	@@ 0 83	@@ 67 27	@@ 225 37	@@ 0 25	@@ 0 44	@@ 101 50	@@ 140 91	@@ 1 75	@@ 61 13	@@ 46 79	@@ 17 33	@@ 0 10	@@ 0 82	@@ 0 10	@@ 0 96	@@ 0 65	@@ 19 85
Pooled error	576	0 08	6 28	30 94	0 02	0 02	11 91	12 57	0 32	7 19	7 20	2 34	0 03	0 21	0 04	0 22	0 19	5 04

+,++ = Significant at P=0 05 and 0 01 respectively, when tested against GxE

*,** = Significant at P=0 05 and 0 01, respectively, when tested against pooled deviation

@ @@ = Significant at P=0 05 and 0 01 respectively, *when tested against pooled error*

Estimates of environmental indices (Ij) given in Table 4 suggested that E1 was the most favourable environment for all the characters, while E2 was favourable for DMP II, AGR, RGR, adaxial and abaxial stomatal densities, days to stigma emergence, plant height, harvest index, number of effective tillers per plant, ear length, ear girth, number of grains per cm^2, 1000 grain weight and grain yield per plant. The E3 environment was favourable only for adaxial and abaxial stomatal densities, days to stigma emergence and number of grains per cm^2 Where as environment E4 was favourable for all the characters except RGR, adaxial and abaxial stomatal densities, days to stigma emergence, plant height, harvest index, ear length and number of grains per cm^2 The E5 environment was favourable for LAI, DMP I, and harvest index while, E6 was favourable for RGR, days to stigma emergance and ear length

4.2.3 Stability parameters

The estimates of stability parameters for morpho-physiological, harvest index and agronomic characters and grain yield and its components are given in Table 5.

4.2.3.1 Morpho-physiological characters

i) Leaf area index

Out of 49 genotypes 24 had higher mean than population mean (5.01). None of the male sterile lines, recorded higher LAI than population mean. Five genotypes exhibited significant regression coefficient, while three male sterile lines, one pollinator, four hybrids and ICTP 8203 were noted to have non-significant deviation from regression

The pollinator RHRBI 138 (6.41) had higher LAI with regression coefficient greater than unity (b_i>1) and non-significant S^2di. Significantly higher

Table 4. Estimates of environmental index (Ij) for each characters under different environments expressed as deviation from grand mean

SN	Characters	E1	E2	E3	E4	E5	E6
1	Leaf area index	0 88	-0 37	-1.72	0 90	0 40	-0 09
2	Dry matter production I /plant (g)	5 03	-2 98	-11 38	12 88	1 99	-5 54
3	Dry matter production II /plant (g)	38 98	7 39	-47 71	23 18	-1 69	-20.15
4	Absolute growth rate (g/day)	0 89	0 21	-1 04	0 21	-0 02	-0 25
5	Relative growth rate (g/g/day) (10^{-4})	0 41	0 28	-0 63	-0 29	0 01	0 22
6	Adaxial stomatal density (mm^2)	-6 94	-3 17	-12 83	9 27	5 62	8 05
7	Abaxial stomatal density (mm^2)	-14 16	-8 47	-18 91	15 77	12 30	13 47
8	Days to stigma emergence	-7 32	-7 89	-7 59	19 23	6 75	-3 18
9	Plant height (cm)	23 68	30 83	-15 26	-7 91	-15 45	-15 89
10	Fodder yield/plant (g)	29 61	0 39	-21 18	8 82	-3 58	-14 06
11	Harvest index (%)	0 52	5 35	-2 78	-3 28	0 76	-0 57
12	No of effective tillers/plant	0 43	0 46	-0 43	0 32	-0 19	-0 59
13	Ear length (cm)	2 36	1 50	-2 72	-1 43	-0 51	0 80
14	Ear girth (cm)	0 70	0 33	-0 60	0 07	-0 34	-0 16
15	No of grains/cm^2	0 65	0 56	0 54	-0 64	-1 15	0 04
16	1000 grain weight (g)	0 78	1 48	-2 07	0 37	0.07	-0 63
17	Grain yield/plant (g)	14 35	8 80	-18 13	3 17	-0 33	-7 86

Table 5 Estimates of stability parameters for morpho-physiological, agronomic characters and grain yield components

Genotype	LAI			DMP I per plant (g)			DMP II per plant (g)		
	Mean	bi	S^2di	Mean	✓bi	✓S^2di	Mean	bi	S^2di
Male sterile line									
I RHRB 1A	3 01	0 66	0 94**	26 81	0 72	41 44**	77 09	0 96	41 88
II RHRB 2A	3 25	1 08	0 07	26 82	0 81	9 77	71 58	0 75	72 29
III RHRB 3A	3 49	1 41	0 06	27 64	1 39	-2 47	68 60	0 82	41 41
IV RHRB 5A	3 85	1 71	0 74**	30 25	1 57	39 72**	73 63	0 94	-16 39
V 9605 A	4 26	0 99	0 25*	40 01	0 84	9 82	123 41	1 02	787 82**
VI 9606 A	3 55	0 57	0 13	29 26	0 77	19 25*	80 86	0 84	82 64*
VII 9607 A	4 59	1 10	1 03**	37 80	0 35	47 77**	122 86	1 10	-3 60
Pollinator									
1 RHRBI 138	6 41	1 27	0 06	60 04	1 85*	63 96**	105 06	1 05	19 41
2 RHBRI 458	5 91	1 56	1 12**	49 07	1 22	62 02**	93 75	0 89	116 05**
3 RHRBI 178	3 56	0 82	0 32**	30 45	1 21	21 04*	101 82	0 81	330 13**
4 9611	6 27	2 36**	1 07**	49 09	1 77	114 87**	106 50	1 15	364 84**
5 9612	5 19	1 65	1 29**	36 80	1 10	60 75**	78 56	0 98	137 23**
Hybrids									
I x 1	5 40	1 01	0 34**	50 16	1 22	50 13**	118 21	1 08	194 70**
I x 2	4 83	0 60	1 00**	44 58	0 80	23 56**	105 81	0 73	491 35**
I x 3	3 37	0 25	0 27**	28 51	0 33	23 19**	110 89	1 06	-0 56
I x 4	6 94	1 85*	1 48**	58 01	2 01*	158 10**	127 93	0 99	64 65
I x 5	4 44	0 97	0 64**	38 71	1 03	39 77**	106 55	0 84	213 50**
II x 1	4 29	0 70	0 01	39 86	0 85	21 29**	116 63	1 10	18 02
II x 2	4 86	1 08	0 25*	42 63	1 07	48 14**	117 29	1 23	211 36**
II x 3	3 38	0 46	0 49**	31 82	0 65	59 45**	92 25	0 73	199 10**
II x 4	5 36	1 10	0 49**	48 02	1 17	59 63**	117 68	1 17	105 52**
II x 5	4 53	0 95	0 38**	38 05	0 84	29 67**	109 03	1 10	13 64
III x 1	5 55	1 14	1 11**	47 45	1 20	130 43**	115 47	0 96	265 89**
III x 2	4 72	0 63	0 18	39 57	0 49	3 26	107 11	1 01	64 55
III x 3	3 75	0 90	0 68**	30 98	0 95	102 81**	110 38	0 86	773 08**
III x 4	6 45	1 12	1 15**	55 56	0 97	81 56**	130 97	1 27	84 51*
III x 5	5 75	1 01	0 32*	43 13	0 82	50 18**	118 56	1 26	119 16**
IV x 1	5 48	0 89	1 03**	52 95	1 56	82 27**	115 40	1 16	171 66**
IV x 2	6 06	0 84	0 32**	55 78	1 00	48 68**	113 28	1 10	102 72*
IV x 3	3 86	0 57	0 31**	31 01	0 73	38 57**	107 20	1 37	362 82**
IV x 4	6 39	1 25	1 25**	57 35	1 20	64 40**	123 08	1 27	51 65
IV x 5	5 94	2 08**	0 27**	51 36	1 89*	124 73**	109 68	1 04	291 49**
V x 1	4 59	0 37	0 09	41 40	0 07*	-0 73	122 72	0 82	177 54**
V x 2	5 30	0 95	0 61**	47 26	0 87	44 20**	120 27	0 66	176.42**
V x 3	3 68	0 07*	0 19*	31 95	0 20	6 08	100 25	0 69	-10 31
V x 4	5 08	0 70	0 97**	44 73	0 45	58 74**	123 48	1 07	282 23**
V x 5	4 97	0 62	0 14	37 95	0 64	24 20**	121 21	1 17	553 05**
VI x 1	4 93	0 79	0 79**	49 23	1 23	58 21**	125 23	1 12	41 97
VI x 2	5 58	0 62	0 46**	48 88	0 53	40 31**	121 88	0 93	452 63**
VI x 3	3 74	0 33	1 83**	32 56	0 21	99 65**	108 04	0 99	334 78**
VI x 4	5 93	1 00	1 67**	49 06	1 43	82 75**	136 68	0 79	57 16
VI x 5	6 38	1 23	2 43**	49 20	0 84	148 26**	124 29	0 83	74 30*
VII x 1	6 42	1 16	0 82**	54 26	1 19	108 36**	118 36	0 85	600 30**
VII x 2	5 80	0 87	0 56**	49 63	0 70	21 06*	127 76	0 84	314 57**
VII x 3	4 11	0 24	0 56**	33 32	0 34	40 01**	110 30	0 79	64 19
VII x 4	6 44	1 12	0 83**	54 73	2 02*	199 08**	130 34	1 48*	247 16**
VII x 5	5 89	0 80	0 90**	46 51	0 54	41 29**	123 78	0 86	165 15**
Checks									
ICTP 8203	4 51	1 00	1 14	41 06	0 57	99 28**	116 13	0 76	74 32
MLBH 267	7 34	2 29**	3 29**	54 36	2 58**	189 63**	126 51	1 44*	149 64**
Mean	5 01			42 77			110 88		
S E ±	0 41	0 41		3 67	0 43		6 71	0 22	

Table 5 Contd

Genotype	AGR (g/day)			RGR (g/g/day)			Adaxial stomatal density (mm^2)		
	Mean	bi	S^2di	Mean (10^{-2})	bi	S^2di (10^{-4})	Mean	bi	S^2di
Male sterile line									
I RHRB 1A	1 49	0 85	0 16**	3 06	0 88	0 74**	93 18	1 88	139 83**
II RHRB 2A	1 33	0 60	0 08**	2 89	0 12	0 07**	96 04	0 62	233 71**
III RHRB 3A	1 22	0 74	0 08**	2 80	0 95	0 58**	94 17	0 39	62 88**
IV RHRB 5A	1 29	0 64	0 01	2 89	-0 27	0 77**	98 50	0 89	148 29**
V 9605 A	2 50	0 95	0 90**	3 29	1 12	0 72**	91 33	0 75	17 25
VI 9606 A	1 52	0 89	0 13**	2 96	0 16	0 46**	88 28	0 89	82 90**
VII 9607 A	2 53	1 12	0 13**	3 46	0 39	0 34**	87 02	1 05	18 74
Pollinator									
1 RHRBI 138	1 32	0 72	-0 01	1 63	0 47	0 01	85 07	1 72	103 36**
2 RHBRI 458	1 33	0 74	0 03*	1 90	0 56	0 05*	70 55	1 25	19 12
3 RHRBI 178	2 13	0 54	0 43**	3 73	0 78	1 58**	78 39	0 20	113 25**
4 9611	1 69	0 76	0 39**	2 33	-0 59*	0 51**	69 26	1 13	40 71**
5 9612	1 23	0 89	0 04*	2 18	0 57	0 07**	91 93	1 44	77 26**
Hybrids									
I x 1	2 02	1 22	0 16**	2 51	1 59	0 13**	83 57	0 44	32 66*
I x 2	1 84	0 83	0 47**	2 56	1 02	0 50**	97 56	1 40	206 37**
I x 3	2 45	1 18	0 11**	4 02	1 46	0 67**	87 98	0 81	112 85**
I x 4	2 08	0 94	0 39**	2 46	0 81	0 84**	82 27	1 40	20 80
I x 5	2 03	0 79	0 35**	3 04	0 48	0 66**	100 55	0 74	66 48**
II x 1	2 29	1 17	0 08**	3 17	1 62	0 23**	85 71	1 47	76 59**
II x 2	2 22	1 27	0 22**	2 96	1 70	0 39**	89 79	0 48	85 43**
II x 3	1 82	0 73	0 24**	3 23	1 72	0 93**	88 79	0 81	168 72**
II x 4	2 06	1 26	0 03	2 60	1 31	0 20**	95 16	1 11	47 28**
II x 5	2 10	1 14	0 07**	3 08	0 77	0 33**	92 76	0 75	117 51**
III x 1	2 02	1 14	0 23**	2 66	1 74	0 29**	88 21	0 99	89 49**
III x 2	2 00	1 10	0 07**	2 88	0 66	0 16**	86 48	1 32	118 69**
III x 3	2 38	0 56	0 90**	3 87	-0 01	1 01**	86 67	1 40	86 34**
III x 4	2 23	1 50	0 05*	2 46	1 55	0 32**	80 40	1 00	43 90**
III x 5	2 23	1 48	0 14**	2 91	1 55	0 32**	93 65	0 62	160 19**
IV x 1	1 86	1 11	0 15**	2 32	1 77	0 19**	91 76	0 67	16 18
IV x 2	1 71	1 04	0 09**	2 03	0 98	0 12**	25 24	1 23	68 66**
IV x 3	2 25	1 32	0 45**	3 59	0 63	0 48**	89 67	0 79	100 93**
IV x 4	1 94	1 40	0 20**	2 20	1 27	0 38**	80 04	1 16	32 38*
IV x 5	1 73	0 72	0 40**	2 32	0 73	0 66**	93 60	1 68	158 91**
V x 1	2 44	0 93	0 28**	3 18	0 58	0 42**	87 12	0 88	79 58**
V x 2	2 19	0 50	0 09**	2 83	0 31	0 22**	81 53	0 42	51 12**
V x 3	2 02	0 91	0 00	3 39	1 73	0 02	93 08	1 13	191 16**
V x 4	2 33	1 34	0 26**	2 97	1 43	0 39**	87 63	0 82	24 98
V x 5	2 48	1 07	0 52**	3 41	0 35	0 21**	97 41	1 43	152 48**
VI x 1	2 26	1 28	0 11**	2 79	1 94	0 13**	89 25	0 40	144 42**
VI x 2	2 17	1 16	0 34**	2 68	1 22	0 27**	81 10	0 94	13 97
VI x 3	2 30	1 14	0 35**	3 58	1 33	0 99**	88 47	1 10	239 40**
VI x 4	2 63	0 73	0 08**	3 15	0 82	0 26**	84 51	0 94	88 81**
VI x 5	2 23	1 05	0 09**	2 80	2 12	0 13**	97 01	1 60	38 2*
VII x 1	1 92	0 75	0 45**	2 35	1 18	0 50**	77 97	1 08	-10 20
VII x 2	2 34	1 03	0 33**	2 81	1 54	0 15**	80 73	0 84	70 07**
VII x 3	2 30	0 74	0 08**	3 58	0 48	0 23**	86 64	0 30	19 55
VII x 4	2 23	1 78*	0 65**	2 51	1 97	0 59**	80 01	0 95	77 96**
VII x 5	2 30	1 06	0 12**	2 88	1 79	0 08**	87 22	1 44	100 52**
Checks									
ICTP 8203	2 24	0 79	0 07**	3 11	0 66	0 27**	92 35	1 70	197 85**
MLBH 267	2 13	1 27	0 12**	2 57	0 79	0 61**	85 35	0 32	42 09**
Mean	2 02			2 87			87 97		
S E ±	0 22	0 35		0 30	0 75		4 50	0 50	

Table 5 Contd

Genotype	Abaxial stomatal density (mm^2)			Days to stigma emergence			Plant height (cm)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
Male sterile line									
I RHRB 1A	118 88	1 46	188 53**	50 72	0 91	0 58	118 56	1 10	37 08**
II RHRB 2A	118 23	1 29	315 14**	51 55	1 04	3 79**	128 27	1 57**	19 78*
III RHRB 3A	120 64	1 01	302 47**	54 11	1 27**	2 97**	110 58	0 94	97 90**
IV RHRB 5A	122 64	1 55	68 12**	54 88	1 14**	2 64**	119 07	1 25	344 90**
V 9605 A	123 29	1 18	43 63**	49 83	0 92	-0 13	153 38	1 06	10 56
VI 9606 A	119 08	1 42	103 15**	51 00	0 88*	-0 10	133 84	1 41*	63 92**
VII 9607 A	102 78	1 09	21 40	49 11	0 90	0 04	150 08	1 12	29 63**
Pollinator									
1 RHRBI 138	106 52	1 66	43 18**	58 77	1 12*	2 49**	199 28	1 03	158 09**
2 RHBRI 458	105 83	1 15	153 98**	60 22	1 07	2 83**	183 88	1 10	19 42*
3 RHRBI 178	102 08	0 49	86 24**	49 77	1 00	1 65**	154 13	0 71	-4 56
4 9611	82 42	1 17	70 20**	60 44	1 20**	8 46**	153 30	0 90	68 14**
5 9612	117 94	1 03	112 76**	59 16	1 01	1 75**	144 88	1 23	55 87**
Hybrids									
I x 1	104 86	0 71	92 95**	50 77	0 90	0 74	187 52	0 93	32 60**
I x 2	122 75	0 95	152 08**	55 77	1 16**	0 01	194 21	0 77	40 21**
I x 3	111 25	0 65	115 00**	46 33	0 88*	2 95**	158 61	1 05	2 52
I x 4	104 46	0 57	14 54	55 44	1 25**	1 72**	184 38	0 84	45 91**
I x 5	123 34	1 23	98 73**	51 66	1 01	0 60	162 30	0 82	1 73
II x 1	103 35	0 82	253 18**	49 22	0 87**	0 82*	178 53	0 98	13 58
II x 2	117 15	0 70	104 09**	51 83	0 85**	0 62	181 99	1 20	27 66**
II x 3	112 78	0 95	41 38*	44 11	0 88*	2 99**	153 17	1 17	45 92**
II x 4	110 38	1 01	99 40**	53 50	1 07	0 54	176 77	1 02	24 79**
II x 5	116 47	0 22*	108 41**	50 05	0 86**	1 53**	161 79	1 14	24 05**
III x 1	104 54	1 20	90 52**	51 77	1 02	0 16	185 67	0 72	29 09**
III x 2	106 94	1 23	131 96**	52 11	0 80**	0 95*	183 23	0 88	24 12**
III x 3	102 84	1 05	78 82**	46 94	1 02	2 67**	155 81	0 68	59 04**
III x 4	97 03	1 26	53 96**	54 00	0 98	0 44	166 43	0 65*	21 18*
III x 5	116 53	0 96	279 33**	52 38	1 08	-0 06	155 00	0 81	32 16**
IV x 1	110 92	0 88	-3 05	57 11	1 06	1 09**	184 94	1 38*	13 17
IV x 2	115 15	1 47	61 22**	57 61	1 06	1 18**	187 86	1 05	18 07*
IV x 3	115 17	1 02	333 16**	50 88	0 99	2 48**	165 61	1 10	16 79
IV x 4	103 64	0 82	33 26*	57 27	1 17**	2 17**	178 85	0 79	42 82**
IV x 5	121 38	1 73*	152 66**	55 22	0 98	2 15**	175 26	1 21	45 17**
V x 1	116 75	0 77	167 36**	49 88	0 82**	0 96*	186 37	0 79	37 80**
V x 2	102 55	1 03	112 95**	53 61	0 97	0 10	197 05	1 10	26 95**
V x 3	115 50	0 94	315 71**	46 72	0 84**	1 54**	163 97	0 92	115 21**
V x 4	103 30	0 32	15 26	53 00	0 90	1 28**	180 82	0 98	34 12**
V x 5	121 77	0 78	180 44**	51 83	0 96	0 50	168 59	0 85	51 62**
VI x 1	113 32	0 43	347 46**	53 50	0 95	-0 01	188 20	1 06	37 27**
VI x 2	108 73	0 68	26 95	53 77	0 92	0 73	182 99	1 07	116 45**
VI x 3	110 23	1 22	388 57**	47 61	0 87*	1 25**	155 98	1 03	103 17**
VI x 4	100 06	0 67	95 28**	54 83	1 19**	3 11**	171 19	0 93	11 39
VI x 5	114 97	1 45	206 35**	53 72	1 05	0 38	167 61	0 76	45 40**
VII x 1	100 01	0 70	4 62	52 88	1 00	0 81*	197 73	1 00	22 45*
VII x 2	105 97	1 35	180 82**	54 22	1 00	0 39	193 31	1 04	0 22
VII x 3	104 42	0 78	-2 64	47 05	0 87	4 00**	160 35	0 77	111 90**
VII x 4	94 17	0 35	80 72**	55 50	1 06	0 81*	176 30	0 94	89 28**
VII x 5	111 25	1 57	168 57**	53 27	0 96	-0 23	169 07	0 89	15 76
Checks									
ICTP 8203	112 20	1 03	186 66**	50 22	0 98	0 23	181 56	0 90	245 83**
MLBH 267	105 19	0 76	13 01	57 16	1 11*	1 34**	161 77	1 12	116 63**
Mean	110 23			52 66			167 91		
S E ±	5 31	0 34		0 59	0 05		3 50	0 16	

Table 5 Contd

Genotype	Fodder yield per plant (g)			Harvest index (%)			No of effective tillers per plant		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
Male sterile line									
I RHRB 1A	31 42	0 69	26 46**	33 56	1 42	8 80**	2 73	1 56	0 31**
II RHRB 2A	27 01	0 48**	10 97	35 79	2 07	47 86**	2 68	1 18	0 40**
III RHRB 3A	35 45	0 90	40 49**	27 92	1 92	13 42**	2 03	1 36	0 03
IV RHRB 5A	38 51	1 09	12 55	30 33	0 67	25 65**	1 84	1 26	0 06*
V 9605 A	52 35	0 96	52 34**	31 10	0 79	26 65**	2 09	1 15	0 12**
VI 9606 A	31 06	0 63*	42 80**	33 50	0 95	3 17	1 60	0 84	0 03
VII 9607 A	56 78	1 16	22 65*	31 17	1 20	12 74**	2 12	1 26	0 02
Pollinator									
1 RHRBI 138	58 23	0 96	11 14	21 27	0 64	7 85*	1 75	0 92	0 05
2 RHBRI 458	47 36	0 67	25 65**	25 46	0 38	43 38**	1 54	0 83	0 06*
3 RHRBI 178	47 32	0 69	19 36*	27 56	0 43	2 31	3 22	1 74	0 39**
4 9611	52 90	0 82	55 62**	27 82	0 80	3 96	2 00	1 30	0 01
5 9612	37 03	0 97	39 42**	34 47	1 27	53 85**	1 91	1 41	0 01
Hybrids									
I x 1	59 67	1 26	3 68	35 40	1 49	9 57**	1 83	0 73	0 01
I x 2	55 16	0 98	14 93	35 03	0 16	25 64**	1 50	0 53	0 02
I x 3	46 37	1 01	11 45	35 72	1 63	15 09**	2 86	1 35	0 00
I x 4	70 35	1 05	76 67**	38 43	0 49	10 99**	1 99	0 93	0 03
I x 5	45 80	0 62*	-0 24	43 31	0 47	33 06**	2 54	1 06	0 45**
II x 1	49 75	1 01	6 48	38 16	1 20	0 83	2 21	0 91	0 19**
II x 2	49 11	0 98	15 21	35 12	1 18	1 91	2 11	1 13	0 00
II x 3	38 86	0 78	10 10	39 00	1 19	22 16**	2 86	0 83	0 05
II x 4	56 07	1 00	165 35**	38 80	0 67	7 66*	2 07	1 03	0 01
II x 5	43 36	0 95	19 45*	39 55	1 54	4 50	2 54	0 99	0 52**
III x 1	58 85	1 09	7 55	36 32	0 68	11 72**	1 66	0 61	-0 01
III x 2	55 54	1 09	17 37*	32 52	1 03	11 67**	1 57	0 69	0 01
III x 3	48 48	0 87	84 21**	34 57	0 66	32 09**	2 46	1 22	0 06*
III x 4	59 64	0 91	59 45**	37 46	1 60	17 99**	1 89	0 79	0 00
III x 5	47 62	1 13	-0 22	41 29	1 17	26 05**	2 11	1 15	0 00
IV x 1	57 68	1 49**	152 33**	34 03	1 36	15 55**	1 60	0 85	0 04
IV x 2	62 58	1 31	9 64	31 56	0 70	32 09**	1 45	0 67	-0 01
IV x 3	47 50	1 27	10 64	33 71	0 60	22 58**	2 09	0 83	-0 01
IV x 4	65 71	1 60**	19 76*	36 42	0 96	20 62**	1 61	0 82	0 02
IV x 5	53 73	0 84	83 83**	40 31	0 85	53 10**	1 88	0 96	0 03
V x 1	57 32	0 79	54 75*	33 44	0 78	6 32*	1 62	0 82	-0 01
V x 2	58 68	0 94	3 97	33 62	0 44	9 07**	1 43	0 57	0 06*
V x 3	47 71	0 72	15 95	34 31	1 34	1 63	2 26	1 11	0 02
V x 4	63 00	1 55**	25 19**	36 95	1 43	9 84**	1 67	0 74	0 05
V x 5	49 36	1 07	23 54**	41 24	1 25	0 76	2 00	1 02	0 13**
VI x 1	57 61	1 01	18 97*	34 76	0 51	6 25*	1 68	0 63	0 02
VI x 2	59 63	1 11	164 29**	34 88	0 63	1 37	1 45	0 56	0 02
VI x 3	45 53	1 01	50 84**	36 70	1 33	26 22**	2 42	1 25	0 11**
VI x 4	57 12	0 92	8 17	35 18	1 16	2 70	1 78	1 01	0 02
VI x 5	52 09	0 80	13 91	38 85	0 74	2 98	1 90	0 79	0 07*
VII x 1	61 93	1 34*	200 22**	37 05	1 01	7 90**	1 45	0 47	0 03
VII x 2	64 43	1 00	63 85**	33 07	1 41	18 14**	1 43	0 47	0 01
VII x 3	47 10	0 58*	7 18	36 32	1 25	0 95	2 46	1 55	0 09**
VII x 4	73 02	2 18**	72 59**	35 46	0 63	8 99**	1 49	0 96	0 02
VII x 5	52 53	0 75	8 96	38 88	0 94	5 26	1 99	1 02	-0 01
Checks									
ICTP 8203	56 11	0 59**	40 47**	34 07	0 49	-1 08	1 76	1 11	0 04
MLBH 267	53 91	1 16	39 50**	36 74	1 28	2 12	2 53	1 79*	0 00
Mean	51 92			34 86			1 99		
S E ±	3 06	0 17		1 86	0 60		0 14	0 31	

Table 5 Contd .

Genotype	Ear length (cm)			Ear girth (cm)			No of grains per cm^2		
	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i	Mean	b_i	S^2d_i
Male sterile line									
I RHRB 1A	13 08	0 84	0 32	9 06	1 30	-0 02	18 72	1 48	1 23**
II RHRB 2A	14 74	1 21	0 24	9 80	1 64*	0 07	17 89	0 25	2 44**
III RHRB 3A	14 04	1 44*	0 77**	9 48	1 53	0 09*	16 35	1 74	0 00
IV RHRB 5A	12 43	0 98	0 16	8 76	1 80**	-0 02	21 92	-0 14	3 09**
V 9605 A	18 81	0 96	0 71**	11 24	1 20	0 10*	19 07	2 17*	1 42**
VI 9606 A	14 52	0 88	1 46**	10 85	1 36	0 21**	20 64	0 99	0 33
VII 9607 A	22 23	0 82	0 18	11 25	0 67	-0 02	15 40	1 89	0 40
Pollinator									
1 RHRBI 138	19 50	1 40	0 76**	10 77	1 74*	0 24**	14 89	1 05	-0 05
2 RHBRI 458	18 13	1 13	4 13**	11 99	0 79	0 11*	14 34	1 27	0 03
3 RHRBI 178	15 48	0 82	-0 18	8 56	0 24*	0 09*	16 48	1 02	0 68*
4 9611	17 73	0 65	0 49	10 35	1 80**	0 00	17 06	0 36	1 15**
5 9612	15 92	1 01	1 68**	10 23	1 90**	0 01	21 19	3 33**	1 48**
Hybrids									
I x 1	19 29	0 60	0 39	11 05	1 33	0 07	16 75	0 85	0 22
I x 2	19 57	1 04	0 71**	11 36	0 90	-0 02	16 61	1 31	0 15
I x 3	16 94	0 91	0 07	9 35	0 99	-0 02	16 90	1 24	0 60*
I x 4	19 13	0 97	1 05**	11 07	1 15	0 05	19 43	-0 87**	0 53*
I x 5	17 84	0 59	-0 06	10 31	0 89	0 09*	19 90	1 89	0 07
II x 1	20 45	0 62	0 76**	11 20	1 08	0 12*	15 68	1 04	0 14
II x 2	20 51	0 96	-0 01	11 53	0 63	0 02	15 78	0 75	0 21
II x 3	16 87	0 85	-0 09	9 15	0 87	0 04	16 78	1 12	0 32
II x 4	18 24	1 23	0 10	10 86	0 91	-0 01	19 09	-0 60**	4 41**
II x 5	18 34	1 24	0 41	10 51	0 91	0 22**	18 13	1 30	0 31
III x 1	20 59	1 16	0 74**	10 87	0 92	0 01	16 25	-0 01	0 08
III x 2	21 21	1 32	0 17	11 35	0 44	0 09*	14 70	1 92	0 18
III x 3	17 07	1 25	1 78**	9 50	0 04**	0 27**	16 48	1 80	0 19
III x 4	19 42	1 24	0 15	11 22	0 60	0 00	18 24	1 40	1 02**
III x 5	19 47	1 00	-0 11	10 80	1 04	-0 01	18 30	1 50	0 95*
IV x 1	18 02	0 89	0 00	10 63	1 33	0 15**	19 75	-0 03	1 08**
IV x 2	18 91	0 98	0 21	11 29	1 33	0 01	17 27	0 85	0 31
IV x 3	16 80	1 03	0 50*	9 21	0 72	0 07	19 03	0 16	1 02**
IV x 4	17 99	1 18	-0 05	10 64	1 28	0 01	21 82	0 57	0 52*
IV x 5	18 02	1 16	0 04	10 29	1 49	-0 01	22 17	1 09	0 64
V x 1	20 45	0 75	0 44	11 33	0 76	0 07	16 77	0 65	1 06**
V x 2	22 83	0 98	0 80**	12 31	0 56	0 10*	16 02	1 15	-0 02
V x 3	18 76	1 06	1 38**	10 11	0 14**	-0 01	17 81	0 85	0 23
V x 4	20 58	0 81	1 18**	11 41	1 17	0 07	19 88	0 32	2 09**
V x 5	19 81	0 71	0 00	11 30	0 71	0 03	21 24	1 07	0 08
VI x 1	20 68	0 84	0 05	11 99	0 84	0 03	17 03	-0 07	-0 02
VI x 2	21 55	1 29	0 12	12 94	0 56	0 00	15 28	1 21	0 38
VI x 3	16 89	1 03	0 59*	10 28	0 79	0 02	18 88	2 89**	1 44**
VI x 4	19 82	0 79	0 14	11 70	0 99	0 02	19 72	0 28	-0 07
VI x 5	19 82	0 67	-0 05	11 53	0 72	-0 02	21 66	1 26	0 42
VII x 1	24 54	0 87	1 20**	11 67	0 73	0 08	15 98	0 69	0 06
VII x 2	25 58	0 74	0 65*	12 55	0 95	0 00	14 28	1 02	0 22
VII x 3	19 55	0 77	0 54*	10 35	0 41	0 05	16 58	0 74	0 20
VII x 4	22 18	1 51**	0 50*	11 82	1 29	0 05	18 45	0 69	0 18
VII x 5	21 24	1 37	3 24**	11 32	0 97	-0 03	20 00	1 17	1 68**
Checks									
ICTP 8203	20 63	1 24	1 47**	11 01	0 63	0 43**	17 11	0 29	0 22
MLBH 267	19 78	0 96	0 24	10 62	1 65*	0 04	20 93	1 90	2 71**
Mean	18 89			10 78			17 97		
S E ±	0 40	0 21		0 14	0 30		0 44	0 59	

Table 5 Contd

Genotype	1000 grain weight (g)			Grain yield per plant (g)		
	Mean	bi	S^2di	Mean	bi	S^2di
Male sterile line						
I RHRB 1A	11 11	1 19	-0 06	25 90	0 90	-2 43
II RHRB 2A	10 44	1 50	0 42	27 31	0 95	21 14 **
III RHRB 3A	11 91	0 80	2 24**	20 20	0 91	13 56 *
IV RHRB 5A	11 46	1 19	0 25	22 12	0 62	13 73 *
V 9605 A	11 86	0 39*	0 04	37 10	0 87	7 19
VI 9606 A	11 45	0 92	1 15**	27 15	0 82	2 90
VII 9607 A	13 50	0 47	0 91**	38 09	1 05	19 45 **
Pollinator						
1 RHRBI 138	12 50	0 77	-0 11	22 16	0 63	1 67
2 RHBRI 458	12 13	0 80	0 09	25 05	0 90	17 91 **
3 RHRBI 178	10 31	0 91	0 14	27 69	0 56*	17 26 **
4 9611	11 71	1 11	0 29	29 95	0 94	22 75 **
5 9612	10 43	1 85**	0 69**	26 93	0 95	17 29 **
Hybrids						
I x 1	14 11	1 70**	-0 13	41 69	1 13	7 95
I x 2	13 61	1 43	0 11	37 00	0 93	24 56 **
I x 3	11 53	0 57	0 03	39 10	1 04	8 80
I x 4	12 99	1 42	1 55**	49 38	1 13	59 66 **
I x 5	12 25	0 95	0 10	47 41	0 98	38 49 **
II x 1	12 64	1 83**	-0 05	44 78	1 31	1 31
II x 2	12 79	1 37	0 84**	41 11	1 12	40 09 **
II x 3	10 63	0 72	-0 12	36 58	0 86	52 57 **
II x 4	12 80	0 92	0 27	45 35	1 01	63 57 **
II x 5	11 77	0 39*	0 16	43 45	1 30	9 97
III x 1	14 68	1 90**	1 38**	41 21	0 86	12 82 *
III x 2	14 73	0 78	0 85**	34 51	0 86	21 70 **
III x 3	12 02	0 15**	1 01**	37 18	0 80	23 35 **
III x 4	13 04	0 63	-0 12	48 50	1 30	13 23 *
III x 5	12 92	0 63	0 17	48 56	1 23	58 31 **
IV x 1	12 55	0 80	1 62**	39 56	1 26	44 17 **
IV x 2	13 43	1 40	0 24	35 48	0 90	3 41
IV x 3	11 09	1 16	0 04	34 39	0 85	9 06
IV x 4	12 65	0 68	0 72**	44 00	1 01	14 19 *
IV x 5	12 27	1 08	0 03	45 17	1 35	33 35 **
V x 1	14 06	1 72*	1 23**	40 68	0 68	14 48 *
V x 2	13 18	1 16	0 77**	40 53	0 80	19 73 **
V x 3	11 25	0 71	0 28	34 79	0 81	10 71
V x 4	13 05	1 10	0 77**	45 89	1 26	53 70 **
V x 5	11 85	1 42	0 32	50 07	1 32	60 74 **
VI x 1	13 39	1 29	0 09	43 98	1 06	25 93 **
VI x 2	14 69	0 50	0 35	42 70	1 03	29 40 **
VI x 3	10 69	0 84	0 02	39 69	1 13	1 56
VI x 4	12 36	0 68	0 08	48 20	0 90	0 03
VI x 5	12 59	0 44	1 04**	48 53	1 02	18 56 **
VII x 1	14 18	1 20	0 50*	44 51	1 24	81 86 **
VII x 2	13 92	1 05	0 34	43 02	1 21	69 26 **
VII x 3	12 15	0 55	0 17	39 90	0 82	12 58 *
VII x 4	13 71	0 81	1 19**	45 60	1 26	39 65 **
VII x 5	12 34	1 15	-0 02	47 83	0 87	33 05 **
Checks						
ICTP 8203	14 42	0 80	0 23	39 59	0 67	13 03 *
MLBH 267	10 82	0 94	-0 10	46 82	1 42*	38 43 **
Mean	12 49			38 90		
S E ±	0 36	0 29		2 44	0 21	

*,** significant at P = 0 05 and P = 0 01, respectively

mean (6 27) coupled with bi>1 and significant deviation from regression were recorded for pollinator, 9611.

Among the hybrids and checks LAI ranging from 3 37 to 7 34. Though, the hybrids I x 4, IV x 5 and MLBH-267 had significant deviation from regression, produced significantly higher LAI with regression coefficient greater than one The hybrids I x 1, II x 4, III x 5, V x 2, VI x 4 and VII x 4 also exhibited higher mean with regression coefficient near to unity (bi = 1) and significant S^2di

ii) Dry mater production I

None of female parents recorded higher dry matter production at flowering than the population mean (42 77 g). Out of remaining genotypes, 25 had expressed higher mean than that of population The dry matter production I of the genotypes ranged from 26.81 g in RHRB 1A to 60.04 g in RHRBI 138 Regression coefficient was significant for six genotypes

The 25 genotypes exhibited relatively lower and 19 genotypes higher values than unity and five genotypes *viz.*, 9612, I x 5, II x 2, III x 4 and IV x 2 exhibited values of the regression coefficient near to unity.

Significantly higher dry matter production I coupled with bi > 1 but significant deviation from regression were recorded in case of pollinator, RHRBI 138 and hybrids, I x 4, IV x 5, VII x 4 and MLBH 267 Among the genotypes three females *viz.*, RHRB 2A, RHRB 3A, 9605A, and three hybrids *viz* , III x 2, V x 1 and V x 3 showed non-significant mean square deviation for this character.

iii) Dry matter production II

The data presented in Table 5 revealed that, for DMP II, 28 genotypes produced higher dry matter production at maturity than the population mean (110.88 g) None of the pollinators expressed higher dry matter at maturity than population mean The remaining genotypes produced DMP II ranging from 68.60 to 136.68 g. As regards to regression coefficient all genotypes exhibited non-significant values except VII x 4 and MLBH 267

Among parents, 9607 A and RHRBI 138 had regression coefficient near to one (bi = 1) with non-significant mean square deviation. Also, they had higher (122.86 g) and lower (105 06 g) mean values than population mean (110.88 g) respectively

Higher dry matter production at maturity was expressed by hybrids, I x 3 (110 89 g), I x 4 (127.93 g), II x 1 (116 63 g) and VI x 1 (125 23 g) with regression coefficient near to unity (bi = 1) and non-significant S^2di. The hybrid IV x 4 expressed higher mean with regression coefficient greater than one (bi > 1) and hybrid VI x 4 and population, ICTP 8203 had regression coefficient less than one (bi < 1) and non-significant deviation from regression.

The mean square deviation was significant in 32 genotypes

iv) Absolute growth rate

Thirty two genotypes displayed higher AGR than the population mean (2 02 g/day) Among all the genotypes, hybrid VI x 4 possessed highest value of AGR (2 63 g/day) and the male sterile line, RHRB 3A had lowest (1 22 g/day) such value. The estimates of regression coefficient was significant only in case of hybrid, VII x 4 (bi = 1 78).

Among the parents, 9605 A (2.50 g/day) and 9607 A (2.53 g/day) had significantly higher mean with regression coefficient near to unity, though had significant mean square deviations

The hybrid V x 3 expressed higher (2.02 g/day) mean with regression coefficient near to unity (bi = 1) and hybrid, II x 4 (2 06 g/day) had regression coefficient than unity (bi>1) and non-significant deviation from regression

The mean square deviation exhibited by parents, RHRB 5A, and RHRBI 138 and two hybrids were non-significant

v) Relative growth rate

For relative growth rate, out of 49 genotypes, 26 exhibited higher mean value than the population mean (0.0287 g/day) The rest of the genotypes had relative growth rate ranging from 0.0163 to 0 0283 g/g/day. All the male sterile lines exhibited higher value for relative growth rate except RHRB 3A than population mean (0 0287 g/g/day). None of the genotypes showed significant regression coefficient except, pollinator, 9611

The 22 genotypes displayed relatively higher and 24 genotypes lower values than unity and three genotypes *viz.*, RHRB 3A (bi=0.95), I x 2 (bi = 1 02) and IV x 2 (bi = 0 98) exhibited values of the regression coefficient near to one

Only one hybrid *viz.*, V x 3 was count to have significantly higher mean (0.0339 g/g/day) with regression coefficient more than one (bi>1) and non-significant S^2di The mean square deviation were significant for all the genotypes except, male RHRBI 138 and hybrid V x 3 which displayed non-significant values

vi) Adaxial stomatal density

Among the genotypes studied, 23 possessed lower adaxial stomatal densities than the population mean (87.97 mm^2). All the pollinators exhibited lower mean ranging from 69.26 to 85.07 mm^2 than the population mean except, 9612 Among rest of the genotypes, VII x 1 possessed lowest (77 97 mm^2) and I x 5 highest (100 55 mm^2) adaxial stomatal density.

Among the parent male sterile line 9607 A had unit regression coefficient with non-significant mean square deviation and lower mean (87 02 mm^2) while, male sterile line, 9605 A expressed regression coefficient less than one ($bi<1$) and pollinator, RHRBI 458 had regression coefficient greater than one ($bi>1$) with non-significant deviation from regression The former parent, 9605 A showed high, while the latter parent RHRBI 458 showed low adaxial stomatal density

Two hybrid combinations *viz.*, VI x 2 (81.10 mm^2) and VII x 1 (77 97 mm^2) exhibited lower mean with regression coefficient equal to one The hybrids, which had lower mean with $bi>1$ was I x 4 (82 27 mm^2) and with $bi<1$ were V x 4 (87.63 mm^2) and VII x 3 (86 64 mm^2). However, one hybrid, IV x 1 expressed high mean with regression coefficient less than one ($bi<1$). All these above hybrids also showed non-significant mean square deviations.

Nine genotypes expressed non-significant mean square deviations

vii) Abaxial stomatal density

For abaxial stomatal densities, female (9607 A), four males *viz* , RHRBI 138, RHRBI 458, RHRBI 178 and 9611 and seventeen hybrid possessed lower abaxial stomatal densities than the population mean (110.23 mm^2). The rest of the genotypes expressed abaxial stomatal densities ranging from 110.38 to 123 34 mm^2. Among the genotypes, inbred 9611 had lowest abaxial stomatal density (82.42 mm^2) followed by VII x 4 (94 17 mm^2) and III x 4 (97 03 mm^2). The estimates of regression coefficient were significant in case of hybrids II x 5 and IV x 5

Only one parent, 9607A had lower mean (102.78 mm^2), with unit regression coefficient and non-significant S^2di. Among the hybrids, I x 4, IV x 1, V x 4, VI x 2, VII x 1, VII x 3 and MLBH 267 possessed lower abaxial stomatal densities except IV x 1 (high value of 110 92 mm^2) with regression coefficient less than unity (bi<1) and non-significant S^2di

The mean square deviation was significant for 41 genotypes for this trait

4.2.3.2 Harvest index and agronomic characters

i) Days to stigma emergence

Out of 49 genotypes studied, 24 had average mean value lower than population mean (52.66 days) The hybrids II x 3, I x 3, III x 3, V x 3, VII x 3 and VI x 3 were very early which took 44.11, 46.33, 46 94, 46 72, 47.05 and 47.61 days to stigma emergence, respectively. Inbred, 9611 was very late which required 60 44 days to stigma emergence All the genotypes flowered between 44 11 and 60 44 days. Nineteen genotypes showed significant regression coefficient.

Among the parents RHRB 1A (50.72), 9605A (49 83) and 9607A (49 11 days) had average value lower than population mean with regression coefficient equal to one and non-significant S^2di. The female, 9606A had mean lower than population (52.66 days) and estimate of regression coefficient was significantly less than one with non-significant deviation from regression

The combinations I x 1, I x 5, III x 1, III x 5, V x 5 and population ICTP 8203 had bi values near to unity non-significant deviation from regression and lower mean Regression coefficient was significantly greater and lower than one with non-significant S^2di were recorded in case of hybrids, I x 2 and II x 2 respectively Among the female parents RHRB 2A, RHRB 3A and RHRB 5A exhibited significant, while of the remaining genotypes, sixteen exhibited non-significant deviation from the regression for this trait.

ii) Plant height

The data presented in Table 5 revealed that 26 genotypes were comparatively taller and had mean greater than the population mean (167.91 cm). The inbred, RHRBI 138 was found to be tallest (199 28 cm) among all the genotypes studied All the male sterile lines exhibited lower mean for plant height than the male parents except 9611 and 9612 The RHRB 3A was found to be relatively dwarf (110 58 cm) among the female parent studied Among, female parent, RHRB 2A and 9606 A had regression coefficient significantly higher than one and two hybrid also showed significant regression coefficient

Among the parents, male sterile line, 9605 A had bi $\approx$ 1 and inbred RHRB 178 had bi < 1 being non-significant S^2di with lesser of plant height (153 38 and 154.13 cm, respectively) The hybrid, which showed higher mean with regression coefficient near to unity (bi = 1) and non-significant mean square deviation were . II x 1 (178 53 cm), VI x 4 (171 19 cm), VII x 2 (193 31 cm) and VII x 5 (169 07 cm)

Significantly higher mean (184 94 cm) coupled with bi > 1 and non-significant S^2di was noted in case of hybrid, IV x 1. All the genotypes expressed significant mean square deviation except, ten.

iii) Fodder yield per plant

Twenty eight genotypes displayed higher fodder yield per plant than population mean (51 92 g). The fodder weight of the genotypes ranged from 27 01 g in RHRB 2A to 73.02 g in VII x 4. Significant regression coefficient was noted in 10 genotypes.

Among the parents, females 9605 A had higher mean with $b_i \approx 1$ and deviation from regression was significant, however, male parent RHRBI 138 also produced higher mean (58.23 g) with regression coefficient near to unity and the deviation from regression was non-significant.

Non-significant deviation from regression with unit regression coefficient ($b_i = 1$) and higher fodder yield were noted in the hybrids I x 2 (55 16 g), III x 1 (58 85 g), V x 2 (58.68 g) and VI x 4 (57.12 g). The hybrids, I x 1 (59.67 g) and IV x 2 (62 68 g) had higher mean with $b_i > 1$ and non-significant S^2d_i, while, two crosses, VI x 5 (52 09 g) and VII x 5 (52 53 g) had higher mean with $b_i<1$ and non-significant S^2di.

The mean square deviation were non-significant in three parents *viz.*, RHRB 2A, RHRB 5A and RHRBI 138 and in 17 hybrids.

iv) Harvest index

For harvest index, 27 genotypes expressed higher mean than population mean (34.86) All the inbreeds exhibited lower harvest index. Among all the genotypes, hybrid I x 1 possessed highest (43.31) and inbred RHRBI 138 had lowest (21.27) harvest index. None of the genotypes was found significant for regression coefficient.

Twenty two genotypes each had relatively higher and lower value (b_i) than one and five genotypes *viz* , 9606A, III x 2, IV x 4, VII x 1 and VII x 5 exhibited values of the regression coefficient near to unity None of the male parent, however, displayed higher harvest index than population mean. Though the female parent, RHRB 2A had significant S^2di value with higher mean (35 79) and regression coefficient greater than one (bi>1)

Among the hybrids studied seven combinations *viz.*, II x 1 (38 16), II x 2 (35 12), II x 5 (39.55), V x 5 (41.24), VI x 4 (35.18), VII x 3 (36 32) and MLBH 267 (36 74) had regression coefficient greater than one and two hybrids, VI x 2 (34 88) and VI x 5 (38 85) had regression coefficient less than one with non-significant mean square deviation. Also they had higher mean than population mean (34 86)

The mean square deviation were non-significant for three parents *viz* , 9606A, RHRBI 178, 9611 and 11 hybrids and check ICTP 8203

4.2.3.3 Grain yield and its components

i) Number of effective tillers per plants

Among the genotypes studied, 24 possessed higher number of effective tillers per plant than population mean (1 99). The rest of the genotypes had effective tillers ranging from 1 43 to 1.91 per plant The inbred parent RHRBI 178 produced the highest number of effective tillers per plant (3 22)

Male sterile lines, RHRB 3A, 9607 A and inbred 9611 exhibited higher mean with regression coefficient greater than one and non-significant S^2di The estimates of regression coefficient was significant in case of check hybrid MLBH 267 with higher effective tillers (2.53) per plant, and non-significant deviation from regression (S^2di = - 0.00).

Higher mean effective tillers were expressed by four crosses *viz.*, I x 4 (1.99) II x 4 (2.07), V x 3 (2.26) and VII x 5 (1.99) with unit regression coefficient (bi = 1) and non-significant S^2di. The crosses I x 3 (2.86), II x 2 (2 11) and III x 5 (2 11) were found to have higher mean with bi greater than one (bi>1) and non-significant S^2di. However, higher mean bi<1 and non-significant deviation from regression were expressed by the crosses, II x 3 (2 86) and IV x 3 (2.09)

As regard mean square deviation, six parents and nine hybrids showed significant values for this trait.

ii) Ear length

The data on ear length showed that, the 27 genotypes expressed higher ear length than the population mean (18.89 cm). Among the parents only male sterile line 9607 A and inbred RHRBI 138 recorded higher ear length than the population mean While, the remaining genotypes, the ear length ranged from 12.43 to 18.81 cm The regression coefficient was non-significant for all the genotypes except RHRB 3A and VII x 4 (bi = 1.44 and 1.51, respectively)

Among the parents, only female parent, 9607A had regression coefficient less than one with non-significant S^2di and higher mean (22.23 cm).

The hybrid VII x 2 had highest ear length (25.58 cm) among all genotypes studied. The hybrids II x 2 (20.51 cm), III x 5 (19.47 cm), IV x 2 (18 91 cm) and MLBH 267 (19.78 cm) had bi value near to unity (bi = 1), non-significant deviation from regression and higher mean ear length Three combinations, which expressed significantly higher ear length with regression coefficient more than one (bi>1) and non-significant S^2di were III x 2, III x 4 and VI x 2, while, the combinations *viz* , I x 1, V x 1, V x 5, VI x 1, VI x 4 and VI x 5 had significantly higher ear length with regression coefficient less than one (bi<1) and non-significant S^2di. Among the genotypes, parents, RHRB 3A, 9605A, 9606A, RHRBI 138, RHRBI 458 and 9612 and sixteen hybrids showed significant mean square deviation

iii) Ear girth

For ear girth, 28 genotypes had means greater than the population mean (10 78 cm) Among all the genotypes, hybrid VII x 2 possessed highest ear girth (12 55 cm) and inbred, RHRBI 178 had ears with lowest girth (8 56 cm) Nine genotypes were found to have significant regression coefficient

The female parent 9607 A showed significantly higher mean (11.25 cm) with regression coefficient less than unity and S^2di non-significant.

The hybrids *viz.*, I x 2 (11.36 cm), II x 4 (10.86 cm), III x 1 (10.87 cm), III x 5 (10 80 cm), VI x 4 (11 70 cm), VII x 2 (12 55 cm), and VII x 5 (11 32 cm) with regression coefficient near to unity (bi = 1), however, hybrids, I x 1, I x 4, IV x 2, V x 4 and VII x 4 with regression coefficient higher than unity (bi>1) and hybrids, II x 2, III x 4, V x 1, V x 5, VI x 1, VI x 2, VI x 5 and VII x 1 with regression coefficient lower than unity (bi<1) All these hybrids had higher mean and non-significant deviation from regression. Four male sterile lines, two inbreds and twenty nine hybrids exhibited non-significant deviation from regression.

iv) Number of grains per cm^2

For number of grains, four female, one male and eighteen hybrids produced higher number of seeds per cm^2 than the population mean (17.97). The rest of the genotypes produced seeds ranging from 14.28 (VII x 2) to 22.17 (IV x 5) per cm^2 The estimates of regression coefficient significantly greater than one in case of two parents, 9605A and 9612 and a hybrid IV x 3 for this trait

One male sterile line i.e. 9606A had significantly higher mean (20.64) with unit regression coefficient and non-significant S^2di. Though the inbred, 9612 had significant deviation from regression, produced significantly higher number of seeds per cm^2 with regression coefficient significantly higher than one

Two hybrids, IV x 5 (22 17) and V x 5 (21.24) expressed higher mean, $b_i \approx 1$ and non-significant S^2d_i. However, the hybrids, I x 5 (19.90), II x 5 (18 13) and VI x 5 (21 66) had regression coefficient greater than one ($b_i>1$) and hybrids VII x 4 (18 45) and VI x 4 (19.72) had regression coefficient less than one ($b_i<1$) with high mean and non-significant means squares deviation.

The mean square deviations were significant for four females, three males and thirteen hybrids

v) 1000-grain weight

For 1000 grain weight, two parents *viz* , 9607 A and RHRBI 138 and twenty three hybrids produced grains weighing higher than the population mean (12.49 g) The thousand seed weight of the genotypes ranged from 10 31 to 14 73 g Regression coefficient was significantly greater than one in case of pollinator 9612 and hybrids I x 1, II x 1, III x 1 and V x 1

Among the genotypes studied, RHRBI 178 had smaller seeds (10.31 g/1000 grains) and the hybrid III x 2 had the bolder seeds (14 73 g/1000 grains) Among the parents, inbred, RHRBI 138 produced higher mean (12 50 g) with regression coefficient less than unity and non-significant S^2di

Three hybrids *viz.*, III x 4, III x 5, VI x 2 and population ICTP 8203 exhibited relatively lower, while five hybrids *viz.*, I x 1, I x 2, II x 2, IV x 1 and VI x 1 had higher value of regression coefficient than unity, which had mean greater than population mean (12 49 g) and non-significant means square deviation

The hybrids, II x 4 and VII x 2 expressed higher mean (12.80 and 13 92 g, respectively) with regression coefficient near to unity (bi = 1) and non-significant deviation from regression

Among the genotypes three male steriles, one male parent and thirteen hybrids displayed significant mean square deviation (Table 5)

vi) Grain yield per plant

The data on grain yield per plant presented in Table 5 revealed that none of the parents produced grain yield higher than the population mean (38 90 g) The genotypes 9607 A produced highest (38.09 g) grain yield followed by 9605 A (37 10 g) and 9611 (29.95 g) among the parents

As regard to hybrids and checks for grain yield per plant, 29 hybrids and ICTP 8203 produced higher grain yield than population mean, ranging from 34.39 to 50 07 g/plant. The hybrid V x 5 produced the highest grain yield (50 07 g) per plant The female 9605 A had high mean among the parents with non-significant regression coefficient and mean square deviation Among all genotype studied, 16 genotypes each, had values of regression coefficient grater than one and seventeen had such value less than one and seventeen had with such a value of regression coefficient near unity

As regards to regression coefficient, the hybrid check MLBH 267 exhibited significantly higher value (bi = 1.42) and inbred, RHRBI 178 had significantly lower value (bi = 0 56) than unity

The six hybrids expressed higher mean than population mean (38 90 g) of which two hybrids *viz.*, I x 3 (39.10 g) and VI x 4 (48 20 g) had regression coefficient near unity (bi = 1) and four hybrids *viz.*, I x 1 (41 69 g), II x 1 (44.78 g), II x 5 (43 45 g) and VI x 3 (39 69 g) had value of regression coefficient higher than unity (bi>1) All these hybrids had non-significant deviation from regression

Among the genotypes, four parents, RHRB 1A, 9605A, 9606A and RHRBI 138 and nine hybrids showed non-significant mean square deviation.

4.3 Heat unit requirement

Data on total unit accumulated from sowing to days to stigma emergence (flowering) and sowing to maturity for parents, hybrids and checks during E1, E2, E3, E4, E5 and E6 environments are presented in Table 6

Differences in total heat units accumulated from sowing to days to stigma emergence and maturity were highly significant due to genotypes during all the environments studied In general, total heat unit accumulated from sowing to days to stigma emergence were higher during E1 (474) followed by E6 (442), E2 (435), E3 (411), E5 (350) and lower during E4 (274). All the pollinators required more heat units (445) for days to stigma emergence than male sterile lines (387) and hybrids (392) in all the environments studied. The range of heat units accumulated from sowing to days to stigma emergence was form 404 (II x 3, III x 3 and VII x 3) to 548 (9612), 376 (III x 3) to 494 (RHRBI 458), 349 (II x 3) to 478 (RHRBI 458), 165 (II x 3) to 358 (9611), 300 (II x 3) to 441 (9611) and 325 (II x 3) to 561 (9611) during E1, E2, E3, E4, E5 and E6 environments, respectively The data on overall heat unit requirement revealed that, the hybrid combination II x 3 recorded lowest (320) and parent, 9611 required higher number of (470) of heat units from sowing to days to stigma emergence.

Average heat units accumulated from sowing to maturity were comparable during E1 (777) and E6 (783). Average heat units accumulated

Table 6 Total heat units accumulated from sowing to flowering and maturity for parents and hybrids during different environments

Parents and hybrids	Sowing to flowering							Sowing to maturity						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
Male sterile line														
I RHRB 1A	461	443	390	254	327	407	380	765	734	635	544	643	746	678
II RHRB 2A	464	423	406	269	313	407	380	768	719	645	573	622	747	679
III RHRB 3A	442	416	418	326	360	493	409	747	713	657	646	690	838	715
IV RHRB 5A	464	465	431	321	369	475	421	768	759	671	639	701	817	726
V 9605 A	461	407	390	242	327	403	372	765	705	635	528	643	743	670
VI 9606 A	470	423	412	265	330	432	388	773	719	651	565	647	770	688
VII 9607 A	440	404	387	223	317	386	360	744	703	633	502	628	727	656
Mean	457	426	405	271	335	429	387	761	722	647	571	654	770	687
Pollinator														
1 RHRBI 138	526	465	457	333	404	535	453	827	759	694	655	753	887	762
2 RHBRI 458	532	494	478	342	404	528	463	833	787	710	679	753	878	773
3 RHRBI 178	449	433	401	272	338	411	384	753	730	642	577	659	750	685
4 9611	545	477	439	358	441	561	470	847	772	679	698	801	913	785
5 9612	548	491	454	331	399	499	454	850	784	691	652	744	845	761
Mean	520	472	446	327	397	507	445	822	766	683	652	715	855	753
Hybrids														
I x 1	467	423	398	265	322	411	381	771	720	640	565	636	750	680
I x 2	492	455	428	310	381	467	422	792	749	668	627	718	805	726
I x 3	420	388	381	204	303	376	344	724	689	630	479	605	707	639
I x 4	489	459	404	328	398	470	425	789	752	645	649	744	809	731
I x 5	458	430	401	262	344	407	384	762	728	642	561	667	750	685
Mean	465	431	402	274	350	424	391	768	728	645	576	674	764	692
II x 1	458	404	393	231	317	371	362	762	703	637	521	629	711	660
II x 2	485	436	409	260	322	407	387	786	736	648	557	636	747	685
II x 3	404	377	349	165	300	325	320	707	678	611	437	599	654	614
II x 4	479	433	409	291	346	444	401	781	731	649	610	671	781	704
II x 5	473	413	390	234	309	386	368	776	710	635	517	615	727	663
Mean	460	413	390	236	319	387	368	762	712	636	528	630	724	665
III x 1	452	433	398	265	344	428	387	756	729	640	564	667	766	687
III x 2	483	436	433	234	330	419	389	784	732	674	516	647	758	685
III x3	404	376	372	245	306	391	349	707	678	625	532	609	731	687
III x 4	489	453	409	270	360	456	406	789	746	648	577	690	794	706
III x 5	464	416	407	277	346	423	389	768	713	646	589	671	762	691
Mean	458	423	404	258	337	423	384	761	720	647	556	657	762	683
IV x 1	524	480	433	313	381	496	438	824	774	673	630	718	842	744
IV x 2	517	486	445	323	396	505	445	815	779	684	643	640	852	752
IV x 3	470	426	401	271	327	436	388	773	724	642	577	644	773	689
IV x 4	522	477	423	333	401	505	444	821	772	663	655	749	852	752
IV x 5	517	456	428	283	363	448	416	815	749	668	600	694	786	718
Mean	510	465	426	305	374	478	426	810	760	666	621	709	821	731
V x 1	456	416	401	212	324	415	371	759	713	642	488	639	754	666
V x 2	476	449	428	277	349	440	403	779	743	669	589	675	777	705
V x 3	427	413	372	198	307	386	351	738	710	625	473	612	727	647
V x 4	483	436	401	279	357	478	406	784	732	642	596	686	821	610
V x 5	480	426	407	259	346	415	389	781	724	648	552	671	754	688
Mean	464	428	402	245	337	427	384	768	724	645	540	657	767	683
VI x 1	485	436	420	277	352	455	404	786	732	660	587	678	793	706
VI x 2	498	436	431	279	360	456	410	797	732	671	593	690	794	713
VI x 3	443	397	378	217	311	398	357	747	697	629	594	618	739	654
VI x 4	485	416	415	306	372	505	417	786	713	654	624	705	852	723
VI x 5	479	446	412	282	360	466	408	781	741	651	596	690	805	711
Mean	478	426	411	272	351	456	399	779	723	653	579	676	797	701
VII x 1	467	439	415	278	344	451	399	771	736	654	593	667	789	702
VII x 2	479	443	436	291	352	459	410	781	737	676	610	678	797	713
VII x 3	404	392	384	206	309	379	346	707	692	632	481	615	719	641
VII x 4	489	459	420	306	387	490	425	789	752	660	624	726	835	731
VII x 5	482	439	428	273	355	448	404	784	734	668	580	682	785	706
Mean	464	434	417	271	349	445	397	766	730	658	578	674	785	699
Mean (Hybrids)	471	431	407	266	345	434	392	774	728	650	568	678	775	694
Checks														
ICTP 8203	446	413	393	263	341	419	379	750	710	637	561	661	758	679
MLBH 267	489	462	431	306	393	521	434	789	755	672	624	736	870	741
Grand mean	474	435	411	274	350	442	396	777	731	653	578	675	783	670
S E ±	3 99	5 11	3 59	5 44	4 22	6 09	1 14	3 61	4 94	2 87	8 42	6 20	6 40	1 35
C D at 0 05	11 24	14 38	10 1	15 31	11 88	17 15	2 23	10 15	13 89	8 08	23 71	17 46	18 00	2 64

were lower in number in E2 (731), E5 (675), E3 (653) and E4 (578) environments as compared those required E1 and E6 In general pollinators which accumulated on an average 753 heat units till maturity required higher heats units than male sterile lines (687) and hybrids (694) if all the six environments were considered The heat units accumulated from sowing to maturity ranged from 707 (II x 3, III x 3 and VII x 3) to 850 (9612), 678 (II x 3 and III x 3) to 787 (RHRBI 458), 611 (II x 3) to 710 (RHRBI 458), 437 (II x 3) to 698 (9611), 599 (II x 3) to 801 (9611), 654 (II x 3) to 913 (9611) and 614 (II x 3) to 785 (9611) during E1, E2, E3, E4, E5, E6 and over environments also, respectively

Number of parents and hybrids which showed almost constant number of heat units from sowing to days to stigma emergence (flowering) and maturity during two different environments are presented in Table 7.

The hybrid based on male sterile line RHRB 5A required higher number heat units followed by 9606 A, while those based on RHRB 2A, accumulated lower number of heat units. All the hybrids which involved male parents RHRBI 458 and 9611 accumulated more heat units than those derived from the other pollinators from sowing to days to stigma emergence and maturity

In general, among the parents, female RHRB 5A and male parent 9611 required highest, while RHRBI 178 accumulated lowest number of heat units Among the hybrids IV x 2, IV x 4 and IV x 1 required higher number of heat unit from sowing to days to stigma emergence and maturity

4.4 Heat unit efficiency

The data regarding total dry matter production at days to stigma emergence and maturity and grain yield per plant (Table 1) and cumulative

Table 7. Parents and hybrids showing identical number of heat units from sowing to flowering and maturity in different environments

Sr No	Parents/ hybrids	Heat unit requirement from sowing to flowering	Sr No	Parents/ hybrids	Heat unit requirement from sowing to maturity
1	RHRB 5A	464 (E1) and 465 (E2)	1	9606 A	773 (E1) and 770 (E6)
2	RHRBI 458	532 (E1) and 528 (E6)	2	RHRBI 178	753 (E1) and 750 (E6)
3	V x 4	483 (E1) and 478 (E6)	3	9612	850 (E1) and 845 (E6)
4	VII x 4	489 (E1) and 490 (E6)	4	II x 4	781 (E1) and 781 (E6)
5	RHRB 3A	416 (E2) and 418 (E3)	5	III x 4	789 (E1) and 794 (E6)
6	III x 2	436 (E2) and 433 (E3)	6	IV x 3	773 (E1) and 773 (E6)
7	III x 3	376 (E2) and 372 (E3)	7	V x 1	759 (E1) and 754 (E6)
8	VI x 2	436 (E2) and 431 (E3)	8	V x 2	779 (E1) and 777 (E6)
9	VI x 4	416 (E2) and 415 (E3)	9	VI x 2	797 (E1) and 794 (E6)
10	9605 A	407 (E2) and 403 (E6)	10	VII x 5	784 (E1) and 785 (E6)
11	III x 1	433 (E2) and 428 (E6)	11	RHRBI 138	759 (E2) and 753 (E5)
12	III x 4	453 (E2) and 456 (E6)	12	I x 4	645 (E3) and 649 (E4)
13	V x 1	416 (E2) and 415 (E6)	13	9606 A	651 (E3) and 647 (E5)
14	VI x 3	397 (E2) and 398 (E6)	14	9607 A	633 (E3) and 628 (E5)
15	9611	439 (E3) and 441 (E5)	15	I x 1	640 (E3) and 636 (E5)
16	RHRB 2A	406 (E3) and 407 (E6)	16	IV x 3	642 (E3) and 644 (E5)
17	9607 A	387 (E3) and 386 (E6)	17	V x 1	642 (E3) and 639 (E5)
18	I x 5	401 (E3) and 407 (E6)	18	V x 2	669 (E3) and 675 (E5)
19	II x 2	409 (E3) and 407 (E6)	19	VII x 2	676 (E3) and 678 (E5)
20	II x 5	390 (E3) and 386 (E6)			
21	VII x 3	384 (E3) and 379 (E6)			

heat unit requirement (Table 6) were considered for determining heat unit efficiency The data regarding efficiency of heat conservation in terms of dry matter produced and grain yield per unit of heat absorbed by the genotypes in different environments are presented in Table 8

i) Dry matter production I

In general, heat unit efficiency for dry matter production of days to stigma emergence were higher in E4 (0 2033) followed by E5 (0 1279), E1 (0 1007), E2 (0 0914), E6 (0 0841) and E3 (0 0763) Among parents, heat unit efficiency for DMP I ranged from 0 0733 to 0.1272 in E1, 0.0508 to 0 1444 in E2, 0 0179 to 0 0815 in E3, 0 1259 to 0.2558 in E4, 0 0701 to 0 1379 in E5, 0.0368 to 0 1052 in E6 and 0.0675 to 0.1324 over environments, while in hybrids it was 0 0682 to 0.1579, 0 0668 to 0.1228, 0.0536 to 0 1273, 0.1358 to 0 3141, 0 0703 to 0.1971, 0 0525 to 0.1320 and 0 0798 to 0.1366 in respective and over environments, respectively.

Among the females, 9607 A had highest HUE in E1 (0 1144) and E6 (0 1052) and 9605 in E2 (0 0907), E3 (0 0815), E4 (0 1990), E5 (0.1247) and also over environments (0.1076) The males RHRBI 138 had highest HUE in E1 (0 1272), E2 (0 1444), E3 (0.0724), E4 (0 2558), E6 (0.0982) and over environments (0 1324) and RHRBI 458 had higher (0.1379) HUE in E5 environment.

The hybrids which had highest HUE were VII x 1 (0.1579), VI x 2 (0 1228), VI x 5 (0 1273), VII x 4 (0 3141), I x 1 (0 1971), III x 3 (0.1320) and I x 4 (0 1366) in respective and over environments respectively. In general, hybrids involving parents 9607 A, 9606 A, RHRBI 138, RHRBI 458, 9611 and 9612 available as one of the parent had higher HUE for DMP at days to stigma emergence able 8 Heat unit efficiency for dry matter production and grain yield as influenced under different environments

Genotypes	Dry matter production at days to stigma emergence (g) (10^{-2})							Dry matter production at maturity (g) (10^{-2})						
	E1	E2	E3	E4	E5	E6	Pooled	E1	E2	E3	E4	E5	E6	Pooled
ale sterile line														
RHRB 1A	8 59	6 95	4 50	12 59	7 01	4 43	7 05	13 91	10 85	4 71	20 00	13 20	7 02	11 36
RHRB 2A	7 33	6 66	3 27	12 91	8 17	6 15	7 05	11 55	10 34	4 55	17 93	11 85	8 10	10 54
RHRB 3A	7 92	5 08	2 70	13 61	9 17	4 22	6 75	14 86	10 24	4 54	11 59	9 70	6 67	9 59
RHRB 5A	9 37	7 49	1 79	13 99	8 92	3 68	7 18	14 24	10 55	3 65	14 80	10 28	7 46	10 14
9605 A	10 97	9 07	8 15	19 90	12 47	7 86	10 76	18 22	16 81	9 02	29 69	26 13	13 49	18 42
9606 A	7 70	6 28	3 60	13 71	8 93	7 44	7 53	13 92	14 72	6 15	17 60	11 37	7 59	11 76
9607 A	11 40	8 84	7 40	16 12	11 21	10 52	10 51	21 60	18 31	10 32	30 51	19 59	14 57	18 71
ean	9 03	7 19	4 41	14 55	9 40	6 19	8 06	15 44	13 07	6 10	19 77	14 48	9 17	12 84
ollinator														
RHRBI 138	12 72	14 44	7 24	25 58	13 68	9 82	13 24	16 65	16 07	7 44	20 54	13 25	9 53	13 77
RHBRI 458	11 58	9 76	5 28	16 33	13 79	9 03	10 59	16 21	13 85	6 30	14 08	12 42	9 62	12 12
RHRBI 178	9 43	6 41	4 77	15 83	10 13	3 94	7 93	14 95	13 56	7 73	25 00	15 46	13 25	14 76
9611	11 60	7 11	4 60	18 20	13 27	9 54	10 44	15 40	13 62	7 23	23 59	13 82	8 64	13 56
9612	8 27	8 00	3 79	15 24	7 29	7 90	8 11	14 71	10 84	4 69	15 44	7 54	8 51	10 32
ean	10 74	9 17	5 15	18 32	11 72	8 26	10 13	15 59	13 57	6 66	19 62	12 92	9 81	12 87
ybrids														
I x 1	9 96	11 49	8 85	25 04	19 71	9 89	13 16	21 87	16 61	9 80	22 13	21 62	12 75	17 37
I x 2	9 24	10 76	7 12	18 06	11 00	9 54	10 55	22 22	15 00	10 40	13 87	14 34	12 80	14 56
I x 3	7 91	8 10	7 20	17 09	6 87	6 30	8 28	20 25	16 60	9 43	30 05	18 25	12 49	17 34
I x 4	10 22	10 01	7 78	27 24	18 42	12 30	13 66	21 95	17 80	12 26	22 86	15 16	14 85	17 49
I x 5	8 57	10 07	5 74	21 12	9 72	9 30	10 09	17 58	16 29	9 21	20 42	19 66	10 91	15 55
II x 1	10 84	8 16	8 52	20 72	14 23	8 06	10 99	21 34	17 00	9 73	27 53	17 12	14 70	17 65
II x 2	8 89	10 28	8 86	24 26	11 83	7 44	11 02	19 21	15 53	8 74	29 93	20 09	11 69	17 12
II x 3	11 47	8 91	7 39	20 67	10 64	5 86	9 94	17 52	15 63	7 45	20 06	17 24	13 30	15 01
II x 4	8 58	10 33	8 47	24 36	14 14	10 72	11 98	19 37	16 83	9 49	26 96	16 99	11 72	16 71
II x 5	9 09	7 98	7 01	22 15	10 27	10 69	10 35	19 45	15 41	9 40	27 94	17 29	11 47	16 43
III x 1	10 22	7 86	8 99	27 54	11 77	12 88	12 27	21 89	17 08	10 72	22 91	13 42	15 03	16 80
III x 2	8 76	9 31	7 01	19 32	11 62	9 66	10 16	19 53	16 22	9 79	25 30	13 76	11 22	15 63
III x 3	13 15	6 68	5 36	13 58	11 04	5 25	8 87	17 46	15 92	8 92	25 46	25 92	11 18	17 05
III x 4	10 01	9 98	10 45	26 90	17 65	13 20	8 75	21 68	17 67	10 12	29 57	20 58	13 17	18 51
III x 5	8 70	8 07	8 00	19 50	15 89	10 19	11 09	22 21	15 26	9 22	27 17	16 67	13 21	17 14
IV x 1	12 07	12 17	9 32	24 16	12 32	6 64	12 08	20 42	18 28	9 15	20 56	13 51	11 19	15 52
IV x 2	14 21	10 95	9 54	19 08	14 04	9 56	12 52	19 66	17 19	9 28	21 11	12 56	10 94	15 06
IV x 3	8 36	8 56	5 65	15 03	7 03	5 47	7 98	19 71	14 36	7 94	29 60	14 13	9 58	15 56
IV x 4	10 54	10 30	10 42	21 86	18 32	9 78	12 92	21 69	16 46	10 91	24 22	14 97	10 57	16 36
IV x 5	14 67	8 77	7 10	22 72	17 70	7 44	12 35	18 78	19 38	9 41	19 25	15 17	9 70	15 26
V x 1	9 89	10 33	10 01	19 27	12 22	9 55	11 17	19 13	17 99	12 84	29 65	22 52	12 12	18 42
V x 2	11 91	11 84	8 21	19 10	14 64	7 85	11 72	20 44	18 17	13 71	19 20	18 02	12 99	17 05
V x 3	6 82	6 76	8 80	19 24	10 57	8 06	9 11	17 06	15 99	10 59	24 03	15 94	11 63	15 48
V x 4	10 00	8 04	10 52	16 83	16 21	7 94	11 02	24 04	18 04	13 36	22 21	15 44	11 72	17 38
V x 5	9 50	9 23	8 25	17 05	11 40	6 15	9 76	20 59	17 60	13 00	32 84	14 97	10 10	17 61
VI x 1	9 56	9 49	10 32	25 98	15 69	8 07	12 17	22 02	17 85	11 56	26 66	16 05	13 30	17 73
VI x 2	9 42	12 28	9 13	18 91	16 41	9 11	11 92	22 94	18 98	12 42	18 48	16 75	12 69	17 09
VI x 3	11 12	7 90	9 37	14 09	8 58	5 50	9 10	20 91	15 48	10 16	22 95	21 67	9 84	16 51
VI x 4	9 15	9 23	8 79	25 35	13 15	9 56	11 77	20 74	18 45	14 74	25 93	20 97	13 97	18 91
VI x 5	8 24	9 10	12 73	25 16	15 55	7 65	12 07	19 39	18 44	13 72	26 09	15 94	12 76	17 49
VII x 1	15 79	11 65	10 34	21 68	18 06	7 80	13 59	22 95	19 48	12 74	17 19	15 41	12 89	16 87
VII x 2	10 48	10 88	10 83	22 08	13 02	9 19	12 10	23 84	17 31	13 93	20 19	17 71	14 44	17 91
VII x 3	11 48	7 96	7 92	16 48	8 95	7 89	9 63	20 24	16 57	11 83	28 19	15 02	14 05	17 20
VII x 4	9 06	8 83	9 25	31 41	15 12	10 20	12 87	26 65	18 27	11 11	24 62	15 31	11 49	17 82
VII x 5	8 59	9 08	10 90	22 47	12 97	9 75	11 50	17 71	17 81	10 98	27 80	18 60	14 17	17 54
ean	10 20	9 52	8 72	21 56	13 49	8 77	11 17	20 61	17 06	10 81	24 23	17 03	12 29	16 83
hecks														
CTP 8203	8 32	9 50	7 23	16 43	17 53	9 18	10 82	17 68	18 30	10 93	24 71	18 11	14 02	17 09
LBH 267	10 73	8 97	5 80	32 95	12 70	10 82	12 53	21 12	18 19	8 39	28 96	16 98	10 66	17 60
rand mean	10 07	9 14	7 63	20 33	12 79	8 41	10 75	19 27	16 17	9 66	23 19	16 18	11 58	15 84
E ±	0 60	0 50	0 50	1 30	0 60	0 70		2 00	0 80	0 50	1 20	0 50	0 80	
D at 5%	1 80	1 30	1 40	3 70	1 80	2 00		5 50	2 30	1 40	3 50	1 50	2 10	

Table 8 Contd

Genotypes	Grain yield per plant (g) (10^{-2})						
	E1	E2	E3	E4	E5	E6	Pooled
Male sterile line							
I RHRB 1A	4.95	4.39	1.26	5.54	4.20	2.66	3.81
II RHRB 2A	4.76	4.65	0.85	6.52	4.47	3.08	4.02
III RHRB 3A	5.12	3.97	0.93	2.75	2.36	1.72	2.82
IV RHRB 5A	3.79	3.29	1.00	3.71	4.03	2.42	3.04
V 9605 A	6.50	5.98	2.92	7.10	6.41	4.48	5.53
VI 9606 A	4.81	5.41	1.98	4.79	4.13	2.58	3.94
VII 9607 A	*7.82*	*6.50*	3.09	*6.70*	6.14	4.50	5.80
Mean	5.38	4.86	1.71	5.18	4.50	3.02	4.11
Pollinator							
1 RHRBI 138	3.95	3.65	1.62	3.07	3.28	1.85	2.90
2 RHBRI 458	4.96	3.28	0.93	4.00	3.86	2.30	3.23
3 RHRBI 178	4.27	4.02	2.20	6.30	4.56	3.17	4.03
4 9611	5.00	4.21	1.76	5.89	3.93	2.20	3.81
5 9612	4.59	4.23	0.94	5.47	3.05	2.88	3.53
Mean	4.56	3.88	1.48	4.92	3.86	2.45	3.49
Hybrids							
I x 1	7.37	7.67	3.14	7.06	6.79	4.64	6.12
I x 2	7.21	5.97	3.67	5.61	4.34	3.63	5.09
I x 3	7.53	7.58	3.26	8.19	5.65	4.77	6.11
I x 4	9.60	7.09	4.80	7.56	5.48	5.71	6.75
I x 5	7.04	8.10	3.57	9.73	7.21	6.15	6.92
II x 1	8.44	7.64	3.11	9.99	6.74	5.10	6.78
II x 2	6.53	6.68	2.89	9.80	7.10	3.70	6.00
II x 3	6.06	7.19	2.26	7.82	6.98	5.79	5.95
II x 4	6.54	7.39	3.65	10.12	7.04	4.37	6.44
II x 5	7.88	7.67	3.32	10.41	6.43	4.19	6.55
III x 1	7.49	6.97	4.24	7.21	5.21	4.83	5.99
III x 2	6.68	5.95	3.34	5.94	4.62	3.67	5.03
III x 3	5.94	6.77	3.18	8.78	6.48	3.97	5.74
III x 4	8.51	8.26	4.06	8.24	7.76	4.37	6.85
III x 5	8.64	6.78	3.24	10.02	8.31	5.35	7.02
IV x 1	7.04	7.73	3.26	5.75	4.91	3.07	5.32
IV x 2	5.57	5.55	2.41	6.11	5.31	3.40	4.71
IV x 3	6.22	5.11	2.97	7.34	5.11	3.45	4.94
IV x 4	7.56	6.49	4.16	6.51	6.47	3.87	5.85
IV x 5	6.95	8.65	2.57	8.60	6.18	4.82	6.28
V x 1	6.37	6.95	4.62	8.25	7.18	3.99	6.10
V x 2	6.98	7.02	4.63	6.63	5.38	3.88	5.74
V x 3	5.76	6.64	3.10	7.27	6.16	3.78	5.37
V x 4	9.23	7.70	4.53	6.59	6.69	3.92	6.46
V x 5	8.94	8.28	4.74	11.85	6.20	4.34	7.27
VI x 1	7.70	6.98	4.23	9.34	5.62	3.92	6.22
VI x 2	7.90	7.03	3.85	6.07	6.39	4.49	5.98
VI x 3	7.37	7.03	2.83	8.41	7.09	4.15	6.06
VI x 4	7.43	7.97	4.73	8.69	6.86	4.71	6.67
VI x 5	8.01	7.85	5.07	9.74	6.38	4.37	6.82
VII x 1	8.99	8.35	4.51	5.90	6.05	3.96	6.34
VII x 2	9.04	7.17	4.31	6.11	5.85	3.56	6.03
VII x 3	7.57	7.16	4.10	8.47	5.33	5.10	6.22
VII x 4	9.13	7.31	4.30	7.41	5.13	4.14	6.23
VII x 5	6.87	7.47	3.78	9.44	7.75	5.76	6.77
Mean	7.50	7.20	3.73	7.99	6.22	4.35	6.13
Checks							
ICTP 8203	5.86	6.66	3.60	7.81	6.33	4.96	5.82
MLBH 267	7.61	7.80	2.56	9.81	6.66	3.95	6.31
Grand mean	6.84	6.52	3.18	7.27	5.71	3.96	5.55
S E ±	0.30	0.40	0.30	0.40	0.30	0.30	
C D at 5%	0.80	1.00	0.70	1.10	0.80	0.70	

ii) Dry matter production II

Average heat unit efficiency for dry matter production at maturity were 0.2319, 0.1927, 0.1618, 0.1617, 0.1158 and 0.0966 in E4, E1, E5, E2, E6 and E3 environments, respectively. The mean HUE over environments was 0.1584. The heat unit efficiency for DMP II of parents were ranged from 0.1155 to 0.2160 in E1, 0.1024 to 0.1831 in E2, 0.0365 to 0.1032 in E3, 0.1159 to 0.3051 in E4, 0.0754 to 0.2613 in E5, 0.0667 to 0.1457 in E6 and 0.0959 to 0.1871 over environments. Heat unit efficiency for DMP II recorded on hybrids were ranged from 0.1706 to 0.2665, 0.1436 to 0.1948, 0.0745 to 0.1474, 0.1387 to 0.3284, 0.1256 to 0.2592, 0.0958 to 0.1503 in E1, E2, E3, E4, E5 and E6 environments, respectively and 0.1456 to 0.1891 over environments.

The highest HUE among male sterile lines was displayed by 9607 A in E1, E2, E3, E4, E5 and E6 and also over environments and values of the HUE were 0.2160, 0.1831, 0.1032, 0.3051, 0.1457 and 0.1871, respectively. 9605A however, showed highest such value in E5 (0.2613). When the pollinators were considered, RHRBI 138 exhibited highest HUE in E1 (0.1665) and E2 (0.1607) and RHRBI 178 in E3 (0.773), E4 (0.2500), E5 (0.1546), E6 (0.1325) and over the environments (0.1476).

As regard hybrids, the combinations VII x 4 in E1 (0.2665), VII x 1 in E2 (0.1948), VI x 4 in E3 (0.1474), V x 5 in E4 (0.3284), III x 3 in E5 (0.2592), III x 1 in E6 (0.1503) and VI x 4 (0.1891) over environments had highest HUE for dry matter production II. The hybrid combinations based on the parents, 9607 A, 9606 A, 9611, RHRBI 138 and RHRBI 178 had higher values of heat unit efficiency for DMP at maturity.

iii) Grain yield per plant

For grain yield per plant the average heat unit efficiency was highest in E4 (0.0727), followed by E1 (0.0684), E2 (0.0652), E5 (0.0571), E6

(0.0396) and E3 (0.0318) The over environments the mean value of heat unit efficiency was 0.0555

Heat unit efficiency for grain yield per plant ranged from 0.0379 to 0.782, 0.0329 to 0.0650, 0.0085 to 0.0309, 0.0275 to 0.0710, 0.0236 to 0.0641, 0.0172 to 0.0450 and 0.0304 to 0.0580 among females and from 0.0395 to 0.0500, 0.0328 to 0.0423, 0.0093 to 0.0220, 0.0307 to 0.0630, 0.0305 to 0.0456, 0.0185 to 0.0317 and 0.0290 to 0.0403 among males in E1, E2, E3, E4, E5, E6 and over environments, respectively. Heat absorbed by hybrids for grain yield per unit were ranged from 0.0557 to 0.0960 in E1, 0.0511 to 0.0865 in E2, 0.0226 to 0.0507 in E3, 0.0561 to 0.1185 in E4, 0.0434 to 0.0831 in E5, 0.0307 to 0.0615 in E6 and 0.0471 to 0.0727 over environments

Highest heat unit efficiency for grain yield per plant was noticed in case of 9607A in all the environments and over environments among the female parents except in E4 and E5, where the female, 9605 A exhibited highest HUE for this trait. However, 9611 in E1, 9612 in E2 and RHRBI 178 in E3, E4, E5, E6 and over environments among the male parents were observed to be the highest in respect of HUE for grain yield per plant

The hybrid combinations I x 4 in E1 (0.0960), IV x 5 in E2 (0.0865), VI X 5 in E3 (0.0507), V x 5 in E4 (0.1185) and over environments (0.0727), III x 5 in E5 (0.0831) and I x 5 in E6 (0.0615). In general, the hybrids having 9607 A, 9606A, RHRB 2A, 9611 and 9612 as one of the parent expressed higher heat unit efficiency for grain yield per plants

4.5 Effect of photoperiod on flowering

4.5.1 Delay in days to stigma emergence (flowering)

Delay in flowering (days to stigma emergence) over the normal (E1) day length (13.36 h) is presented in Table 9 Data presented in this table,

Table 9 Days to stigma emergence (flowering) in normal (E1) day length and delay in days to stigma emergence in rest of the environments

Genotypes	Days to stigma emerg(E1)	Delay in days to stigma emergence (flowering)						
		E2	E3	Pooled	E4	E5	E6	Pooled
1	2	3	4	5	6	7	8	9
Male sterile line								
I RHRB 1A	44 66	0 00	-2 00	-1 00	23 67	12 34	2 34	12 78
II RHRB 2A	44 33	0 00	0 67	0 34	29 00	11 67	2 00	14 24
III RHRB 3A	42 66	1 34	3 34	2 34	36 67	18 34	9 00	21 34
IV RHRB 5A	44 66	2 67	3 34	3 00	33 00	17 00	5 34	18 45
V 9605 A	43 00	-1 00	0 00	-0 50	24 33	13 66	4 00	14 00
VI 9606 A	45 00	-1 67	-0 34	-1 00	23 00	12 00	3 00	12 67
VII 9607 A	42 33	-1 00	0 33	-0 33	23 67	13 67	4 00	13 78
Mean	43 80	0 05	0 76	0 40	27 62	14 10	4 24	15 32
Pollinator								
1 RHRBI 138	50 33	-2 33	0 33	-1 00	30 33	15 00	7 33	17 55
2 RHBRI 458	52 00	-1 67	1 33	-0 17	29 66	13 33	6 66	16 55
3 RHRBI 178	41 33	2 00	2 00	2 00	28 33	14 67	3 67	15 56
4 9611	53 66	-5 33	-5 33	-5 33	29 00	15 67	6 67	17 11
5 9612	53 33	-1 33	-2 67	-2 00	26 33	11 33	1 33	13 00
Mean	50 13	-1 74	-0 87	-1 30	28 73	14 00	5 13	15 95
Hybrids								
I x 1	45 33	-1 00	-2 67	-1 83	23 33	11 00	2 00	12 72
I x 2	47 66	-0 33	-1 33	-0 83	30 67	15 67	4 00	16 78
I x 3	37 66	1 34	4 34	2 84	25 66	16 00	5 34	15 66
I x 4	46 33	0 67	-2 33	-0 83	32 67	19 00	4 67	18 78
I x 5	44 00	0 66	0 00	0 33	27 00	15 33	3 00	15 11
Mean	44 19	0 26	-0 39	-0 06	27 86	15 40	4 20	15 81
II x 1	43 66	-1 66	-0 33	-0 99	22 67	11 67	1 00	11 78
II x 2	47 00	-2 00	-1 67	-1 83	21 66	10 00	1 00	10 89
II x 3	36 33	1 33	2 00	1 66	23 67	16 33	3 33	14 44
II x 4	46 33	-1 33	-1 33	-1 33	28 67	13 00	4 00	15 22
II x 5	45 66	-2 00	-3 00	-2 50	21 34	10 00	0 00	10 45
Mean	43 79	-1 13	-0 86	-0 99	23 60	12 20	1 86	12 55
III x 1	43 66	0 67	-0 33	0 17	27 67	15 00	5 67	16 11
III x 2	46 66	-1 66	0 67	-0 49	21 00	11 34	1 34	11 23
III x3	37 33	0 67	4 00	2 33	29 33	16 00	7 67	17 67
III x 4	47 33	-1 00	-2 00	-1 50	25 00	14 33	3 67	14 33
III x 5	43 66	0 34	1 00	0 67	29 34	16 33	5 34	17 01
Mean	43 72	-0 19	0 67	0 24	26 46	14 60	4 73	15 27

Table 9 Contd

1	2	3	4	5	6	7	8	9
IV x 1	50 33	-1 00	-2 67	-1 83	28 00	12 67	3 67	14 78
IV x 2	50 33	0 00	-1 33	-0 66	28 67	12 67	3 67	15 00
IV x 3	45 00	-0 67	-3 34	-2 00	26 00	10 66	2 66	13 11
IV x 4	51 00	-3 00	-4 67	-3 83	28 66	14 66	2 00	15 11
IV x 5	50 33	-3 00	-3 00	-3 00	24 00	11 67	0 00	11 89
Mean	49 39	-1 53	-3 00	-2 26	27 06	12 46	2 40	13 97
V x 1	43 66	-1 00	0 00	-0 50	21 00	13 67	3 67	12 78
V x 2	46 00	0 33	1 00	0 66	26 33	14 33	3 66	14 77
V x 3	38 33	2 67	2 33	2 50	24 00	15 00	6 33	15 11
V x 4	47 00	-1 34	-2 67	-2 00	22 66	13 33	4 00	13 33
V x 5	45 66	-1 33	-1 66	-1 49	24 34	13 67	2 00	13 34
Mean	44 13	-0 13	-0 20	-0 16	23 66	14 00	3 93	13 86
VI x 1	47 00	-1 34	-0 34	-0 84	24 66	13 33	2 66	13 55
VI x 2	47 66	-2 66	-0 33	-1 49	23 34	13 34	3 00	13 23
VI x 3	40 00	-0 34	1 66	0 66	23 66	14 66	6 00	14 77
VI x 4	45 66	-2 33	0 34	-0 99	31 67	17 00	8 34	19 00
VI x 5	46 00	0 66	-1 34	-0 34	28 00	15 00	4 00	15 67
Mean	45 26	-1 20	0 00	-0 60	26 26	14 66	4 80	15 24
VII x 1	45 33	0 33	-0 33	0 00	27 67	12 67	5 00	15 11
VII x 2	46 33	-1 00	1 00	0 00	27 33	14 33	5 67	15 78
VII x 3	37 33	3 00	4 67	3 83	25 67	17 00	8 00	16 89
VII x 4	47 00	1 00	-0 67	0 16	28 33	17 00	5 33	16 89
VII x 5	46 33	-1 00	0 00	-0 50	25 33	13 67	3 67	14 22
Mean	44 46	0 46	0 93	0 69	26 86	14 93	5 53	15 77
Mean (Hybrids)	44 99	-0 49	-0 41	-0 45	25 95	14 04	3 86	14 62
Grand mean	45 38	-0 57	-0 27	-0 42	26 55	14 10	4 12	14 92
S E ±	0 45							
C V (%)	1 73							

E1 = 2nd week of June (normal), day length (13 36 h)

E2 = 1st week of July, day length (13 26 h)

E3 = 1st week of August, day length (13 15 h)

E4 = 1st week of January, day length (12 16 h)

E5 = 1st week of February, day length (12 20 h)

E5 = 1st week of March, day length (13 08 h) indicated that all the male sterile lines used, were different in their response to photoperiod (day length). It is clear from the data that no much delay occured in flowering over normal day length in E2 (-0.57 days), E3 (-0.27 days) and *kharif* pooled environments (-0.42 days). In contrast delay in flowering was much more in summer day length environments i.e. E4 (26.55 days) followed by that in E5 (14.10 days), E6 (4.12 days) and overall summer environment day length (14.92 days).

Among the male sterile lines, RHRB 3A and RHRB 5A flowered in 42.66 and 44.66 days, respectively under normal day length but they took more number of days to flowering than rest of the male sterile lines under different day lengths. The flowering of RHRB 3A was delayed by 1.34, 3.34, 36.67, 18.34 and 9.00 days and followed that of RHRB 5A was delayed by 2.67, 3.34, 33.00, 17.00 and 5.34 days more than normal day length in E2, E3, E4, E5 and E6 environments, respectively. Male strile lines, RHRB 1A, RHRB 2A (except in E4) and 9606A showed lower photoperiodic response in all the environments (-2.00 to 23.67 days delay in flowering) than rest of the male sterile lines. 9607A was earliest to flower (42.33 days) under normal day length and was relatively less photoperiod sensitive (-1.00 days) to highly sensitive (23.67 days).

All the pollinators except, RHRBI 178 flowered 50.33 to 53.66 days under normal (13.36 h) day length and showed delay in flowering by -5.33 to 30.33 days under different day lengths (Table 9). The pollinator RHRBI 178, flowered in 41.33 days (early) under normal day length and showed delay by 2.00, 2.00, 28.33, 14.67 and 3.67 days in E2 (13.26 h), E3 (13.15 h), E4 (12.16 h), E5 (12.20 h) and E6 (13.08 h) environments day length, respectively. Among the pollinators, 9611 was late, which required highest number of days (53.66) to stigma emergence (flowering) but was least sensitive in E2 and E3 (5.33 days early in flowering) to highly sensitive in E4, E5 and E6 environments (29.00, 15.67 and 6.67 days delay in flowering, respectively). RHRBI 138 and RHRBI 458 were more sensitive in summer environments (6 66 to 30.33 day delay in flowering). However, 9612 showed consistently less delay in flowering in all the environments In general, if we considered all the male sterile lines and pollinators together, it was found that they showed different photoperiodic response and on an average male sterile lines and pollinators took 15.32 and 15 95 more days to flower, respectively than those required in normal sowing date.

It could be seen from Table 9, hybrids were flowered within a span of 36 33 (II x 3) to 51.00 (IV x 4) days under normal day length but were delayed by -0.49, -0 41, 25.95, 14.04 and 3.86 days under E2, E3, E4, E5 and E6 environment day length, respectively Among the hybrids I x 4 (18.78), II x 4 (15 22), III x 3 (17 67), IV x 4 (15.11), V x 3 (15 11), VI x 4 (19 00), VII x 3 (16.89) and VII x 4 (16.89 days) on an average showed consistently delay in flowering under all the environment day length studied. If we considered all the environments, the hybrid combinations I x 1 (12.72 days), II x 2 (10.89), III x 2 (11 23), IV x 5 (11 89), V x 1 (12.78), VI x 2 (13.23) and VII x 5 (14.22 days) were flowered relatively early

The hybrids based on male sterile lines RHRB 2A and 9605A were early in flowering while, those based on 9607A and RHRB 1A expressed delayed flowering Hybrid involving inbred parent 9611 on an average more delayed in flowering under different environmental day length, while those involving inbreds 9612 and RHRBI 138 recorded lower delay in flowering under various environment day lengths.

4.5.2 Photoperiod sensitivity

The data on photoperiod sensitivity (Table 10) indicated that parents and hybrids differed in the photoperiod sensitivity The highest mean value for photoperiod sensitively was recorded in E4 (58.50) followed by that in E5 (31 07), E6 (9 08), E3 (-0 59) and E2 (-1 25). The photoperiod sensitivity was found to be negligible under *kharif* environment day length The pollinator showed less photoperiod sensitively than male sterile lines and hybrid in all the environment studies except E6, where it was lower in male sterile lines (9 68) as well as in hybrids (8 57) also Among parents, photoperiod sensitivity ranged from -9.93 to 5 97 in E2, -9 93 to 7 82 in E3, 49 37 to 85.95 in E4, 21 24 to 42 99 in E5 and 2.49 to 21.09 in E6, while in hybrids it was -5.96 to 8 03, -9 15 to 12 51, 45 00 to 78.56, 21 57 to 45 53 and 0 00 to 21 43 respectively, in respective environments

Among the male sterile lines RHRB 5A displayed higher photoperiod sensitivity under *kharif* environments i.e. E2 (5 97) and E3 (7 47) and was followed by RHRB 3A with 3.14 in E2 and 7.82 in E3 environments (Table 10) While under summer, highest photoperiod sensitivity was also shown by RHRB 3A (85.95, 42.99 and 21.09) followed by RHRB 5A (73 85, 38.06 and 11 95) in E4, E5 and E6 environments, respectively Lower nagnitude of photoperiod sensitivity was noticed in case of 9606 A in E2 (-3 71) and E4 (51 11), RHRB 1A in E3 (-4 47) and RHRB 2A in E5 (26 32) and E6 (4 51)

The pollinator, RHRBI 178 was found to the most photoperiod ensitive if all the environments were considered (37 64) followed by RHRBI 38 (34 86) The inbred, 9612 was the least photoperiod sensitive among the arents

Table 10 Photoperiod sensitivity in different environment over normal environment (E1) at Rahuri

Genotypes	Photoperiod sensitivity (%)						
	E2	E3	Pooled	E4	E5	E6	Pooled
Male sterile line							
I RHRB 1A	0 00	-4 47	-2 23	53 00	27 63	5 23	28 61
II RHRB 2A	0 00	1 51	0 76	65 41	26 32	4 51	32 07
III RHRB 3A	3 14	7 82	5 48	85 95	42 99	21 09	50 02
IV RHRB 5A	5 97	7 47	6 71	73 89	38 06	11 95	41 31
V 9605 A	-2 32	0 00	-1 16	56 58	31 76	9 30	32 55
VI 9606 A	-3 71	-0 75	-2 22	51 11	26 66	6 66	28 15
VII 9607 A	-2 36	0 77	-0 77	55 91	32 29	9 44	32 55
Mean	0 11	1 73	0 91	63 05	32 19	9 68	34 97
Pollinator							
1 RHRBI 138	-4 62	0 65	-1 98	60 26	29 80	14 56	34 86
2 RHBRI 458	-3 21	2 55	-0 32	57 03	25 63	12 80	31 82
3 RHRBI 178	4 83	4 83	4 83	68 54	35 49	8 87	37 64
4 9611	-9 93	-9 93	-9 93	64 04	29 20	12 43	31 88
5 9612	-2 49	-5 00	-3 75	49 37	21 24	2 49	24 37
Mean	-3 47	-1 73	-2 59	57 31	27 92	10 23	31 81
Hybrids							
I x 1	-2 20	-5 89	-4 03	51 46	24 26	4 41	26 71
I x 2	-0 69	-2 79	-1 74	64 35	32 87	8 39	35 20
I x 3	3 55	11 52	7 54	68 13	42 48	14 17	41 58
I x 4	1 44	-5 02	-1 79	70 51	41 01	10 07	40 53
I x 5	1 50	0 00	0 75	61 36	34 84	6 81	34 34
Mean	0 72	-0 43	0 14	63 16	35 09	9 65	35 96
II x 1	-3 80	-0 75	-2 26	51 92	26 72	2 29	26 98
II x 2	-4 25	-3 55	-3 89	46 08	21 27	2 12	23 15
II x 3	3 66	5 50	4 56	65 15	44 94	9 16	39 74
II x 4	-2 87	-2 87	-2 87	61 88	28 05	8 63	32 85
II x 5	-4 38	-6 57	-5 47	46 73	21 90	0 00	22 87
Mean	-2 32	-1 64	-1 98	54 35	28 39	4 44	29 06
III x 1	1 53	-0 75	0 38	63 37	34 35	12 98	36 89
III x 2	-3 55	1 43	-1 06	45 00	24 30	2 87	24 06
III x3	1 79	10 71	6 24	78 56	42 86	20 54	47 33
III x 4	-2 11	-4 22	-3 16	52 82	30 27	7 75	30 27
III x 5	0 77	2 29	1 52	67 20	37 42	12 23	38 96
Mean	-0 31	1 89	0 78	61 39	33 84	11 27	35 50
IV x 1	-1 98	-5 30	-3 63	55 63	25 17	7 29	29 36
IV x 2	0 00	-2 64	-1 31	56 96	25 17	7 29	29 80
IV x 3	-1 48	-7 42	-4 44	57 77	23 68	5 91	29 13
IV x 4	-5 88	-9 15	-7 50	56 19	28 74	3 92	29 62
IV x 5	-5 96	-5 96	-5 96	47 68	23 18	0 00	23 62
Mean	-3 06	-6 09	-4 56	54 84	25 18	4 88	28 30
V x 1	-2 29	0 00	-1 14	48 09	31 31	8 40	29 27
V x 2	0 71	2 17	1 43	57 23	31 15	7 95	32 10
V x 3	6 96	6 07	6 52	62 61	39 13	16 51	39 42
V x 4	-2 85	-5 68	-4 25	48 21	28 36	8 51	28 36
V x 5	-2 91	-3 63	-3 26	53 30	29 93	4 38	29 21
Mean	-0 07	-0 21	-0 14	53 88	31 97	9 15	31 66
VI x 1	-2 85	-0 72	-1 78	52 46	28 36	5 65	28 82
VI x 2	-5 58	-0 69	-3 12	48 97	27 98	6 29	27 75
VI x 3	-0 85	4 15	1 65	59 15	36 65	15 00	36 92
VI x 4	-5 10	0 74	-2 16	69 36	37 23	18 26	41 61
VI x 5	1 43	-2 91	-0 73	60 86	32 60	8 69	34 06
Mean	-2 59	0 11	-1 24	58 16	32 56	10 77	33 83
VII x 1	0 72	-0 72	0 00	61 04	27 95	11 03	33 33
VII x 2	-2 15	2 15	0 00	58 98	30 93	12 23	34 04
VII x 3	8 03	12 51	10 25	68 76	45 53	21 43	45 24
VII x 4	2 12	-1 42	0 34	60 27	36 17	11 34	35 93
VII x 5	-2 15	0 00	-1 07	54 67	29 50	7 92	30 69
Mean	1 31	2 50	1 90	60 74	34 01	12 79	35 84
Mean (Hybrids)	-1 08	-0 91	-1 00	57 67	31 20	8 57	32 49
Grand mean	-1 25	-0 59	-0 92	58 50	31 07	9 08	32 88
S E ±	1 43	1 26	2 12	1 67	1 28	0 66	1 94
C D at 5%	4 03	3 53	6 07	4 69	3 61	1 85	5 39

As regards hybrids I x 3, II x 3, III x 3, V x 3, VI x 3 and VII x 3 exhibited consistently higher intensities of photosensitivity in all the environments. The highest photoperiod sensitivity was observed in case of VII x 3 in E2 (8.03), E3 (12 51), E5 (43 53) and E6 (21 43) and III x 3 in E4 (78.56). The hybrids, I x 1, II x 2, III x 2, II x 5, IV x 5 and VI x 2 were the less photoperiod sensitive in all the environments.

4.6 Correlation studies

4.6.1 Analysis of variance

The mean sum of squares for morpho-physiological characters, harvest index and agronomic characters and grain yield and its components for individual environment of parents is presented in Table 11. The variances due to parents were highly significant for all the characters, in all the environments.

4.6.2 Genotypic and phenotypic correlation coefficients

The genotypic and phenotypic correlation coefficient between seventeen pairs of morpho-physiological, harvest index and important agronomic characters and grain yield and its components studied over six different environments have been given in environmentwise fashion in Appendices III to VIII

4.6.3 Correlation of grain yield with other characters

Genotypic and phenotypic correlations of grain yield with sixteen other characters, as observed in different environments have been given in Table 12

a) Positive correlations

The characters which showed positive and significant correlations with grain yield uniformly in all the environments considered for this study, have been listed below in decreasing order of magnitude of correlation coefficients.

Table 11. Mean sum of squares for parents for morpho-physiological, agronomic characters and grain yield components

SN	Characters	E1	E2	E3	E4	E5	E6
1	Leaf area index	5.78**	4.03**	2.59**	10.90**	11.35**	13.04**
2	Dry matter production I /plant (g)	356.47**	378.60**	186.74**	1191.83**	506.77**	599.20**
3	Dry matter production II /plant (g)	1409.86**	1460.59**	620.75**	3103.03**	2695.51**	1147.87**
4	Absolute growth rate (g/day)	0.74**	0.85**	0.22**	1.87**	1.99**	1.13**
5	Relative growth rate (g/g/day) (10^{-4})	0.74**	1.33**	1.23**	2.51**	2.43**	5.04**
6	Adaxial stomatal density (mm^2)	469.69**	359.73**	539.97**	949.41**	161.50*	498.67**
7	Abaxial stomatal density (mm^2)	684.14**	276.78**	665.03**	1161.51**	632.39**	651.98**
8	Days to stigma emergence	56.05**	34.62**	35.49**	112.40**	64.41**	83.26**
9	Plant height (cm)	1361.11**	2488.00**	2531.98**	1948.30**	2496.95**	2688.33**
10	Fodder yield/plant (g)	755.38**	351.32**	235.43**	607.58**	425.29**	387.63**
11	Harvest index (%)	61.44**	133.11**	102.73**	98.30**	98.89**	117.75**
12	No of effective tillers/plant	0.57**	0.65**	0.19 **	2.74**	1.38**	0.53**
13	Ear length (cm)	26.27**	24.85**	31.52**	24.71**	31.97**	51.53**
14	Ear girth (cm)	3.33**	4.11**	3.86**	2.33**	4.00**	3.44**
15	No of grains/cm^2	33.19**	18.97**	15.21**	18.76**	18.44**	27.61**
16	1000-grain weight (g)	2.92**	4.61**	10.41**	3.11**	5.93**	6.89**
17	Grain yield/plant (g)	250.54**	283.67**	98.92**	368.01**	227.08**	158.35**

*,** significant at $P = 0.05$ and $P = 0.01$, respectively

Environments	Characters															
	LAI	DMP I	DMP II	AGR	RGR	Adaxial stomatal density	Abaxial stomatal density	Days to stigma emergence	Plant height	Fodder yield/ plant	Harvest index	No of effective tillers/ plant	Ear length	Ear girth	No of grains/ cm^2	1000 grain weight
E1 (G)	NS	NS	0 816	0 901	0 477	NS	NS	NS	NS	0 574	0 508	NS	0 733	0 487	NS	NS
(P)	NS	NS	0 784	0 860	0 442	NS	NS	NS	NS	0 505	0 530	NS	0 668	0 464	NS	NS
E2 (G)	NS	NS	0 696	0 842	0 545	NS	NS	-0 342	NS	0 455	0 529	NS	0 600	0 326	NS	NS
(P)	NS	NS	0 693	0 813	0 505	NS	NS	-0 326	NS	0 424	0 517	NS	0 571	0 320	NS	NS
E3 (G)	0 605	0 683	0 931	0 926	NS	NS	NS	-0 518	0 523	0 768	0 812	0 653	0 834	0 498	NS	0 657
(P)	0 571	0 664	0 903	0 873	NS	NS	NS	-0 467	0 502	0 714	0 785	0 518	0 783	0 473	NS	0 587
E4 (G)	0 512	0 408	0 746	0 571	NS	NS	-0 366	NS	NS	NS	0 572	0 379	0 541	0 317	NS	-0 345
(P)	0 466	0 380	0 716	0 564	NS	NS	-0 306	NS	NS	NS	0 585	0 400	0 530	0 351	NS	NS
E5 (G)	0 507	0 423	0 811	0 712	0 354	-0 512	-0 625	NS	0 367	0 487	NS	NS	0 607	0 375	NS	NS
(P)	0 498	0 431	0 800	0 698	0 337	NS	-0 510	NS	0 355	0 473	NS	NS	0 578	0 387	NS	NS
E6 (G)	NS	NS	0 753	0 599	NS	0 318	0 314	-0 326	0 311	0 459	0 480	NS	0 620	0 466	NS	0 470
(P)	NS	NS	0 744	0 594	NS	NS	NS	-0 325	0 305	0 452	0 479	NS	0 614	0 467	NS	0 466

Significant at at 5% level = 0 304
Significant at 1% level = 0 393
NS = Non-significant

These characters were DMP II, AGR, ear length and ear girth. The ranges for r values as observed in different environment are given below .

Grain yield with		Range for `r' value		
Dry matter production II	G	0.696 (E2)	to	0.931 (E3)
	P	0 693 (E2)	to	0 903 (E3)
Absolute growth rate	G	0 571 (E4)	to	0 926 (E3)
	P	0 564 (E4)	to	0.873 (E3)
Ear length	G	0 541 (E4)	to	0.834 (E3)
	P	0 530 (E4)	to	0.783 (E3)
Ear girth	G	0.317 (E4)	to	0.498 (E3)
	P	0.320 (E2)	to	0 473 (E3)

Some other characters also showed significant and positive genotypic and phenotypic correlations with grain yield but these correlations listed below were limited to few environments only. However, abaxial, stomatal density showed positive and significant correlation with grain yield in E6 environment at genotypic level only.

Grain yield with	Environments
Harvest index	E1, E2, E3, E4 and E6
Fodder yield per plant	E1, E2, E3, E5 and E6
Leaf area index	E3, E4 and E5
Dry matter production I	E3, E4 and E5
Relative growth rate	E1, E2 and E5
Plant height	E3, E5 and E6
1000 grain weight	E3 and E6
No. of effective tillers per plant	E3 and E4

b) Negative correlations

None of the characters showed negative and significant correlations with grain yield uniformly in all the environments, however, two characters exhibited significant and negative genotypic and phenotypic correlations with grain yield only in few environments were :

Grain yield with	Environments
Days to stigma emergence	E2, E3, and E6
Abaxial stomatal density	E4 and E5

However, adaxial surface showed significant positive and negative association with grain yield in E6 and E5 respectively at genotypic level only. While, 1000 grain weight exhibited negative and significant correlation with grain yield only in E4 environment at genotypic level.

The character, number of grains per cm^2 showed uniformly non-significant correlations with grain yield in all the environments considered for study in existing material.

4.6.4 Inter-relationship of yield components

4.6.4.1 Correlation of morpho-physiological characters with other characters

i) Leaf area index

a. Positive correlations

The characters which showed positive and significant genotypic and phenotypic correlations with LAI, uniformly in all the environments considered for this study and listed in decreasing order of magnitude of correlation coefficients were : DMP I, plant height, fodder yield per plant, DMP

II and ear girth except DMP II in E2 at genotypic and ear girth in E4 at phenotypic level

Leaf area index with		Range for `r' value		
DMP I	G	0 784 (E2)	to	0.951 (E4)
	P	0 774 (E2)	to	0.948 (E4)
Plant height	G	0 453 (E4)	to	0.839 (E3)
	P	0.443 (E4)	to	0 824 (E3)
Fodder yield per plant	G	0.330 (E4)	to	0 814 (E3)
	P	0.319 (E4)	to	0 787 (E3)
DMP II	G	0 338 (E6)	to	0 762 (E3)
	P	0 326 (E2)	to	0 732 (E3)
Ear girth	G	0 333 (E4)	to	0 733 (E3)
	P	0 427 (E2)	to	0 673 (E3)

Some other characters also showed significant and positive genotypic and phenotypic correlations with LAI but these correlations listed below were limited to few environments

LAI with	Environments
Days to stigma emergence	E1, E2, E4, E5 and E6
Ear length	E1, E3 E4, E5 and E6
1000 grain weight	E3
No of effective tiller per plant	E3
AGR	E3

b) Negative correlations

Relative growth rate, adaxial and abaxial stomatal densities showed significant and negative genotypic and phenotypic correlations with LAI, uniformly in all the environments considered for this study except abaxial surface in E2 at phenotypic level

However, effective tillers per plant also showed significant and negative genotypic and phenotypic correlations with LAI in E5 and in E2 and E6 at genotypic level only Both genotypic and phenotypic negative and significant correlations of LAI with harvest index in E1 and E2 and AGR were observed in E6 only. Number of grains per cm^2 showed consistently non-significant ~~correlations with LAI in all the environment~~ studied

ii) Dry matter production I

a) Positive correlations

Leaf area index, fodder yield per plant, DMP II, ear length and plant height showed significant and positive genotypic and phenotypic correlation with DMP I, uniformly in all the environments except fodder yield per plant in E4 at phenotypic level, considered for the study as listed below

DMP I with		Range for `r' value		
LAI	G	0 784 (E2)	to	0.951 (E4)
	P	0 774 (E2)	to	0 948 (E4)
Fodder yield per plant	G	0.305 (E4)	to	0.881 (E5)
	P	0 585 (E2)	to	0.834 (E5)
DMP II	G	0.431 (E6)	to	0.858 (E3)
	P	0 440 (E6)	to	0.838 (E3)
Ear length	G	0 402 (E1)	to	0 829 (E3)
	P	0 394 (E1)	to	0 770 (E3)

Plant height	G	0.537 (E4)	to	0.820 (E2)
	P	0.526 (E4)	to	0.796 (E5)

Positive and significant genotypic and phenotypic associations of DMP I was also noted with some other characters but, these associations were observed only in few environments as listed below ·

DMP I with	Environments
Days to stigma emergence	E1, E2, E4, E5 and E6
Ear girth	E1, E2, E3, E5 and E6
1000 grain weight	E2, E3 and E6
No of effective tiller per plant	E3
AGR	E3

The characters, number of grains per cm^2 and 1000 grain weight also significant positive association at genotypic level only in E2 and E5, respectively.

b) Negative correlations

Relative growth rate and abaxial stomatal density showed uniformly, significant negative genotypic and phenotypic correlations with DMP I in all the environments except abaxial stomatal density in E3 at phenotypic level Other significant and negative associations, observed only in few environments were

DMP I with	Environments
Adaxial stomatal density	E1, E2, E3, E4, and E5
No. of effective tiller per plant	E2, E5 and E6

Harvest index	E1 and E2
No of grains per cm^2	E6
AGR	E6

iii) Dry matter production II

a) Positive correlations :

The characters that showed significant and positive genotypic and phenotypic correlations with DMP II, uniformly in all the environments considered for this study and in decreasing order of magnitude of r values were, fodder yield per plant, ARG, ear length, DMP I, plant height and LAI except at genotypic level in E2 in case of LAI. In all the environments the r values were usually high The ranges for significant r values for association in different pairs of characters, as observed in various environments, were as follows

DMP II with		Range for `r' values		
Fodder yield per plant	G	0.743 (E4)	to	0 945 (E3)
	P	0 699 (E4)	to	0.885 (E3)
AGR	G	0 723 (E6)	to	0 900 (E5)
	P	0.729 (E6)	to	0 900 (E5)
Ear length	G	0.609 (E5)	to	0.942 (E3)
	P	0.593 (E5)	to	0.864 (E3)
DMP I	G	0.431 (E6)	to	0 858 (E3)
	P	0.440 (E6)	to	0.838 (E3)
Plant height	G	0.399 (E4)	to	0 800 (E2)
	P	0.390 (E4)	to	0 737 (E3)
LAI	G	0.338 (E6)	to	0.762 (E3)
	P	0.326 (E2)	to	0 732 (E3)

Dry matter production II also showed significant and positive genotypic and phenotypic associations with some other traits. However, these associations, listed below, were observed only in a few environments

DMP II with	Environments
Ear girth	E1, E2, E3, E5, and E6
1000 grain weight	E2, E3 and E6
No of effective tillers per plant	E3 and E4
RGR	E4 and E5
Harvest index	E3

b) Negative correlation

The correlation between DMP II and adaxial and abaxial stomatal densities were negatively significant at both genotypic and phenotypic level in E2, E3, E4 and E5 environments except adaxial stomatal density in E2 and E3 at phenotypic level While its correlation with number of grains per cm^2 in E6 both at genotypic and phenotypic level and in E2 at genotypic level only and with harvest index in E5 both at genotypic and phenotypic level. Days to stigma emergence showed consistently non-significant correlations with DMP II in all the environments

iv) Absolute growth rate

a) Positive correlations

Dry matter production II, RGR, fodder yield per plant and ear length showed significant positive genotypic and phenotypic correlations with AGR, uniformly in all the environments except RGR at genotypic level in E3 environment. The ranges for the magnitude of r values for different pairs of characters are given below .

AGR with		Range for `r' values		
DMP II	G	0.723 (E6)	to	0.881 (E3)
	P	0.729 (E6)	to	0.878 (E3)
RGR	G	0.624 (E1)	to	0.821 (E4)
	P	0.352 (E3)	to	0.811 (E4)
Fodder yield per plant	G	0.370 (E6)	to	0.769 (E3)
	P	0.372 (E6)	to	0.721 (E3)
Ear length	G	0.321 (E5)	to	0.810 (E3)
	P	0.312 (E5)	to	0.722 (E1)

Other significant positive genotypic and phenotypic associations of ARG presented below, were noted only in few environments

AGR with	Environments
1000 grain weight	E2, E3 and E6
Ear girth	E1, E2 and E3
No. of effective tillers per plant	E3 and E4
Plant height	E2 and E3
Harvest index	E3
LAI	E3
DMP I	E3

Similarly, adaxial and abaxial stomatal densities showed significant positive only genotypic correlation with ARG in E6 and E1, respectively

b) Negative correlations

A few significant and negative genotypic and phenotypic associations of ARG, as recorded in different environment were :

AGR with	Environments
Days to stigma emergence	E2, E3, E4, E5, and E6
Abaxial stomatal density	E3 and E4
LAI	E6

The correlation between ARG and harvest index and adaxial stomatal density in E5 and with DMP I in E6 were significantly negative at genotypic level only Number of grains per cm^2 exhibited consistently non-significant correlation with AGR in all the environments

v) Relation growth rate

a) Positive correlations :

Only absolute growth rate exhibited significant and positive genotypic and phenotypic correlations with RGR, uniformly in all the environments except its association in E3 at genotypic level. The values of r ranged from 0 624 (E1) to 0 821 (E4) and 0 352 (E3) to 0 811 (E4) for genotypic and phenotypic level, respectively However, some other positive correlations observed in a few environments at both genotypic and phenotypic level are listed below

RGR with	Environments
No of effective tillers per plant	E4, E5, and E6
Harvest index	E1, E2 and E3
DMP II	E4 and E5

Adaxial stomatal density	E1 and E3
Abaxial stomatal density	E1

b) Negative correlations

Dry matter production I and LAI showed, uniformly negative and significant genotypic and phenotypic correlations with RGR in all the environments considered for study. Other some trait also showed significant negative genotypic and phenotypic correlations, observed only in a few environments were

RGR with	Environments
Days to stigma emergence	E1, E2, E4, E5, and E6
Plant height	E1, E3, E5 and E6
Ear girth	E3 and E6

The characters, fodder yield per plant, ear length, number of grains per cm^2 and 1000 grain weight exhibited non-significant r values uniformly, in all the environments considered for this study.

vi) Adaxial stomatal density

a) Positive correlations

Adaxial stomatal density only the character showed significant and positive genotypic and phenotypic correlations with abaxial stomatal density uniformly in all the environment except in E5 at phenotypic level considered for the study. The values of r ranged from 0.477 (E5) to 0.932 (E1) and 0 708 (E3) to 0 925 (E1) for genotypic and phenotypic level, respectively

Some other characters also showed significant and positive genotypic and phenotypic correlations with adaxial stomatal density but these correlations listed below were limited to a few environments only.

Adaxial stomatal density with	Environments
Number of grains per cm^2	E1, E2, E3 and E4
Harvest index	E2 and E4
RGR	E1 and E3
1000 grain weight	E6

Also, harvest index and ARG were significantly positive with adaxial stomatal density at genotypic level only in E5 and E6, respectively.

b) Negative correlations

Only leaf area index exhibited significant negative correlations with adaxial stomatal density in all the environments at both genotypic and phenotypic level Other significant and negative genotypic and phenotypic associations were observed in only a few environments have been given below

Adaxial stomatal density	Environments
DMP I	E1, E3, E4 and E5
Plant height	E1, E2, E3 and E4
Fodder yield per plant	E3, E4 and E5
Days to stigma emergence	E1, E3 and E6
DMP II	E4 and E5
Ear length	E3
Ear girth	E3

However, there were some traits which exhibited significantly negative correlation with adaxial stomatal density only at genotypic level but these correlations presented below were observed in one to three environments only

Adaxial stomatal density	Environments
Ear length	E2, E4 and E5
Ear girth	E2 and E5
1000 grain weight	E1 and E3
DMP II	E2 and E3
Plant height	E5
DMP I	E2
AGR	E5

Number of effective tillers per plant showed non-significant correlations consistently with adaxial stomatal density in all the environments.

vii) Abaxial stomatal density

a) Positive correlations

The characters, abaxial stomatal density showed significant and positive genotypic and phenotypic correlations with adaxial stomatal density and number of grains per cm^2 uniformly in all the environments studies except in E5 at phenotypic level in case of former and in E5 and E6 at both genotypic and phenotypic level in latter. Similarly, abaxial stomatal density also exhibited significant positive correlations with RGR in environment E1 and with harvest index in E6, both at genotypic and phenotypic level. However, in case of AGR significantly positive correlation with abaxial stomatal density was found in E1 environment only at genotypic level

b) Negative correlations

Dry matter production I and LAI exhibited negative and significant genotypic and phenotypic correlations with abaxial stomatal density uniformly in all the environments except at phenotypic level in E3 and E2 respectively, where it was non-significant and negative A negative and significant genotypic and phenotypic correlations, however, noticed in few environments were as follows

Abaxial stomatal density	Environments
DMP II	E2, E3, E4 and E5
Ear length	E2, E3, E4 and E5
Days to stigma emergence	E1, E3 and E6
Plant height	E2, E3 and E4
Fodder yield per plant	E2, E3 and E4
AGR	E3 and E4
Ear girth	E3
1000 grain weight	E3

While, some characters which showed significant and negative association of abaxial stomatal density with plant height and fodder yield per plant in E5 and with ear girth in E2 at genotypic level only. Number of effective illers per plant showed negative and non-significant correlation with abaxial stomatal density in all the environments except in E2, where it was positive and non-significant

4.6.4.2 Correlation of harvest index and agronomic characters with other characters

i) Days to stigma emergence

a) Positive correlations

The characters which showed positive and significant genotypic and phenotypic correlations with days to stigma emergence, uniformly in all the environments except in E3 considered for correlation studies and listed in order of decreasing magnitude were, LAI and DMP I

Days to stigma emergence		Range for r value		
LAI	G	0 634 (E4)	to	0 858 (E2)
	P	0 585 (E4)	to	0 808 (E2)
DMP I	G	0.455 (E2)	to	0 749 (E6)
	P	0 435 (E2)	to	0.736 (E6)

However, some positive and significant genotypic and phenotypic correlations noticed in one or two environments were ·

Days to stigma emergence	Environments
Plant height	E1 and E6
Ear girth	E1 and E6
Fodder yield per plant	E6

Also, plant height showed significantly positive correlation with days to stigma emergence in E3 at genotypic level only

b) Negative correlations

None of the characters exhibited significant and negative genotypic and phenotypic correlations with days to stigma emergence uniformly, in all the environments studied. However, some characters showed negative and significant genotypic and phenotypic associations but these correlations listed below, were recorded only in few environments only

Days to stigma emergence	Environments
AGR	E2, E3, E4, E5 and E6
RGR	E2, E3, E4, E5 and E6
No of effective tillers per plant	E3, E4, E5 and E6
Adaxial stomatal density	E1, E3 and E6
Abaxial stomatal density	E1, E3 and E6
Harvest index	E3 and E6

The characters, harvest index and no. of effective tillers per plant was also found to be significant and negatively correlated with days to stigma emergence in E1 environment at genotypic level only No significant correlation of days to stigma emergence with DMP II, ear length, number of grains per cm^2 and 1000 grain weight were observed in any of the environment

) Plant height

The characters which exhibited positive and significant genotypic nd phenotypic correlations with plant height uniformly in all the environments onsidered for correlations studies and listed in order of decreasing magnitude ere, fodder yield per plant, DMP I, ear length, LAI, DMP II and ear girth

lant height with		Range for r value		
odder yield per plant	G	0.528 (E4)	to	0.901 (E6)
	P	0.503 (E4)	to	0.893 (E6)
MP I	G	0 537 (E4)	to	0.870 (E3)
	P	0 526 (E4)	to	0 842 (E3)

Ear length	G	0 555 (E4)	to	0.854 (E5)
	P	0.541 (E4)	to	0 830 (E5)
LAI	G	0.453 (E4)	to	0 839 (E3)
	P	0.443 (E4)	to	0 824 (E3)
DMP II	G	0.399 (E4)	to	0 800 (E2)
	P	0.390 (E4)	to	0.733 (E2)
Ear girth	G	0 404 (E4)	to	0 718 (E5)
	P	0 363 (E4)	to	0 710 (E5)

Other characters also showed significant and positive genotypic and phenotypic associations with plant height, but these character listed below, were noted in few environments only

Plant height with	Environments
1000 grain weight	E1, E2, E3 and E6
AGR	E2 and E3
Days to stigma emergence	E1 and E6
No of effective tillers per plant	E3

Similarly, days to stigma emergence was significantly and positively associated with plant height in E3 at genotypic level only

b) Negative correlations

None of the characters showed significant and negative genotypic and phenotypic correlations with plant height, uniformly in all the environments However, some negative and significant genotypic and phenotypic correlations noticed in a four different environments were .

Plant height with	Environments
Harvest index	E1, E2, E4 and E6
No of effective tillers per plant	E1, E2, E5 and E6
Number of grains per cm^2	E2, E4, E5 and E6
Abaxial stomatal density	E2, E3, E4 and E5
Adaxial stomatal density	E1, E2, E3 and E4
RGR	E1, E3, E5 and E6

While, correlations between adaxial stomatal density and plant height was negatively and significantly in E5 at genotypic level only.

ii) Fodder yield per plant

The characters which showed significantly positive genotypic and phenotypic associations with fodder yield per plant, uniformly in all the environments and listed in decreasing order of magnitude of correlations were DMP II, plant height, DMP I, ear length, LAI and AGR except its association with DMP I in E4 at phenotypic level. The ranges for the value of significant correlation coefficients as observed in various environments were

Fodder yield per plant with		Range for r value		
DMP II	G	0 743 (E4)	to	0 945 (E3)
	P	0.699 (E4)	to	0.885 (E3)
Plant height	G	0 515 (E1)	to	0.901 (E6)
	P	0 486 (E1)	to	0.893 (E6)
DMP I	G	0.305 (E4)	to	0.881 (E5)
	P	0 585 (E2)	to	0.834 (E5)

Ear length	G	0 678 (E1)	to	0.853 (E3)
	P	0 670 (E1)	to	0.804 (E6)
LAI	G	0 330 (E4)	to	0 814 (E3)
	P	0.319 (E4)	to	0 787 (E3)
AGR	G	0.370 (E6)	to	0 769 (E3)
	P	0.372 (E6)	to	0.721 (E3)

Four other characters also exhibited significant and positive genotypic and phenotypic correlations with fodder yield per plant but these correlations listed below, were limited to a few environments only.

Fodder yield per plant	Environments
Ear girth	E1, E2, E3, E5 and E6
1000-grain weight	E2, E3, E5 and E6
No. of effective tillers per plant	E3
Days to stigma emergence	E6

While, the correlation between harvest index and fodder yield per plant was found to be significant and positive only in E3 at genotypic level

b) Negative correlations

None of the characters showed significant and negative genotypic and phenotypic correlations with fodder yield per plant, uniformly in all the environments A few negative significant genotypic and phenotypic associations, however, noticed in different environments were as follow :

Fodder yield per plant	Environments
Harvest index	E1, E2, E4, E5 and E6
Abaxial stomatal density	E2, E3 and E4

Adaxial stomatal density	E3, E4 and E5
Number of grains per cm^2	E4, E5 and E6
No of effective tillers per plant	E5

The correlation of fodder yield per plant with abaxial stomatal density in E5 was observed to be significantly negative at genotypic level only. No significant correlation of fodder yield per plant with RGR was observed in any of the environments

v) Harvest index

a) Positive correlations

Only the character number of grains per cm^2 exhibited significantly positive genotypic and phenotypic correlation with harvest index, uniformly in all the environments except that of non-significant correlations in E1 The values of r ranged from 0 540 (E4) to 0.773 (E6) and 0.445 (E4) to 0.748 (E6) for genotypic and phenotypic level, respectively Similarly, some positive and significant genotypic and phenotypic correlations noticed in one or wo environments only were

Harvest index with	Environments
RGR	E1 and E2
Adaxial stomatal density	E2 and E4
No of effective tillers per plant	E2 and E3
AGR	E3
DMP II	E3
Abaxial stomatal density	E6
Ear length	E3
000 grain weight	E3

Also, the correlation of harvest index with adaxial stomatal density in E5, RGR and fodder yield per plant in E3 environment were observed to be significant and positive at genotypic level only

b) Negative correlations

None of the characters studied, showed significant and negative genotypic and phenotypic correlations with harvest index, uniformly in all the environments However, some other negative and significant correlations observed in a few environments are listed below :

Harvest index with	Environments
Fodder yield per plant	E1, E2, E4, E5 and E6
Plant height	E1, E2, E4 and E6
Days to stigma emergence	E3 and E6
LAI	E1 and E2
DMP I	E1 and E2
DMP II	E5

Harvest index also showed negative significant association with AGR in E5, with days to stigma emergence in E1 and with 1000 grain weight in E2 at genotypic level only No Significant association of ear girth with harvest index was noticed in any of the environments.

4.6.4.3 Correlation of grain yield components with other characters

i) Number of effective tillers per plant

a) Positive correlations

None of the characters showed significant and positive correlations with no of effective tillers per plant uniformly in all the environments considered for this study Positive and significant genotypic and phenotypic correlations of effective tillers per plant were noted with some other characters but such correlations were observed only in one to three environments which are as follows

No of effective tillers per plant	Environments
RGR	E4, E5 and E6
AGR	E3 and E4
DMP II	E3 and E4
Harvest index	E2 and E3
Fodder yield per plant	E3
Plant height	E3
LAI	E3
DMP I	E3
Ear length	E3

b) Negative correlations

None of the characters exhibited significant and negative genotypic and phenotypic correlations with no. of effective tillers per plant, uniformly in all the environments. However, some negative and significant genotypic and phenotypic correlations noticed in a few environments were

No of effective tillers per plant	Environments
Ear girth	E1, E2, E4, E5 and E6
1000 grain weight	E1, E2, E4, E5 and E6
Plant height	E1, E2, E5 and E6
Days to stigma emergence	E3, E4, E5 and E6
DMP I	E2, E5 and E6

Ear length	E5 and E6
LAI	E5
Fodder yield per plant	E5

Where as, some character which showed significant and negative correlation with no of effective tillers per plant at genotypic level only, those were LAI in E2 and E6, days to stigma emergence in E1 and ear length in E2. While, the characters adaxial and abaxial stomatal densities and number of grains per cm^2 showed non-significant correlation with no. of effective tillers per plant consistently in all the environments

ii) Ear length

a) Positive correlations

The characters which showed significant and positive genotypic and phenotypic correlations with ear length, uniformly in all the environment considered for the study, listed in decreasing order of magnitude of correlation coefficients were DMP II, plant height, fodder yield per plant, DMP I, ear girth and AGR The ranges for the value of significant correlation coefficients as observed in various environments were

Ear length with		Range for r value		
DMP II	G	0 609 (E5)	to	0 942 (E3)
	P	0 593 (E5)	to	0.864 (E3)
Plant height	G	0 555 (E4)	to	0.854 (E5)
	P	0 541 (E4)	to	0.830 (E5)
Fodder yield per plant	G	0.678 (E1)	to	0.853 (E3)
	P	0 670 (E1)	to	0.797 (E3)
DMP I	G	0 402 (E1)	to	0.829 (E3)
	P	0 394 (E1)	to	0 770 (E3)

Ear girth	G	0 575 (E1)	to	0 824 (E6)
	P	0 546 (E1)	to	0 816 (E6)
AGR	G	0 321 (E5)	to	0 810 (E3)
	P	0 312 (E5)	to	0 722 (E1)

Some other characters also showed significant and positive genotypic and phenotypic correlations with ear length but these correlations listed below, were limited in a few environments only.

Ear length with	Environments
LAI	E1, E3, E4, E5 and E6
1000 grains weight	E1, E2, E3, E5 and E5
No of effective tillers per plant	E3
Harvest index	E3

b) Negative correlations

None of the characters showed significant and negative genotypic and phenotypic correlations with ear length, uniformly in all the environment studied However, some negative and significantly genotypic and phenotypic correlations noticed in a few environments were .

Ear length with	Environments
Abaxial stomatal density	E2, E3, E4 and E5
Number of grains per cm^2	E2, E4, E5 and E6
No. of effective tillers per plant	E5 and E6
Adaxial stomatal density	E3

While, ear length also showed significantly negative correlations with adaxial stomatal density in E2, E4 and E5, with no. of effective tillers per plant in E2 and with number of grains per cm^2 in E1, at genotypic level, where as correlation of RGR, and days to stigma emergence with ear length were observed to be non-significant, uniformly in all the environments

iii) Ear girth

a) Positive correlations

The characters that showed significant and positive genotypic and phenotypic correlations with ear girth, uniformly in all the environments considered for correlation study and listed in order of decreasing magnitude of r values, were ear length, plant height and LAI (except in E4 at phenotypic evel) The ranges for magnitude of significant r values for these correlations, as observed in various environments, is given below

Ear girth with		Range for r value		
Ear length	G	0.575 (E1)	to	0.815 (E5)
	P	0.546 (E1)	to	0.798 (E5)
Plant height	G	0 404 (E4)	to	0 718 (E5)
	P	0.363 (E4)	to	0 710 (E5)
LAI	G	0 333 (E4)	to	0.733 (E3)
	P	0 427 (E2)	to	0 673 (E3)

Some other characters also exhibited significant and positive genotypic and phenotypic associations with ear girth but these correlations isted below were limited to a few environments only

Ear girth with	Environments
DMP I	E1, E2, E3, E5 and E6
DMP II	E1, E2, E3, E5 and E6

Fodder yield per plant	E1, E2, E3, E5 and E6
1000 grain weight	E3, E5 and E6
AGR	E1, E2 and E3
Days to stigma emergence	E1 and E6

Also, the correlation of ear girth with 1000-grain weight in E1 environment was observed to be significant and positive at genotypic level only

b) Negative correlations

Number of effective tillers per plant showed significant and negative genotypic and phenotypic correlations with ear girth uniformly in all environments except in E3 Other negative and significant genotypic and phenotypic correlations observed only in a few environments are listed below

Ear girth with	Environments
Number of grains per cm^2	E4, E5 and E6
RGR	E3 and E6
Adaxial stomatal density	E3
Abaxial stomatal density	E3

The correlation of ear girth with some traits were also exhibited negative and significant at genotypic level only in certain environments, those were abaxial stomatal density in E2 and adaxial stomatal density in E2 and E5 environments. While the correlation between ear girth and harvest index was observed to be non-significant consistently in all the environments under study

iv) Number of grains per cm^2

a) Positive correlations :

Two character which showed positive and significant genotypic and phenotypic associations with number of grains per cm^2 uniformly in all the environments were harvest index and abaxial stomatal density except in E1 and E5 respectively, where they were non-significant The ranges for the values of significant correlation coefficients as observed in various environments were

Number of grains per cm^2		Range for r value		
Harvest index	G	0 540 (E4)	to	0 773 (E6)
	P	0 445 (E4)	to	0 748 (E6)
Abaxial stomatal density	G	0 357 (E3)	to	0 661 (E2)
	P	0 348 (E3)	to	0.540 (E2)

Number of grains per cm^2 also showed significant and positive genotypic and phenotypic associations with adaxial stomatal density in E1, E2, E3 and E4 environments.

b) Negative correlations

Only the character ear length exhibited significant and negative genotypic and phenotypic associations with number of grains per cm^2 in all the environments except E3 and E1 (where it significant at genotypic level only) Other negative and significant genotypic and phenotypic associations observed only in a few environments are listed below

Number of grains per cm^2	Environments
Plant height	E2, E4, E5 and E6
1000-grain weight	E1, E3 and E6

Ear girth	E4, E5 and E6
Fodder yield per plant	E4, E5 and E6
DMP I	E6
DMP II	E6

Association of number of grains with some characters were also observed to be negative and significant in certain environments at genotypic level only, those were fodder yield per plant in E3, DMP I and DMP II in E2 environment

The characters, LAI, AGR, RGR and no. of effective tillers per plant showed non-significant r values with number of grains per cm^2 consistently in all the environment under study

v) 1000-grains weight

a) Positive correlations

Ear length exhibited positive and significant genotypic and phenotypic correlations with 1000 grain weight, uniformly in all the environments except in E4, where it was non-significant The values of correlation coefficient ranged from 0 452 (E5) to 0 706 (E6) and 0 415 (E5) to 0.678 (E6) for genotypic and phenotypic, respectively.

However, some other characters also showed positive and significant genotypic and phenotypic associations with 1000 grain weight but these characters listed below, were limited to a few environments.

1000 grain weight with	Environments
Plant height	E1, E2, E3 and E6
Fodder yield per plant	E2, E3, E5 and E6

Ear girth	E3, E5 and E6
DMP I	E2, E3 and E6
DMP II	E2, E3 and E6
AGR	E3 and E6
LAI	E3
Adaxial stomatal density	E6
Harvest index	E3

Correlation of 1000 grain weight with some characters was also positive and significant in few environments at genotypic level only, those were DMP I in E5, ARG in E2 and ear girth in E1, environment

b) Negative correlations

Effective tillers per plant showed negative and significant genotypic and phenotypic correlations with 1000 grain weight, uniformly in all the environment considered for correlation study except in E3 where it was non-significant Other characters also showed significantly negative genotypic and phenotypic correlations with 1000 grain weight, but these characters given below were limited to a few environment only

1000 grain weight with	Environments
Number of grains per cm^2	E1, E3 and E6
Abaxial stomatal density	E3

Where as correlation of 1000 grain weight with two other characters were also negatively significant in few environments at genotypic level only, those were harvest index in E2 and adaxial stomatal density in E1 and E3 environments While, RGR and days to stigma emergence showed non-significant correlation with this trait consistently in all the environments.

4.7 Genotypic path coefficient analysis

The genotypic correlation coefficients of sixteen, morpho-physiological characters, harvest index and agronomic characters and grain yield components were partitioning into direct and indirect effects, as observed in different environments

4.7.1 Direct effects of causal components on grain yield

The direct effect of sixteen different morpho-physiological, harvest index and agronomic and grain yield components observed in different environments have been given in Table 13

Among all the causal components of grain yield, harvest index and DMP II showed positive and direct effects on grain yield, uniformly in all the environments considered for study except in E2 the case of latter, where it was negative The values of this direct effects ranged from 0.163 (E3) to 2 172 (E2) and 0 419 (E6) to 22.627 (E3) for harvest index and DMP II, respectively

Under all environments, DMP II showed highest positive direct effects among all the other characters considered for path analysis except in E2 and E6, where the character AGR and fodder yield per plant were ranked first, respectively Similarly, other characters exerting positive direct effects were RGR, 1000-grain weight, no of effective tillers per plant and abaxial stomatal density in *khanf* environments and fodder yield per plant in summer environments, uniformly, have been listed below in decreasing order of magnitude of direct effects. The ranges for direct effects as observed in different environments are given below .

Direct effect of	Range		
RGR	0.052 (E3)	to	0.600 (E1)
1000 grain weight	0 101 (E1)	to	0.508 (E2)
No of effective tillers per plant	0 008 (E1)	to	0 499 (E3)

Table 13 Direct effect of sixteen causal variable on grain yield in pearl millet under different enrivonments

Environment	Characters															
	LAI	DMP I	DMP II	AGR	RGR	Adaxial stomatal density	Abaxial stomatal density	Days to stigma emergence	Plant height	Fodder yield per plant	Harvest index	No of effective tillers/plant	Ear length	Ear girth	No of grains per cm^2	1000 grain weight
E1	0.018	-0.106	1.778	-1.187	0.334	-0.355	0.287	-0.126	-0.331	0.079	0.578	0.008	0.172	0.018	0.210	0.101
E2	-2.482	11.483	-10.486	13.385	0.600	-0.450	0.212	2.437	-3.001	-0.637	2.172	0.499	-3.566	1.206	-1.807	0.508
E3	0.056	-11.888	22.627	-12.671	0.052	-0.126	0.130	-0.057	0.304	-0.957	0.163	0.044	0.035	-0.153	0.031	0.321
E4	-0.879	-2.083	5.219	-3.333	-0.560	0.036	-0.143	0.015	-0.244	0.075	0.728	-0.070	-0.101	0.136	-0.037	-0.058
E5	0.592	-0.224	1.201	-0.416	0.237	-0.027	-0.019	-0.290	0.082	0.017	0.567	-0.121	-0.085	-0.269	-0.095	0.093
E6	0.208	-0.106	0.419	0.538	-0.478	0.006	0.254	-0.049	-0.475	0.560	0.510	0.139	-0.291	0.302	-0.044	0.021

ɔaxial stomatal density	0.130 (E3)	to	0.287 (E1)
ɔdder yield per plant	0.017 (E5)	to	0.560 (E6)

7.2 Morpho-physiological characters vs grain yield

Leaf area index

Direct effect of LAI on grain yield was positive in all the ıvironments except E2 and E4, where it was negative. The highest value ı.592) of this was noticed in E5 and the lowest (0.018) in E1 (Table 14). direct contribution of LAI *via* DMP II was high in all the environments except E2, as compared to all other indirect effects The estimated value of indirect fects of DMP II ranged from 17.249 (E3) to 0.141 (E6) The indirect effect *via* ⊃00 grain weight was positive, though small in all the environments Indirect ɔntribution through adaxial stomatal density was also positive in E1, E2, E3 ıd E5, while negative in rest of the environments The indirect effect *via* dder yield per plant was positive in all the environments except E2 and E3, th highest value of 0.346 in E6. Indirect effect of LAI was consistently low *via* r girth and number of grains per cm^2 though its contribution was positive in me and negative in other environments. The values of indirect effects *via* ЗR were greater in E4 and E6, while in remaining environments it was gative Highest and positive indirect estimates *via* DMP I was observed in (9.002) only and negative in rest of the environments. Indirect effects *via* t of the characters it was either negative or positive with lower values in all environments

⊃ry matter production I

Dry matter production I showed negative direct effects on grain d in all the environments except in E2, where it was positive and highest 483) However, a substantial indirect positive influence *via* DMP II (except ⁚2) and 1000 grain weight was recorded for this character (Table 14)

able 14. Direct and indirect effects of different morpho-physiological, agronomic characters and yield components to grain yield at different environments

Characters	Environments					
	E1	E2	E3	E4	E5	E6
1	2	3	4	5	6	7
) Morpho-physiological characters						
LAI vs grain yield						
irect effects	0 018	-2 482	0 056	-0 879	0 592	0 208
direct effects via						
MP I	-0 093	9 002	-10 595	-1 982	-0 196	-0 096
MP II	1 206	-3 051	17 249	3 066	0 480	0 141
3R	-0 317	-1 786	-5 725	0 017	-0 005	-0 181
3R	-0 168	-0 411	-0 027	0 113	-0 122	0 337
daxial stomatal density	0 182	0 164	0 072	-0 018	0 015	-0 002
)axial stomatal density	-0 134	-0 067	-0 057	0 067	0 009	-0 103
nergence	-0 101	2 091	-0 003	0 010	-0 203	-0 038
ant height	-0 183	-1 913	0 255	-0 111	0 053	-0 283
odder yield/plant	0 062	-0 246	-0 779	0 025	0 011	0 346
arvest index	-0 298	-0 813	0 045	-0 012	-0 012	-0 039
fective tillers/plant	-0 002	-0 167	0 024	0 008	0 066	-0 044
ır length	0 063	-0 932	0 026	-0 051	-0 062	-0 148
ır girth	0 010	0 531	-0 112	0 045	-0 142	0 136
) of grains/cm^2	0 013	-0 037	-0 005	0 004	0 013	0 005
00 grain weight	0 004	0 088	0 179	0 009	0 010	0 003
value	0 262	-0 030	0 605**	0 512**	0 507**	0 241
, DMP I vs grain yield						
rect effects	-0 106	11 483	-11 883	-2 083	-0 224	-0 106
direct effects via						
.I	0 016	-1 946	0 050	-0 836	0 520	0 188
/IP II	1 076	-5 465	19 408	2 697	0 589	0 180
3R	-0 114	0 058	-6 484	0 407	-0 025	-0 167
3R	-0 239	-0 414	-0 032	0 357	-0 129	0 387
axial stomatal density	0 211	0 141	0 059	-0 016	0 018	-0 001
axial stomatal density	-0 156	-0 075	-0 041	0 054	0 008	-0 096
ıergence	-0 089	1 109	-0 001	0 009	-0 166	-0 037
ınt height	-0 222	-2 462	0 265	-0 131	0 067	-0 354
dder yield/plant	0 055	-0 382	-0 841	0 023	0 015	0 379
rvest index	-0 288	-1 347	0 042	-0 078	-0 158	-0 087
ective tillers/plant	-0 002	-0 188	0 019	0 008	0 079	-0 068
r length	0 069	-1 991	0 029	-0 043	-0 064	-0 202
r girth	0 011	0 578	-0 113	0 03	-0 16	0 215
of grains/cm^2	-0 045	0 619	-0 005	0 004	0 022	0 016
)0 grain weight	0 013	0 243	0 217	0 006	0 03	0 008
/value	0 193	-0 038	0 683**	0 408**	0 423**	0 254

ble 14. Contd ....

1	2	3	4	5	6	7
. DMP II vs grain yield						
rect effects	1 778	-10 486	22 627	5 219	1 201	0 419
direct effects via						
l	0 013	-0 722	0 043	-0 516	0 236	0.07
MP I	-0 064	5 984	-10 197	-1 077	-0 11	-0 046
3R	-1 01	11 454	-11 158	-2 621	-0 374	0 389
3R	0 041	0 139	-0 009	-0 174	0 103	-0 073
axial stomatal density	0 044	0 153	0 047	-0 017	0 019	0 001
axial stomatal density	-0 008	-0 093	-0 051	0 087	0 008	-0 015
ergence	-0 032	-0 430	0 013	-0 003	0 036	0 002
nt height	-0 168	-2 401	0 236	-0 097	0 037	-0 329
dder yield/plant	0 075	-0 583	-0 904	0 056	0 013	0 472
rvest index	-0 044	-0 505	0 091	-0 075	-0 230	-0 091
ective tillers/plant	0 000	-0 144	0 028	-0 024	0 008	-0 013
r length	0 142	-3 233	0 033	-0 069	-0 052	-0 252
r girth	0 011	0 661	-0 102	0 037	-0 115	0 185
of grains/cm^2	0 012	0 603	-0 002	0 006	0 008	0 021
00 grain weight	0 028	0 300	0 237	0 015	0 021	0 014
value	0 816**	0 696**	0 931**	0 746**	0 811**	0 753**
AGR vs grain yield						
ect effects	-1 187	13 385	-12 671	-3 333	-0 416	0 538
irect effects via						
	0 005	0 331	0 025	0 004	0 007	-0 070
P I	-0 010	0 050	-6.083	0 254	-0 014	0 033
P II	1 513	-8 973	19 925	4 106	1 080	0 303
R	0 208	0 413	0 016	-0 460	0 183	-0 373
axial stomatal density	-0 080	0 094	0 023	-0 009	0 012	0 002
axial stomatal density	0 090	-0 064	-0 048	0 063	0 005	0 057
ergence	0 018	-1 174	0 023	-0 010	0 126	0 030
nt height	-0 061	-1 318	0 150	-0 180	0 010	-0 076
lder yield/plant	0 057	-0 451	-0 735	0 048	0 007	0.207
vest index	0 140	0.234	0 113	-0 031	-0 188	-0 029
ctive tillers/plant	0 001	-0 057	0 029	-0 033	-0 031	0 038
length	0 131	-2 588	0 029	-0 049	-0 027	-0 110
girth	0 006	0 430	-0 067	0 021	-0 052	0 030
of grains/cm^2	0 045	0 324	0 000	0 004	-0 001	0 010
0 grain weight	0 026	0 206	0 196	0.012	0 009	0 008
alue	0 901**	0 842**	0 926**	0 571**	0 712**	0 599**

able 14. Contd .....

1	2	3	4	5	6	7
/. RGR vs grain yield						
irect effects	0 334	0 600	0 052	-0 560	0 237	-0 478
idirect effects via						
AI	-0 009	1 698	-0 029	0 491	-0 306	-0 147
'MP I	0 076	-7 918	7 355	1 330	0 122	0 086
'MP II	0 219	-2 423	-3.709	1 625	0 524	0 064
GR	-0 741	9 205	-3 757	-2 737	-0 322	0 420
daxial stomatal density	-0 227	0 003	-0 045	0 005	0 001	0 001
baxial stomatal density	0 194	-0 012	-0 007	0 006	0 001	0 071
mergence	0 081	-1 723	0 016	-0 014	0 215	0 037
lant height	0 121	0 780	-0 153	0 060	-0 031	0 168
odder yield/plant	-0 003	-0 051	0 241	0 021	-0 003	-0 090
arvest index	0 317	0 928	0 056	0 035	-0 053	-0 002
ffective tillers/plant	0 001	0 092	0 005	-0 033	-0 082	0 077
ar length	0 045	-0 499	-0 007	-0 013	0 016	0 073
ar girth	-0 004	-0 091	0 067	-0 006	0 057	-0 142
o of grains/cm^2	0 057	0 018	0 004	0 000	-0 010	-0 004
000 grain weight	0 016	-0 064	-0 026	0 009	-0 011	-0 002
' value	0 477**	0 545**	0 063	0 22	0 354*	0 134
'i. Adaxial stomatal density vs grain yield						
irect effects	-0 355	-0 450	-1 126	0 036	-0 027	0 006
idirect effects via						
AI	-0 099	0 905	-0 032	0 438	-0 329	-0 074
MP I	0 063	-3 609	5 597	0 920	0 150	0 021
MP II	-0 220	3 575	-8 382	-2 510	-0 833	0 064
GR	-0 266	-2 801	2 351	0 796	0 192	0 168
GR	0 214	-0 004	0 019	-0 078	-0 005	-0 103
baxial stomatal density	0 267	0 190	0 102	-0 122	-0 009	0 199
nergence	0 067	-0 295	0 031	-0 003	0 060	0 023
ant height	0 148	1 862	-0 179	0 137	-0 025	-0 100
odder yield/plant	-0 012	0 152	0 509	-0 034	-0 011	0 048
arvest index	0 136	0 784	0 040	0 288	0 227	0 119
fective tillers/plant	-0 001	0 082	0 002	0 005	-0 015	-0 029
ar length	-0 020	1 178	-0 014	0 035	0 026	-0 042
ar girth	-0 003	-0 406	0 091	-0 032	0 122	0 014
o of grains/cm^2	0 092	-1 110	0 012	-0 020	-0 025	-0 006
000 grain weight	-0 031	-0 029	-0 105	-0 016	-0 010	0 010
value	0 067	0 026	-0 085	-0 160	-0 512**	0 318*

able 14. Contd .....

1	2	3	4	5	6	7
ii. Abaxial stomatal density vs grain yield						
irect effects	0 287	0 212	0 130	-0 143	-0 019	0 254
idirect effects via						
AI	-0 009	0 786	-0 025	0 412	-0 292	-0 085
MP I	0 058	-4 060	3 755	0 786	0 100	0 040
MP II	-0 049	4 613	-8 914	-3 195	-0 514	-0 026
GR	-0 373	-4 035	4 645	1 459	0 112	0 122
GR	0 226	-0 034	-0 003	0 024	-0 007	-0 134
daxial stomatal density	-0 331	-0 402	-0 098	0 031	-0 013	0 005
nergence	0 056	-0 069	0 021	-0 003	0 061	0 029
ant height	0 071	1 985	-0 123	0 122	-0 029	0 069
odder yield/plant	-0 007	0 229	0 481	-0 049	-0 006	-0 161
arvest index	0 082	0 654	0 003	0 183	-0 121	0 239
fective tillers/plant	-0 002	0 021	-0 008	0 009	0 001	-0 030
ar length	-0 001	1 701	-0 020	0 053	0 044	0 033
ar girth	-0 001	-0 391	0 056	-0 031	0 048	-0 018
of grains/cm^2	0 092	-1 195	0 011	-0 019	0 003	-0 025
00 grain weight	-0 010	-0 109	-0 119	-0 004	0 007	0 002
value	0 089	-0 093	-0 207	-0 366*	-0 625**	0 314*
Harvest index and agronomic characters						
Days to stigma emergence vs grain yield						
rect effects	-0 126	2 437	-0 057	0 015	-0 290	-0 049
direct effects via						
I	0 015	-2 130	0.003	-0 557	0 413	0 162
MP I	-0 075	5 226	-0 136	-1 270	-0.128	-0 080
MP II	0 450	1 848	-5 319	-0 912	-0 151	-0 018
R	0 168	-6 449	5 138	2 140	0 181	-0 332
R	-0,215	-0 424	-0 015	0 497	-0 175	0 366
axial stomatal density	0 189	-0 054	0 069	-0 008	0 006	-0 003
axial stomatal density	-0 128	-0 006	-0 049	0 025	0 004	-0 149
nt height	-0 164	-0 526	0 094	-0 068	0 021	-0 231
dder yield/plant	0 020	-0 029	-0 017	-0 011	0 005	0 219
rvest index	-0 190	-0 624	-0 121	-0 002	-0 001	-0 195
ective tillers/plant	-0 002	-0 064	-0 020	0 027	0 067	-0 060
r length	0 005	0 718	-0 006	0 008	-0 019	-0 064
r girth	0 011	0 119	-0 018	0 001	-0 022	-0 094
of grains/cm^2	0 027	-0 417	-0 008	0 002	-0 001	0 013
00 grain weight	-0 007	-0 075	-0 057	-0 003	-0 019	0 000
value	-0 021	-0 342*	-0 518**	-0 116	-0 11	-0 326*

ble 14. Contd .....

1	2	3	4	5	6	7
Plant height vs grain yield						
ect effects	-0 331	-3 001	0 304	-0 244	0 082	-0 475
lirect effects via						
I	0 010	-1 583	0 047	-0 398	0 382	0 124
IP I	-0 071	9 420	-10 339	-1 119	-0 181	-0 079
IP II	0 902	-8 390	17 548	2 082	0 545	0 291
R	-0 220	5 877	-6 250	-0 250	-0 050	0 086
R	-0 122	-0 156	-0 026	0 138	-0 088	0 170
axial stomatal density	0 158	0 279	0 074	-0 020	0 008	0 001
axial stomatal density	-0 061	-0 140	-0 053	0 071	0 007	-0 037
ys to stigma emergence	-0 062	0 427	-0 017	0 004	-0 073	-0 024
lder yield/plant	0 041	-0 455	-0 841	0 040	0 013	0 505
vest index	-0 255	-1 024	0 004	-0.271	-0 143	-0 211
ective tillers/plant	-0 003	-0 189	0 021	0 018	0.058	-0 055
length	0 105	-2 681	0 024	-0 056	-0 072	-0 228
girth	0 012	0 721	-0 095	0 055	-0 193	0 207
of grains/cm^2	-0 048	0 960	-0 007	0 020	0 045	0 024
0 grain weight	0 061	0 234	0 128	-0 008	0 026	0 013
alue	0 115	0 299	0 523**	0 062	0 367*	0 311*
Fodder yield per plant vs grain yield						
ect effects	0 079	-0 637	-0 957	0 075	0 017	0 560
irect effects via						
	0 014	-0 959	0 046	-0 290	0 383	0 128
P I	-0 073	6 884	-10 457	-0 635	-0 197	-0 072
P II	1 675	-9 592	21.383	3 876	0 915	0 353
R	-0 855	9 481	-9 741	-2 137	-0 181	0 199
R	-0 013	0 048	-0 013	-0 153	-0 045	0 076
xial stomatal density	0 056	0 107	0 067	-0 016	0 018	0 001
xial stomatal density	-0 026	-0 076	-0 065	0 093	0 006	-0 073
s to stigma emergence	-0 033	0 111	-0 001	-0 002	-0 082	-0 019
t height	-0 171	-2 145	0 268	-0 129	0 066	-0 428
vest index	-0 242	-1 048	0 051	-0 412	-0 316	-0 218
ctive tillers/plant	0 000	-0 136	0 027	-0 010	0 061	-0 029
length	0 116	-2 867	0 030	-0 070	-0 066	-0 237
girth	0 007	0 471	-0 097	0 035	-0 162	0 177
of grains/cm^2	0 023	0 494	-0 010	0 024	0 034	0 026
0 grain weight	0 014	0 320	0 237	-0 017	0 036	0 014
alue	0 574**	0 455**	0 768**	0 233	0 487**	0 459**

Table 14. Contd ....

1	2	3	4	5	6	7
iv. Harvest index vs grain yield						
)irect effects	0 578	2 172	0 163	0.728	0.567	0 510
ndirect effects via						
.AI	-0 010	0 929	0 016	0.014	-0 012	-0 016
)MP I	0 053	-7 121	-3 049	0 224	0 062	0 018
)MP II	-0 135	2 438	12 550	-0 541	-0 486	-0 075
\GR	-0 287	1 442	-8 758	0 142	0 138	-0 031
⌐GR	0 183	0 257	0 018	-0 027	-0 022	0 002
ıdaxial stomatal density	-0 084	-0 162	-0 031	0 014	-0 011	0 001
ıbaxial stomatal density	0 041	0 064	0 002	-0 036	0 004	0 119
)ays to stigma emergence	0 041	-0 700	0 042	0 000	0 000	0 019
'lant height	0 146	1 415	0 008	0 091	-0 021	0 196
odder yield/plant	-0 033	0 307	-0 300	-0 043	-0 009	-0 240
ffective tillers/plant	0 002	0 237	0 022	-0 012	-0 002	0 009
ar length	0 017	0 697	0 017	0 002	0 012	0 055
ar girth	0 001	-0 167	-0 023	0 020	0 035	-0 049
lo of grains/cm^2	0 002	-1 106	0 018	-0 020	-0 061	-0 034
000 grain weight	-0.008	-0 172	0 117	0 015	-0 024	-0 004
' value	0 508**	0 529**	0 812**	0 572**	0 171	0 480**
) Grain yield components						
. Effective tillers per plant vs grain yield						
irect effects	0 008	0 499	0 044	-0 070	-0 121	0 139
ıdirect effects via						
⁴ıl	-0 004	0 830	0 031	0 101	-0 323	-0 066
MP I	0 027	-4 322	-5 037	0 231	0 147	0 052
MP II	-0 104	3.025	14 330	1 773	-0 083	-0 040
GR	-0 122	-1 519	-8 442	-1 580	-0 105	0 146
GR	0 062	0 110	0 006	-0 262	0 161	-0.264
daxial stomatal density	0 067	-0 074	-0 005	-0 003	-0 003	-0 001
baxial stomatal density	-0 063	0 009	-0 025	0 018	0 000	-0.054
ays to stigma emergence	0.041	-0 312	0 025	-0 006	0 160	0 021
ant height	0 145	1 138	0 146	0 063	-0 039	0 189
)dder yield/plant	-0 002	0 173	-0 594	0 011	-0 008	-0.115
arvest index	0.171	1 033	0 080	0 128	0 008	0 032
ar length	-0 027	1 097	0 018	0 012	0.040	0 097
ar girth	-0 013	-0 996	0 002	-0 075	0 141	-0 164
) of grains/cm^2	0 008	-0 316	-0 004	-0 001	0 006	-0 004
)00 grain weight	-0.048	-0 256	0 079	0 037	0 056	-0 011
value	0 146	0 119	0 653**	0.379*	-0 075	-0 043

Table 14. Contd .....

1	2	3	4	5	6	7
ii. Ear length vs grain yield						
Direct effects	0 172	-3 566	0 035	-0 101	-0 085	-0 291
Indirect effects via						
LAI	0 007	-0 649	0 041	-0 440	0 432	0 106
DMP I	-0 042	6 412	-9 858	-0 898	-0 168	-0 074
DMP II	1 468	-9.508	21 310	3 577	0 732	0 362
AGR	-0 904	9 715	-10 259	-1 612	-0 134	0 204
RGR	0 088	0 084	-0 010	-0 070	-0 450	0 120
Adaxial stomatal density	0 042	0 149	0 051	-0 013	0 008	0 001
Abaxial stomatal density	-0 001	-0.101	-0 072	0 075	0 010	-0.028
Days to stigma emergence	-0 004	-0 494	0 009	-0 001	-0.065	0.011
Plant height	-0 203	-2.257	0 210	-0 136	0.070	-0 373
Fodder yield/plant	0 054	-0 512	-0 816	0 052	0 013	0 456
Harvest index	0 058	-0.425	0 077	-0 014	-0 084	-0 096
Effective tillers/plant	-0 001	-0 154	0 022	0 009	0 057	-0 046
Ear girth	0 010	0 773	-0 112	0 105	-0 219	0 249
No of grains/cm^2	-0.064	0.825	0 000	0 019	0 043	0 026
000 grain weight	0 054	0 305	0 205	-0 012	0 042	0 015
r' value	0 733**	0 600**	0 834**	0 541**	0 607**	0 620**
iii. Ear girth vs grain yield						
Direct effects	0 018	1 206	-0 153	0 136	-0 269	0 302
ndirect effects via						
AI	0 011	-1 093	0 041	0 292	0 313	0 094
DMP I	-0 065	5.509	-8.805	-0 460	-0 133	-0 076
DMP II	1 033	-5 746	15 131	1.412	0 516	0 256
AGR	-0 386	4 771	-5 526	-0 515	-0 080	0 054
RGR	-0 074	-0 045	-0 023	0 025	-0 050	0 225
daxial stomatal density	0 059	0 151	0 075	-0 008	0 012	0 000
baxial stomatal density	-0 022	-0 069	-0 047	0 033	0 003	-0 015
Days to stigma emergence	-0 074	0 240	-0 007	0 000	-0 024	-0 015
lant height	-0 217	-1 796	0 188	-0 099	0 059	-0 326
odder yield/plant	0 032	-0 249	-0 605	0.019	0.010	0.328
arvest index	0 047	-0 301	0 024	0 105	-0 073	-0 084
ffective tillers/plant	-0 005	-0 413	-0 001	0 039	0.063	-0 076
ar length	0 099	-2 286	0 026	-0 078	-0 069	-0 240
o of grains/cm^2	-0 004	0 299	-0 002	0.013	0 043	0.024
000 grain weight	0 035	0 148	0 180	-0 013	0 053	0 014
' value	0 487**	0 326*	0 498**	0.317*	0.375*	0.466**

able 14. Contd ....

1	2	3	4	5	6	7
. No. of grains/cm^2 vs grain yield						
irect effects	0 210	-1 807	0 031	-0 037	-0 095	-0 044
direct effects via						
AI	0 001	-0.051	-0.008	0 097	-0.082	-0 024
MP I	0 023	-3 933	1 766	0 247	0 051	0 038
MP II	0 099	3 499	-1 618	-0 894	-0.105	-0 199
GR	-0 255	-2 402	-0 180	0 377	-0 003	-0 120
GR	0 091	-0 006	0 008	0 000	0 026	-0 146
daxial stomatal density	-0 156	-0.276	-0 047	0 020	-0 007	0 001
baxial stomatal density	0 126	0 140	0 046	-0 074	0 001	0 141
ays to stigma emergence	-0 016	0 562	0 015	-0 001	-0 002	0 014
lant height	0 076	1 594	-0 071	0 137	-0.039	0 252
odder yield/plant	0 009	0 174	0 304	-0 050	-0 006	-0 333
arvest index	0 005	1 330	0 094	0 393	0 363	0 394
ffective tillers/plant	0 000	0 087	-0 006	-0 003	0 008	0 013
ar length	-0 052	1 628	0 000	0 052	0 038	0 169
ar girth	0 000	-0 200	0.008	-0 050	0 122	-0 161
00 grain weight	-0 058	-0 128	-0 127	0 015	-0 019	-0 012
value	0 103	0 211	0 216	0 229	0 251	0 084
. 1000 grain weight vs grain yield						
irect effects	0 101	0 508	0 321	-0.058	0 093	0 021
direct effects via						
AI	0 001	-0 432	0 032	0 134	0 065	0 027
MP I	-0 013	5 486	-8 062	0 226	-0 072	-0 040
MP II	0 495	-6 188	16 723	-1 299	0 278	0 268
GR	-0 310	5 431	-7 764	0 701	-0 042	0 207
GR	0 053	-0 075	-0 004	0 090	-0 028	0 040
daxial stomatal density	0 110	0 025	0 041	0.010	0 003	0 003
axial stomatal density	-0 027	-0 046	-0 048	-0 009	-0 001	0 026
ays to stimga emergence	0 009	-0 362	0.010	0.001	0.058	0 001
ant height	-0 199	-1 383	0 122	-0 033	0 023	-0 285
odder yield/plant	0 011	-0 401	-0 707	0 022	0 006	0 360
arvest index	-0 048	-0 737	0 060	-0 193	-0 148	-0 101
fective tillers/plant	-0 004	-0 251	0 011	0 045	0 172	-0 070
ar length	0 092	-2 140	0 023	-0 020	-0 038	-0 205
ar girth	0 006	0 351	-0 086	0 031	-0 154	0 194
of grains/cm^2	-0 120	0 451	-0 012	0 009	0 020	0 024
value	0 156	0 241	0.657**	-0 345*	0 134	0 470**
esidual effects	-0 004	-0 075	-0 009	-0 005	-0 004	-0 009

Higher indirect estimates *via* DMP II were observed in E1, E3 and E4 environment, with the highest value of 19.408 recorded in E3, While the lowest estimate *via* DMP II noticed in E5 and E6, with lowest value of 0 180 in E6. The magnitude of estimates of indirect effect *via* 1000 grain weight was higher in E2 and E3 with the highest value (0.243) observed in the former case The values of indirect effect *via* LAI were greater in E5 and E6 and lower in E3, while it was negative in remaining three environments. The indirect influence through ear girth was positive in all the environments except E3 and E5, where it was negative, with highest value of 0.578 in E2. Contribution of DMP I *via* number of grains per cm^2 was positive and highest (0.619) in E2 and lower in E4, E5 and E6 where as negative in E1 and E3. Indirect effect *via* fodder yield per plant was noticed to be positive in all the environments except in E2 and E3, with highest value in E6 (0.379), while, indirect effect *via* adaxial stomatal density was positive in all the environments except in E4 and E6, with highest value of 0 211 in E1 Contribution of DMP I *via* RGR was positive and considerable in E6 and E4 with highest values of 0 387 and 0 357, respectively However, in remaining environments its indirect effect *via* RGR were always negative The indirect effects *via* rest of the characters were too small to make substantial contribution in any environments.

iii) Dry matter production II

Among all the componential causal characters of yield partitioned by path analysis, DMP II showed uniformly much higher positive direct effect on grain yield in all the environments except in E2, where it was negative The highest value (22.627) of its direct contribution was recorded in E3, followed by 5 219 in E4, 1 778 in E1, 1.201 in E5 and 0.419 in E6 The indirect influence hrough 1000 grain weight was positive with a lower in magnitude (Table 14) in all the environments except in E2 and E3 where it was moderate in magnitude having values of 0 300 and 0 237, respectively. The indirect contribution to grain yield *via* AGR were higher in E2 (11 454) and E6 (0.389) than rest of the environments where it was negative. While, contribution indirect effect *via* ear girth was positive in all the environments except E3 and E5, with higher values of 0 661 and 0 185 observed in E2 and E6, respectively. Indirect effect *via* adaxial stomatal density and number of grains per cm^2 were positive in all the environments except in E4 and E3, respectively The highest estimated value of indirect effect *via* adaxial stomatal density and *via* number of grains per plant noticed in E2 were 0 153 and 0 603, respectively Similarly, indirect contribution through fodder yield per plant was also positive in all the environments except in E2 and E3, with highest value of 0.472 in E6. Dry matter production II exhibited appreciable positive indirect effect *via* ear length n E1 and E3 environments only, and *via* DMP I was higher and positive 5.984) in E2 only, while other environments always showed negative effect. As regards the indirect effects *via* remaining causation characters, it was either negative or positive with lower values in all the environments

v) Absolute growth rate

Direct effect of AGR on grain yield was positive in E2 and E6, with higher estimated values of 13.385 and 0.538, respectively. However, emaining its direct influence was always negative. Indirect effect of AGR was positive and consistently high *via* DMP II except in E2, where it was negative The highest value (19 925) of this direct effect was noticed in E3, followed by 4.106 in E4, 1 513 in E1 and 1.080 in E5. In contrast, to this indirect effects *via* 000 grain weight and LAI were lower in magnitude, though positive in all the environments except in E6 of latter case, where it was negative. The highest alues of indirect effect *via* 1000-grain weight were 0.206 in E2 and 0.196 in .3, while, highest value (0.331) was noticed in E2 for AGR indirect effect *via*

LAI Similarly, indirect contribution of AGR *via* RGR were also positive in all the environments except in E4 and E6, with pronounced values of 0.413, 0.208 and 0.183 in E2, E1 and E5, respectively. Also, AGR showed positive indirect effect on grain yield *via* fodder yield per plant in all the environments except in E2 and E3, where it was negative. The indirect contribution *via* number of grains per cm^2 and ear girth were positive and highest in E2, being 0.324 and 0.430 respectively and low in E1, E4 and E6, where as in E3 and E5 it was negative Indirect effect *via* abaxial and adaxial stomatal densities was always lower in magnitude though positive in E1, E4, E5 and E6 and E2, E3, E5 and E6 respectively, while, it rest of the environments in negative. Indirect effects *via* the all remaining traits were meagre in all the environments.

v) Relation growth rate

Direct effect of RGR on grain yield was positive and moderate in magnitude in E1, E2 and E5 while, positive and low of magnitude in E3, with its highest magnitude of 0.600 in E2 environment (Table 14). Indirect contribution of RGR through DMP I was positive and high in E3 (7.355) and E4 (1 330), while positive and of low magnitude in E1, E5 and E6, with lowest value of 0 076 in E1 The indirect influenced of RGR through DMP II, were moderate magnitude in E4 (1.625), E5 (0.524) and E1 (0.219) and rest of enviroments showed low or negative values. Indirect contribution of RGR *via* harvest index was positive in E2, E1, E3 and E4 with highest value 0.928 in former and negative in E5 and E6. The indirect contribution *via* AGR was of higher magnitude in E2 (9 205) and E6 (0.420) and remaining environments showed negative effect. Similarly, the positive contribution of RGR *via* LAI also higher n magnitude of 1 698 in E2 and 0.491 in E4 and rest of the environments were negative. The indirect effect through days to stigma emergence was positive in all the environments except E2 and E4, with the highest value (0.215) in E5 and lowest (0 016) in E3 Contribution of abaxial stomatal density, was also positive in all the environments except in E2 and E3, with highest value in E1 (0.194). While, indirect effect *via* no. of effective tillers per plant was positive and appreciable in all the environments except E4 and E5 Indirect effects *via* remaining characters were negligible.

vi) Adaxial stomatal density

Adaxial stomatal density showed negative direct effect on grain yield in all the environments except in E4 and E6 where it was positive The magnitude of direct effect was low in all the environments (Table 14) However, a substantial indirect positive effects *via* harvest index, DMP I, AGR and abaxial stomatal density were observed for this character in four to all environments Higher indirect estimates *via* harvest index were 0.784, 0.288, 0.227, 0 136 and 0 119 in E2, E4, E5, E1 and E6 environments respectively However, the magnitude of estimates of indirect effect *via* DMP I was higher in E3, E4 and E5 with the highest values of 5.597, 0 920 and 0.150, respectively Similarly, higher indirect contribution *via* AGR were observed in E3, E4, E5 and E6 environments with highest value of 2.351 in E3 and lowest 0.168 in E6. The values of indirect effect *via* abaxial stomatal density were greater in E1, E6 and E2 than those of the remaining environments, which were positive or negative The higher estimates of the indirect effect *via* DMP II were noticed positive in E2 and E6, with the highest value of 3.575 in the case of former, while in other environments it was negative. Contribution of adaxial stomatal density *via* plant height was positive in E1, E2 and E4, with highest value of 1.862 in E2 and rest of the environments noticed negative. Where as, indirect effect *via* fodder yield per plant also positive in E2, E3 and E6 with highest, value of 0.509 in E3 and other environments always negative However, the indirect effect *via* LAI was only comparatively considerable with higher of its magnitude in E2 (0.905) and E4 (0 438) and rest of environment it showed negative effect. The indirect effects *via* rest of the characters, were too small to make substantial contribution in any environments

vii) Abaxial stomatal density

The direct effect of abaxial stomatal density on grain yield was positive in all the environments except in E4 and E5, where it was negative with the considerable higher values of 0.287 and 0.254 in E1 and E6 environments, respectively (Table 14). Indirect effect *via* DMP I was positive in all environments except in E2 where it was negative. The higher, 3.755 and 0.786 magnitude of this indirect effect *via* DMP I was noticed in E3 and E4, respectively The indirect effect through AGR was also comparatively considerable in some environments with higher order of magnitude in E3 (4.645), E4 (1 459), E6 (0 122) and E5 (0.112) Indirect positive effect *via* harvest index were 0.654, 0.239, 0.183, 0.082 and 0.003 in E2, E6, E4, E1 and E3 respectively, while its effect in E5 was negative. Contribution of abaxial stomatal density *via* LAI were positive and moderate in magnitude in E2 (0.786) and E4 (0 412), where as other environments showed negative effects Indirect effect *via* DMP II showed positive and highest (4.613) effect only in E2 environment while, the rest of environments were negative. Similarly, its indirect effect *via* RGR also positive in E1 and E4, with highest value of 0.226 in E1 and rest environments were negative. The indirect effect *via* plant height was positive in all the environments excepts E3 and E5, with highest value in E2 (1 985) While, the contribution of abaxial stomatal density *via* ear length was positive in all the environments except in E1 and E3, having the higher estimate of 1 701 in E2. The indirect contribution *via* remaining characters was uniformly meager in all the environments.

4.7.3 Harvest index and agronomic characters vs grain yield

i) Days to stigma emergence

Direct effect of days to stigma emergence on grain yield was either lower in magnitude, though positive, as in E2 and E4 or was negative, as in E1, E3, E5 and E6 (Table 14) Indirect effect *via* AGR was consistently high in magnitude though positive in E3, E4, E5 and E1 and negative in E2 and E6, with the higher estimates of 5 138 in E3 and 2.140 in E4. Indirect effect *via* DMP II was positive and moderate in E2 and E1 and negative in rest of the environments While, positive indirect effect *via* LAI were observed in E5, E6, E1 and E3 and rest of the environments were negative. The contribution of days to stigma emergence *via* RGR was positive and higher in E4 and E6, with highest values of 0 497 and 0.366, respectively. The contribution indirect *via* ear length and fodder yield per were positive and appreciable in E2 and E6, being 0 718 and 0 219, respectively and in rest of the environments it was negligible though positive or negative However, indirect effect *via* DMP I also found to be negative in all the environments except E2, in which estimated value was highest 5.226. In contrast, contribution of days to stigma emergence *via* adaxial stomatal density should positive in some and negative in some environments, with highest positive value of 0 189 in E1. Indirect effect *via* harvest index and 1000-grain weight were negative in all the environments All other indirect effects of days to stigma emergence of low magnitude and hence not important

ii) Plant height

Plant height showed positive direct effect on grain yield in E3 and E5, while, negative in rest of the environments (Table 14) Indirect effect *via* DMP II was positive in all the environments except E2, where it was negative and it had comparatively, higher values than those of other indirect contributions except in E2, where it through DMP I and AGR The highest and lowest estimated indirect effects *via* DMP II were 17.548 in E3 and 0 291 in E6, respectively The magnitude of estimates of plant height indirect through DMP I and AGR were only highest in E2 being values of 9.420 and 5 877, respectively and in rest of the environments it were negative Indirect contribution *via* 1000 grain weight and adaxial stomatal density was positive in all the environments with comparatively lower in magnitude except in E4, where it was negative The higher values of the indirect effect *via* 1000 grain weight and adaxial stomatal density were 0.234 and 0.279 both in E2 environment, respectively. Indirect effect *via* fodder yield per plant was also positive in all the environment except E2 and E3, with the highest value of 0.505 in E6 environment and rest environments were negative The positive and appreciable indirect effect of plant height were observed *via* days to stigma emergence in E2 and *via* ear length in E1, being higher values of 0 427 and 0 105, respectively and rest of the environments were negligible. Indirect effect of plant height *via* number of grains per cm^2 was positive in all the environments except E1 and E3, with highest value in E2 (0.960). Indirect effect *via* ear girth was noticed to be high in E2 and E6 and lower in E1 and E4 and negative in E3 and E5. While its contribution through LAI was positive in all the environments except E2 and E4, with higher value of 0 382 in E5 The remaining indirect effects *via* rest of the characters in different environments were of low in magnitude and to be any practical value.

iii) Fodder yield per plant

Fodder yield per plant showed direct positive effect on grain yield in all the environment except E2 and E3, with the highest value in E6 (0.560) and lowest in E5 (0 017) (Table 14). The indirect contribution of fodder yield per plant *via* DMP II was, uniformly higher in all the environments except in E2, where it was negative, with the highest values 21.383 followed by 3 876, 1.675, 0.915 and 0.353 in E3, E4, E1, E5 and E6 respectively. The higher estimates of the indirect effect *via* AGR were noticed in E2 and E6 with highest value of 9 481 and 0 199, respectively. Contribution of fodder yield per plant *via* LAI was positive in E5, E6, E3 and E1 environments, however, it was negative in E2 and E4. Indirect effect *via* 1000 grain weight and adaxial stomatal density were positive in all the environments except in E4, where it was negative. However, contribution of fodder yield per plant *via* DMP I was negative in all the environments except in E2, where its value was higher and positive (6.844) Indirect effect *via* number of grains per cm^2 was positive though lower in magnitude in all the environments except E3, where it was negative. Indirect contribution *via* plant height and harvest index were negative in all the environments except in E3 and E5 in case of farmer and in E3 in latter, where it was positive but lower in magnitude. In contrast, indirect effect *via* ear girth was positive in all the environments except in E3 and E5, with the highest values of 0 471 (E2) and 0.177 (E6). Indirect effects *via* rest of the characters were too meagre to make any worth while contribution.

iv) Harvest index

Harvest index showed uniformly highest positive direct effect on grain yield in all the environments except in E3 where it was positive but low (Table 14) The highest value (2.172) of this direct effect was observed in E2 and was followed by 0 728 in E4, 0 578 in E1, 0 567 in E5 and 0.510 in E6. Indirect contribution *via* DMP II was higher and positive in E3 and E2 environments only, with the values of 12 550 and 2.438, respectively and rest of the environments were negative. Similarly, indirect effect of harvest index *via* ear length and plant height was positive in all the environments except E5 in case of latter, where values was negative, with its highest magnitude *via* ear length was 0 697 and *via* plant height was 1 415 both in E2 environments However, indirect effect *via* abaxial stomatal density was positive with lower in magnitude in all the environments except E4, where it was negative Indirect effects *via* AGR was considerable in E2, E4 and E5 with highest of 1 442 in E2, where as its contribution *via* RGR also considerable in E1 and E2 environments only and rest will be in low magnitude. Indirect effect *via* fodder yield per plant was negative in all the environments except in E2, where it was positive effect (0 307). Harvest index made higher indirect contribution to grain yield *via* LAI and DMP I in E2 and E4, respectively than in the remaining environments. Indirect contribution *via* all other characters were meagre.

4.7.4 Grain yield components vs grain yield

i) Number of effective tillers per plant

Direct effect of effective tillers per plant on grain yield was positive in E1, E2, E3 and E6 and negative in remaining environments Number of effective tillers per plant *via* DMP II contributed considerably high indirect effect in E3, E2 and E4 environments with the high values of 14 330, 3 025 and 1 773, respectively (Table 14) The estimate of this indirect effect was negative in remaining environments. Indirect effect *via* harvest index was positive in all the environments under study, with highest value of 1.033 in E2 and lowest 0.008 in E5

Number of effective tillers per plant *via* plant height contributed high and positive indirect effect in all the environment except E5, with high values of 1 138, 0 189, 0 146 and 0.145 in E2, E6, E3 and E1 environments, respectively Positive indirect contributions *via* ear length were also noticed in all the environments except E1, with highest value in E2 (1.097) and in E6 (0.097) Contribution of effective tillers per plant *via* LAI was positive in E2, E3 and E4, while it was negative in E1, E5 and E6, with the highest positive values of 0.830 in E2 environment. Number of effective tillers per plant should positive indirect effect *via* DMP I in E1, E4, E5 and E6 and *via* RGR in E1, E2, E3 and E5 and negative in rest of the environments. The highest and the lowest estimated indirect effects of DMP I were 0.231 in E4 and 0.027 in E1 and of RGR were 0 161 in E5 and 0.006 in E3, respectively. Indirect effect *via* ear girth was considerable in E5 environment only, while the rest environments it was in low magnitude or negative. However, the indirect effect *via* AGR was negative in all the environments except E6, where its value was positive and higher in magnitude of 0 146 The indirect contribution *via* remaining characters were uniformly meagre in all the environments

ii) Ear length

Direct effect of ear length on grain yield was positive in E1 and E3, while negative in rest of the environments (Table 14). The highest value of its direct contribution was recorded in E1 (0.172). The indirect effect of ear length *via* DMP II was considerable except in E2, where it was negative. The highest value (21 310) of this direct effect was observed in E3 and was followed by 3.577 in E4, 1.468 in E1, 0 732 in E5 and 0.362 in E6. Contribution of ear length *via* 1000 grain weight and adaxial stomatal density was positive in all the environments except in E4, where it was negative. The highest value (0.305) of 1000 grain weight and (0.149) of adaxial stomatal density indirect effect was noticed in E2. The positive indirect effect *via* ear girth were noted in E1, E2, E4 and E6, with highest values of 0 773 in E2 and 0.249 in E6. Similarly, ear length also showed positive indirect effect *via* fodder yield per plant in all the environments except E2 and E3, being a highest estimates of 0.456 in E6 Indirect effects *via* number of grains per cm^2 was noticed to be high (0.825) in E2 and lower in rest of the environment though positive or negative. Contribution of ear length *via* AGR was positive in E2 and E6 with higher value of 9.715 in case of farmer and negative in rest of the environments. Ear length showed appreciable indirect effect *via* LAI in E5 and E6 environments only with respective value of 0.432 and 0.106, however, rest of environment showed negligible effects. Indirect contribution *via* DMP I was observed to be negative in all the environments except in E2, where it was positive and highest with the magnitude of 6.142. The indirect effect of ear length, *via* RGR was positive in E1, E2 and E6 and negative in rest of the environments. The indirect effect *via* other characters were either meagre or negative in magnitude in all the environments.

iii) Ear girth

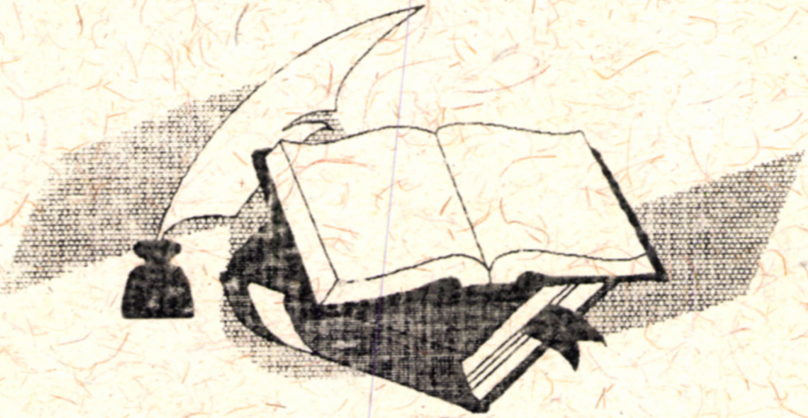
Direct effects of moderate to lower magnitude of ear girth on grain yield were positive in all the environments except E3 and E5, with higher values observed in E2 (1.206), and E6 (0.302) environments (Table 14). This characters also showed positive indirect effects *via* DMP II in all the environments except E2, with comparatively higher values in E3 (15.131), E4 (1.412), E1 (1.033), E5 (0.516) and E6 (0.256) environments. Contribution of ear girth *via* 1000 grain weight had much pronounced effect in all the environments except in E4, with the highest value (0.180) in E3 and the lowest (0.014) in E6. The indirect effect *via* LAI was also positive in all the environment except in E2, where it was negative, with the higher value of 0.313 and lower 0.011 observed in E5 and E1, respectively. Contribution of ear girth *via* fodder yield per plant was observed to be positive in E6, E1, E4 and E5, with higher estimate of 0.328 in case of farmer. The indirect contribution of ear girth *via* DMP II was observed to be higher (5.509) in E2 environment only, however, negative in rest of the environments. The indirect effect *via* AGR was positive in E2 and E6 environments with higher value of 4.771 in E2 and its effect was negative in remaining environments. Similarly, ear girth showed positive and considerable indirect effect *via* RGR in E6 and other environments showed negligible effect The indirect effect of ear girth *via* number of grains per cm^2 on grain yield was positive in E2, E4, E5 and E6 and negative in rest of the environments Contribution of ear girth *via* other characters were lower in magnitude

iv) Number of grain per cm^2

Direct effect of number of grains per cm^2 on grain yield was positive in E1 and E3, with higher value 0 210 in E1, while negative in rest of the environments (Table 14) Indirect contribution of number of grains per cm^2 *via* harvest index was positive in all the environments and had, comparatively, higher values in some environments than those of other indirect contribution. The highest value (1 330) of this effect was noted in E2 which was followed by 0 394 (E6), 0 393 (E4) and 0.363 (E5). The indirect effect *via* DMP I was positive in all the environments except in E2, where it was negative and lowest in that environment among all characters, with the highest value (1.766) in E3 and lowest (0 023) in E1 Also, indirect effect *via* abaxial stomatal density was positive and appreciable in E6, E2, E1 and E3 and rest of the environment were negligible. The contribution of number of grains per cm^2 through ear length was positive in E2, E4, E5 and E6, with highest value in E2 (1.628). Indirect effect *via* DMP II showed considerable and positive in E2 and E1 and negative in rest of the environments. Contribution of number of grains per cm^2 *via* plant height was positive in all the environments except E3 and E5, with comparatively higher values of 1 594, 0 252 and 0.137 in E2, E6 and E4 environments, respectively Indirect effect *via* days to stigma emergence was positive only in E2, E3 and E6 environments While indirect effect *via* AGR was negative in all the environments except E4, Where it was positive and considerable being value of 0 377. The values of rest of the indirect contributions effecting yield *via* other characters were low in magnitude.

v) 1000 grain weight

Direct effect of 1000 grain weight on grain yield was positive and moderate in E1, E2 and E3, while positive and of low magnitude in E5 and E6 environments and it was negative in E4 (Table 14). The indirect effect *via* adaxial stomatal density was positive though low in magnitude in all the environments, with highest value of 0.110 in E1. However, the magnitude of its indirect effects *via* DMP II was considerable in E3, E1, E5 and E6 environments with highest value of 16.723 followed by 0.495, 0.278 and 0.268 respectively, while in E2 and E4 it was negative. Indirect effect *via* fodder yield per plant was positive in all the environments except E2 and E3, where it was negative, with the considerable highest value in E6 (0 360). The contribution of 1000 grain weight *via* LAI and days to stigma emergence was lower in magnitude though positive in all the environments except in E2, where it was negative The higher estimates of the indirect contributions of 1000 grain weight through AGR were noticed in E2, E4 and E6 with the comparatively highest value of 5.431 in E2, while in E1, E3 and E5 it had always negative estimates Indirect effect *via* DMP I was positive comparatively high in E2 and E4 environments only, while remaining environments were negative. Positive indirect effect of 1000-grain weight *via* number of grains per cm^2 in all the environments except E1 and E3, being its highest magnitude of 0.451 in E2 The indirect effect *via* ear girth was appreciable, the highest indirect effect being 0 351 in E2 and 0.194 in E6, while rest of the environment showed negligible effect though positive or negative. The indirect effect *via* remaining characters, were too small to make substantial contribution in any environment



DISCUSSION

5. DISCUSSION

Plant breeders aim at finding superior genotypes from the available gene pool or from genetically heterogeneous population. But selection is a difficult task since phenotypic expression is determined not only by genotype but also by environment. Obiviously critical assessment of the material with which the breeder is working, physiological traits become necessary. Wallace *et al.* (1972) suggested that identification of these physiological components of yield and their genetic control should make it possible to plan crosses to maximise segregation of genotypes possessing the physiological complementation and balance required for high yields, thereby leading to more rapid and predictable yield improvement. The most effective use of physiological components will be in the selection of parents for crosses

It is necessary to understand the resources controlling crop growth/yield in individual environment and the reasons for the differential genotypic performance across environments as a response to the varying resources in those environments. Bindinger *et al.* (1996) suggested that crop yield is a direct product of the resources available in the environment, the fraction of those resources captured by the crop, thereby the effectiveness of the crop in converting captured resources into dry matter and the fraction of dry matter partitioned to harvestable yield.

Genotypes with high dry matter production coupled with high harvest index would be desirable for improving present yield levels in pearl millet which are more or less plateaued Improvement in yield levels should come through the complementation of physiological components of yield in desirable genotypes Very limited information is available on variability and genetics of harvest index and almost nil on physiological components of yield like AGR, RGR, DMP and LAI in pearl millet

Stable genotypes are particularly of great importance in countries such as India, where the environmental conditions under which a crop is grown differ from state to state and even within the state A stable variety/hybrid is required for its commercial exploitation over a wide range of agroclimatic conditions If adaptability in real sense is due to the genetic make up, preliminary evaluation can be done to identify stable genotypes in a short period.

Several hybrids have been successfully released by Bajra Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri and found superior with respect to stability and productivity. Advancement in diversification of parents and their hybrids in pearl millet is continuous process Thus in heterosis breeding information on stability of newly developed parents and behaviour of hybrids under different environments is quite important. Therefore, the present study provides information on the growth analysis, stability behaviour, heat unit requirement and efficiency, effect of photoperiod on flowering, correlation and path analysis for morpho-physiological traits of new male sterile and inbred/parents of pearl millet and their hybrids and their utility in breeding programme. The result presented under chapter four have been discussed in brief in the following pages.

5.1 Growth analysis

The growth analysis undertaken to know the physiological basis for differences in yield among the genotypes under different environments provided an opportunity to study the effect of environmental changes on morpho-physiological characters and yield of these genotypes at same location

The leaf area development at days to stigma emergence was greatly influenced by environmental changes In general, genotypes had high LAI at flowering in E4 followed by E1, E5 E6, E2 and E3. Low temperatures prevailed during E4 and E5 stimulated the initiation of higher number of basal tillers per plant, while in E1 and E6 initial effect of high temperatures produced the earlier tillering, resulting in higher LAI than E2 and E3 environments. Ong (1983) also reported that initial effect of high temperature was on earlier tillering whereas at low temperature (19 °C) tillering continued *via* basal tillers. The hybrids had higher LAI than either of the parents at flowering in all the environments. The hybrids involving parents 9607A, 9606A, RHRB 5A, 9611, RHRBI 138 and RHRBI 458 had higher LAI at flowering in different environments than other hybrids. Since LAI development is more powerful determinant of canopy photosynthesis and grain and dry matter yield, the selection of these parents may be useful for developing high yielding hybrids having higher LAI, a much quicker rate in the early part of the growth and maintaining the high photosynthetic surface for longer time coupled with high harvest index

The high performing hybrids for grain yield in different environments also recorded high LAI at flowering as compared to all other low yielding parents and hybrids with few excep-tion (Table 15) High LAI in these hybrids during early growth (flowering) may have helped them to intercept maximum light

The differences among genotypes were significant for dry matter production per plant at flowering and maturity in individual environment and on pooled basis, indicating presence of large variability for this characters in pearl

		(g)	(g)	(g/day)	(g/g/day) (10^{-2})	stomatal density	stomatal density	stigma emer-gence	height (cm)	yield/ plant (g)	index (%)	effective tillers/ plant	(cm)	(cm)	grains/ cm^2	grain weight (g)	yield/ plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
E1																	
I x 4	6 70	50 00	173 20	3 52	3 56	71 12	92 44	46 33	206 26	93 60	43 75	2 56	22 13	11 86	19 10	14 22	75 81
V x 4	6 96	48 30	188 40	4 00	3 88	84 14	101 38	47 00	200 66	114 93	38 58	2 03	21 16	11 73	18 33	15 25	72 38
VII x 4	6 31	44 30	210 26	4 74	4 08	63 80	77 63	47 00	207 43	146 70	34 24	2 20	26 76	12 71	19 13	15 78	72 03
VII x 2	6 55	50 23	186 26	3 89	3 74	71 61	83 52	46 33	215 23	100 23	37 94	1 70	28 14	13 20	15 40	16 00	70 65
V x 5	5 96	45 60	160 80	3 29	3 62	96 39	123 86	45 66	185 36	82 56	43 47	2 40	20 65	11 28	22 76	12 17	69 88
G M	5 90	47 79	149 88	2 91	3 28	81 02	96 07	45 38	191 62	81 54	35 39	2 43	21 25	11 49	18 63	13 28	53 26
E2																	
IV x 5	4 98	39 96	145 20	3 01	3 67	90 09	107 20	47 33	211 36	70 83	44 95	2 56	20 43	10 95	22 53	14 34	64 80
III x 4	5 69	45 16	131 86	2 48	3 06	85 15	92 14	46 33	183 53	58 57	46 71	2 40	21 71	11 35	19 86	14 12	61 67
VII x 1	5 69	51 20	143 36	2 63	2 95	73.21	91 62	45 66	230 13	67 90	42 82	1 76	26 42	12 17	16 10	17 05	61 46
IV x 1	6 20	58 43	141 63	2 38	2 53	91 20	106 19	49 33	224 53	72 40	42 33	2 36	19 31	11 21	20 90	13 96	59 92
V x 5	5 34	39 36	124 16	2 52	3 36	90 73	114 23	44 33	198 40	52 23	46 93	2 56	20 87	11 29	21 16	14 82	59 91
G M	4 64	39 79	118 30	2 25	3 15	84 78	101 77	44 81	198 77	52 32	40 21	2 46	20 40	11 12	18 53	13 98	47 71
E3																	
VI x 5	5 24	52 46	89 33	1 15	1 67	75 97	79 84	44 66	164 96	40 36	36 93	1 53	17 57	11 21	23 33	12 50	33 06
VI x 4	4 40	36 50	96 43	1 87	3 10	66 74	77 78	46 00	162 00	34 93	32 05	1 60	18 42	10 96	20 26	10 89	30 98
V x 2	3 47	35 16	91 70	1 77	2 98	76 84	83 94	47 00	187 06	42 00	33 95	1 53	20 34	11 93	16 60	10 37	30 96
I x 4	3 59	31 46	79 06	1 49	2 89	69 42	100 67	44 00	167 43	42 86	39 28	1 86	17 94	10 51	17 76	11 09	30 95
V x 5	3 73	33 56	84 23	1 58	2 88	71 32	94 98	44 00	167 76	33 63	36 49	2 03	18 31	11 13	21 80	8 93	30 74
G M	3 29	31 38	63 09	0 99	2 25	75 12	91 32	45 11	152 69	30 75	32 08	1 56	16 18	10 18	18 52	10 42	20 78
E4																	
V x 5	5 02	44 16	181 43	3 92	4 05	92 53	117 56	70 00	157 86	58 10	36 16	1 93	18 58	11 22	20 66	11 72	65 50
II x 4	7 01	70 96	164 40	2 67	2 40	113 36	131 45	75 00	175 26	87 96	37 47	2 16	15 72	10 96	22 43	12 74	61 70
III x 5	6 93	54 03	159 96	3 03	3 09	92 85	120 95	73 00	158 93	58 50	37 04	2 53	18 31	10 95	18 30	13 47	59 02
VI x 5	9 74	70 86	155 46	2 42	2 24	121 12	156 16	74 00	163 30	59 70	36 93	2 16	19 38	11 47	20 10	13 52	58 05
VI 1	7 08	72 06	156 60	2 42	2 23	85 75	103 84	71 66	186 20	73 16	34 90	1 86	19 77	11 80	16 86	13 93	54 86
G M	5 91	55 65	134 08	2 23	2 59	97 23	126 01	71 93	160 01	60 75	31 58	2 31	17 47	10 87	17 33	12 87	42 08

Table 15 Contd

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
E5																	
III x 5	6 60	55 06	111 86	1 78	2 22	104 00	136 62	60 00	135 76	43 60	51 49	1 90	18 98	10 25	15 46	13 14	55 79
VII x 5	5 38	46 03	126 93	2 53	3 17	95 60	123 06	60 00	150 63	50 33	41 71	1 73	20 52	11 13	19 46	12 70	52 90
IV x 4	8 80	73 53	112 16	1 21	1 33	82 69	117 24	65 66	163 60	57 76	42 09	1 30	17 50	10 20	22 06	11 66	48 46
VI x 4	6 87	48 96	147 90	3 09	3 46	99 80	109 01	62 66	155 76	56 90	32 66	1 30	19 21	11 22	19 60	12 29	48 41
I x 5	4 07	33 43	131 06	3 05	4 27	108 84	150 44	59 33	151 70	43 96	36 67	2 30	17 49	9 98	18 00	11 95	48 09
G M	5 41	44 77	109 32	2 01	2 88	93 58	122 54	59 48	152 46	48 34	35 62	1 80	18 39	10 45	16 82	12 56	38 58
E6																	
I x 4	7 57	57 80	120 16	2 08	2 46	95 28	110 94	51 00	167 16	55 53	38 47	1 30	19 64	11 06	19 13	11 54	46 24
I x 5	4 72	37 86	81 90	1 47	2 58	108 36	128 71	47 00	148 53	40 80	47 25	1 90	18 87	9 88	19 26	11 44	46 18
VII x 5	5 89	43 70	111 36	2 26	3 12	85 91	122 25	50 00	156 26	40 53	42 30	1 36	24 61	11 08	18 20	12 14	45 27
III x 5	6 32	43 16	100 66	1 92	2 84	101 74	136 62	49 00	142 06	32 33	40 69	1 63	20 67	10 53	19 70	12 16	40 83
VI x 4	6 24	48 36	119 06	2 36	3 00	89 30	109 33	54 00	150 43	44 76	33 78	1 16	20 21	11 80	19 46	11 67	40 17
G M	4 92	37 22	90 76	1 78	3 09	96 01	123 72	49 50	152 02	37 86	34 29	1 40	19 69	10 63	18 01	11 86	31 04
Pooled																	
V x 5	4 97	37 95	121 21	2 48	3 41	116 76	121 77	51 83	168 59	49 36	41 24	2 00	19 81	11 30	21 24	11 85	50 07
I x 4	6 64	58 01	127 93	2 08	2 46	82 27	104 46	55 44	184 38	70 35	38 43	1 99	19 13	11 07	19 43	12 99	49 38
III x 5	5 75	43 13	118 56	2 23	2 91	93 65	116 53	52 38	155 00	47 62	41 29	2 11	19 47	10 80	18 30	12 92	48 56
VI x 5	6 38	49 20	124 29	2 23	2 80	108 20	114 97	53 72	162 61	52 09	38 85	1 90	19 82	11 53	21 66	12 59	48 53
III x 4	6 45	35 36	130 97	2 23	2 46	80 40	97 03	54 00	166 43	59 64	37 46	1 89	19 42	11 22	18 24	13 40	48 50
G M	5 01	42 77	110 88	2 02	2 87	87 97	110 23	52 66	167 91	51 92	34 86	1 99	18 89	10 78	17 97	12 49	38 90

I - RHRB 1A, II - RHRB 2A, III - RHRB 3A, IV - RHRB 5A, V - 9605 A, VI - 9606 A, VII - 9607 A
1 - RHRBI 138, 2 - RHRBI 458, 3 - RHRBI 178, 4 - 9611 and 5 - 9612

millet In general, dry matter production per plant at flowering was high in E4 followed by E1, E5, E2, E6 and E3. However, at maturity it was high in E1 followed by E4, E2, E5, E6 and E3 The higher dry matter production per plant at flowering and maturity in E4 and E5 might be due to greater diurnal temperature range prevailing during January to April 1997 (maximum 37 6 and minimum 6.7°C) and more sunshine hours (maximum 10.5 h), leading to more per degree dry matter conservation Similarly, E1 and E2 received optimum temperature of around 30°C during grain filling period (maximum temperature ranged from 28 1 to 34.6°C) and longer day length above 13 hours upto flowering period prevailed during 15th June to 25th August, 1996 (day length ranged from 13 03 to 13 46 h) for optimum growth and may absorbed greater photosynthetically active radiation due to longer day length which helped in conservation of dry matter per plant at both the stages Niwas and Sastri (1995) observed that greater absorbed PAR, sunshine hours and diurnal temperature range among the weather parameters and CGR and dry matter conservation among the growth parameters contributed more to higher dry matter production Muchow (1989) also reported that high biomass accumulation was associated with long growth duration, especially the duration of grain filling suggesting high cumulative radiation interception and with high radiation use efficiency.

In general, hybrids involving parents 9607A, 9606A, 9605A, 9611, and RHRBI 138 had higher dry matter production per plant at maturity. Since dry matter production at maturity is highly correlated with yield, as revealed from correlation analysis in the present study also, genotypes with high dry matter production per plant at maturity coupled with high grain yield would be desirable. Most of the high performing hybrids for grain yield in the present study also recorded high dry matter production per plant at maturity (Table 15). The results of present investigations confirms the finding of Veersekharan and Rao (1971 a), Ruwali *et al* (1983a) and Mungse and Harinarayana (1985) with regards to close association between leaf area and dry matter production in high yielding genotypes

Significant differences were observed among genotypes for AGR between flowering and maturity in all the environments. In general, the hybrids had higher AGR between flowering and maturity than their parents in individual environment Environmental effects were pronounced on AGR, since it was high in E1 (2 91 g/day) as compared to E2(2 25 g/day), E4 (2 23 g/day), E5 (2.01 g/day), E6 (1.78 g/day) and E3 (0.99 g/day) Although, dry matter production per plant at flowering and maturity was high in E4 as compared to E1 environment, the low AGR observed in E4 was mainly due to longer duration required for completion of the particular growth stage indicating that amount of dry matter accumulates per plant was not proportionate to the duration of growth Data from the Table 15 revealed that all the high performing hybrids for grain yield also recorded high AGR in respective environments with few exceptions as compared to other low yielding hybrids.

Differences were significant for RGR between flowering and maturity due to genotypes in individual environment and on pooled basis RGR was influenced considerably due to environmental changes The high RGR in environments, E1 (0 0328 g/g/day), E2 (0 0315 g/g/day) and E6 (0 0309 g/g/day) than remaining environments may be due to high temperature and day length (Appendix I) In-consistent differences for RGR among genotypes during different environments due to interactions of genotypes, temperature and photoperiod also noticed by Eagles (1971). Most of the high yielding hybrids recorded reasonably high RGR in respective environments (Table 15) Veersekharan and Rao (1971 b), Ruwali *et al.*(1983) and Mungse (1987) reported results on similar line

At flowering stage genotypic differences in both adaxial and abaxial stomatal densities were significant in all the environments. It was observed in the present study that comparatively abaxial leaf surface displayed a higher number of stomatae/mm^2 than the adaxial leaf surface in all the environments (Table 15). Similar results were also reported by Singh and Singh (1989) in pearl millet The *kharif* environments *viz.,* E1, E2 and E3 had lower number of stomatae/ mm^2 as compared to summer environments (E4, E5 and E6), indicating that environments influenced the stomatel densities. Therefore, it may be said that stomatal densities increased under dry season with low humidity environmental condition as compared with those grown in moist season(*kharif*) and high humidity conditions (Meidner and Mansfield, 1968).

Subramanian and Maheswari (1989) reported that the transpiration efficiency of pearl millet was more responsive to the increase in atmospheric moisture They also noticed that decrease in photosynthetic rate relative to that in transpiration rate under water stress was slightly more in dry season, which indicates that, with increasing atmospheric dryness, photosynthetic process is more susceptible to water stress than transpiration.

The data in Table 15 indicated that high yielding hybrids expressed low stomatal densities/mm^2 having high dry matter production at maturity indicating these hybrids would be more productive under drought situation The hybrids based on parents 9607A, 9611 and RHRBI 138 had lower stomatal densities in all the environments than other parents Since relationship between stomatal density and photosynthesis is very useful for screening high photosynthetic capacity of genotypes because counting of stomatae is much easier than measuring photosynthesis and it suitable for plant breeder to select high photosynthetic and high yielding genotypes Das and Rajendrudu (1977) reported that high correlation of the faster rate of carbon fixation and phosphate absorption with greater frequencies of veins and stomata in the leaves Reddy (1987) also observed that genotypes having low stomatal number but having high dry matter had a higher photosynthetic efficiency

Differences among genotypes were significant for harvest index in all the environments and on pooled basis. Harvest index, in general, was high in E2 (40 21%) followed by E5 (35.62%), E1 (35.39%), E6 (34.29%), E3 (32 08%) and E4 (31 58%). Hybrids recorded high harvest indices as compared to parents. In spite of high LAI (Large assimilatory surface) and dry matter production per plant in E4, the harvest indices were low as compared to other environments, suggesting that the assimilate translocation and partitioning in the sink was inefficient in E4 environment

The data in Table 15 indicates that the high yielding hybrids in respective environments not only produced high amount of dry matter per plant but also recorded high harvest indices revealing their better efficiency of dry matter production and its distribution in economic organs (earheads) The present studies, therefore, implies that selection for high harvest index coupled with high dry matter production may be possible for evolving superior and more stable hybrids in pearl millet. Hybrids based on female parents RHRB 1A, RHRB 2A, 9607A and male parent 9612 in all the environment recorded high harvest indices as compared to hybrids based on other parents.

Vanangamudi *et al.* (1985) and Mungse (1987) also reported high dry matter production and better partitioning in earheads of pearl millet cultivars Misra (1995) reported that the amount of assimilate in the ear at anthesis was equivalent to that of the harvest index values of the plant and length of grain filling period did not affect harvest index, in different environment

Parents and hybrids were early in respect of stigma emergence in E2 followed by E1 and E3 while, late in E4, E5 and E6 environment which may be explained on the basis of low temperatures prevailing during crop growth (Appendix I) Low temperatures stimulated continuous tillers initiation, extending the vegetative stage tremendously and delay the days to stigma emergence in almost all the genotypes. Male sterile line RHRB 3A and pollinator 9611 were most thermosensitive parents Hybrids based on parents RHRB 2A, 9605A, 9607A and RHRBI 178 had early stigma emergence in all he environments Many of the high yielding hybrids considered in the present studies were early to midlate in stigma emergence in respective environments, ndicating possibility of combining high grain yield with early maturity (Table 15) Suryavanshi *et al.* (1990) also noticed that all the male sterile and maintainer ines studied, flowered on an average 18 and 6 days early in *kharif* and *rabi* as compared to summer season, respectively.

Genotypes differed significantly for plant height in all the environments In general, plant height was affected by different sowing date-environments showing a good expression in E1 and E2 as compared to other environments probably, due to higher temperatures (maximum 28.1 to 34.6°C and minimum 19.5 to 23.3°C) and day length (12.56 to 13.46 h) prevailing luring 15th June, 1996 to August, 1996. However, plant height in remaining environments were reduced due to reduction in temperatures and day length Appendix I) Similar finding was also reported by Maiti and Soto (1990) Hybrid based on parents, 9607A, 9605A, RHRBI 138 and RHRBI 458 were aller than other hybrids

Fodder yield per plant showed large variability among genotypes he hybrid combinations with 9607A, 9605A, RHRBI 138 and 9611 exhibited igher fodder yield per plant The high yielding hybrids also showed higher fodder yield per plant as compared to other hybrids with few exceptions (Table 15) Fodder yield per plant was highest in E1 (81.54 g) followed by E4 (60.75 g), E2 (52 32g), E5 (48 34 g), E6 (37 86 g) and E3 (30 75 g) Fodder yield was influenced considerably due to environmental changes In-consistent performance over environments indicated the sensitivity of genotypes to variation in environmental conditions (Dass *et al.*, 1983)

In general, highest number of effective tillers per plant were recorded in E2 (2.46) followed by E1 (2 43), E4 (2.31), E5 (1.80), E3 (1.56) and E6 (1 40) Parents, RHRB 2A, RHRBI 178 and 9612 gave hybrids with more number of effective tillers per plant in all the environments.

Significant variation was observed among genotypes for ear length in individual environment and on pooled basis Hybrids based on the parents, 9607A, RHRBI 138, RHRBI 458 and 9611 had longer ears in all the environments with few exceptions as compared to other hybrids Female parent, 9607A recorded the highest ear length in all the environments among the parents

In case of ear girth, significant variation was observed among the genotypes studied Among the parents, 9605A, 9607A and RHRBI 458 recorded highest ear girth. The hybrid combinations with RHRBI 458 exhibited higher ear girth

On the basis of average performance (Table 15), number of grains per cm^2 were high in E1 (18.63), E2 (18.53), E3 (18 52) and E6 (18 01) as compared to E4 (17 33) and E5 (16 82). Genotypes responded differentially to environmental changes for number of grains per cm^2. The higher number of grains/ cm^2 in E1, E2, E3 and E6 may primarily be attributed to warm temperatures and high day length (Appendix I). The smaller grain size in the extended day length have been reported at ICRISAT (Anonymous, 1982) In general, hybrid based on the parents, RHRB 5A, 9606A, 9611 and 9612 recorded higher number of grains per cm^2 than other hybrids in all the environments

Significant differences were observed among the genotypes for 1000-grain weight in individual environment and on pooled basis. In general, 1000-grain weight was high in E2 (13.98 g), E1 (13.28 g), E4 (12.87 g) and E5 (12 56 g) and low in E6 (11 86 g) and E3 (10.42 g). The high 1000-grain weight in E2 and E1 might be due to warm temperatures prevailing during August, and September, 1996 (Maximum 28.4 to 30.8°C and minimum 20.2 to 22.3°C), while high 1000-grain weight in E4 and E5 may primarily due to high light intensities with longer duration of grain filling period.

Hybrids based on parents 9607A, RHRBI 138, RHRBI 458 and 9611 recorded higher 1000-grain weight than other hybrids in different environments Similarly, many of the high yielding hybrids also recorded high 1000-grain weight revealing that the test weight is an important yield component (Table 15)

All the genotypes exhibited highly significant differences for grain yield per plant in all the environments and on pooled basis. Grain yield ranged between 29 12 to 75 81, 24 99 to 64.80, 5.53 to 33.06, 17.77 to 65.50, 16 34 to 55 79 and 14 42 to 46 24 g per plant in E1, E2, E3, E4, E5 and E6 environments, respectively, indicating wide extent of variability in the genotypes studied In general, highest grain yield per plant was recorded in E1 (53 26 g), followed by E2 (47 71 g), E4 (42.08 g), E5 (38 58 g), E6 (31 04 g) and E3 (20 78 g) LAI beyond optimum level and low temperatures in E4 and E5 might have reduced the photosynthetic efficiency and translocation of assimilates to earheads The low photosynthetic efficiency was also evidenced by low AGR in E4 and E5 environments In contrast, E1 and E2 was the most favourable environments for pearl millet growth, as the minimum and maximum temperatures ranged from 20.2 to 23.3°C and 28 1 to 34 6°C, respectively with longer photoperiod, ranging from 12.24 to 13 46 hours

Genotypes x environments interaction were significant for grain yield indicating the differential response of pearl millet genotypes to environmental changes Hybrids based on male sterile lines, 9607A and 9606A in E1, RHRB 1A and 9607A in E2 9605A and 9607A in E3, RHRB 2A and 9606A in E4 and E5 and 9606A and RHRB 1A in E6 environments and inbreds, 9611 and 9612 in all the environments recorded higher grain yield as compared to other hybrids. Maiti and Soto (1990) also reported that higher grain yield in July sowing date than other sowing dates could be related to a longer photoperiod, higher temperatures and significant difference between day and night temperatures

The data on mean performance of top ranking five high yielding hybrids in each environment for physiological, agronomic and grain yield components are presented in Table 15 A perusal of data in this table revealed that hybrids RHRB 1A x 9611 in E1 and E6, RHRB 5A x 9612 in E2, 9606A x 9612 in E3, 9605A x 9612 in E4 and also on pooled basis and RHRB 3A x 9612 in E5 recorded highest grain yield per plant. The high grain yield in the case of RHRB 1A x 9611 in E1 and E6 was mainly due to its high LAI at flowering, DMP at flowering and maturity, low abaxial and adaxial stomatal densities, high fodder yield/plant, harvest index, number of effective tillers per plant, longer ear and thicker ear girth, high number of grains/ cm^2 and 1000-grain weight. Highest grain yield of RHRB 5A x 9612 in E2 because of high DMP at maturity, AGR and RGR between flowering and maturity, fodder yield per plant, high harvest index, number of effective tillers/plant, higher number of grains/ cm^2 and 1000-grain weight. Whereas, 9606A x 9612 recorded highest grain yield in E3 environment mainly due to high LAI at flowering, DMP at flowering and maturity, fodder yield per plant, harvest index, long and thick ears, highest number of grains/ cm^2 and 1000-grain weight. The hybrid 9605A x 9612 which produced maximum grain yield in E4 and on pooled basis also performed well for DMP at maturity, reasonably high AGR and RGR between flowering and maturity, high harvest index, longer ear and more number of grains/ cm^2 Similarly, high grain yield of RHRB 3A x 9612 in E5 was due to its high mean performance for LAI and DMP at flowering, DMP at maturity, highest harvest index, more number of effective tillers/plant high 1000-grain weight and more ear length.

Data from Table 15 also revealed that high grain yield in rest of the high yielding hybrids by and large depend upon their high mean performance for one or more physiological components *viz.*, LAI, DMP, AGR, RGR and stomatal densities and harvest index, fodder yield/plant and some of yield components like number of effective tillers/plant, ear length, girth, number of grains/ cm^2 and 1000-grain weight. It is, therefore, concluded that high mean performance in pearl millet mainly depend upon high mean performance for LAI at flowering, DMP at flowering and maturity, AGR between flowering and maturity, low stomatal densities, high harvest index, supported by one or more yield components like number of effective tillers/plant, ear length and girth, number of grains/ cm^2 and 1000-grain weight. This conclusion could also be supported by findings of stability, correlation and path analysis which are discussed further.

5.2 Stability analysis

In the present investigation, seven male sterile lines, five male parents and their 35 crosses alongwith two checks were considered for assessing their stability for different morpho-physiological, agronomic characters and grain yield and its components in E1, E2, E3, E4, E5 and E6 environments as per the method suggested by Eberhart and Russell (1966).

Yates and Cochran (1938) proposed that the regression of yield on environmental index as measured by mean yield of all the varieties in particular environment would provide a parameter for characterization of stability of hybrids Allard and Bradshaw (1964) critically reviewed this phenomenon and brought out its implications in applied plant breeding Finlay and Wilkinson (1963) developed a simple dynamic interpretation of varietal adaptation in which they suggested that the linear regression (bi) be considered as a measure of stability

Eberhart and Russell (1966) emphasized the need for considering both the linear (bi) and the non-linear (S^2di) components of G x E interaction in judging the phenotypic stability. Paroda and Hayes (1971) emphasized that linear regression should simply be regarded as measure of the response of particular genotypes, whereas, deviation around the regression line (S^2di) should be considered as a measure of stability, genotype with the lowest deviation being the most stable and vice-versa.

It is unjustified to breed genotypes with only high yield potential because most of the times the yield potential can not be expressed. Therefore, a much higher priority should be given to improve yield stability. It has been suggested by many workers that stability is a genetically controlled character (Allard and Bradshaw, 1964). Therefore, one can breed for stability also and selection for stability can be effective. Hence information on the relative stability of the genotypes for different yield components is essential.

5.2.1 Analysis of variance

The analysis of variance (Table 3) indicated that the mean differences due to genotypes were statistically significant for all the seventeen haracters including grain yield components when tested against G x E and ooled deviation Environmental variance were significant for all the haracters suggesting the presence of genetic variability among the genotypes nd even over environments, G x E interaction was detected for all the haracters which suggested varying responses of genotypes to different nvironments. The genotype x environment interaction was partitioned into near and non-linear (pooled deviation) components The variance due to G x (Linear) was significant for LAI, DMP I, days to stigma emergence, plant eight, fodder yield per plant, ear girth, number of grains per cm^2 and 1000-rain weight This indicated that major portion of interaction was linear in ature and prediction over environment for these characters would be possible ignificance of pooled deviation suggested importance of non-linear omponent for all the characters. Therefore, both linear and non-linear omponents appear to be important for LAI, DMP I, days to stigma emergence, lant height, fodder yield per plant, ear girth, number of grains per cm^2 and 000-grain weight.

Non-linear component of G X E interaction was found to be nportant for DMP II, AGR, RGR, adaxial and abaxial stomatal densities, arvest index, number of effective tillers per plant, ear length and grain yield er plant

In previous studies, Singh and Gupta (1968) reported that large ortion of G x E interaction for grain yield accounted for by linear component as ompared to non-linear component. Tyagi *et al.*(1979) observed significant ear interaction for number of tillers and ear length. They suggested that the table hybrid for a particular character could be expected through the use of able parents for that character, as they obtained the stable hybrids from one both the parents having high stability Kumar *et al.* (1982 b) reported gnificant G x E interaction both for linear and non-linear components for

000-grain weight Sagar (1983) observed significant G x E interaction both or linear and non-linear components for harvest index, however in present tudy only non-linear component of G x E interaction was significant Dass *et l.* (1985) noticed that the parents were less responsive than hybrids for grain ield Pethani and Kapoor (1985) showed both linear and non-linear omponent of G x E interaction to be significant for dry fodder yield. However, hey also observed (1986) that the linear component of G x E interaction was higher in roportion in case of days to earing and ear length, whereas non-linear portion vas greater in magnitude in case of plant height, ear bearing tillers, seed size nd ear weight Mungse (1987) stated that linear component of G x E teraction was significant for productive tillers, LAI at flowering, AGR and RGR etween flowering and maturity, while non-linear component of G x E was gnificant for ear length, 1000-grain weight, grain yield, harvest index, and dry atter production at flowering and maturity. Dahiya *et al.* (1987), Baviskar 1990) and Anarse (1995) stated that linear and non-linear components were ignificant for grain yield. Ramamoorthi *et al.* (1996) observed non-significant near interaction of G x E for grain yield in pearl millet

Considering the environmental indices (Table 4), the E1 was und the most favourable environment followed by E2 and E4 for yield and ost of the characters

.2.2 Stability parameters

The stability parameters estimated for different traits under study re presented in Table 5 and graphically presented in figures 1 to 17.

.2.2.1 Morpho-physiological characters

Leaf area index

The data relating to mean performance, regression coefficient (bi) nd deviation from regression (S^2di) for LAI at flowering (Table 5 and Fig. 1) dicated that 24 genotypes had higher mean than population mean (5.01) Of

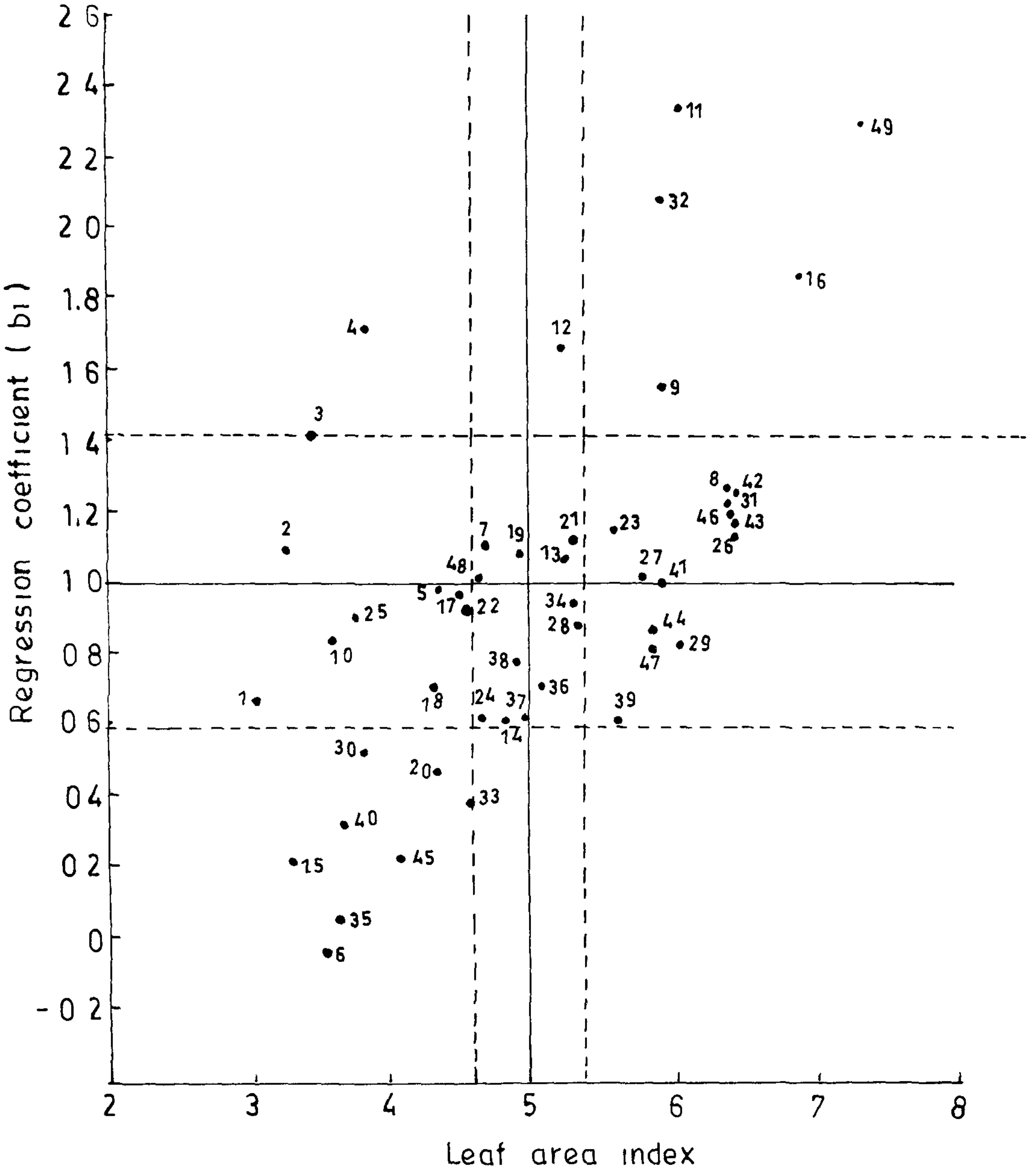


Fig. 1 Relation of leaf area index and stability

these only one genotype expressed higher LAI than mean value of the population with non-significant deviation from regression indicating their stability The pollinator RHRBI 138 had higher LAI (6.41) coupled with above average response (bi > 1) and non-significant deviation from regression, indicating its specific adaptability to favourable conditions

The genotypes, 9611, RHRB 1A x 9611, RHRB 5A x 9612 and MLBH 267 produced significantly higher mean with significant greater bi values The prediction of performance of these genotypes were difficult as they had significant S^2di Mungse (1987) in their studies observed that linear portion of G x E interaction was higher than non-linear for LAI at flowering as observed in present study

ii) Dry matter production I

The data presented in Table 5 and Fig 2 on dry matter production at flowering revealed that 25 genotypes produced higher DMP at flowering than the population mean (42.77g). All the females *viz.,* RHRB 1A (26.81g), RHRB 2A (26 82g), RHRB 3A (27.64g), RHRB 5A (30 25g), 9605 A (40 01g), 9606 A (29 26g) and 9607 A (37 80g) had lower DMP at flowering than the average None of the genotypes exhibited wider or specific adaptability for this traits Genotypes, RHRBI 138, RHRB 1A x 9611, RHRB 5A x 9612, 9607A x 9611 and MLBH 267 exhibited significantly high mean coupled with significantly greater values of the linear component of G x E interaction but significant S^2di hence the prediction of performance of these genotypes was difficult The values of the mean square deviation were non-significant in case of RHRB 2A, RHRB 3A, 9605 A and hybrids, RHRB 3A x RHRBI 458, 9605A x RHRBI 138 and 9605A x RHRBI 178 indicating that the performance of these genotypes over environment would be most predictable In present study linear component of the interaction was found to be most important

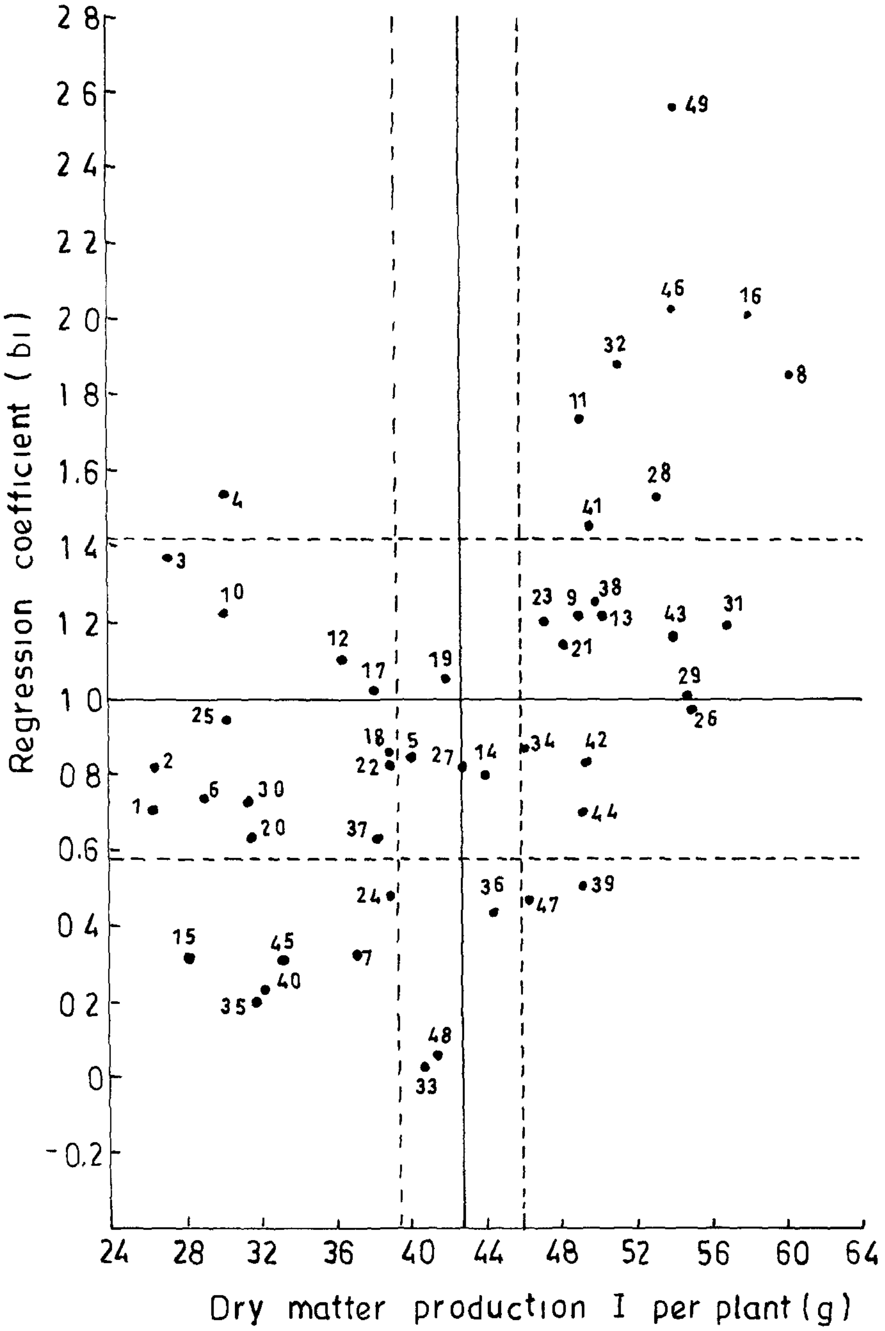


Fig. 2 Relation of dry matter production I per plant and stability

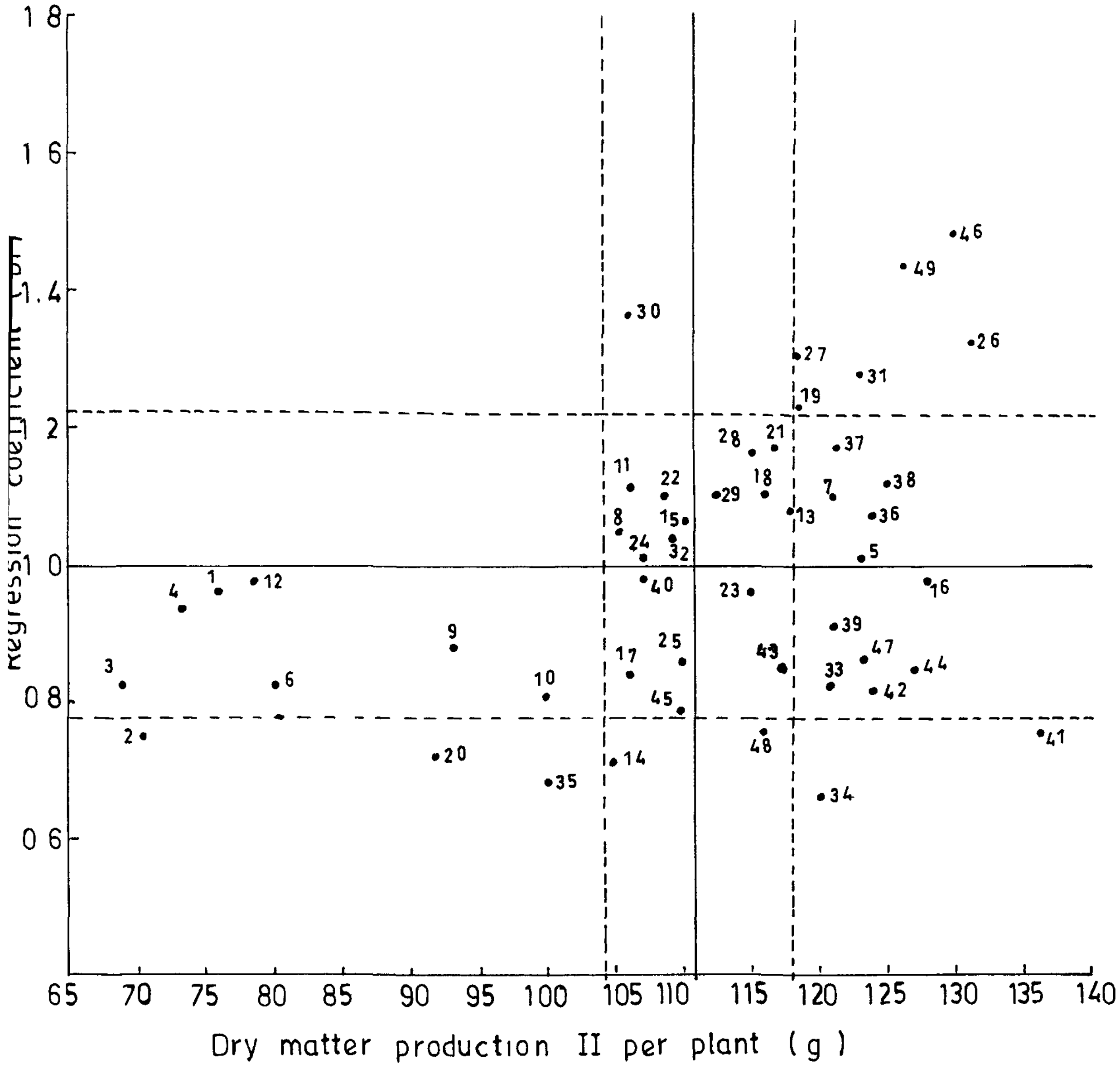
Mungse (1987) also stated the predominance of linear component for this character

iii) Dry matter production II

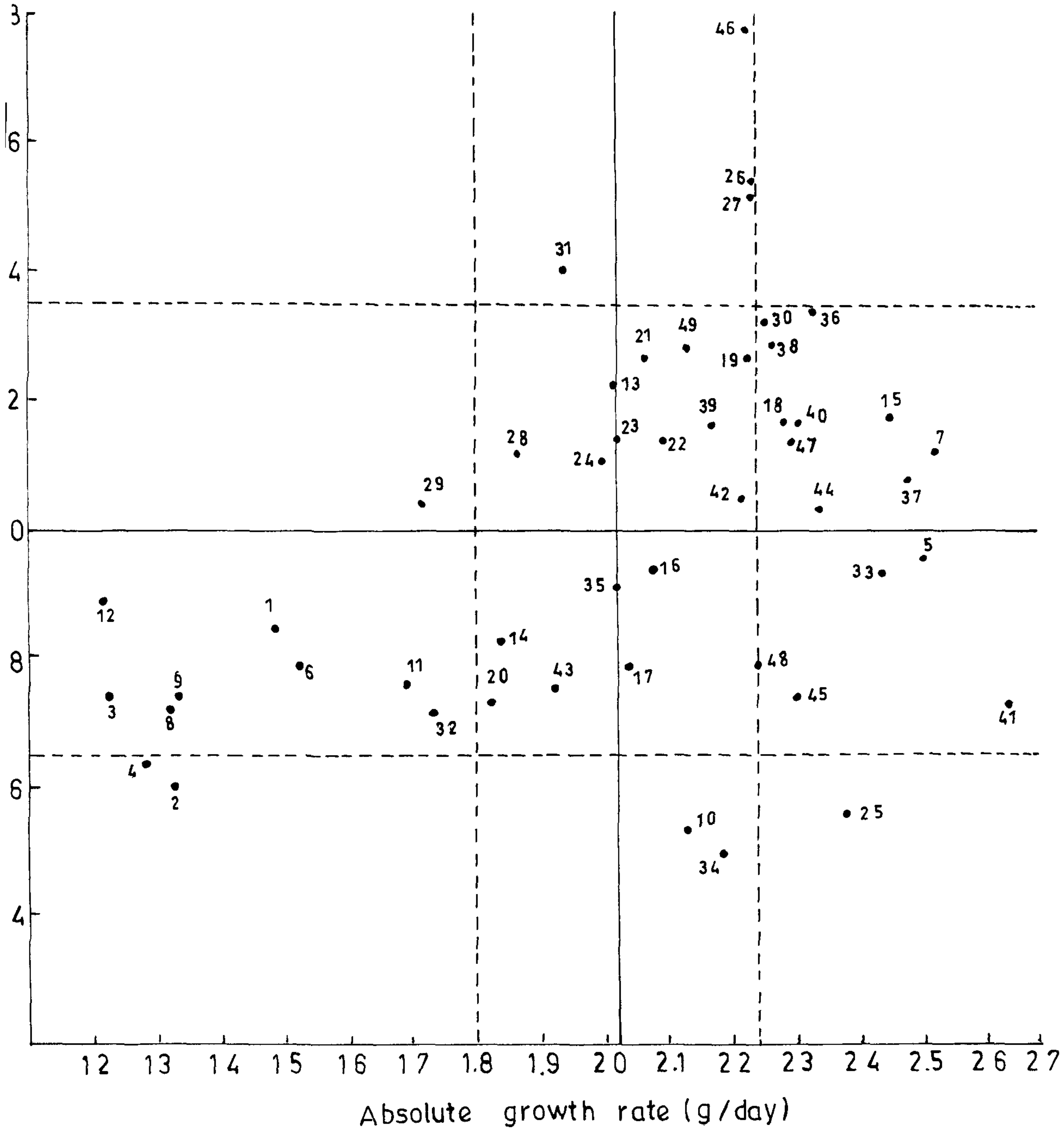
Data on dry matter production at maturity (Table 5 and Fig. 3) indicated that eight genotypes produced higher dry matter production at maturity than the population mean (110.88g) with non-significant mean square deviation The parent 9607A had higher mean with regression coefficient near to one (bi = 1) and non-significant mean square deviation indicating their average stability and wider adaptability. The hybrid RHRB 1A x RHRBI 178, RHRB 1A x 9611, RHRB 2A x RHRBI 138 and 9606A x RHRBI 138 had higher mean than population mean (110.88g), non-significant S^2di with average stability and wider adaptability Hybrid RHRB 5A x 9611 had higher mean with above average response (bi > 1) and non-significant S^2di, indicating their suitability for favourable environments. The hybrid 9606A x 9611 and population ICTP 8203 had high mean with below average response (bi < 1) and non-significant S^2di indicating their suitability under poor environmental conditions for this traits Mungse (1987) had noted the importance of non-linear component of G x E interaction as observed in present study.

iv) Absolute growth rate

Among the parents, male sterile lines 9605A and 9607A produced significantly higher AGR between flowering and maturity than the population mean (2 02 g/day) with regression coefficient near to unity and significant S^2di indicating their adaptability (Table 5 and Fig. 4). Two hybrids displayed higher AGR than the mean value of the population with non-significant S^2di showing their stability Hybrids 9605A x RHRBI 178 had high mean with average response (bi = 1) and non-significant S^2di indicating its



g.3 Relation of dry matter production II per plant and stability



4 Relation of absolute growth rate and stability

stability and wider adaptability and hybrid, RHRB 2A x 9611 had higher mean with above average response (bi > 1) suggesting its suitability for favourable conditions Mungse (1987) observed importance of linear component of interaction for AGR between flowering and maturity.

v) Relative growth rate

Although 26 out of 49 genotypes studied exhibited higher RGR than the population mean (0.0287 g/g/day), 25 expressed significant non-linear response thereby making them unstable for RGR due to presence of high G x E interaction. All females had higher relative growth rate except RHRB 3A than the population mean Only the hybrid 9605A x RHRBI 178 had mean higher than population with regression coefficient more than one (bi > 1) and non-significant S^2di indicating below average stability (Table 5 and Fig 5) and suitability for favourable environments. Mungse (1987) observed non-significant G x E interaction of non-linear component for RGR between flowering and maturity

vi) Adaxial stomatal density

Seven genotypes possessed lower adaxial stomatal densities than the population mean (87.97 mm^2) and had non-significant S^2di (Table 5, Fig. 6). Less number of stomatae is favourable character, therefore lower means are desirable. Somashekarappa (1988) reported that genotypes with low stomatal number per plant would be expected to show low total plant conductance resulting in low transpirational water loss Among the parents, male sterile line 9607A had mean lower than population mean, bi value near to unity (bi = 1) and non-significant S^2di indicating average stability and suitability for all the environments Pollinator RHRBI 458 had bi value greater than unity (bi > 1), non-significant S^2di and lower average than population mean indicating

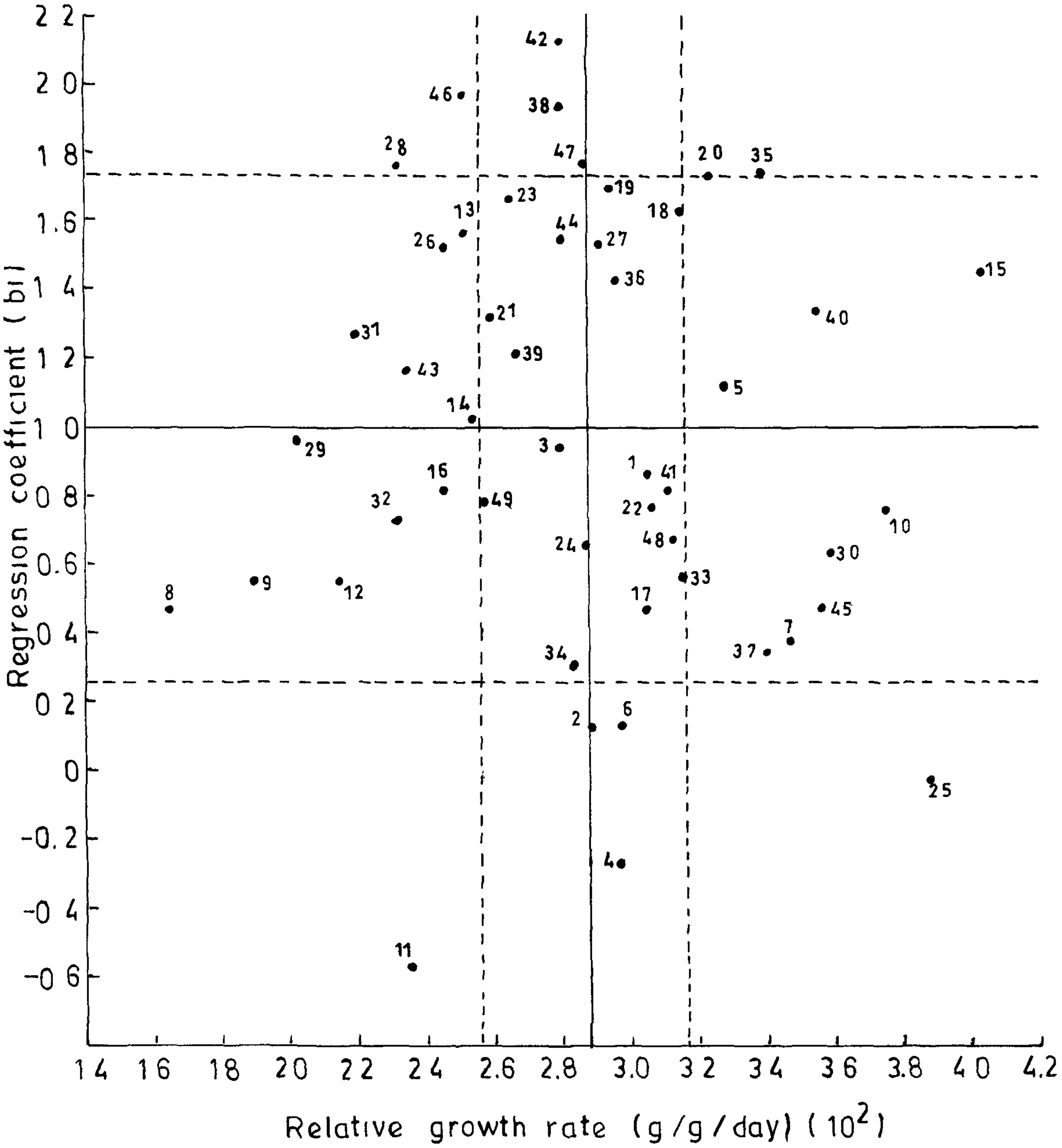


Fig. 5 Relation of relative growth rate and stability

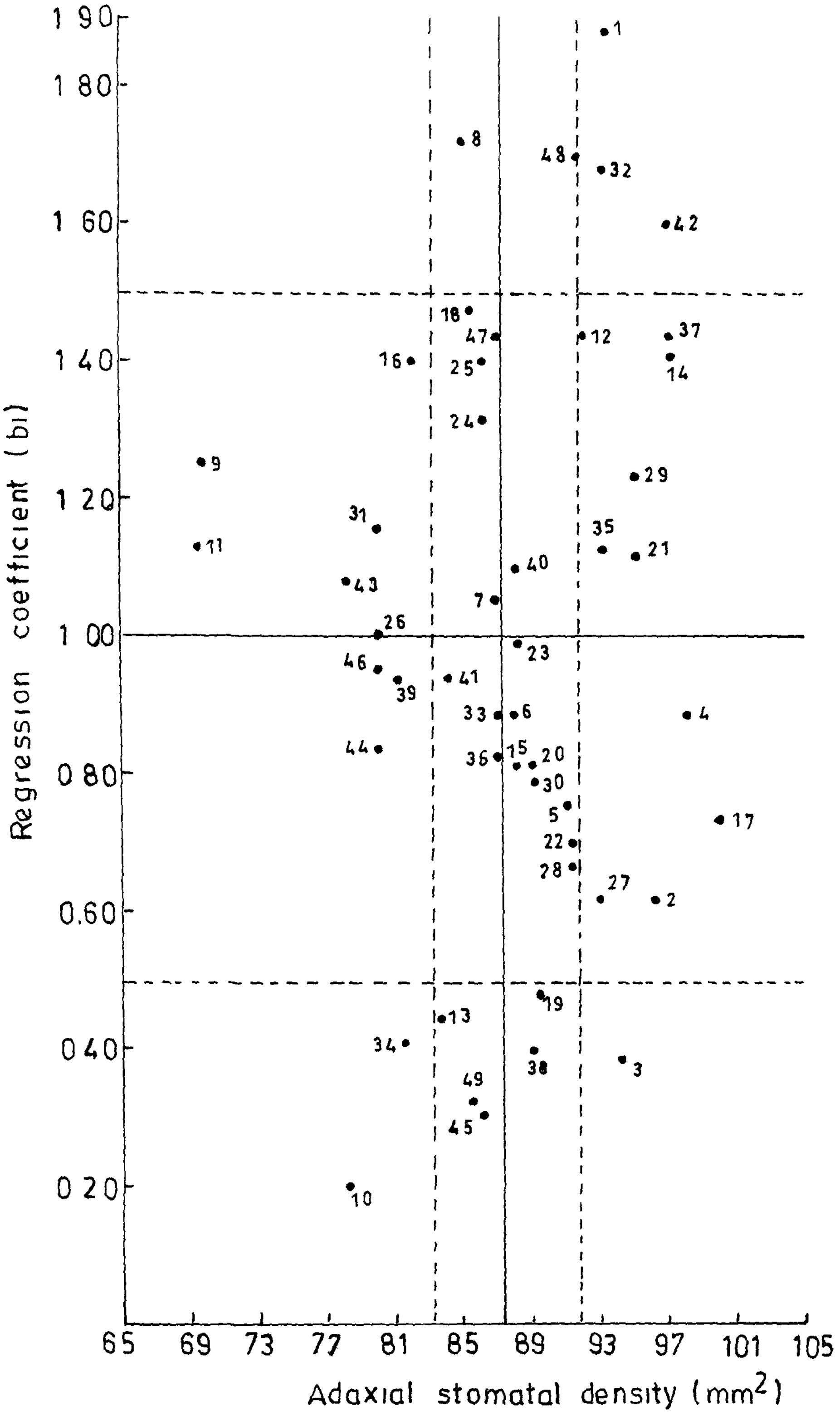


Fig. 6 Relation of adaxial stomatal density and stability

below average stability and thus would be more suitable for favourable environments.

Two hybrids 9606A x RHRBI 458 and 9607A x RHRBI 138 had low mean, with regression coefficient equal to one (bi = 1) and non-significant S^2di indicating average response and suitability for all environments Hybrid RHRB 1A x 9611, had lower mean with bi > 1 and non-significant S^2di indicating above average response and suitability for favourable environments. Hybrids 9605A x 9611 and 9607A x RHRBI 178 had bi < 1 with non-significant S^2di and lower mean than population mean indicating their below average response and specific adaptability to poor environments.

vii) Abaxial stomatal density

Seven genotypes expressed lower abaxial stomatal densities than population mean (110.23 mm^2) with non-significant S^2di. Of these, female, 9607A had lower mean, unit regression coefficient (bi = 1) and non-significant S^2di, indicating their average stability and wider adaptability (Table 5, Fig. 7). Among the hybrids RHRB 1A x 9611, 9605A x 9611, 9606A x RHRBI 458, 9607A x RHRBI 138, 9607A x RHRBI 178 and MLBH 267 had lower mean, regression coefficient less than unity (bi < 1) and non-significant S^2di indicating above average stability and suitability for poor environmental conditions The pollinator 9611 had lowest abaxial stomatal density (82.42 mm^2) then average mean (110.23 mm^2) The prediction of the performance of this pollinator was difficult as they had significant S^2di value. It is interesting to note that the male sterile line 9607A and hybrids RHRB 1A x 9611, 9605A x 9611, 9606A x RHRBI 458, 9607A x RHRBI 138 and 9607A x RHRBI 178 also displayed stability for both adaxial and abaxial stomatal density.

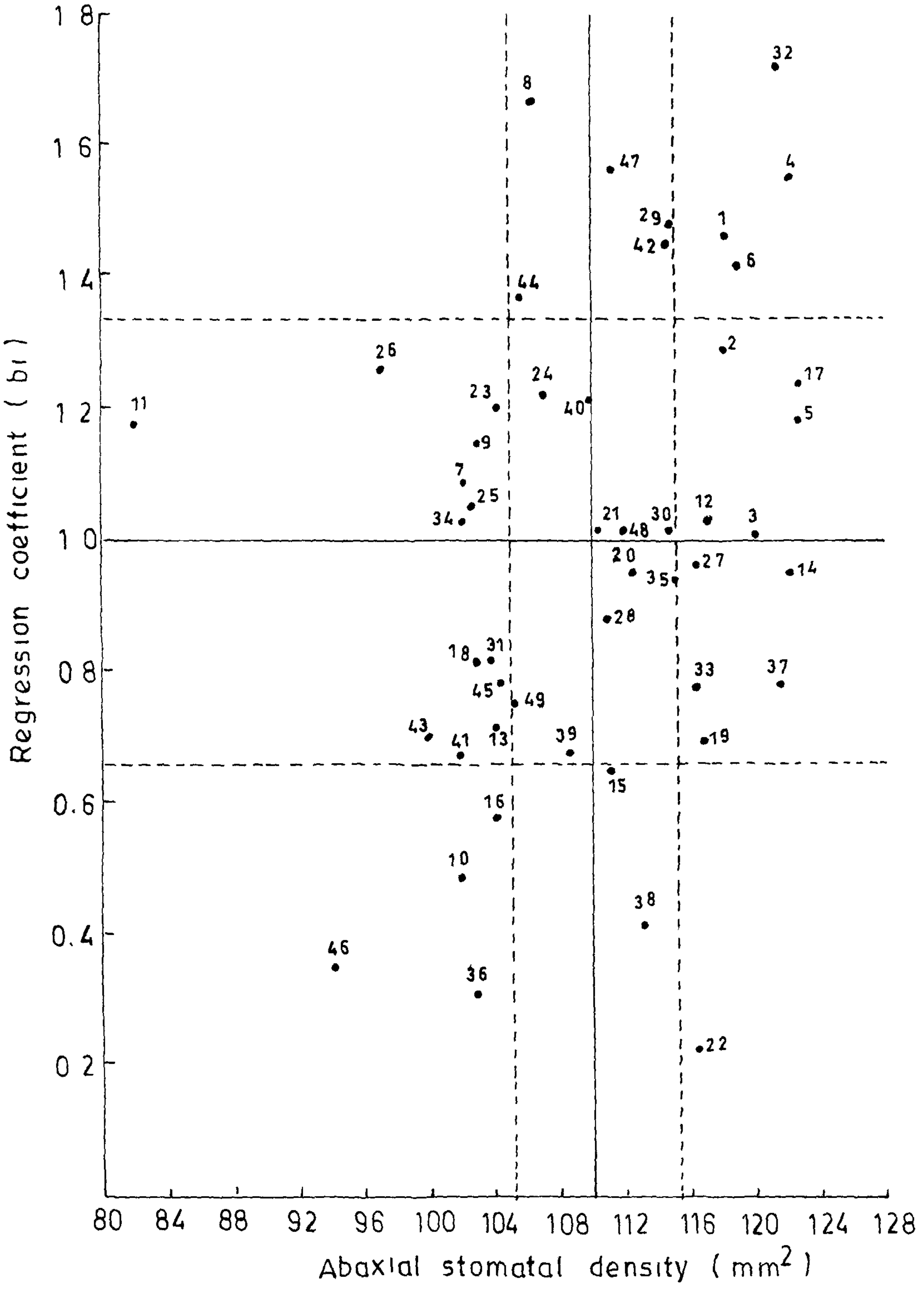


Fig. 7 Relation of abaxial stomatal density and stability

5.2.2.2 Harvest index and agronomic characters

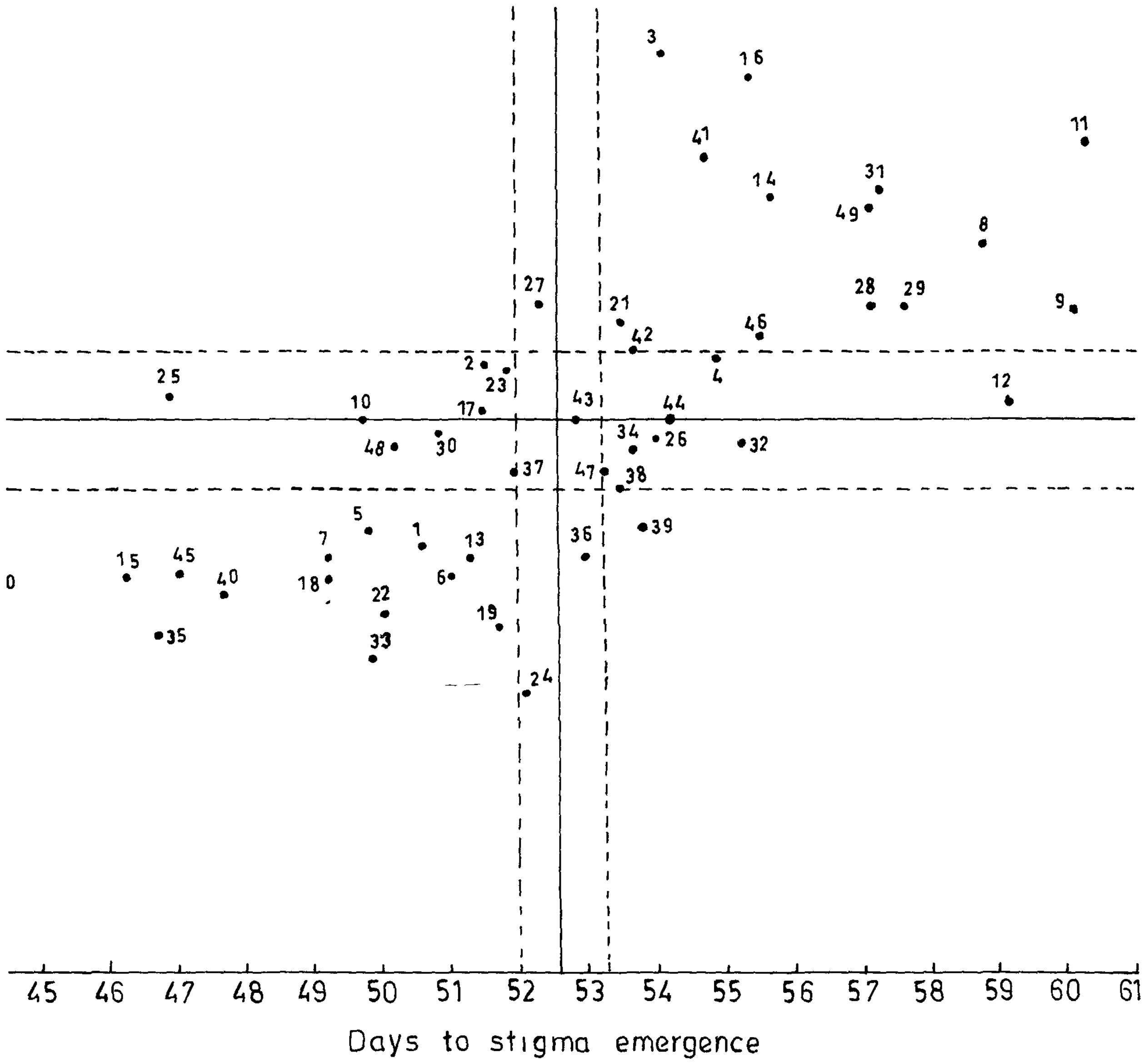
i) Days to stigma emergence

The data relating to stability parameters for days to stigma emergence (Table 5 and Fig 8) indicated that 24 genotypes had lower mean than the population mean (52 66 days). The rest of the genotypes took more number of days to stigma emergence than population mean. Earliness being favourable character, lower means are desirable Among the parents RHRB 1A, 9605A and 9607A possessed average stability as they were early in days to stigma emergence and had bi values near to unity (bi = 1) with non-significant value of S^2di, while female 9606A had significant bi value lower than unity (bi < 1), non-significant S^2di and lower mean indicating above average stability and suitability for low yielding environments.

The combinations RHRB 1A x RHRBI 138, RHRB 1A x 9612, RHRB 3A x RHRBI 138, RHRB 3A x 9612 and 9605A x 9612 and check ICTP 8203 had bi values near to unity, non-significant S^2di and exhibited lower means, indicating average stability with wider adaptability. Hybrid RHRB 2A x RHRBI 458 had bi significantly less than unity (bi < 1), non-significant S^2di and lower mean indicating above average stability and suitability for low yielding environments Tyagi (1987), Suryavanshi *et al.* (1991) and Anarse (1995) in their studies observed that linear portion of G x E interaction was more important for this trait

ii) Plant height

The data presented in Table 5 and Fig. 9 showed that 26 genotypes had more plant height than the population mean (167 91 cm) Of these, 21 were unstable as they had significant S^2di value. Among the



Relation of days to stigma emergence and stability females, RHRB 3A was dwarf, while male parents had plant height ranging from 144 88 to 199.28 cm. Among the parents, 9605 had bi = 1, with non-significant S^2di and lower mean (dwarf) than population mean indicating its average stability and wider adaptability. Inbred RHRBI 178 was dwarf with regression coefficient less than one (bi < 1) and non-significant S^2di indicating suitability for poor environments with above average stability.

Hybrids RHRB 2A x RHRBI 138, 9606A x 9611, 9607A x RHRBI 458 and 9607A x 9612 had bi value near to unity (bi = 1), non-significant S^2di and higher means indicating average stability and wider adaptability Hybrid RHRB 5A x RHRBI 138 had significantly bi value greater than unity (bi > 1), non-significant S^2di and high mean (184.94 cm) indicating below average stability and suitability for high yielding environments. Mungse (1987) and Karale (1994) in their studies observed both linear and non-linear of G x E interaction was important for plant height

iii) Fodder yield per plant

Data on fodder yield per plant (Table 5 and Fig. 10) indicated that nine genotypes produced higher fodder yield per plant than the population mean (51.92g) with non-significant S^2di indicating their stability The inbred RHRBI 138 had high mean (58.23g) with average stability (bi = 1) and non-significant S^2di indicating its wider adaptability in all the environments Among hybrids, RHRB 1A x RHRBI 458, RHRB 3A x RHRBI 138, 9605A x RHRBI 458 and 9606A x 9611 had unit regression coefficient (bi = 1), non-significant S^2di with higher fodder yield/plant indicating average response for wider adaptation Hybrids, RHRB 1A x RHRBI 138 and RHRB 5A x RHRBI 458 had high mean with above average response (bi > 1) and non-significant S^2di indicating its specific adaptability to rich environmental conditions, while hybrid 9606A x 9612 and 9607A x 9612 had higher mean with below average

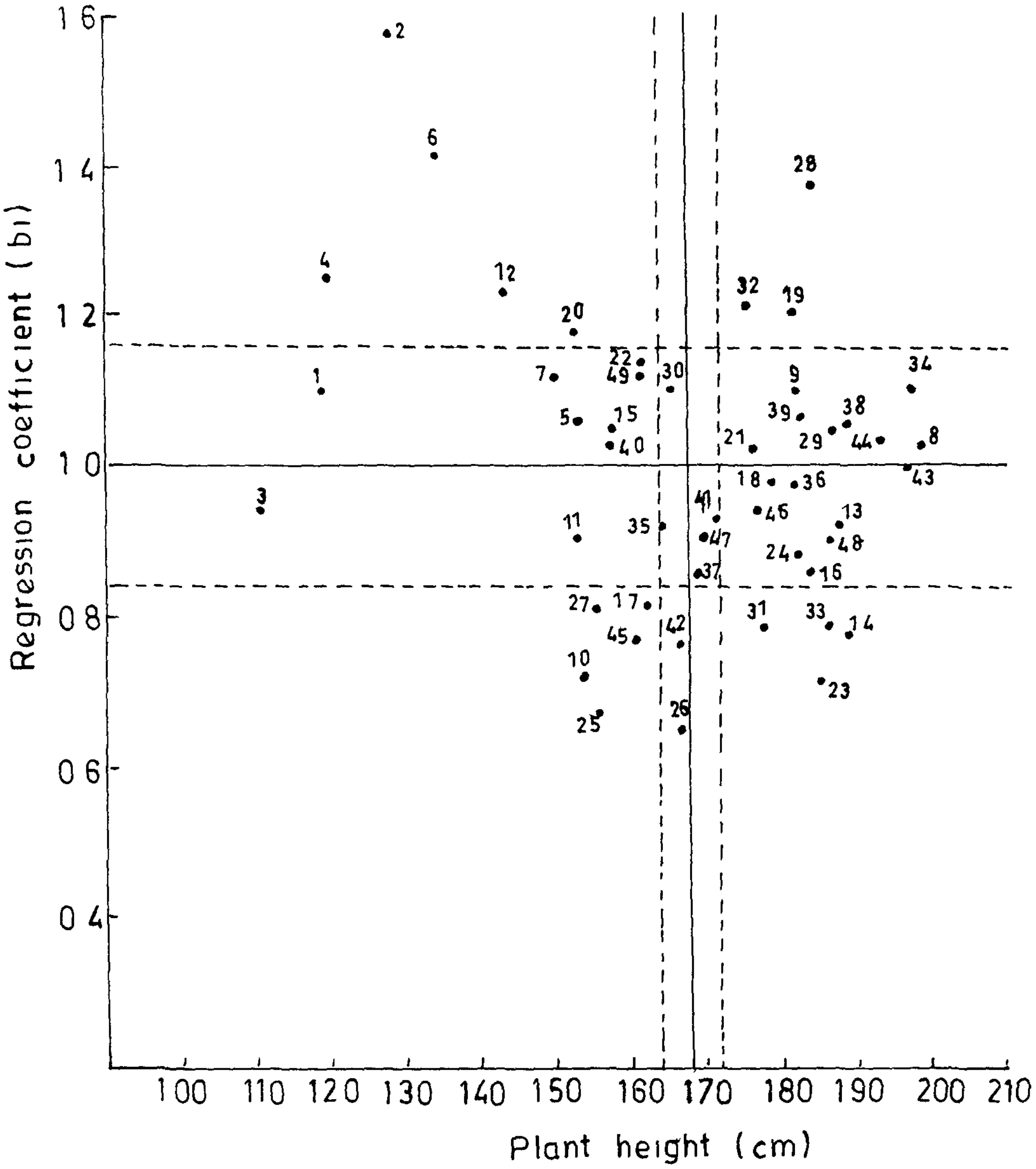


Fig. 9 Relation of plant height and stability

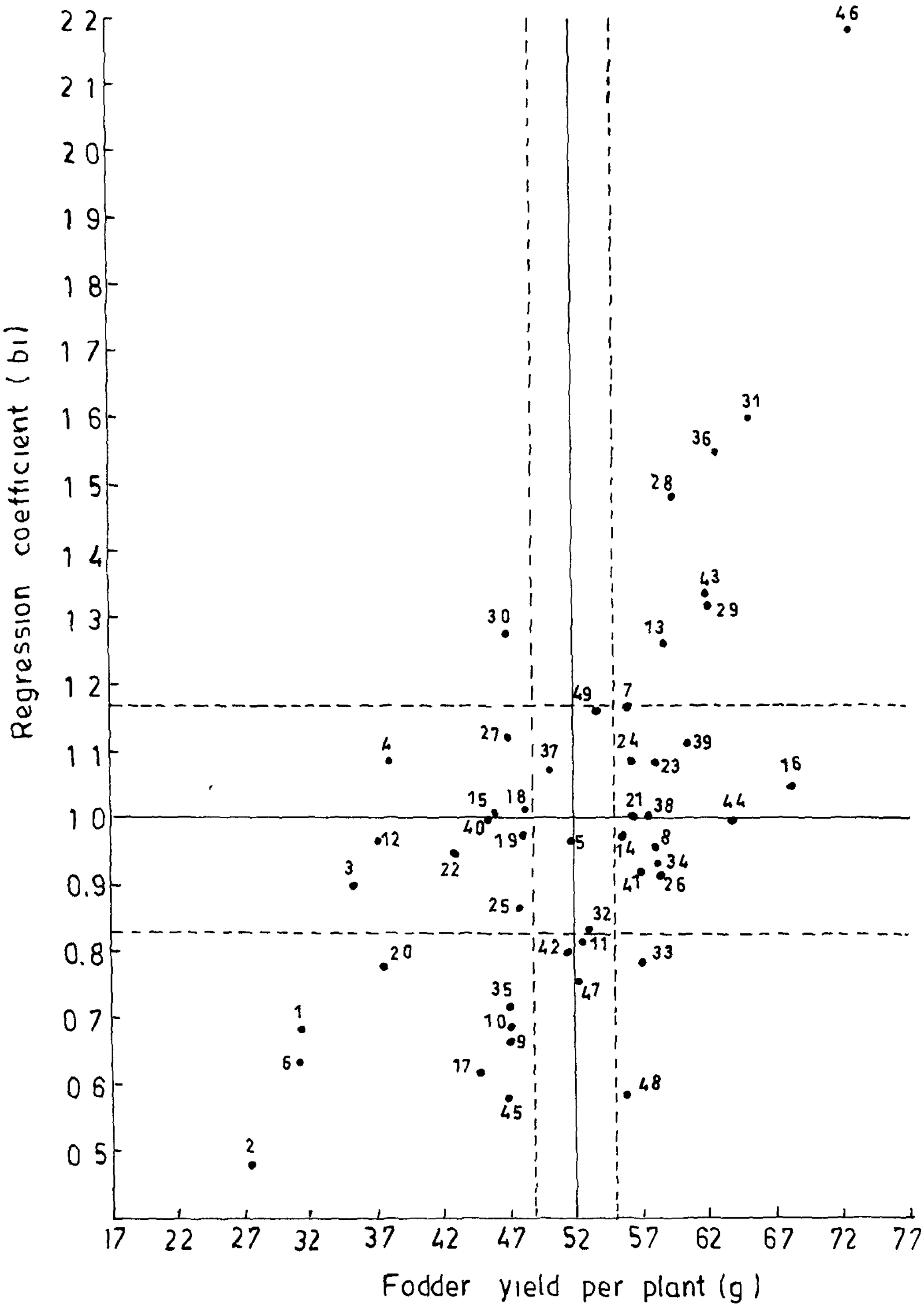


Fig. 10 Relation of fodder yield per plant and stability

response ($b_i < 1$) and non-significant S^2di suggesting its specific adaptability to poor environmental conditions Pethani and Kapoor (1985), Rasal (1992) and Anarse (1995) reported higher linear portion of G x E interaction than non-linear for fodder yield as observed in the present study

iv) Harvest index

The data presented in Table 5 and Fig. 11 revealed that ten genotypes exhibited higher harvest index than population mean (34.86) with non-significant S^2di. All the genotypes exhibited non-significant values of the linear component of G x E interaction. Among the parents, RHRB 2A though unstable as significant S^2di, produced higher mean (35.79) showing above average response ($b_i > 1$) Among the hybrids RHRB 2A x RHRBI 138, RHRB 2A x RHRBI 458, RHRB 2A x 9612, 9605A x 9612, 9606A x 9611, 9607A x RHRBI 178 and MLBH 267 had higher mean with below average stability ($b_i > 1$) and non-significant S^2di, suggesting, its suitability for favourable environments, whereas, hybrids 9606A x RHRBI 458 and 9606A x 9612 had higher mean with above average stability ($b_i < 1$) and non-significant S^2di indicating its specific adaptability to unfavourable environments. The hybrid 9607A x 9612 possessed average stability as they had higher mean than population mean, bi value near to unity ($b_i = 1$) with non-significant value of S^2di. Higher linear component of G x E interaction was reported by Rasal (1992)

5.2.2.3 Grain yield and its components

i) Number of effective tillers per plant

The data on stability parameters for number of effective tillers per plant (Table 5 and Fig. 12) indicated that out of 49 genotypes studied, 13 produced higher number of effective tillers/plant than the population mean

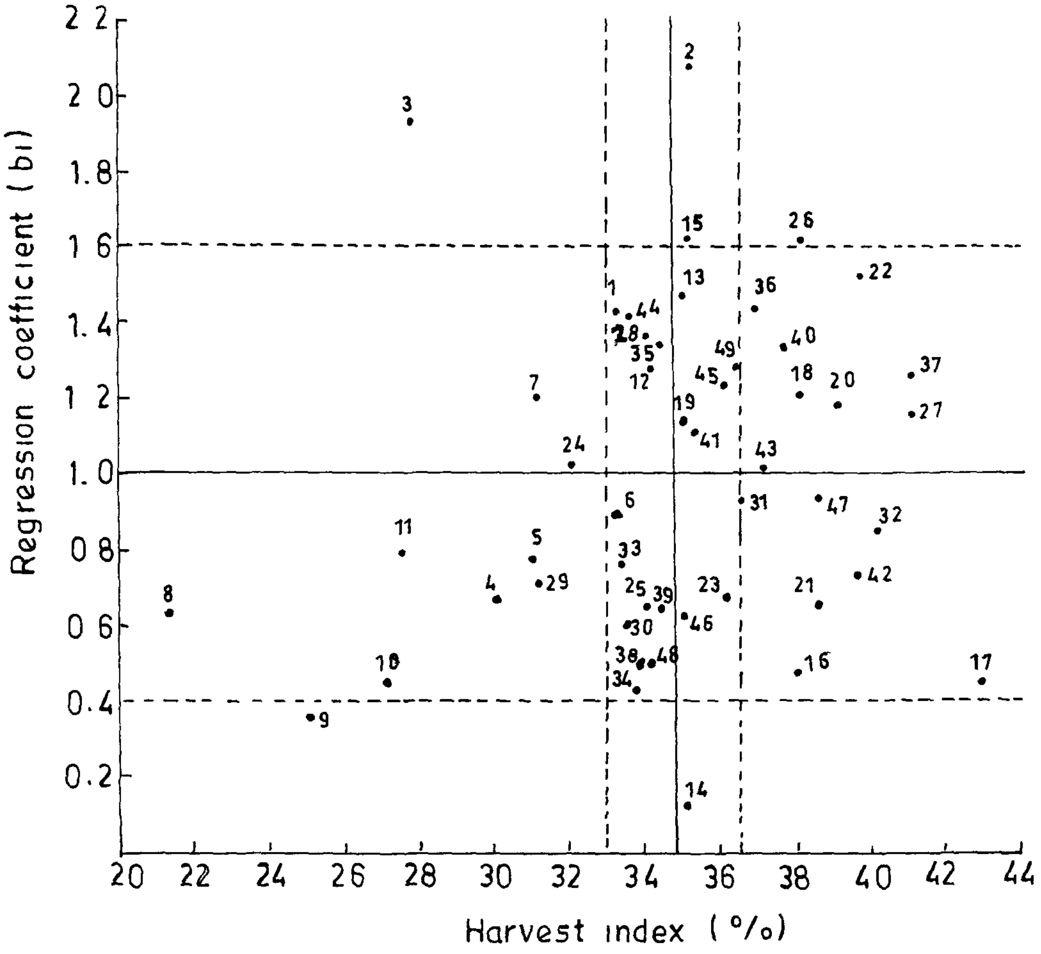


Fig. 11 Relation of harvest index and stability

(1.99) and had non-significant values of S^2di. Male sterile lines RHRB 3A, 9607A and inbred 9611 had mean higher than population mean, bi values greater than one (bi > 1) and non-significant S^2di indicating below average stability and suitability for favourable environments The hybrids RHRB 1A x 9611, RHRB 2A x 9611, 9605A x RHRBI 178 and 9607A x 9612 had higher mean, bi values near to unity (bi = I) and non-significant S^2di suggesting average stability Hybrids RHRB 1A x RHRBI 178, RHRB 2A x RHRBI 458, RHRB 3A x 9612 and MLBH 267 had high mean, bi values greater than unity (bi > 1) and non-significant S^2di indicating below average stability and suitability for favourable environments, while hybrid RHRB 2A x RHRBI 178 and RHRB 5A x RHRBI 178 had bi values less than unity (bi < 1), non-significant S^2di and higher mean than population mean indicating above average stability and suitability for poor environments In the previous studies Baviskar (1990), Rasal (1992), Karale (1994) and Anarse (1995) suggested the importance of linear component for this trait.

ii) Ear length

For ear length, the data presented in Table 5 and Fig 13 revealed that 14 genotypes produced higher ear length than the population mean (18.89 cm) and had non-significant S^2di Among the parents, female 9607A (22 23 cm) had mean higher than population mean, bi value less than one (bi < 1) and non-significant S^2di indicating above average stability and suitability for poor environments. Hybrids, RHRB 2A x RHRBI 458, RHRB 3A x 9612, RHRB 5A x RHRBI 458 and MLBH 267 had bi values near to unity (bi = 1), non-significant value of S^2di and higher mean than population mean indicating average stability and suitability for all environments The hybrids RHRB 3A x RHRBI 458, RHRB 3A x 9611 and 9606A x RHRBI 458 had high means, bi values more than one (bi > 1) and non-significant S^2di indicating

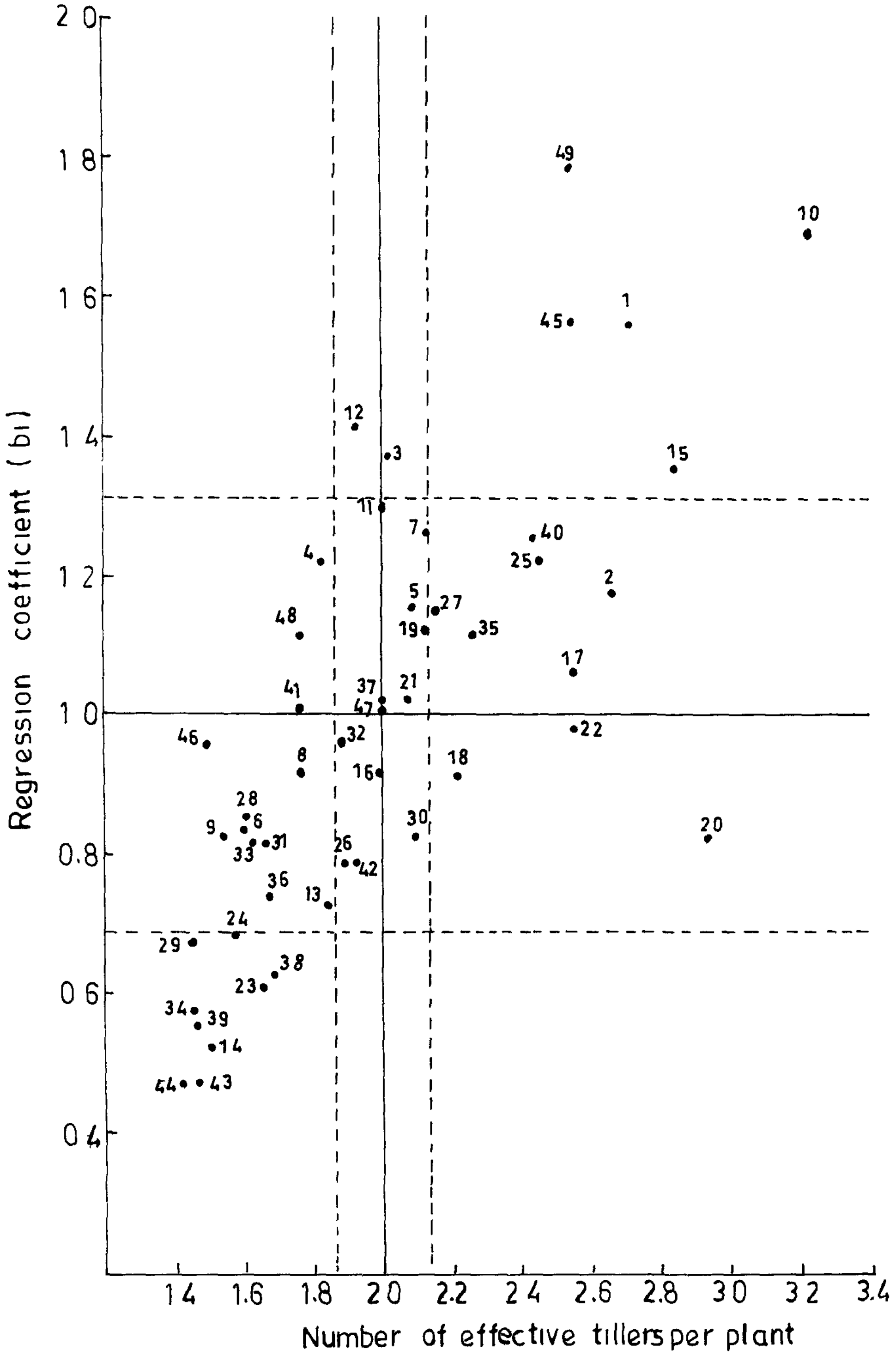


Fig. 12 Relation of number of effective tillers per plant and stability.

below average stability and suitability for favourable environments, whereas, the hybrids RHRB 1A x RHRBI 138, 9605A x RHRBI 138, 9605A x 9612, 9606A x RHRBI 138, 9606A x 9611 and 9606A x 9612 had bi values less than one (bi < 1), non-significant S^2di and higher average than the population mean indicating above stability and thus would be more suitable for unfavourable environments In the present study, linear component was found to be important. Pethani and Kapoor (1986), Rasal (1992) and Anarse (1995) stated the predominance of linear component for this character

iii) Ear girth

The data presented in Table 5 and Fig 14 indicated that 21 genotypes produced higher ear girth than the population mean (10.78 cm) with non-significant S^2di. Of these, female parent 9607A had mean higher than population mean, regression coefficient less than unity (bi < 1) and non-significant S^2di indicating above average stability and suitability for poor environments. Among hybrids, RHRB 1A x RHRBI 458, RHRB 2A x 9611 , RHRB 3A x RHRBI 138, RHRB 3A x 9612, 9606A x 9611, 9607A x RHRBI 458 and 9607A x 9612 recorded higher ear girth than the population mean with average response (bi = 1) and non-significant S^2di indicating their wider adaptability Hybrids, RHRB 1A x RHRBI 138, RHRB 1A x 9611, RHRB 5A x RHRBI 458, 9605A x 9611 and 9607A x 9611 had high mean, regression coefficient greater than unity (bi > 1) and non-significant S^2di indicating above average response and suitability for favourable environments. Hybrids RHRB 2A x RHRBI 458, RHRB 3A x 9611, 9605A x RHRBI 138, 9605A x 9612, 9606A x RHRBI 138, 9606A x RHRBI 458, 9606A x 9612 and 9607A x RHRBI 138 had regression coefficient less than unity (bi < 1), non-significant S^2di and higher mean than population mean indicating their below average response and specific adaptability to poor environments. In the present study both linear and non-linear components of G x E interaction were found to be important

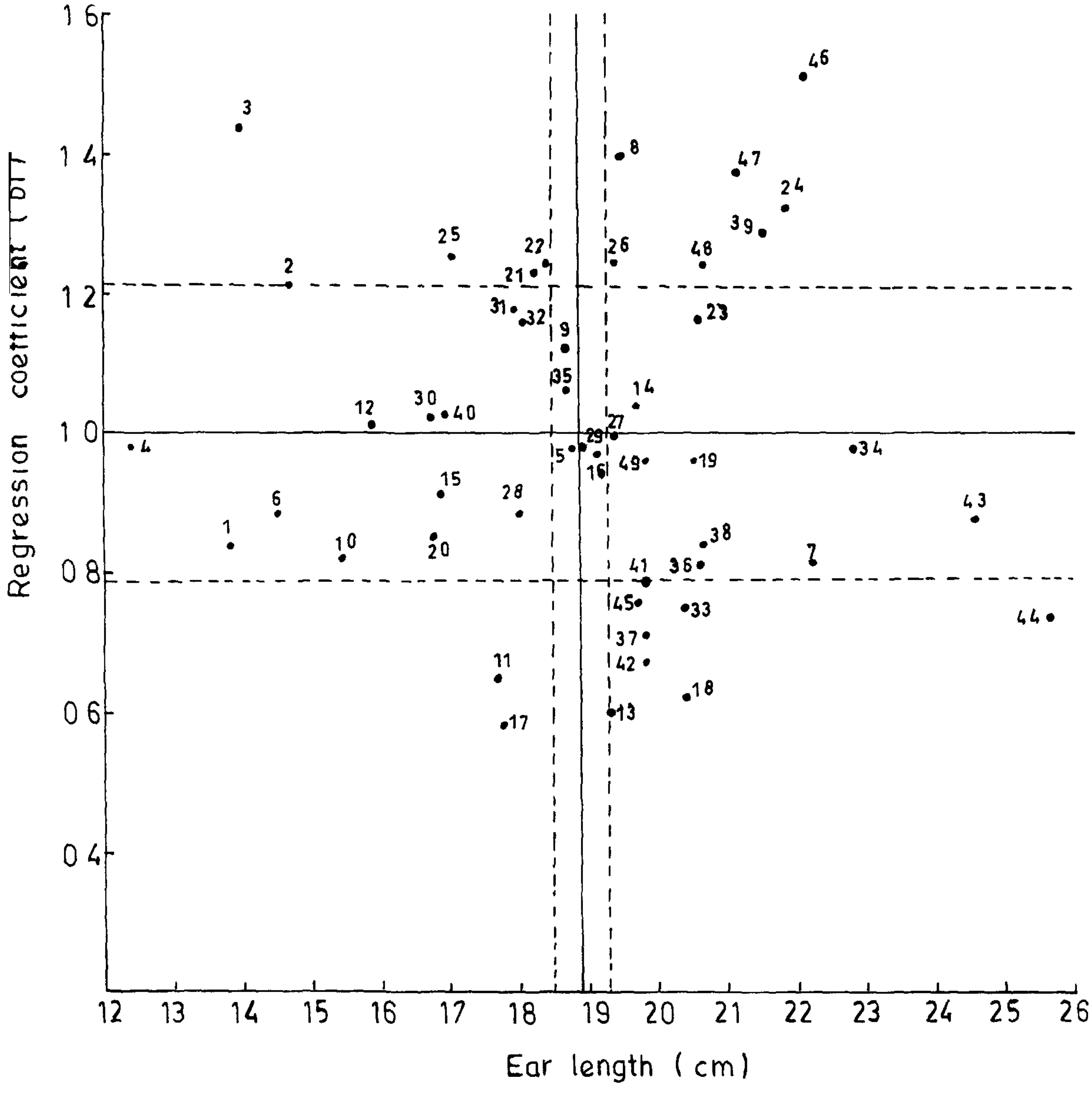


Fig. 13 Relation of ear length and stability

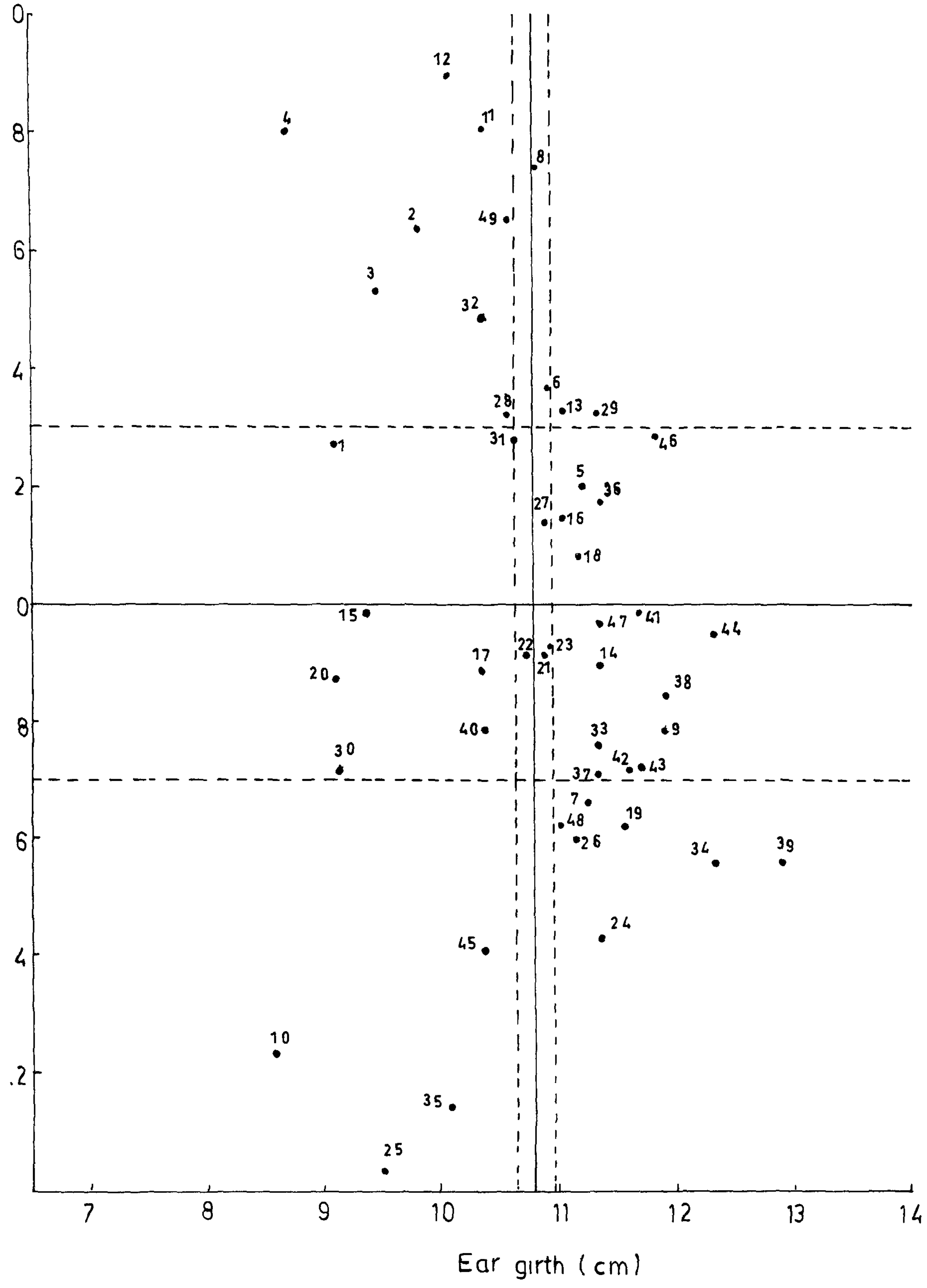


Fig. 14 Relation of ear girth and stability

Suryavanshi (1989), Baviskar (1990), Suryavanshi *et al.* (1991), Rasal (1992) and Karale (1994) have noted the importance of non-linear component of the interaction Anarse (1995) observed that both linear and non-linear component of interaction were more important for this trait.

iv) Number of grains per cm^2

Data on number of grains/cm^2 (Table 5 and Fig. 15) indicated that eight genotypes exhibited higher number of grains/cm^2 than the average of the population (17.97) with non-significant deviation from regression (S^2di). One male sterile line 9606A had higher mean with average response (bi = 1) and non-significant deviation from regression indicating their suitability for wider adaptation The parents 9605A, 9612 and hybrid 9606A x RHRBI 178 had significantly higher number of grains per cm^2, significant bi value greater than one and significant S^2di. Indicating the responsiveness. However, the predication of performance of these genotypes is difficult. Among hybrids RHRB 5A x 9612 and 9605A x 9612 had higher mean with regression coefficient near to unity (bi = 1) and non-significant S^2di indicating average stability and wider adaptability, for this trait, Hybrids RHRB 1A x 9612, RHRB 2A x 9612 and 9606A x 9612 had mean higher than the population mean (17 97) with above average response (bi > 1) and non-significant S^2di indicating their suitability for favourable environments while hybrids 9606A x 9611 and 9607A x 9611 had high mean with below average response (bi < 1) and non-significant S^2di indicating their suitability under poor environments. Karale (1994) had noted the importance of both linear and non-linear component of the G x E interaction for this trait as observed in the present study

v) 1000-grain weight

The data presented in Table 5 and Fig 16 for this character indicated that two parents and twenty three hybrids produced bolder grains

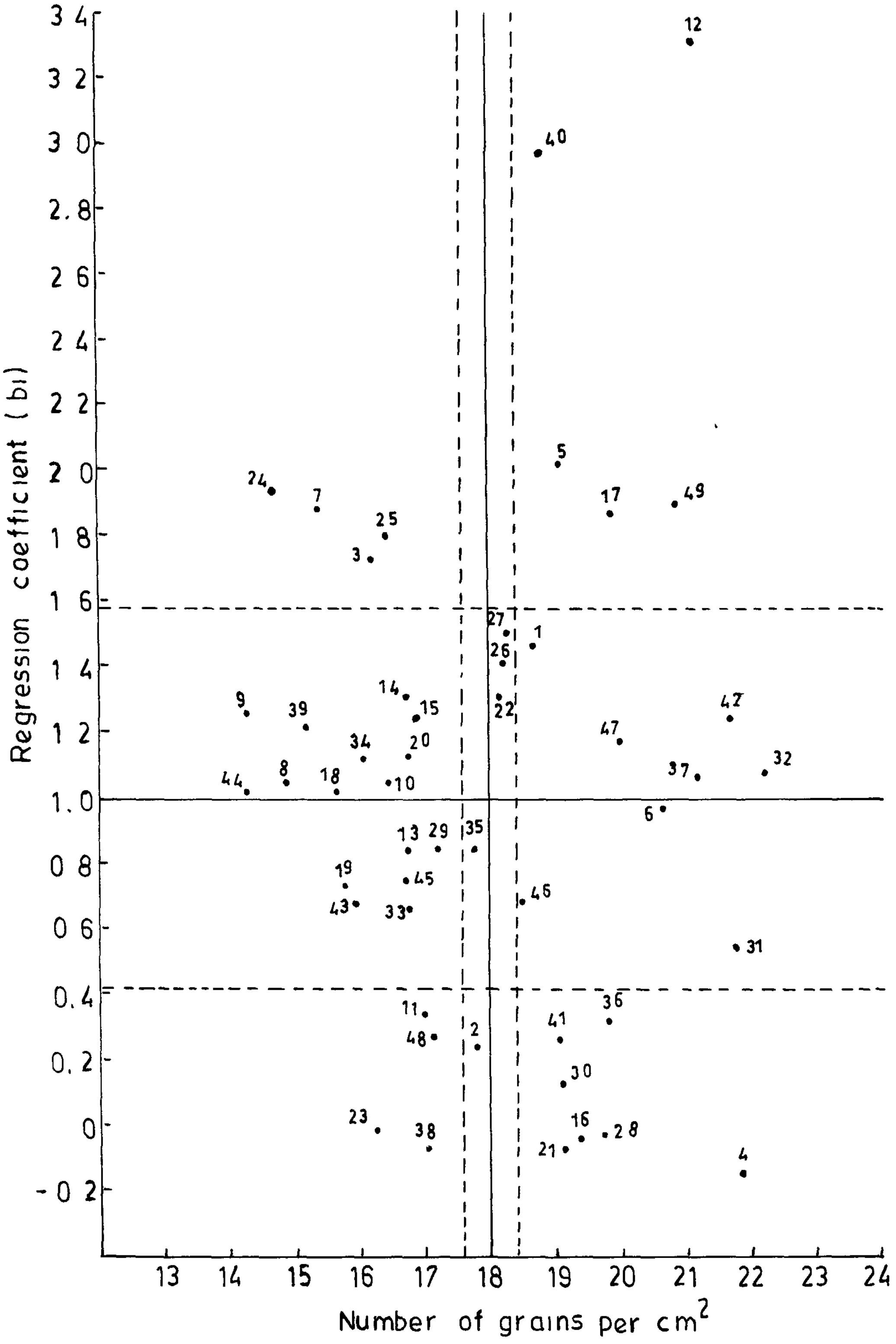


Fig. 15 Relation of number of grains per cm^2 and stability

than population mean Thirteen of these produced bolder grains than the population mean (12.49g) and significant deviation from regression. Genotypes having bolder grains were observed to be unpredictable in their behaviour as were adjudged on the basis of significant S^2di. Twelve genotypes had non-significant S^2di. Among these, inbred RHRBI 138 had value of regression coefficient less than unity ($bi < 1$) non-significant S^2di and higher mean indicating above average stability and specific adaptability to poor environmental conditions Hybrid RHRB 1A x RHRBI 138, RHRB 1A x RHRBI 458, RHRB 2A x RHRBI 138, RHRB 5A x RHRBI 458 and 9606A x RHRBI 138 had average values higher than population mean, bi greater than unity ($bi > 1$) and non-significant S^2di, indicating below average stability and hybrids RHRB 3A x 9611, RHRB 3A x 9612, 9606A x RHRBI 458 and population ICTP 8203 had bi value less than unity ($bi < 1$), non-significant S^2di and higher means than population mean indicating above average stability and specific adaptability to poor environmental conditions. Anarse (1995) in their studies observed above average stability for ICTP 8203 for this character. Hybrids, RHRB 2A x 9611 and 9607A x RHRBI 458 had higher mean with regression coefficient near to unity ($bi = 1$) and non-significant S^2di indicating average stability and wider adaptability for this trait Tyagi (1987) noticed linear regression was significant for 500-grain weight. Mungse (1987) and Rasal (1992) noted higher non-linear portion of G x E interaction than linear for 1000-grain weight Kumar *et al.* (1982 a) and Suryavanshi (1989) reported that the magnitude of linear component was higher than non-linear component

vi) Grain yield per plant

Although 30 out of 49 genotypes studied produced higher grain yield than population mean (38.90 g/plant), twenty four exhibited significant non-linear response, (Table 5, Fig. 17) thereby making them unstable for grain yield due to presence of high G x E interaction Six genotypes produced higher

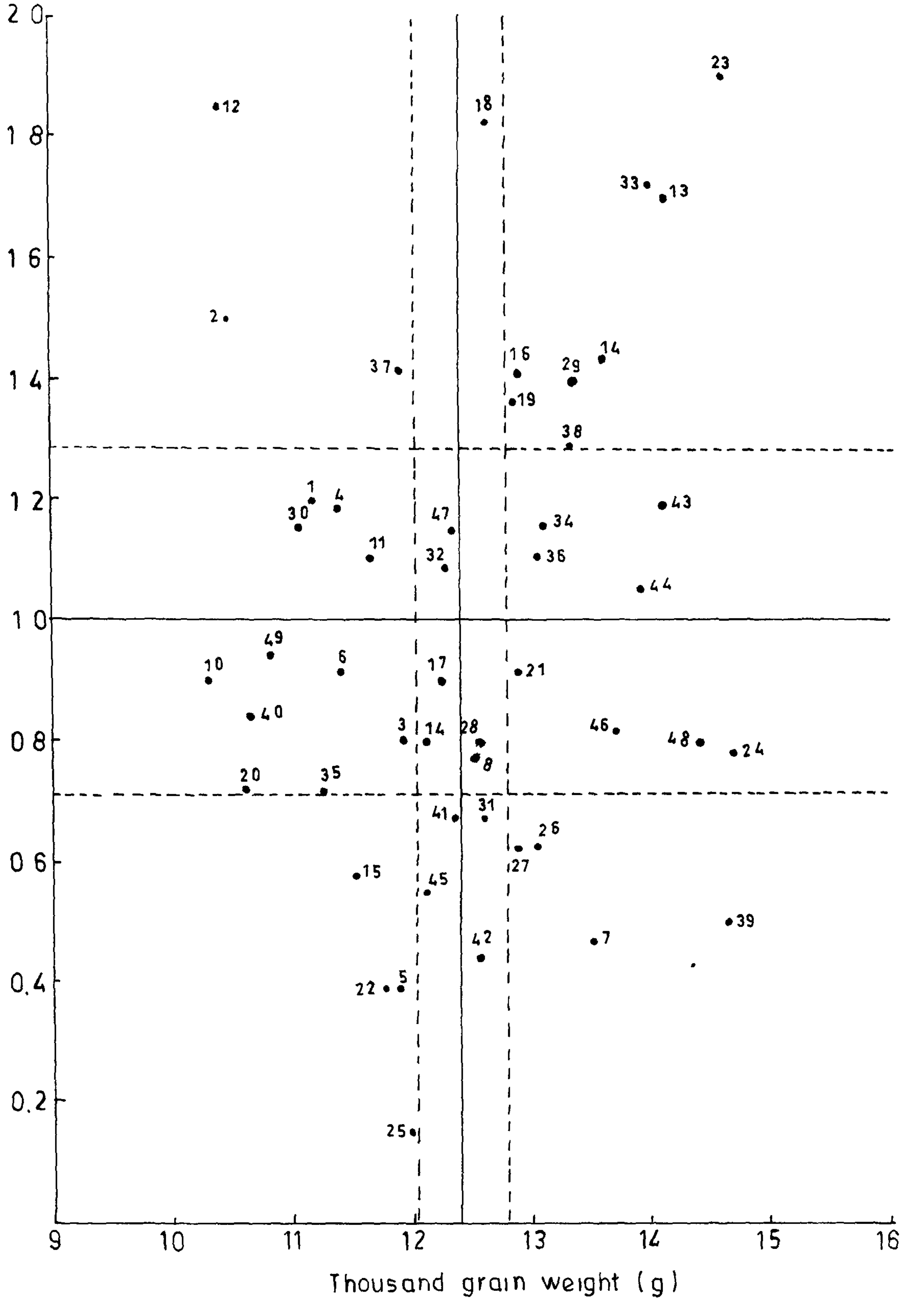
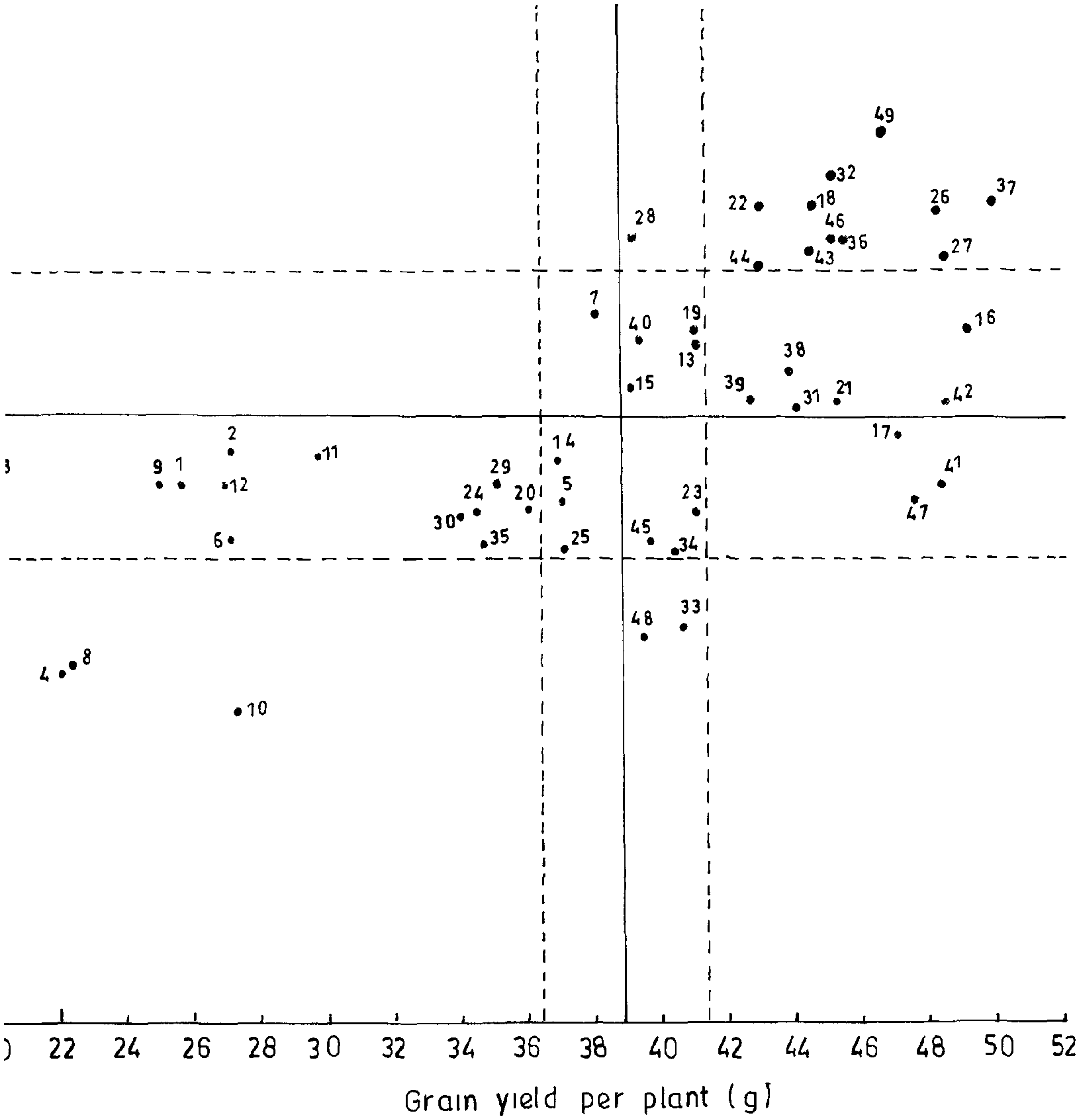


Fig. 16 Relation of thousand grain weight and stability

grain yield than the population mean with non-significant deviation from regression (S^2di) The female 9605A had high mean (37.10 g) among the parents with regression coefficient less than unity ($bi < 1$) and non-significant S^2di suggesting above average stability and its specific adaptability to poor environmental conditions Hybrid check MLBH 267 had higher mean than population mean, significantly greater bi value indicating their responsiveness to favourable environmental changes. The hybrids RHRB 1A x RHRBI 178 and 9606A x 9611 had higher mean with regression coefficient near to unity ($bi = 1$) and *non-significant* S^2di *indicating average stability and wider adaptability* for grain yield Hybrids, RHRB 1A x RHRBI 138, RHRB 2A x RHRBI 138, RHRB 2A x 9612 and 9606A x RHRBI 178 had higher mean with above average response ($bi > 1$) and non-significant deviation from regression indicating their suitability under favourable environmental conditions.

Singh and Gupta (1978) observed large portion of G x E interactions due to linear regression as the environmental means in pearl millet. Mungse (1987), Suryavanshi *et al.* (1991) and Karale (1994) found predominance of non-linear component of G x E interaction for grain yield. Rasal (1992) and Anarse (1995) noted higher linear portion of G x E interaction then non-linear for grain yield Pethani (1993) reported both linear and non-linear portion of G x E interaction in hybrid and parents for grain yield They emphasized that stability is important for newly developed parents at least for hybrid seed production and understanding the behaviour of parents under various environments. They further stressed that even with varying levels of responsiveness high proportion of additive gene interactions may be involved in determining high stability. It was evident from their study, that parent expressed greater range of both bi and S^2di for grain yield, which may be due to fixation of additive gene effects resulting from homozygosity and



. 17 Relation of grain yield per plant and stability complementary gene action, which indicated that genotypes can be isolated with the desirable level of responsiveness and stability in performance

Considering the stability parameters estimated for seventeen characters of each of the foruty nine genotypes, it was observed that, none of the genotypes was ideal with average adaptability for all the traits Pethani and Kapoor (1985) reported that utility of individual regression analysis was evident for the study of G x E interaction. However, it was found that one genotypes, 9606A x 9611 displayed stability for eight characters including grain yield per plant Among the females 9607A exhibited stability for seven and 9605A for three morpho-physiological characters. The hybrids RHRB 1A x RHRBI 138 and 9606A x RHRBI 458 showed stability for six, RHRB 2A x RHRBI 138, RHRB 1A x 9611, RHRB 2A x RHRBI 458, RHRB 3A x 9612, 9605A x 9612, 9606A x 9612 and 9607A x 9612 for five, RHRB 2A x 9611, 9606A x RHRBI 138 and MLBH 267 for four, RHRB 2A x 9612 and RHRB 1A x RHRBI 178 for three characters and hybrid 9606A x RHRBI 178 for grain yield per plant (Table 16). It is interesting to note that hybrids 9606A x 9611 and RHRB 2A x RHRBI 138 with higher mean performance and stability for grain yield, simultaneously also showed stability and high mean performance for harvest index and dry matter production at maturity. Similarly, hybrid RHRB 2A x 9612 showed high mean and simultaneous stability for grain yield, harvest index and number of grains/cm^2 while, hybrid RHRB 1A x RHRBI 178 exhibited stability for grain yield, dry matter production at maturity and number of effective tillers/plant with high mean performance However, male sterile line, 9605A expressed high mean performance among the parents with stability for grain yield and plant height Similarly, 9607A though did not show stability for grain yield/plant, exhibited high mean performance and stability for dry matter production at maturity, adaxial and abaxial stomatal densities, days to stigma emergence, number of effective tillers/plant, ear length and ear girth thus indicating their

Table 16. Stability performance of different genotypes for different morpho-physiological characters in pearlmillet

Sr No	Geno-types	No of traits	General adaptability	Specific adaptability to favourable environments	Specific adaptability to unfavourable environments
1	2	3	4	5	6
1	9606A x 9611	8	Grain yield/plant, plant height, fodder yield/ plant and ear girth	Harvest index	DMP II, ear length and No of grains/cm^2
2	9607A	7	DMP II, adaxial and abaxial stomatal density and days to stigma emergence	No of effective tillers/plant	Ear length and ear girth
3	RHRB 1A x RHRBI 138	6	Days to stigma emergence	Grain yield/plant, fodder yield/ plant, ear girth and 1000-grain weight	Ear length
4	9606A x RHRBI 458	6	Adaxial stomatal density	Ear length	Abaxial stomatal density, harvest index, ear girth and 1000-grain weight
5	RHRB 2A x RHRBI 138	5	DMP II and plant height	Grain yield/plant, harvest index and 1000-grain weight	--
6	RHRB 1A x 9611	5	DMP II and No. of effective tillers/plant	Adaxial stomatal density and ear girth	Abaxial stomatal density
7	RHRB 2A x RHRBI 458	5	Ear length	Harvest index and No of effective tillers/plant	Days to stigma emergence and ear girth

Table 16. Contd ....

1	2	3	4	5	6
8	RHRB 3A x 9612	5	Days to stigma emergence, ear length and ear girth	No of effective tillers/plant	1000-grain weight
9	9605 A x 9612	5	No.of grains/cm^2 and days to stigma emergence	Harvest index	Ear length and ear girth
10	9606 A x 9612	5	-	No.of grains/ cm^2	Harvest index, fodder yield/ plant, ear length and ear girth
11	9607 A x 9612	5	Harvest Index, plant height, No of effective tillers/plant and ear girth	-	Fodder yield/ plant
12	RHRB 2A x 9611	4	No of effective tillers/plant, ear girth and 1000-grain weight	AGR between flowering and maturity	-
13	9606 A x RHRBI 138	4	DMP II	1000-grain weight	Ear length and ear girth
14	MLBH 267	4	Ear length	No of effective tillers/plant and harvest index	Abaxial stomatal density
15	RHRB 2A x 9612	3	-	Grain yield/plant, harvest index and No. of grains/cm^2	-
16	RHRB 1A x RHRBI 178	3	DMP II and grain yield/plant	No. of effective tillers /plant	-
17	9605A	3	Days to stigma emergence and plant height	-	Grain yield/plant
18	9606 A x RHRBI 178	1	-	Grain yield/plant	-

importance in utilization for development new hybrids It is therefore, suggested that the extent of variability and stability existed in the present material may profitably be utilized in future breeding programme so as to develop stable hybrid/population having morpho-physiological complementation

5.3 Heat unit requirement

Information on heat unit requirement is useful in estimating accurate flowering times regardless of planting dates for synchronizing flowering time for breeding and seed production Every crop species is known to require definite number of heat units for flowering and maturity irrespective of environments, if temperatures do not exceed the optimum requirement In the present study heat requirement for male sterile lines, restorers and hybrids studied have been discussed in brief as given below

The average heat units required for days to stigma emergence (flowering) were high in E1 (474) followed by E6 (442), E2 (435), E3 (411), E5 (350) and E4 (274). However, the average heat unit required from sowing to maturity was 777 in E1, 731 in E2, 653 in E3, 675 in E5 and 783 in E6 The genotypes in E1 and E6 had near to similar heat unit requirement Similar observation were also noted in case of E3 and E5 environments upto maturity. Relatively lower heat unit requirement was noted in E4 (578)

Considering the heat unit requirement of individual genotypes it was revealed, that parents RHRB 5A (464 in E1 and 465 in E2), RHRBI 458 (532 in E1 and 528 in E6), RHRB 3A (416 in E2 and 418 E3), 9605A (407 in E2 and 403 in E6), 9611 (439 in E3 and 441 in E5), RHRB 2A (406 in E3 and 407 in E6) and 9607A (387 in E3 and 386 in E6) accumulated around same number of heat units from sowing to days stigma emergence As regards to hybrids, 9605A x 9611 and 9607A x 9611 in E1 and E6, RHRB 3A x RHRBI

458, RHRB 3A x RHRBI 178, 9606A x RHRBI 458 and 9606A x 9611 in E2 and E3, RHRB 3A x RHRBI 138, RHRB 3A x 9611, 9605A x RHRBI 138 and 9606A x RHRBI 178 in E2 and E6 and RHRB 1A x 9612, RHRB 2A x RHRBI 458, RHRB 2A x 9612 and 9607A x RHRBI 178 in E3 and E6 required almost similar number of heat units for days to stigma emergence. Similarly, parents 9606A (773 in E1 and 770 in E6), RHRBI 178 (753 and 750) and 9612 (850 and 845) in E1 and E6, respectively, RHRBI 138 (759 in E2 and 753 in E5), 9606A (651 and 647) and 9607A (633 in E3 and 628 in E5, respectively) accumulated more or less constant number of heat units from sowing to maturity. Hybrids 9605A x RHRBI 138 759 (E1), 754 (E6) and 642 (E3), 639 (E5) and 9605A x RHRBI 458 779 (E1), 775 (E6) and 669 (E3), 675 (E5) required more or less identical heat units from sowing to maturity, while hybrids, RHRB 3A x 9611, 9606A x RHRBI 458 and 9607A x 9612 in E1 and E6, RHRB 1A x RHRBI 138, RHRB 5A x RHRBI 178, and 9607A x RHRBI 458 in E3 and E5 showed almost equal number of heat units from sowing to maturity, indicating the possibility of estimating accurate time of days to stigma emergence/maturity in above genotypes in respective environments.

The hybrids RHRB 2A x 9611 and RHRB 5A x RHRBI 178 accumulated constant heat units from sowing to maturity in E1 and E6 environments (781 and 773, respectively) indicating that these hybrids did not interact much with these environments, showing their insensitivity for maturity in E1 and E6 environments. The rest of the genotypes did show differential interaction with environments as regards to days to stigma emergence and maturity Differences in heat unit requirements during *kharif* and summer season for pearl millet were noted previously at ICRISAT (Anonymous, 1978). Mungse (1987) also observed variation among genotypes in heat unit requirement for flowering and maturity during different growing season. He also observed that some of the genotype required consistent heat unit from sowing to flowering and maturity as observed in present investigation in some environments. Choi *et al.* (1990) reported that days to heading decreased with ate sowing date but growing degree days remained relative constant.

The male sterile line RHRB 5A and pollinator RHRBI 458 required more number of heat units for days to stigma emergence and maturity in all the environments, indicating their more sensitivity to temperature fluctuation. Comparatively less number of heat units accumulated by the female RHRB 3A in E1 and E2 and male parent 9611 in E3 for days to stigma emergence and maturity but more in the remaining environments as compared to other parents. Therefore, these parents seems to be most thermosensitive. The female parent, 9607A and male parent RHRBI 178 and hybrids based on these parents required less number heat units for days to stigma emergence and maturity in different environments as compared to other genotypes suggesting their less sensitivity to temperature changes. Similarly hybrids i.e. RHRB 1A x RHRBI 178, RHRB 2A x RHRBI 178, RHRB 3A x RHRBI 178, RHRB 5A x RHRBI 178, 9605A x RHRBI 178, 9606A x RHRBI 178 and 9607A x RHRBI 178 involving RHRBI 178 also showed less number of heat requirement and thereby segregating

The variation in heat unit requirements for days to stigma emergence and maturity in different environments may mainly be attributed to different genetic make up of the genotypes. In E3 high differences in day and night temperature might have affected the heat unit accumulation prevailed during September and October (maximum 30.8°C and minimum 13.7°C) Arnold (1960) pointed out that when minimum temperature falls below the base temperature, the heat unit value is no longer accurate.

Considering all the environments under study, RHRBI 178 (685) required lesser number of heat unit among the male parents It is interesting to note that all the crosses which involved RHRBI 178 (Table 17) as one of the parent also required lesser number of heat unit upto maturity. Similarly, RHRB 5A which required highest heat unit among the female parents involved in the crosses having higher unit requirement upto maturity (Table 18).

The data presented in Tables 17 and 18 clearly lead to conclude that through systematic breeding programme, hybrids which requires less number of heat units or those possess stability in respect to heat unit requirements, could be developed by involving appropriate male and female parents

5.4 Heat Unit Efficiency

Crop production mainly depends upon the climatic requirements of a particular crop. Temperature affects the growth of plants in numerous ways, from germination of seed to maturity of the crop by influencing various physiological processes including photosynthesis and respiration. Crop productivity was reported to be inhibited at temperature higher than optimum (Gilmore and Rogers, 1958). The efficiency of temperature utilization or heat use varies depending upon the variety and also environments.

In the present study, average heat units efficiency for DMP at days to stigma emergence was high in E4 followed by E5, E1, E2, E6 and E3. However, at maturity average heat unit efficiency for dry matter production was also high in E4 which was followed by E1, E5, E2, E6 and E3. The higher HUE for dry matter production per plant in E4 suggesting that this environment was comparatively more efficient in conversion of absorbed heat into dry matter production than the other environments owing to efficient utilization of natural resources. Also had less number of heat unit requirement from sowing to days to stigma emergence and maturity (274 and 578, respectively). The

Table 17. Crosses and their parents having lesser heat unit requirement for maturity

Sr.No	Name of the cross	Heat unit requirement		
		Crosses	Female parent	Male parent
1	RHRB 1A x RHRBI 178	639	678	685
2	RHRB 2A x RHRBI 178	614	679	685
3	RHRB 3A x RHRBI 178	647	715	685
4	RHRB 5A x RHRBI 178	689	726	685
5	9605 A x RHRBI 178	647	670	685
6	9606 A x RHRBI 178	654	688	685
7	9607 A I x RHRBI 178	641	656	685
	Average	647	687	685

Table 18. Crosses and their parents having higher heat unit requirement for maturity

Sr No.	Name of the cross	Heat unit requirement		
		Crosses	Female parent	Male parent
1	RHRB 5A x RHRBI 138	744	726	762
2	RHRB 5A x RHRBI 458	752	726	773
3	RHRB 5A x RHRBI 178	689	726	685
4	RHRB 5A x 9611	752	726	785
5	RHRB 5A x 9612	718	726	761
	Average	731	726	753

environments *viz*, E1, E5 and E2 were also efficient in conversion of absorbed heat into dry matter production

The study of heat unit efficiency for dry matter production of individual genotypes revealed that female, 9605A was the most efficient in conversion of absorbed heat into DMP I in all the environments and over environment also except in E1 and E6, where the female 9607A was more efficient to convert absorbed heat to produce unit amount of dry matter production at days to stigma emergence. The male parent RHRBI 138 was observed to be more efficient in converting absorbed heat in DMP per plant at days to stigma emergence in E1, E2, E3, E4, E6 and also over environments Male parent, RHRBI 458 was best in E5 for conversion of absorbed heat into dry matter production per plant at days to stigma emergence

The hybrids 9607A x RHRBI 138 in E1, 9606A x RHRBI 458 in E2, 9606A x 9612 in E3, 9607A x 9611 in E4, RHRB 1A x RHRBI 138 in E5, and RHRB 3A x RHRBI 178 in E6 showed highest conversion of absorbed heat to produce unit amount of DMP per plant and over environments, hybrid RHRB 1A x 9611 was most efficient in conversion of absorbed heat into dry matter production per plant at days to stigma emergence. In general parents 9607A, 9606A, RHRBI 138, RHRBI 458 and 9611 gave more efficient hybrids for conversion of absorbed heat into dry matter production per plant at days to stigma emergence.

It is interesting to note that male sterile line 9607A accumulated less number of heat units from sowing to maturity among the parents also had highest HUE in E1, E2, E3, E4, E6 and over environments for DMP per plant at maturity, suggesting its higher efficiency in conversion of absorbed heat into dry matter production per plant at maturity. At E5 environment, male sterile line 9605A was efficient in respect of conversion of absorbed heat into dry matter number of heat units from sowing to maturity which show its highest ability to convert absorbed heat into unit amount of grain yield per plant in E3, E4, E5, E6 and also over environments (0.0220, 0 0630, 0 0456, 0 0317 and 0 0403, respectively) The inbred 9611 and 9612 were also efficient in conversion of absorbed heat into grain yield per plant in E1 (0.0500) and E2 (0 0423) environments, respectively.

The hybrids RHRB 1A x 9611, RHRB 5A x 9612, 9606A x 9612, 9605A x 9612, RHRB 3A x 9612 and RHRB 1A x 9612 showed their highest ability to convert absorbed heat to produce unit amount of grain yield per plant in respective environments The hybrid 9605A x 9612 showed its high ability of conservation of absorbed heat to produce unit amount of grain yield per plant over environments In general, parents, 9607A, 9606A, RHRB 2A, 9611 and 9612 showed their ability to produce hybrids processing higher efficiency in conversion of absorbed heat into grain yield per plant than the other parents.

The variation in heat unit efficiencies for dry matter and grain yield per plant in different environments might be mainly due to genetic make up of the genotypes In environments, E4, E5 and E6 the higher range in temperature was noted during January to May, 1997 having maximum and minimum temperature ranging between 27.1 to 39.1 and 6.7 to 20 8°C respectively, with more sunshine hours ranging between 7.5 to 11.2 hrs. In E1, E2 and E3 environments, due to narrow range in temperature i e. maximum 34.6 and minimum 16 4°C, prevailing during 15th June to 15th October, 1996 with less sunshine hours ranging between 0 8 to 8.7 hrs. (Appendix I) Niwas and Sastri (1995) reported that higher dry matter at vegetative and early reproductive stage might be due to greater absorbed photosynthetically active radiation and greater diurnal temperature range, higher air temperature and more sunshine hours leading to more per degree dry matter conservation.

Uchijma (1975) pointed out the HUE as a function of temperature utilization for productivity depends upon duration, ability to accumulate dry matter and climatic conditions prevailed during the cropping season. Jadhav *et al.* (1996) also suggested that heat unit efficiency can be used as a measure of crop efficiency for use under varying agro-ecological situations in pearl millet.

From the studies on heat unit efficiency for dry matter production at maturity, in general, it was observed that the crosses, RHRB 1A x 9611, RHRB 2A x 9611, RHRB 3A x 9611, RHRB 5A x 9611, 9605A x RHRBI 138, 9606 x 9611 and 9607A x 9611 displayed higher heat unit efficiency and most of the crosses involved 9611 as male parent. The thirteen crosses *viz.,* RHRB 1A x 9611, RHRB 3A x 9612, 9605A x 9612, RHRB 1A x 9612, RHRB 3A x 9611, 9605A x 9611, RHRB 2A x RHRBI 138, RHRB 5A x 9612, 9606A x 9612, RHRB 2A x 9612, RHRB 5A x 9611, 9606A x 9611 and 9607A x 9612 showing higher heat unit efficiency for grain yield per plant The most of these crosses involved either 9612 or 9611 as male parents. Considering data on heat unit efficiency for dry matter and grain yield production of hybrids, the male parent 9612 and 9611 and female parents 9605A and 9607A deserve due considering in future breeding programme.

5.5 Effect of photoperiod on flowering

Flowering is a complex phenotype which is the end result of numerous physiological and biochemical process within a plant. Pearl millet is primarily identified as quantitative short day plant (Bidinger and Rai, 1989). It hastens to flower under short day conditions and flowering is delayed under long day conditions. Pearl millet genotypes exhibit varying response to photoperiod (day length). Therefore, for increasing hybrid flexibility of traditional cultivars of pearl millet depends on strong sensitivity to photoperiod in order to regulate their time of flowering to the environment of their origin. Pearl millet being highly cross pollinated crop, their flowering behaviour of seed parents differs when they are sown at different locations or seasons due to their variable responses to day length and temperature. Two parents of the hybrid must flower simultaneously in order to harvest maximum seed yield If the two seed parents respond differently to the day length of seed production environment, their seed production is often problematic due to lack of flowering synchrony. Therefore, photoperiod sensitivity can be a major factor in hybrid seed production and also for breeding programme.

5.5.1 Delay in days to stigma emergence (flowering)

In the present investigation, all the male sterile lines, pollinator and their hybrid, were affected by photoperiod (day length) as they showed delay in flowering in all the environments over normal environment (E1) However, the crop sown during *kharif* environments i.e. E2 and E3 did not show much delay in flowering over normal day length. But, subsequently the crop sown in summer environments which received lower average photoperiod (12.16 to 13 08 h) against the normal average day length (13 36 h), thereby which resulted in much delay in flowering. The photoperiod was declined (Appendix I) during vegetative stage of the genotypes sown in E4 environment (12.16 h), there by further increase in delay in flowering These findings are similar to those reported by Suryavanshi *et al.* (1990) They observed that all the male sterile lines, and their maintainer flowered early in *kharif* as compared to summer season. Varieties expressed the variation in flowering time under photoperiod which varied from 11 to 12 h was reported by Das (1994) Short photoperiod can be an important factor in controlling the time to anthesis in millet, suggested by Hellmers and Burton,(1972). Maiti and Soto (1990) observed that decline in both temperature and photoperiod had drastic effect on phenology and yield potential of pearl millet cultivars. They also reported hat higher grain yield in July sowing experiment compared to other sowing date, could be related to a longer photoperiod (> 13 h), higher temperature and significant difference between day and night temperature. These observations are in conformity with the present investigations Relatively little effect of genotype or temperature on anthesis date at the 12 h. photoperiod was reported by Begg and Burton (1971). However, Belliard *et al.* (1979) observed that photoperiod sensitive 23 B did not flower with a photoperiod longer than 12 h

The study of delay in flowering of individual genotypes revealed that among the parents, RHRB 3A and RHRB 5A showed comparatively higher delay in flowering than rest of the parents, suggesting their differential photoperiodic response to different day lengths. The less photoperiodic response was noticed in case of RHRB 1A, RHRB 2A (except in E4) and 9606 A, indicating relatively its more insensitivity. Inbred, RHRBI 178 was the earliest to flower under normal (E1) day length and the consistent delay in flowering under different environments, showing its photoperiodic response. However, inbred, 9611 which was least sensitive in both *kharif* environment i.e. E2 and E3 was highly sensitive (delay in flowering) in summer environments i e. E4, E5 and E6, indicating its responsiveness to day length during summer conditions, and its insensitivity for *kharif* environments The inbreds, RHRBI 138 and RHRBI 458 also showed delay in flowering in summer environments. Therefore, these inbreds were found to be most sensitive to day length Inbred, 9612, exhibited consistently less delay in flowering under all the environments studied, suggesting its low sensitivity to day length which is useful in breeding programme.

Some of the parents and hybrids which required similar number of days to flower under normal day length (E1), which showed differential period of delay in flowering under different environment day length for example, male sterile lines RHRB 1A and RHRB 5A flowered in 44.66 days under normal day length, but showed differential delay in flowering under different environment day length, suggesting different photoperiodic response between these two parents. Similar observations were also noticed by Bidinger and Rai (1989). Early flowering under field conditions dose not necessarily indicate photoperiod insensitivity. It can equally well result from hastening effects of high temperature or an inherently short vegetative growth period as reported by Talukdar *et al* (1993)

The hybrids, RHRB 1A x 9611, RHRB 2A x 9611, RHRB 3A x RHRBI 178, RHRB 5A x 9611, 9606A x 9611, 9607A x RHRBI 178 and 9607A x 9611 expressed more delay in flowering in all the environmental day lengths. Most of these crosses involved female parent either RHRB 3A or RHRB 5A or male parent 9611, which exhibited higher photoperiod sensitivity. The hybrids, RHRB 1A x RHRBI 138, RHRB 2A x RHRBI 458, RHRB 3A x RHRBI 458, RHRB 5A x 9612, 9605A x RHRBI 138, 9606A x RHRBI 458 and 9607A x 9612 displayed relatively less difference in flowering in different environments, suggesting their relatively low photoperiodic response, to day length Most of these crosses involved either male or female parent possessing relatively low, photoperiodic response.

From the data of delay in flowering over normal day length revealed that, some pairs of male sterile lines and pollinators, those are presented in Table 19 showed almost more or less constant number of delay in days to flowering during their respective environment indicating, the possibility of estimating accurate time of delay in flowering in the parents. These study also indicated that information of the photoperiodic response of

Table 19. Seed parents (male sterile line and pollinator) showing identical delay in flowering in respective environment

Sr.No.	Environment	Female parent		Male parent	
1	E2	RHRB 3A	(1.34)	RHRBI 178	(2 00)
2	E2	9606A	(-1.67)	RHRBI 458	(-1 67)
3	E2	RHRB 5A	(2.67)	RHRBI 178	(2.00)
4	E2	9606A	(-1.16)	9612	(-1.33)
5	E3	RHRB 1A	(-2 00)	9612	(-2.62)
6	E3	RHRB 2A	(0.67)	RHRBI 138	(0.33)
7	E3	9605A	(0.00)	RHRBI 138	(0 33)
8	E3	9607A	(0.33)	RHRBI 138	(0.33)
9	E4	RHRB 2A	(29.00)	9611	(29.00)
10	E4	RHRB 2A	(29.00)	RHRBI 458	(29.66)
11	E5	RHRB 1A	(12.34)	9612	(11 33)
12	E5	RHRB 1A	(12.34)	RHRBI 458	(13 33)
13	E5	RHRB 2A	(11.67)	9612	(11 33)
14	E5	9605A	(13.66)	RHRBI 458	(13.33)
15	E5	9605A	(13.66)	RHRBI 178	(14.67)
16	E5	9607A	(13.67)	RHRBI 458	(13 33)
17	E5	9607A	(13.67)	RHRBI 178	(14.67)
18	E5	9606A	(12.00)	9612	(11 33)
19	E6	RHRB 2A	(2.00)	9612	(1 33)
20	E6	9605A	(4.00)	RHRBI 178	(3.67)
21	E6	9606A	(3.00)	RHRBI 178	(3 67)
22	E6	9607A	(4.00)	RHRBI 178	(3.67)
23	E6	RHRB 5A	(5.34)	RHRBI 458	(6 66)
24	E6	RHRB5A	(5 34)	9611	(6.67)

Figures in parentheses are delay in flowering (days).

arl millet parents is of great value to the breeder in planning crossing blocks d assisting producers of hybrid seed.

In general, hybrids based on parents RHRB 2A, 9605 A, 9612 d RHRBI 138 showed less delay in flowering and this can be used to velop low photoperiod sensitive hybrids. The hybrids involving, 9607A, HRB 3A, RHRB 1A and 9611 parents expressed more delay in flowering der different environment day length over normal. This study indicates, that increase in photoperiod increases the rate of progress towards hastening wering. Summerfield *et al.* (1985) reported that vernalization, long day and arm temperature hastened flowering in lentils but genotypes showed variation sensitivity to these factors. Longer photoperiod (> 13) and larger difference tween day and night temperature were associated with the days to flowering. his was also confirmed by Maiti and Soto (1990) in pearl millet. In contrast, arberry and Campbell (1984) found that as photoperiod increased from 13.5 15.5 h time taken to panicle initiation increased from 16 to 34 days in a pearl illet hybrid.

.5.2 Photoperiod sensitivity

Breeders can take advantage of photoperiodism to breed hotoperiod sensitive/insensitive genotypes. Low degree of photoperiod ensitivity is desirable to obtain potential yield of genotypes by adjusting ptimal photoperiod with natural day length So that crop could be harvested ith maximum yield within minimum number of days Optimal photoperiod is e critical photoperiod above which delay in panicle initiation is observed. In ther words, it is the threshold photoperiod above which the thermal time for anicle initiation will be influenced by photoperiod. Photoperiod sensitivity was efined as delay in flowering in artificial extended day length of 14.5 or 15.5 h, ver flowering under natural day length of 13.9 h. (Bidinger and Rai, 1989).

otoperiod sensitivity was calculated as the percentage delay in flowering der specific day length compared with the *kharif* normal (E1) day length

From the present study, parents and hybrids showed differential hotoperiod sensitivity. The photoperiod sensitivity was highest during E4 8.50) followed by E5 (31 07), E6 (9.08), E3 (-0.59) and E2 (-1 25). owever, under *kharif* environment day length, photoperiod sensitivity was egligible, suggesting that *Kharif* environments were much more favourable for rop growth This might be due to less difference in the average day length 13 15 to 13 36 h) and also longer photoperiod (> 13h) as suggested by Maiti nd Soto (1990) Among the genotypes, pollinator expressed relatively less hotoperiod sensitivity than the male sterile lines and hybrids in all the nvironments except E6 Considerable variation in sensitivity to day length mong the pearl millet was reported by Evans (1993). They also suggested at sensitivity and insensitivity still have a role in the adaptation in pearl millet.

If we consider individual genotypes, it was revealed that RHRB A, RHRB 3A, RHRBI 138 and RHRB-178 displayed higher photoperiod ensitivity among parents The male sterile lines 9606A in E2 and E4 and HRB 1A in E2, E3, E5 and E6, pollinator, 9611 which showed similar hotoperiod sensitivity in E2 and E3 and 9612 in E4, E5 and E6 environments ere relatively affected less photoperiod sensitive. RHRB 1A would be useful *kharif* as well as summer environments, while pollinator 9611 would be seful in *kharif* season and 9612 in summer environments for developing elatively higher photoperiod insensitive hybrids Similarly hybrids RHRB 1A x HRBI 178, RHRB 2A x RHRBI 178, RHRB 3A x RHRBI 178, 9605A x HRBI 178, 9606A x RHRBI 178 and 9607A x RHRBI 178 showed onsistently higher photo-sensitivity in all the environments, indicating that ese hybrids interacted differentially with day length in respect of days to owering It can be also seen that all these combinations involved inbred, HRBI 178 which was observed to be more photoperiod sensitive. The lower agnitude of photoperiod sensitivity in all the environments was noticed in ase of the hybrids, RHRB 1A x RHRBI 138, RHRB 2A x RHRBI 458, RHRB A x RHRBI 458, RHRB 2A x 9612, RHRB 5A x 9612 and 9606A x RHRBI 58 These combinations involved RHRB 2A, RHRB 5A, 9612 and RHRBI 458 arents possessing relatively less photoperiod sensitivity.

The study of photoperiod sensitivity of individual genotypes also ndicated that some parents showed identical photoperiod sensitivity in their espective environments (Table 20). The identical photoperiod sensitivity for ays to flowering during different environment day length, suggesting that the hotoperiod-insensitive hybrid suitable for cultivation in different environment ould be identified Bidinger and Rai (1989) also suggested that a low degree f photoperiod sensitivity is a requirement for broad adaptation in a pearl millet.

In general, male sterile lines, RHRB 1A, 9607A and RHRB 3A, roduced relatively more sensitive hybrid combinations, while, RHRB 5A and HRB 2A produced relatively less photoperiod sensitive hybrids The ombinations involving, pollinator, RHRB-178 and 9611 were more hotoperiod sensitive and some of those derived from RHRBI 138 and RHRBI 58 and 9612 were lesser photoperiod sensitive. This study suggested that arent having low-photoperiod sensitivity could be used to develop photonsensitive hybrid Bidinger and Rai (1989) also suggested that even the use f less sensitive male sterile line alone will provide some advantage to produce ybrids with minimum sensitivity. Talukdar *et al.* (1993) reported that hotoperiod insensitivity must be assessed by comparison of time to flowering n different day length Photoperiod sensitivity can be a major factor in hybrid eed production were noted previously at ICRISAT (Anonymous, 1996)

able 20. Male sterile lines and pollinators showing identical photoperiod sensitivity in different environments

Sr.No	Environment	Female parent		Male parent	
1	E2	9606A	(-3.71)	RHRBI 458	(-3.21)
2	E2	9606A	(-3.71)	RHRBI 138	(-4.62)
3	E3	RHRB 1A	(-4.47)	9612	(-5.00)
4	E3	9607A	(0.77)	RHRBI 138	(0 65)
5	E4	RHRB 1A	(53.00)	9611	(54.04)
6	E4	9605A	(56.58)	RHRBI 458	(57.03)
7	E4	9606A	(51.11)	9612	(49.37)
8	E4	9607A	(55.91)	9611	(54.04)
9	E5	RHRB 2A	(26.32)	RHRBI 458	(25.63)
10	E5	9606A	(26 66)	RHRBI 458	(25.63)
11	E6	RHRB 5A	(11.98)	9611	(12.43)
12	E6	RHRB 5A	(11.98)	RHRBI 458	(12.80)
13	E6	9606A	(9 30)	RHRBI 178	(8.87)
14	E6	9607A	(9.44)	RHRBI 178	(8.87)

Figures in parentheses are photoperiod sensitivity (%)

Each genotypes had its own genetic control for photoperiod and temperature response. It is assumed that sensitivity to photoperiod indicates that the thermal requirement of the genotypes have been met Likewise, it is assumed that the various degree of insensitivities indicate that the thermal requirements have been met only partially or perhpas not at all. It was with this idea of sensitivity to photoperiod in mind that the pearl millet genotypes included in this study were classified into sensitive and non-sensitive genotypes.

The variation in photoperiod sensitivity during different environments may mainly be attributed to ineffective delay in flowering This difference is not considered to be due to a difference in sensitivity but come about as a result of fact that the genotypes have different optimum photoperiod

During, summer environments (E4, E5 and E6), the lowest temperature prevailed during January to March, 1997 (minimum temperatures ranged from 6 7 to 15 1°C) and photoperiod varied from 11 22 to 12 39 h, as compared to *kharif* environments (Apppendix I). There was retardation of the vegetative and panicle initiation stage which could be attributed to an interaction between photoperiod and temperature, thereby, delay in flowering. Hellmers and Burton (1972) also reported that the effect of night temperature on photoperiod response of pearl millet is dependent both on the variety and on day temperature while day temperature were more important in determining length of floral period than they were in determing the time to reach floral initiation or anthesis The length of the reproductive phase is controlled by both temerperature and day length in sensitive crops as observed in present study, was also previously reported by Horie (1994). Ong (1983) pointed out that the ctual flowering time in pearl millet is also affected by ambient temperatures during the period between floral initition and flowering

The higher mean temperature during *kharif*, environments, hastened flowering time compared to that in summer environments, having ower temperature for longer period. These observations were in conformity with those reported by Das (1994). Also, during *kharif*, heavy clouds cover (sunshine hours ranged from 0 8 to 8 7 h) from June to September, 1996 reduces the effect of photoperiod Francis (1970) revealed that, physical day length may be used to predit plant response for different planting dates in given location When critical intensities of light and critical photoperiod which influence reaction in each crop species are known.

The effectiveness of low photoperiodic response in reducing location effects on flowering time will, therefore vary in different conditions For example with stable temperatures, but different photoperiod across environments photoperiodic response will be the major factor determining flowering time (Kowal and Kassam, 1978). If however, locations with longer photoperiod also have higher mean temperatures, flowering would occur earlier in such locations than would be predicted from day length response determined in a cooler environments as was observed in the present study Turner (1981) also disscussing the role of photoperiod sensitivity in drought adaptation, pointed out that this adptive mechanism had received very little attention in crop season

5.6 Correlation of characters and path-coefficient analysis

Knowledge of relationships among different morpho-physiological traits is of interest to the plant breeder as he would like to know how the improvement in one character may cause simultaneous changes in other characters However, in some cases knowledge of inter-relationships between different characters may be of only limited value because some direct and indirect effects may have profound influence on the associations. In such cases, path coefficient analysis will help in interpreting the associations more precisely by separating the correlation coefficients into components of direct and indirect effects The results of correlations and path coefficient analysis on seventeen characters as observed in different environments, are discussed separately

5.6.1 Correlation between different pairs of characters

Among the genotypic and phenotypic correlations of grain yield with sixteen other morpho-physiological characters, studied in E1, E2, E3 E4, E5 and E6 environments, significant and positive genotypic and phenotypic correlations were observed in all the environments with dry matter production at maturity, AGR between flowering and maturity, ear length and ear girth These characters except ear girth also showed significant and positive genotypic and phenotypic correlations among themselves uniformly in all the environments

Among these associations, consistent and high values of genotypic and phenotypic correlation coefficients (> 0.530) were obtained for associations of grain yield with DMP at maturity, AGR between flowering and maturity and ear length and moderate to high (r = 0.317 to 0 498) for ear girth The characters harvest index and fodder yield/plant showed significant and positive genotypic and phenotypic correlations with grain yield was noticed in all the environments except E5 and E4, respectively Other significant and positive genotypic and phenotypic associations with grain yield, noticed only in a few environments, were RGR between flowering and maturity in E1, E2 and E5 and plant height in E3, E5 and E6. It is significant to note that none of the characters involved in above associations showed negative 'r' value with grain yield in any of the environments. The genotypic and phenotypic correlations of grain yield with LAI and DMP at flowering were either positive and significant or non-significant in all the environments except in E2 at genotypic level, where it was negative though small in magnitude. However, grain yield was positively and significantly associated with 1000-grain weight in E3 and E6 The genotypic and phenotypic associations of grain.yield with number of effective tillers/plant was significant in E3 and E4 and non-significant in E1, E2, E5 and E6 environments

The correlation of grain yield with days to stigma emergence was negative and significant in E2, E3 and E6 and non-significant in E1, E4 and E5 both at genotypic and phenotypic level. The genotypic and phenotypic associations of grain yield with abaxial stomatal density was significant and negative in E4 and E5 In respect of the genotypic and phenotypic associations of grain yield with adaxial stomatal density, the 'r' values were mostly non-significant and negative or positive but smaller in magnitude in all the environments except in E5 (-0.512) and E6 (0.318) where correlation were significant only at genotypic level. The correlations of grain yield with number of grains/cm^2 were non-significant in all the environments both at genotypic and phenotypic level

Previous studies on correlation was mostly confined to one environment i e *kharif* season Phul *et al.* (1974) also noticed positive association of grain yield with tiller number, harvest index, plant height and ear head length in exotic and indigenous inbred lines Mukherji *et al.* (1982) studied 51 inbreds and observed positive association of grain yield with plant height, ear length, ear girth and 1000-grain weight. Reddy and Sharma (1982) observed positive association of grain yield with plant height and tillers/plant.

aveendran and Appadurai (1984) observed positive correlation of grain yield ith productive tillers/plant, panicle length and panicle girth in 53 inbreds. They lso noticed positive correlation of plant height with panicle length and girth. ndal and Gill (1984) observed positive association of grain yield with plant eight, effective tillers, ear length, and mutual association between days to 50 er cent flowering, effective tillers, plant height and earhead length. Manga *et l.* (1985) studied 30 genotypes and observed positive association of grain ield/plant with plant height and tillers per plant, while negative association of ield with days to ear emergence Mungse (1987) observed significant positive orrelations between grain yield and DMP at flowering and maturity, AGR, GR and NAR between flowering and maturity and 1000-grain weight during *harif, rabi* and summer seasons. Rao *et al.* (1987) studied twelve millet enotypes and observed significant positive association of grain yield with lant height, stem dry matter, length and weight of main earhead. They also bserved that tiller number, total leaf area and dry matter, test weight and arvest index positively correlated with grain yield.

Singh and Govila (1989) observed high positive correlation etween 1000-grain weight and grain yield. Patil (1994) indicated that grain eld possessed a high and positive association with effective tillers per plant hile moderate to high for earhead girth, earhead length and plant height. avale *et al.* (1995) studied diverse restorers, maintainers and white grain earl millets and observed that productive tillers were significantly and ositively associated with fodder yield and grain yield. They also noticed that e direction of correlation remained same, only magnitude differences were bserved and suggested that simultaneous selection for ear girth, ear length d fodder yield will be useful in improving grain yield. Balakrishnan and Das 995) observed strong positive correlation of grain yield with plant height, leaf ea, leaf number and earhead thickness. Poongodi and Palanisamy (1995) eported that grain yield per plant showed high positive and significant correlation with plant height, ear length, ear girth and total number of tillers Anarse (1995) observed that fodder yield per plant, plant height, ear length, ear girth, 1000-grain weight and number of total tillers per plant were strongly and positively associated with grain yield per plant and also among themselves in all the four environments studied.

For the associations of grain yield with, DMP at maturity, AGR between flowering and maturity and ear length the values of correlations coefficients were > 0.530 in all the environments. High magnitude of correlation coefficients uniformly in all the environments for these associations would be useful indirectly, for improvement in grain yield through selection as a result of expected correlated response. The 'r' values of grain yield with ear girth ranged between 0.317 to 0.498 also showing its stability though moderate in magnitude from environment to environment. The correlation coefficient values of grain yield with RGR between flowering and maturity, plant height, fodder yield/plant and harvest index ranged between 0.062 to 0.812 These data indicate that the values of associations were not uniforms in all the environments The magnitude of correlated response to selection would be different in different environments Any attempt to look for increase in 'r' value may not be desirable for all the associations but for certain associations like grain yield with fodder yield per plant and harvest index. The presence of such plasticity in 'r' value may provide more opportunity for better selection response

Environmental effects also influenced the association of some of the characters. Hence, correlation studies in different environments shall give better understanding of the association of the characters. This is revealed from the fact that grain yield was strongly correlated with DMP at maturity, GR between flowering and maturity, ear length and ear girth in all the nvironments, while characters like LAI and DMP at flowering, 1000-grain veight and number of effective tillers/plant showed strong positive association vith grain yield in some environment and negative in another. This suggested hat selection for grain yield through certain characters will be more lependable than others.

If we compare the 'r' values and their stability over environments vith the performance of different genotypes (discussed in 5.2.2) certain nteresting observations can be made. The magnitude of 'r' values of different ssociations of grain yield with DMP at maturity, AGR between flowering and naturity, harvest index, ear length, ear girth and fodder yield was different from nvironment to environment. These were also the characters, including grain ield, which in combination with one another or alone showed stability in five rosses (Table 15) Therefore, selection for DMP at maturity, AGR between flowering and maturity, harvest index, ear length, ear girth, and fodder yield per plant will not only ensure higher yield but also enhance chances of getting combinations which transgress beyond the better parents. Though association of grain yield with plant height, RGR between flowering and maturity and 1000-grain weight were positive (except 1000-grain weight in E4) but of moderate to low magnitude is of special significance to the breeder.

In most of the environments, correlations of 1000-grain weight with ear length, ear girth, fodder yield/plant and plant height were significant. However, it was encouraging to note that positive association of 1000-grain weight with above mentioned characters could be obtained through recombination

The other interesting associations were of grain yield with days to stigma emergence (flowering) and abaxial stomatal density The associations f grain yield with days to emergence of stigma was either negative and ignificant or non-significant in all the environments. The association of grain ield with abaxial stomatal density was non-significant in all the environments xcept E4 and E5, where it was significant and negative. Such significant egative correlation is desirable because the breeders are interested in high ield, low stomatal density and early flowering. In the present investigation, as discussed elsewhere, simultaneous stability for grain yield, and early days to emergence of stigma having low stomatal density in a genotypes was also observed. This indicates that early flowering can be combined with higher yields of transgressants Also stomatal densities (adaxial and abaxial) showed mostly significant and positive correlations with number of grains/cm^2 This signifies the importance of stomatal densities, as far as productivity per plant is concerned.

From the present study, it can be concluded that the improved plant type that expected to perform well in the environment under study (grain yield per plant basis) should possess high dry matter production at maturity, AGR between flowering and maturity, longer and thicker ears, higher 1000-grain weight, high fodder yield and high harvest index.

5.6.2 Genotypic path-coefficient analysis

Partitioning of genotypic correlations of grain yield into direct and indirect contribution through other variables shows that harvest index and dry matter production at maturity made appreciable positive and direct contribution to grain yield, consistently in most of the environments. The other components which had direct and consistent contribution towards grain yield but in a moderate to high magnitude, in *kharif* environments (E1, E2 and E3) were, RGR between flowering and maturity, harvest index, 1000-grain weight, number of effective tillers/plant and abaxial stomatal density. In summer environments (E4, E5 and E6) however, DMP, at maturity, fodder yield/plant, harvest index and 1000-grain weight contributed substantially directly to their correlations with grain yield

Under all the environments DMP at maturity showed higher values of positive direct effect on grain yield except in E2 and E6 (where AGR between flowering and maturity and fodder yield/plant were ranked first, respectively) Though DMP at maturity had negative direct effect on grain yield n E2, it showed significantly positive correlation which can mainly due to positive indirect effect *via* AGR between flowering and maturity, DMP at flowering, ear girth, number of grains/cm^2 and 1000-grain weight. The direct contribution of 1000-grain weight was small in magnitude to grain yield but positive in all the environments except E4. Ear girth made moderate to low contribution in E1, E2, E4 and E6. Leaf area index at flowering contributed positively and substantially to low in all the environments except E2 and E4, where it was negative The direct effect of ear length and number of grains/cm^2 were positive in E1 and E3 environments. Plant height made negligible direct contribution in E3 and E5

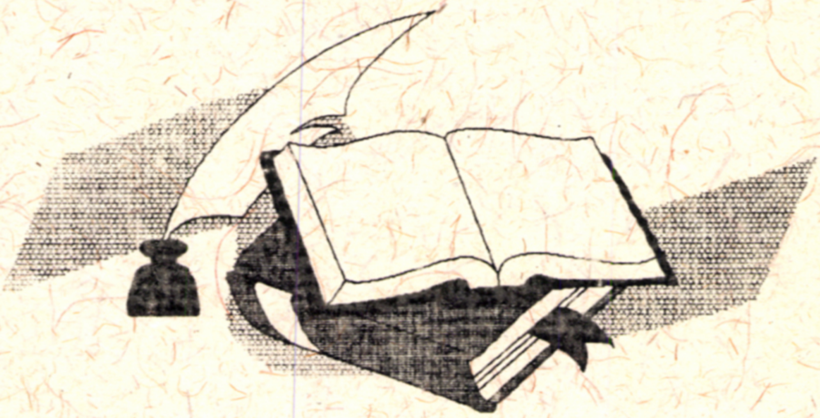
As regards the indirect contribution of the different component of grain yield, DMP at maturity contributed substantially through 1000-grain weight, ear girth, number of grains/cm^2, adaxial stomatal density and fodder yield/plant to its correlation with grain yield/plant. Similarly, indirect contribution of harvest index *via* ear length, plant height, DMP at flowering, RGR between flowering and maturity and abaxial stomatal density to the correlation of harvest index with grain yield was quite significant. Though 1000-grain weight had direct effect in smaller magnitude, its small associations with grain yield was contributed indirectly through adaxial stomatal density in all the environments and through fodder yield/plant, ear girth, DMP at maturity, LAI at owering, days to stigma emergence and number of grains/cm^2 in most of the nvironments The fodder yield/plant had direct effect in most of the nvironments, its association with grain yield was contributed indirectly *via* MP at maturity, ear girth, 1000-grain weight, LAI at flowering, number of rains/cm^2 and adaxial stomatal density. Relative growth rate between owering and maturity had direct contribution in moderate to higher magnitude, n all the environments except E4 and E6, its association with grain yield was ontributed indirectly through DMP at flowering and maturity, harvest index, number of effective tillers/plant, and days to stimga emergence plant height Abaxial stomatal density showed direct effect on grain yield in considerable amount in all the environments except E4 and E5 contributed *via* harvest ndex, DMP at flowering, AGR between flowering and maturity, and plant height n most of the environments. Number of effective tillers/plant contributed hrough harvest index in all the environments and through ear length, plant height, DMP at flowering and RGR between flowering and maturity in most of the environments

The direct contribution of LAI at flowering to its correlation with grain yield was moderate to low in all the environments except E2 and E4 Also, LAI at flowering contributed indirectly and positively to its correlation with grain yield through 1000-grain weight in all the environment and through DMP at maturity, fodder yield/plant, ear girth and number of grains/cm^2 in most of the environments Though plant height had negative direct effect on grain yield in four environment and positive in two, showed positive correlation with grain yield in all the environment. Similarly, indirect contributions to correlation of ear length with grain yield were appreciable in magnitude through DMP at maturity, 1000-grain weight, ear girth, fodder yield/plant and number of grains/cm^2 in most of the environments Also, the correlation of ear girth with grain yield in all the environments was contributed by DMP at maturity, 1000-grain weight, fodder yield/plant, and number of grains/cm^2 in most of the environments The direct contribution of the number of grains/cm^2 to grain yield was inconsistent. However, number of grains/cm^2 contributed positively to its correlation with grain yield through harvest index in all the environments and through DMP at flowering, abaxial stomatal density, ear length and plant height in most of the environments

From the path analysis of grain yield, it can be concluded that harvest index, number of effective tillers/plant, 1000-grain weight, RGR between flowering and maturity and abaxial stomatal density are the most important components of grain yield in all the *kharif* environments (E1, E2 and E3) These characters contributed directly and indirectly through each other to their correlation with grain yield Similarly, the characters, harvest index, DMP at maturity and fodder yield/plant were found to be important component of grain yield in most of the summer environments (E4, E5 and E6) The low residual effects in all the environments signifies that the characters chosen for path analysis are adequate and appropriate.

In most of the previous studies data of normal season was considered for path analysis. The importance of effective tillers per plant as component of grain yield was noticed previously by different workers (Phul *et al.,* 1974, Mukherji *et al*, 1982, Reddy and Sharma, 1982, Raveendran and Appadurai, 1984; Manga *et al.,* 1985; Baviskar, 1990; Hepziba *et al.,* 1993, Patil, 1994, Das and Balakrishnan, 1994 and Poongodi and Palanisamy, 1995) Harvest index contributed substantially to grain yield reported by Phul *et al.* (1974) and Rao *et al.* (1987) Importance of 1000-grain weight in the contribution to grain yield was observed by Mukherji *et al.* (1982), Hapse and Ugale (1988), Baviskar (1990), Patil (1994) and Anarse (1995). Positive direct effect of total dry matter on grain yield was noticed by Rao *et al* (1987) odder yield had high magnitude of direct effect with grain yield as reported by narse (1995) and Navale *et al.* (1995) Hapse and Ugale (1988) noticed that ant height had negative direct effect on grain yield, it showed positive orrelation, may be due to panicle girth, effective tillers and 1000-grain weight

From the studies on correlation and path analysis, in general, it an be inferred that, magnitude of the values of correlation and path coefficient ere found to influenced by change in environmental condition. The dry matter roduction at maturity, ear length, ear girth, harvest index, 1000-grain weight, odder yield per plant, AGR and RGR between flowering and maturity, abaxial tomatal density and number of effective tillers/plant the important grain yield ontributing characters. When we consider correlation, path analysis and tability together it is interesting to note that these above mentioned characters re the important component of grain yield and whenever there was stability for rain yield, there was simultaneous stability for one or more of these yield omponent Selection for one or more of these traits would be helpful in nprovement of grain yield of the genotype.



SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

The investigation entitled, "Phenotypic stability and association of orpho-physiological characters in pearl millet [*Pennisetum glaucum* (L.) R r.]" were undertaken during the period from 1995-1997 at Rahuri with a view o study (i) Phenotypic stability of different genotypes for important characters ii) isolate genotypes suitable for different seasons under consideration (iii) the eat unit requirement for flowering and maturity and effect of day length on lowering and (iv) association of grain yield and important characters

The details of material used and methodology adopted during this investigation have been described in chapter 3 in Material and Methods. Analysis of variance indicated the presence of genetic variability for all the characters

The studies on *per se* performance revealed that hybrids had in general, higher mean values than the corresponding parents for most of the characters with few exception Seasonal differences were very pronounced for all the characters Mean values for LAI at flowering, DMP at flowering and maturity and fodder yield/plant were high in E4 and E1 environments. Performance of genotypes was high for AGR and RGR between flowering and maturity, adaxial and abaxial stomatal densities, days to stigma emergence, plant height, harvest index, number of grains per cm^2, 1000-grain weight and grain yield during E1 and E2 as compared to other environments Flowering was substantially delayed during summer environments

Among the female parent 9607 A produced higher grain yield in *kharif* environments while, 9605 A exhibited higher grain yield during summer environments. The female parent 9607 A possessed bolder grains, was early in flowering, had longer and thicker ears, high dry matter production at maturity, igher LAI at flowering, high AGR and RGR between flowering and maturity, ow stomatal densities and higher fodder yield per plant. The parent 9605 A ad thicker ears, high dry matter production at flowering and maturity, high odder yield/plant and more number of grains/ cm^2 and showed relatively higher harvest index

The male parents 9611, 9612 and RHRBI 138 were found elatively more promising as they exhibited higher intensity of expression for ive or more important attributes. The hybrid combinations RHRB 1A x 9611, roduced higher grain yield in E1 and E6, RHRB 5A x 9612 in E2, 9606A x 9612 in E3, 9605A x 9612 in E4 and RHRB 3A x 9612 in E5, environments.

Considering the performance of in all the environments, 9605A x 9612, RHRB 1A x 9611, RHRB 3A x 9612, 9606A x 9612, RHRB 3A x 9611 and 9606A x 9611 were found to be superior in respect of grain yield. The hybrids showing higher performance of grain yield in different environments, have also displayed higher intensity of expression for one or more other morpho-physiological characters.

Growth analysis studies indicated that the genotypic differences or grain yield were mainly due to differences in faster leaf area development and its maintenance at higher level for a longer period, dry matter production at lowering and maturity, AGR between flowering and maturity, lower stomatal densities, high harvest index and one or more yield component like ear length, effective tillers, number of grains/ cm^2 and 1000-grain weight. Physiological components viz , LAI, DMP, AGR, stomatal densities and harvest index were more important in this respect

Genotype x environment (linear) was observed to be the mportant for LAI, DMP I, days to stigma emergence, plant height, fodder yield per plant, ear girth, number of grains/ cm^2 and 1000-grain weight.

The non-linear component of G x E interaction was found to be mportant for DMP-II, AGR, RGR, adaxial and abaxial stomatal densities, arvest index, number of effective tillers per plant, ear length and grain yield er plant.

The E1 environment i.e. sowing in 2nd week of June, was the most favourable, while E3 i e sowing in 1st week of August was poor as djudged from the data on environmental indices.

The female parent, 9607 A displayed average stability for DMP at maturity, adaxial and abaxial stomatal densities, days to stigma emergence, while it exhibited below average stability for number of effective tillers/plant and above average stability for ear length and ear girth. Female 9605 A showed stability for grain yield (high mean among the parents) under unfavourable condition and possessed average stability for days to stigma emergence 9606 A was found to possess average stability and wider adaptability for number of grains/ cm^2, however, it exhibited stability for days to stigma emergence under low yielding environments. The female RHRB 1A displayed average stability for days to stigma emergence, while RHRB 3A showed below average stability for number of effective tillers/plant.

The male parent RHRBI 138 exhibited stability for LAI at flowering and 1000-grain weight under favourable and unfavourable conditions, respectively, while it possessed average stability for fodder yield per plant The parents, 9611 and RHRBI 458 showed below average stability for number effective tillers/plant and adaxial stomatal density, respectively.

The hybrid combinations 9606A x 9611 and RHRB 1A x RHRBI 178 possessed wider adaptability, while RHRB 1A x RHRBI 138, RHRB 2A x RHRBI 138, RHRB 2A x 9612 and 9606A x RHRBI 178 exhibited suitability under favourable conditions for grain yield.

The hybrid 9606A x 9611 showed wider adaptability for fodder yield/plant, ear girth and plant height, suitability under favourable conditions for arvest index and suitability under unfavourable conditions for dry matter oduction at maturity, ear length and number of grains/ cm^2 Hybrid RHRB 1A RHRBI 178 displayed wider adaptability for dry matter production at maturity nd adaptability under favourable conditions for number of effective llers/plant

The cross combination RHRB 1A x RHRBI 138 possessed wider daptability for days to stigma emergence, suitability under favourable onditions for ear girth, 1000-grain weight and fodder yield per plant and uitability under unfavourable condition for ear length While, RHRB 2A x 9612 isplayed suitability under favourable environments for harvest index and umber of grains/ cm^2

Hybrid RHRB 2A x RHRBI 138 showing wider adaptability for DMP at maturity and plant height, also showed adaptability under favourable condition for harvest index and 1000-grain weight

None of the genotypes was found to be ideal with wider adaptability for all the characters.

Genotypes showing wider adaptability or suitability under favourable or unfavourable conditions for grain yield and fodder yield also showed stability simultaneously, for one or more yield components It can, therefore, be suggested that while making selection attention should be paid to the phenotypic stability of the characters associated with the grain yield.

The crosses showing stability for grain yield and its important components involved one or both of its parents possessing stability for grain yield and one or more yield attributes

From the studies on *per se* performance and stability analysis, it an be concluded that the female parents viz , 9605 A, 9606 A and 9607 A and e male parents 9611, 9612, RHRBI 178 and RHRBI 138 are promising and eserve due consideration in future breeding programme. The crosses btained by using these parents, would prove to be the potential combinations nd need to be assessed further for their performance in future.

Heat unit requirement studies indicated that there was variation in eat unit requirement of pearl millet for flowering and maturity during *kharif* nd summer environments. Average heat units accumulated were 474, 435, 11, 274, 350 and 442 from sowing to flowering and 777, 731, 653, 578, 675 nd 783 from sowing to maturity during E1, E2, E3, E4, E5 and E6 nvironments, respectively.

The genotypes recording consistent heat unit requirement from owing to flowering and maturity during two different environments were dentified None of the genotypes showed constant heat unit requirements for lowering and maturity in all the different environments.

Parents RHRB 3A, RHRB 5A and RHRBI 458 were observed to e the most thermosensitive genotypes. The female parent 9607 A and male arent RHRBI 178 were found to be less sensitive to temperature changes. Through systematic breeding programme, hybrids which require less number of eat units or those possess stability in respect of heat unit requirement, could e developed by involving appropriate male or female parents

The efficiency of temperature utilization or heat use varies, depending upon the genotypes and also environments. Average, heat unit efficiency was higher in E4 environment for dry matter at flowering and maturity d grain yield. This sowing date was comparatively more efficient in onversion of absorbed heat into dry matter production and grain yield

Female parents, 9607 A and 9605 A were found to be more fficient for utilization of absorbed heat to produce unit amount of dry matter nd grain yield

Male parent RHRBI 138 and RHRBI 178 were found to be most fficient in respect of conversion of absorbed heat into dry matter production at naturity The former was superior in respect of production of dry matter at lowering, while latter showed its highest ability to produce unit amount of grain ield, utilizing absorbed heat.

The high dry matter accumulation, heat unit requirement and heat se efficiency could be related to the comparatively higher mean temperature.

From the studies of heat use efficiency, in general it could be concluded that the parents, 9607 A, 9606 A, RHRB 2A , RHRBI 178, 9611 and 9612 have ability to produce hybrids possessing higher efficiency in conversion of absorbed heat into dry matter and grain yield production. The crosses obtained by using one or both of these parents need to be carefully assessed further for their performance In general, it was observed that the parents having high heat unit requirement and heat unit efficiency produced hybrids with high utilization of absorbed heat i.e. produced high grain yield.

All the genotypes showed difference in their response to day length as they showed delay in flowering in all the environments. Delay in flowering was very less during *kharif* environments, while more during summer environments The male sterile lines and pollinators showing identical delay in flowering i.e. having synchronization of flowering in same environments were identified

Female parents RHRBI 1A, RHRBI 2A and 9606 A and male arent 9612 were observed to be less sensitive to photoperiod, the inbred 611 *was found to be insensitive for kharif* environmental day length.

The hybrid derived from one of the parents RHRB 2A , 9605 A, 612 and RHRBI 138 showed less delay in flowering and need to be assessed rther for their performance in future.

Effect of photoperiod on flowering also studies showed that there vas differential photoperiod sensitivity in different environments *Kharif* nvironments were most favourable for crop growth as photoperiod sensitivity vas meagre The pollinator expressed relatively lower photoperiod sensitivity han male steriles and hybrids in most of the environments. The seed parents showing more or less similar photoperiod sensitivity in same environment were identified The photo-insensitive hybrids suitable for cultivation in different environment were also identified.

Female RHRB 1A showed relatively less photoperiod sensitivity in *kharif* as well as summer environmental day length. Pollinator, 9611 and 9612 displayed relatively less photoperiod sensitivity for *kharif* and summer environments, respectively.

This study suggest that parent having low photoperiod sensitivity could be used to develop photo-insensitive hybrid The photoperiod sensitivity/ response can give an idea about planting schedules of seed parents in cross pollinated crop like pearl millet for synchronizing the flowering time for breeding and seed production programme.

In all the environments, the values of genotypic and phenotypic correlation coefficients of grain yield with dry matter production at maturity, AGR between flowering and maturity and ear length were high (> 0.530) and oderate to high (0 317 to 0 498) with ear girth All these characters were also ositively correlated among themselves

Harvest index, fodder yield/plant, plant height and RGR between owering and maturity showed significant and positive genotypic and henotypic association with grain yield in only some of the environments.

The genotypic and phenotypic associations of 1000-grain weight vith ear length, ear girth, fodder yield/plant, plant height, DMP I and DMP-II vere positive and significant in certain environments These associations are of special significance to the breeder as it is excepted to bring about good genetic advance in grain yield.

Significant and negative association of days to stigma emergence and non-significant or negative abaxial stomatal density with grain yield was observed in certain environments. This would be useful to pick up early flowering, low stomatal density and high yielding genotypes.

Improvement in componental characters including dry matter production at maturity, AGR, ear length, ear girth and fodder yield, through selection is expected to result in the improvement of single plant yield as a result of expected correlated response because genotypic and phenotypic associations of these characters with grain yield were significant and high

The correlation study shows that as for as productivity per plant is concerned an improved plant type should have high dry matter production at maturity, high AGR between flowering and maturity, longer and thicker earhead, higher 1000-grain weight, high fodder yield/plant and high harvest index

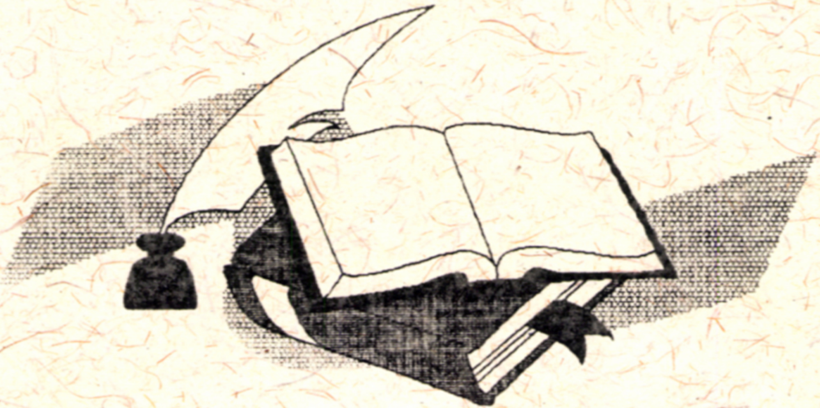
Partitioning of genotypic correlations of grain yield into direct and idirect effects shows that harvest index and dry matter production at maturity iade appreciable positive and direct contribution to grain yield in most of the nvironments

Harvest index, 1000-grain weight, RGR, number of effective illers/plant and abaxial stomatal density in *khanf* environments (E1, E2 and 3), while DMP at maturity, fodder yield/plant and harvest index in summer nvironments (E4, E5 and E6) had moderate to small direct effects Their ositive correlation with grain yield was contributed substantially and indirectly ia ear length, ear girth, DMP I, AGR, number of grains/ cm^2, adaxial stomatal ensity and plant height in most of the environments

From the studies on correlation and path analysis, in general, it can be concluded that, magnitude of the values of correlations and path coefficient were found to be influenced by changes in environmental conditions

Dry matter production at maturity, ear length, ear girth, harvest index, 1000-grain weight, fodder yield per plant, AGR and RGR between flowering and maturity, abaxial stomatal density and number of effective tillers/plant *are the important grain yield contributing characters. Selection for* one or more of these traits would be helpful in improvement of grain yield of the genotype

When we consider the studies on correlation, path and stability analysis together, the above mentioned traits seems to the important component of grain yield and whenever, there was stability for grain yield there was stability for one or more of these yield components.



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*** Originals are not seen.**

APPENDICES

8. APPENDICES

Appendix-I Rainfall, temperature, humidity, open pan evaporation, sunshine hours and day length during crop growth period in 1996-97 at Central Campus, MPKV, Rahuri

Meteo week	Dates	Rainfall (mm)	Temperature (°C)		Humidity (%)		Open pan evaporation (mm)	Sunshine hours (hrs)	Daylength (hrs)
			Maximum	Minimum	Morning	Evening			
1	2	3	4	5	6	7	8	9	10
June, 1996									
23	4-10	28 8	37 8	23 6	78	38	10 1	9 0	13 43
24	11-17	27 1	34 6	23 2	88	54	7 0	6 1	13 45
25	18-24	10 9	32 4	23 0	79	60	8 5	7 4	13 46
26	25-1	-	33 0	23 0	79	49	8 9	8 7	13 45
July, 1996									
27	2-8	65 8	32 9	19 5	88	66	6 8	6 4	13 42
28	9-15	7 4	31 4	23 3	89	63	4 7	4 7	13 39
29	16-22	3 0	30 8	22 6	85	71	5 2	2 6	13 35
30	23-29	4 4	28 1	21 2	85	71	4 1	0 8	13 30
31	30-5	3 2	30 4	21 6	86	63	5 6	3 8	13 24
August, 1996									
32	6-12	11 6	29 3	21 7	89	73	4 7	2 2	13 18
33	13-19	11 3	30 4	22 3	87	61	5 4	4 5	13 11
34	20-26	41 5	30 1	21 3	86	60	5 3	4 5	13 03
35	27-2	39 0	28 4	20 8	90	40	3 3	2 6	12 56
September, 1996									
36	3-9	56 8	29 8	21 1	89	65	3 7	4 2	12 48
37	10-16	102 9	30 0	21 5	88	66	4 4	5 7	12 40
38	17-23	30 0	30 5	20 2	87	54	4 9	7 6	12 31
39	24-30	6 6	30 8	20 6	87	56	4 5	6 3	12 24
October, 1996									
40	1-7	115 9	29 5	20 8	89	66	4 4	5 0	12 16
41	8-14	-	30 4	16 4	81	38	4 4	8 0	12 08
42	15-21	6 2	30 6	15 6	82	41	4 4	8 8	12 02
43	22-28	203 8	29 1	19 9	89	65	2 9	8 4	11 53
44	29-4	4 5	29 1	13 7	84	32	3 6	9 0	11 47
November, 1996									
45	5-11	4 5	29 1	14 4	83	43	3 8	8 2	11 38
46	12-18	-	29 2	12 7	79	39	3 8	9 8	11 34
47	19-25	-	29 5	10 6	84	34	3 1	9 6	11 30
48	26-2	-	29 6	9 9	80	28	3 3	9 7	11 26

Appendix-I. Contd ...

1	2	3	4	5	6	7	8	9	10
December, 1996									
49	3-9	-	27 7	8 5	85	37	3 6	9 6	11 22
50	10-16	-	27 9	10 1	84	38	3 3	8 2	11 20
51	17-23	-	27 9	11 7	86	38	3 3	6 0	11 19
52	24-31	-	25 4	9 0	76	31	3 9	8 8	11 20
January, 1997									
1	1-7	-	27 6	9 0	79	34	3 8	8 6	11 22
2	8-14	11 7	27 1	11 5	87	49	3 5	7 5	11 25
3	15-21	-	27 1	10 2	85	48	3 8	8.6	11 29
4	22-28	-	27 1	6 7	82	27	4 1	10 1	11 34
5	29-4	-	29 5	9 3	82	37	5 1	10 0	11 39
February, 1997									
6	5-11	-	29 5	7 5	82	26	5 2	10 0	11 45
7	12-18	-	29 9	7 2	79	25	8 2	10 3	11 52
8	19-25	-	30 2	8 7	75	20	6 1	10 5	11 59
9	26-4	-	34 2	11 6	69	15	7 3	10.2	12 07
March, 1997									
10	5-11	-	34 7	13 6	65	19	7 0	9 5	12 16
11	12-18	-	35 9	14 7	65	19	7 9	10 1	12 24
12	19-25	-	34 6	13 3	65	23	8 9	9 6	12 30
13	26-1	-	35 3	15 1	69	35	8 9	10 0	12 39
April, 1997									
14	2-8	-	34 3	13 1	63	22	8 1	9 6	12 47
15	9-15	-	36 3	15 1	66	20	9 4	10 2	12 56
16	16-22	-	35 8	17 1	59	24	9 1	10 1	13 03
17	23-29	-	37 6	20 8	64	28	9.8	7 5	13 11
18	30-6	14 2	30 1	17 8	74	30	7 4	8 6	13 17
May, 1997									
19	7-13	-	37 8	18 6	62	24	10 4	10 6	13 24
20	14-20	-	39 7	19 7	63	20	12 2	11 2	13 30
21	21-27	-	39 1	18 5	72	22	12 2	10 8	13 35
22	28-3	0 5	36 8	19 6	75	29	10 9	10 5	13 39
June, 1997									
23	4-10	-	36 3	22 1	77	33	9 9	9 7	13 43
24	11-17	-	33 5	21 5	84	53	8 3	7 5	13 45
25	18-24	-	31 3	22 1	87	58	5 8	3 0	13 46
26	25-1	-	31 4	23 2	85	57	7 1	4 3	13 45

Appendix-II. symbols with their respective serial numbers used for different parents, hybrids and checks

Sr No	Symbol	Details of parent/hybrid/ check	Sr No	Symbol	Details of parent/hybrid/ check
1	I	RHRB 1A	26	III x 4	x 9611
2	II	RHRB 2A	27	III x 5	x 9612
3	III	RHRB 3A	28	IV x 1	RHRB 5A x RHRBI 138
4	IV	RHRB 5A	29	IV x 2	x RHRBI 458
5	V	9605A	30	IV x 3	x RHRBI 178
6	VI	9606A	31	IV x 4	x 9611
7	VII	9607A	32	IV x 5	x 9612
8	1	RHRBI 138	33	V x 1	9605A x RHRBI 138
9	2	RHRBI 458	34	V x 2	x RHRBI 458
10	3	RHRBI 178	35	V x 3	x RHRBI 178
11	4	9611	36	V x 4	x 9611
12	5	9612	37	V x 5	x 9612
13	I x 1	RHRB 1A x RHRBI 138	38	VI x 1	9606A x RHRBI 138
14	I x 2	x RHRBI 458	39	VI x 2	x RHRBI 458
15	I x 3	x RHRBI 178	40	VI x 3	x RHRBI 178
16	I x 4	x 9611	41	VI x 4	x 9611
17	I x 5	x 9612	42	VI x 5	x 9612
18	II x 1	RHRB 2A x RHRBI 138	43	VII x1	9607A x RHRBI 138
19	II x 2	x RHRBI 458	44	VII x 2	x RHRBI 458
20	II x 3	x RHRBI 178	45	VII x 3	x RHRBI 178
21	II x 4	x 9611	46	VII x 4	x 9611
22	II x 5	x 9612	47	VII x 5	x 9612
23	III x 1	RHRB 3A x RHRBI 138	48	-	ICTP 8203
24	III x 2	x RHRBI 458	49	-	MLBH 267
25	III x 3	x RHRBI 178			

						stomatal density	stomatal density	stigma emer-gence	height	yield/ plant	index	effective tillers/ plant			grains per cm^2	grain weight	yield/ plant
LAI	1 000	0 884**	0 678**	0 267	-0 504**	-0 513**	-0 467**	0 804**	0 553**	0 784**	-0 516**	-0 216	0 367*	0 573**	0 062	0 038	0 262
DMP I	0 832**	1 000	0 605**	0 096	-0 716**	-0 594**	-0 544**	0 708**	0 670**	0 691**	-0 498**	-0 252	0 402**	0 616**	-0 214	0 125	0 190
DMP II	0 611**	0 630**	1 000	0 851**	0 123	-0 124	-0 027	0 253	0 508**	0 942**	-0 076	-0 058	0 825**	0 581**	0 056	0 278	0 816**
AGR	0 241	0 155	0 863**	1 000	0 624**	0 224	0 314*	0 142	0 186	0 720**	0 242	0 103	0 761**	0 325*	0 215	0 261	0 901**
RGR	-0 477**	-0 657**	0 152	0 623**	1 000	0 640**	0 477**	-0 643**	-0 364*	-0 040**	0 549**	0 187	0 263	-0 221	0 272	0 158	0 477**
Adaxial stomatal density	-0 436**	-0 492**	-0 141	0 131	0 466**	1 000	0 932**	-0 531**	-0 446**	-0 157	0 235	-0 187	-0 119	-0 165	0 438**	-0 309*	0 067*
Abaxial stomatal density	-0 416**	-0 462**	-0 053	0 223	0 520**	0 925**	1 000	-0 445**	-0 213	-0 089	0 142	-0 218	-0 005	-0 076	0 439**	-0 095	0 089
Days to stigma emergence	0 725**	0 618**	0 195	-0 152	-0 586**	-0 478**	-0 410**	1 000	0 494**	0 259	-0 329*	-0 322*	0 030	0 585**	0 130	-0 073	-0 021
Plant height	0 498**	0 628**	0 476**	0 186	-0 326*	-0 413**	-0 210	0 467**	1 000	0 515**	-0 442**	-0 439**	0 612**	0 654**	-0 229	0 601**	0 115
Fodder yield/plant	0 705**	0 631**	0 864**	0 683**	-0 002	-0 121	-0 085	0 227	0 486**	1 000	-0 419**	-0 029	0 678**	0 409**	0 110	0 142	0 574**
Harvest index	-0 456**	-0 432**	-0 098	0 171	0 439**	0 185	0 148	-0 245	-0 401**	-0 387*	1 000	0 296	0 100	0 081	0 009	-0 082	0 508**
Effective tillers/plant	-0 215	-0 173	0 003	0 123	0 178	-0 160	-0 180	-0 226	-0 317*	-0 080	0 237	1 000	-0 159	-0 703**	0 040	-0 472**	0 146
Ear length	0 318*	0 394**	0 776**	0 722**	0 249	-0 099	-0 003	0 006	0 597**	0 670**	0 051	-0 122	1 000	0 575**	-0 305*	0 533**	0 733**
Ear girth	0 522**	0 552**	0 534**	0 314*	-0 181	-0 172	-0 086	0 560**	0 626**	0 379*	0 084	-0 498**	0 546**	1 000	-0 019	0 345*	0 487**
No of grains/cm^2	0 037	-0 194	0 058	0 205	0 253	0 386*	0 397**	0 134	-0 221	0 110	0 029	0 056	-0 286	-0 026	1 000	-0 570**	0 103
1000 grain weight	0 052	0 107	0 197	0 174	0 091	-0 158	-0 061	-0 095	0 499**	0 180	-0 179	-0 374*	0 475**	0 288	-0 497**	1 000	0 156
Grain yield/plant	0 225	0 228	0 784**	0 860**	0 442**	0 021	0 067	-0 025	0 108	0 505**	0 530**	0 176	0 668**	0 464**	0 107	0 043	1 000

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*, ** significant at P = 0 05 and P = 0 01, respectively

						density	density	emer-gence		plant		tillers/ plant					
LAI	1 000	0 784**	0 291	-0 133	-0 684**	-0 365*	-0 316*	0 858**	0 638**	0 386*	-0 374*	-0 334*	0 261	0 440**	0 021	0 174	-0 030
DMP I	0 774**	1 000	0 521**	0 004	-0 689**	-0 314*	-0 354*	0 455**	0 820**	0 599**	-0 620**	-0 376*	0 558**	0 480**	-0 342*	0 478**	-0 038
DMP II	0 326*	0 536**	1 000	0 856**	0 231	-0 341*	-0 440**	-0 176	0 800**	0 915**	-0 232	-0 288	0 907**	0 548**	-0 334*	0 590**	0 696**
AGR	-0 062	0 052	0 871**	1 000	0 688**	-0 209	-0 301	-0 482**	0 439**	0 708**	0 108	-0 113	0 726**	0 356*	-0 179	0 406**	0 842**
RGR	-0 619**	-0 663**	0 244	0 673**	1 000	-0 007	-0 056	-0 707**	-0 260	0 079	0 427**	0 183	0 140	-0 075	-0 010	-0 126	0 545**
Adaxial stomatal density	-0 317*	-0 283	-0 251	-0 131	0 025	1 000	0 894**	-0 121	-0 620**	-0 238	0 361*	0 165	-0 330*	-0 337*	0 614**	-0 057	0 026
Abaxial stomatal density	-0 269	-0 325*	-0 344*	-0 216	-0 016	0 890**	1 000	-0 028	-0 661**	-0 359*	0 301	0 042	-0 477**	-0 324*	0 661**	0 215	-0 093
Days to stigma emergence	0 808**	0 435**	-0 159	-0 440**	-0 669**	-0 118	-0 031	1 000	0 175	0 046	-0 287	-0 128	-0 201	0 098	0 231	-0 149	-0 342*
Plant height	0 611**	0 794**	0 733**	0 403**	-0 249	-0 589**	-0 631**	0 169	1 000	0 715**	-0 471**	-0 379*	0 752**	0 598**	-0 531**	0 461**	0 299
Fodder yield/plant	0 389*	0 585**	0 838**	0 649**	0 052	-0 199	-0 304*	0 033	0 670**	1 000	-0 482**	-0 272	0 804**	0 390*	-0 273	0 629**	0 455**
Harvest index	-0 339*	-0 566**	-0 245	0 042	0 349*	0 320*	0 254	-0 274	-0 429**	-0 450**	1 000	0 476**	-0 195	-0 139	0 612**	-0 339*	0 529**
Effective tillers/plant	-0 276	-0 320*	-0 225	-0 082	0 158	0 178	0 093	-0 122	-0 346*	-0 271	0 348*	1 000	-0 308*	-0 827**	0 175	-0 503**	0 119
Ear length	0 247	0 542**	0 840**	0 678**	0 130	-0 285	-0 432**	-0 192	0 739**	0 759**	-0 179	-0 265	1 000	0 641**	-0 457**	0 600**	0 600**
Ear girth	0 427**	0 468**	0 527**	0 355*	-0 056	-0 286	-0 271	0 100	0 580**	0 377*	-0 144	-0 690-**	0 624**	1 000	-0 166	0 291	0 326*
No of grains/cm^2	0 007	-0 298	-0 294	-0 170	-0 036	0 524**	0 540**	0 225	-0 485**	-0 251	0 545**	0 087	-0 426**	-0 162	1 000	-0 252	0 211
1000 grain weight	0 180	0 349**	0 387*	0 258	-0 091	-0 007	-0 091	-0 103	0 365*	0 469**	-0 194	-0 335*	0 469**	0 260	-0 229	1 000	0 241
Grain yield/plant	0 024	0 015	0 693**	0 813**	0 505**	0 063	-0 060	-0 326*	0 284	0 424**	0 517**	0 077	0 571**	0 320*	0 189	0 182	1 000

*, ** significant at P = 0 05 and P = 0 01, respectively

						density	density	emer-gence		plant		tillers/ plant					
LAI	1.000	0.891**	0.762**	0.452**	-0.521**	-0.576**	-0.442**	0.054	0.839**	0.814**	0.278	0.552**	0.734**	0.733**	-0.149	0.560**	0.605**
DMP I	0.876**	1.000	0.858**	0.512**	-0.619**	-0.471**	-0.316*	0.011	0.870**	0.880**	0.256	0.424**	0.829**	0.741**	-0.149	0.678**	0.683**
DMP II	0.732**	0.838**	1.000	0.881**	-0.164	-0.370*	-0.394**	-0.235	0.776**	0.945**	0.555**	0.663**	0.942**	0.669**	-0.072	0.739**	0.931**
AGR	0.412**	0.475**	0.878**	1.000	0.297	-0.186	-0.367*	-0.405**	0.493**	0.769**	0.691**	0.666**	0.810**	0.436**	0.014	0.613**	0.926**
RGR	-0.504**	-0.602**	-0.108	0.352*	1.000	0.359*	-0.050	-0.281	-0.502**	-0.252	0.345*	0.111	-0.189	-0.437**	0.144	-0.081	0.063
Adaxial stomatal density	-0.524**	-0.386**	-0.258	-0.078	0.336*	1.000	0.783**	-0.546**	-0.589**	-0.532**	0.247	0.040	-0.404**	-0.594**	0.373*	-0.327*	-0.085
Abaxial stomatal density	-0.418**	-0.288	-0.360*	-0.327*	-0.053	0.708**	1.000	-0.379*	-0.405**	-0.503**	0.019	-0.189	-0.555**	-0.363*	0.357*	-0.370*	-0.207
Days to stigma emergence	0.056	0.020	-0.205	-0.348*	-0.262	-0.461**	-0.342*	1.000	0.308*	0.017	-0.743**	-0.445**	-0.164	0.116	-0.272	-0.177	-0.518**
Plant height	0.824**	0.842**	0.737**	0.450**	-0.462**	-0.548**	-0.382*	0.294	1.000	0.880**	0.028	0.480**	0.691**	0.619**	-0.233	0.400**	0.523**
Fodder yield/plant	0.787**	0.807**	0.885**	0.721**	-0.188	-0.490**	-0.475**	0.018	0.843**	1.000	0.314*	0.621**	0.853**	0.633**	-0.317*	0.739**	0.768**
Harvest index	0.245	0.238	0.471**	0.548**	0.248	0.142	0.036	-0.656**	0.052	0.286	1.000	0.490**	0.471**	0.147	0.578**	0.365*	0.812**
Effective tillers/plant	0.474**	0.367*	0.509**	0.495**	0.059	-0.001	-0.156	-0.377*	0.432**	0.538**	0.378*	1.000	0.505**	-0.015	-0.133	0.245	0.653**
Ear length	0.705**	0.770**	0.864**	0.717**	-0.168	-0.354*	-0.504**	-0.156	0.667**	0.797**	0.453**	0.382*	1.000	0.731**	-0.005	0.639**	0.834**
Ear girth	0.673**	0.670**	0.606**	0.390*	-0.367*	-0.514**	-0.333*	0.100	0.595**	0.590**	0.185	0.007	0.693**	1.000	-0.053	0.562**	0.498**
No of grains/cm^2	-0.157	-0.151	-0.068	0.021	0.159	0.332*	0.348*	-0.254	-0.216	-0.289	0.497**	-0.178	-0.007	-0.018	1.000	-0.395**	0.216
1000 grain weight	0.483**	0.594**	0.636**	0.506**	-0.063	-0.277	-0.338*	-0.179	0.366*	0.607**	0.345*	0.167	0.569**	0.544**	-0.310*	1.000	0.657**
Grain yield/plant	0.571**	0.664**	0.903**	0.873**	0.065	-0.045	-0.173	-0.467**	0.502**	0.714**	0.785**	0.518**	0.783**	0.473**	0.188	0.587**	1.000

*, ** significant at P = 0.05 and P = 0.01, respectively

						stomatal density	stomatal density	stigma emer-gence	height	yield/ plant	index	effective tillers/ plant			grains/ cm^2	grain weight	yield/ plant
LAI	1 000	0 951**	0 587**	-0 005	-0 559**	-0 499**	-0 469**	0 634**	0 453**	0 330*	-0 016	-0 115	0 501**	0 333*	-0 111	-0 152	0 512**
DMP I	0 948**	1 000	0 517**	0 122	-0 638**	-0 442**	-0 377*	0 609**	0 537**	0 305*	-0 108	-0 111	0 431**	0 221	-0 119	-0 108	0 408**
DMP II	0 580**	0 526**	1 000	0 787**	0 311*	-0 481**	-0 612**	-0 175	0 399**	0 743**	-0 104	0 340*	0 685**	0 271	-0 171	-0 249	0 746**
AGR	-0 004	-0 105	0 791**	1 000	0 821**	-0 239	-0 438**	-0 642**	0 075	0 641**	-0 043	0 474**	0 484**	0 155	-0 113	-0 210	0 571**
RGR	-0 561**	-0 628**	0 307*	0 811**	1 000	0 140	-0 042	-0 888**	-0 247	0 273	0 047	0 468**	0 124	-0 044	0 002	-0 160	0 220
Adaxial stomatal density	-0 426**	-0 372*	-0 390*	-0 188	0 124	1 000	0 857**	-0 218	-0 559**	-0 446**	0 396**	-0 074	-0 351*	-0 233	0 555**	0 281	-0 160
Abaxial stomatal density	-0 395**	-0 318*	-0 527**	-0 388*	-0 053	0 817**	1 000	-0 177	-0 497**	-0 653**	0 252	-0 124	-0 528**	-0 228	0 517**	0 066	-0 366*
Days to stigma emergence	0 585**	0 569**	-0 166	-0 604**	-0 826**	-0 187	-0 149	1 000	0 280	-0 151	-0 003	-0 382*	-0 081	0 007	-0 055	0 055	-0 116
Plant height	0 443**	0 526**	0 390*	0 077	-0 236	-0 470**	-0 435**	0 268	1 000	0 528**	-0 373*	-0 258	0 555**	0 404**	-0 560**	0 136	0 062
Fodder yield/plant	0 319*	0 294	0 699**	0 605**	0 258	-0 386*	-0 561**	-0 147	0 503**	1 000	-0 566**	0 150	0 690**	0 254	-0 663**	0 294	0 233
Harvest index	-0 058	-0 136	-0 126	-0 049	0 078	0 306*	0 204	-0 031	-0 335*	-0 472**	1 000	0 176	-0 019	0 144	0 540**	-0 265	0 572**
Effective tillers/plant	-0 061	-0 074	0 330*	0 439**	0 417**	-0 021	-0 079	-0 372*	-0 218	0 158	0 211	1 000	-0 122	-0 551**	0 036	-0 642**	0 379*
Ear length	0 473**	0 399**	0 656**	0 480**	0 135	-0 298	-0 465**	-0 086	0 541**	0 671**	0 005	-0 060	1 000	0 770**	-0 511**	0 199	0 541**
Ear girth	0 292	0 204	0 272	0 171	-0 014	-0 171	-0 203	-0 005	0 363*	0 251	0 196	-0 395**	0 719**	1 000	-0 367*	0 226	0 317*
No of grains/cm^2	-0 125	-0 128	-0 211	-0 154	-0 012	0 440**	0 445**	-0 015	-0 503**	-0 608**	0 445**	-0 035	-0 499**	-0 332*	1 000	-0 249	0 229
1000 grain weight	-0 113	-0 097	-0 212	-0 178	-0 121	0 118	-0 001	0 080	0 069	0 220	-0 192	-0 449**	0 170	0 181	-0 178	1 000	-0 345*
Grain yield/plant	0 466**	0 380*	0 716**	0 564**	0 238	-0 126	-0 306*	-0 130	0 065	0 239	0 585**	0 400**	0 530**	0 351*	0 146	-0 278	1 000

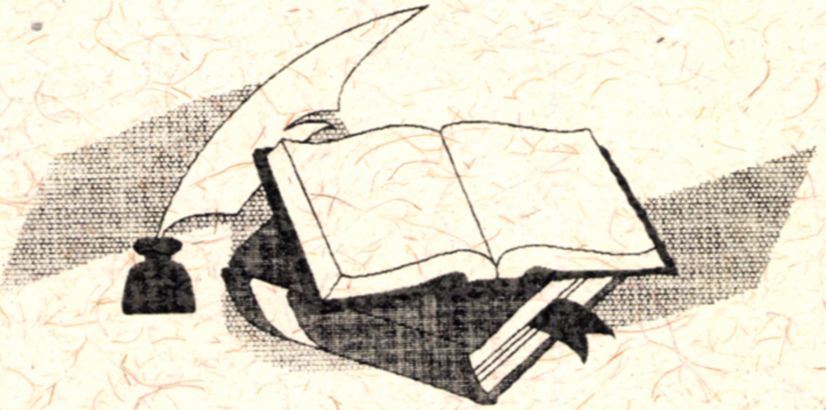
*, ** significant at P = 0 05 and P = 0 01, respectively

						density	density	emer-gence				plant					
LAI	1 000	0 878**	0 399**	0 012	-0 516**	-0 557**	-0 493**	0 698**	0 645**	0 648**	-0 021	-0 546**	0 729**	0 529**	-0 138	0 110	0 507**
DMP I	0 876**	1 000	0 490**	0 060	-0 545**	-0 672**	-0 446**	0 570**	0 809**	0 881**	-0 279	-0 658**	0 751**	0 594**	-0 229	0 324*	0 423**
DMP II	0 401**	0 497**	1 000	0 900**	0 437**	-0 694**	-0 428**	-0 126	0 454**	0 762**	-0 405**	-0 069	0 609**	0 430**	-0 087	0 232	0 811**
AGR	0 016	0 069	0 900**	1 000	0 773**	-0 461**	-0 268	-0 434**	0 119	0 434**	-0 331*	0 253	0 321*	0 193	0 008	0 102	0 712**
RGR	-0 514**	-0 538**	0 437**	0 772**	1 000	-0 020	-0 031	-0 740**	-0 374*	-0 190	-0 093	0 641**	-0 191	-0 212	0 109	-0 120	0 354*
Adaxial stomatal density	-0 323*	-0 352*	-0 373*	-0 256	-0 023	1 000	0 477**	-0 208	-0 304*	-0 677**	0 400**	0 125	-0 306*	-0 454**	0 261	-0 108	-0 512**
Abaxial stomatal density	-0 419**	-0 370*	-0 361*	-0 228	-0 026	0 279	1 000	-0 211	-0 352*	-0 340*	-0 213	-0 004	-0 522**	-0 177	-0 033	0 075	-0 625**
Days to stigma emergence	0 672**	0 542**	-0 123	-0 418**	-0 711**	-0 165	-0 184	1 000	0 250	0 283	-0 001	-0 551**	0 224	0 083	0 005	-0 200	-0 110
Plant height	0 634**	0 796**	0 452**	0 124	-0 363*	-0 162	-0 302	0 244	1 000	0 802**	-0 251	-0 479**	0 854**	0 718**	-0 471**	0 285	0 367*
Fodder yield/plant	0 606**	0 834**	0 731**	0 425**	-0 170	-0 374*	-0 297	0 274	0 766**	1 000	-0 557**	-0 501**	0 777**	0 602**	-0 351*	0 389*	0 487**
Harvest index	-0 008	-0 243	-0 362*	-0 301	-0 093	0 266	-0 167	-0 008	-0 232	-0 477**	1 000	0 014	-0 147	-0 128	0 639**	-0 261	0 171
Effective tillers/plant	-0 533**	-0 633**	-0 064	0 246	0 658**	0 052	0 019	-0 532**	-0 473**	-0 446**	0 035	1 000	-0 473**	-0 526**	-0 063	-0 600**	-0 075
Ear length	0 711**	0 733**	0 593**	0 312*	-0 189	-0 195	-0 442**	0 216	0 830**	0 735**	-0 125	-0 443**	1 000	0 815**	-0 452**	0 452**	0 607**
Ear girth	0 515**	0 585**	0 434**	0 205	-0 196	-0 222	-0 143	0 081	0 710**	0 584**	-0 090	-0 497**	0 798**	1 000	-0 456**	0 572**	0 375*
No of grains/cm^2	-0 123	-0 210	-0 079	0 009	0 101	0 043	-0 068	0 005	-0 449**	-0 333*	0 565**	-0 057	-0 420**	-0 439**	1 000	-0 206	0 251
1000 grain weight	0 082	0 288	0 200	0 084	-0 115	0 118	0 090	-0 180	0 267	0 358*	-0 196	-0 535**	0 415**	0 545**	-0 253	1 000	0 134
Grain yield/plant	0 498**	0 431**	0 800**	0 698**	0 337*	-0 223	-0 510**	-0 112	0 355*	0 473**	0 233	-0 054	0 578**	0 387*	0 228	0 121	1 000

*, ** significant at P = 0 05 and P = 0 01, respectively

						stomatal density	stomatal density	stigma emer- gence	height	yield/ plant	index	tillers/ plant			cm²	weight	plant
LAI	1 000	0 905**	0 338*	-0 336*	-0 705**	-0 354*	-0 406**	0 780**	0 597**	0 617**	-0 077	-0 317*	0 508**	0 450**	-0 115	0 130	0 241
DMP I	0 904**	1 000	0 431**	-0 311*	-0 809**	-0 201	-0 379**	0 749**	0 746**	0 676**	-0 171	-0 488**	0 694**	0 711**	-0 362*	0 380*	0 254
DMP II	0 343*	0 440**	1 000	0 723**	0 153	0 152	-0 061	-0 042	0 694**	0 843**	-0 178	-0 096	0 865**	0 612**	-0 476**	0 641**	0 753**
AGR	-0 324*	0 295	0 729**	1 000	0 780**	0 313*	0 226	-0 618**	0 160	0 370*	-0 057	0 272	0 379*	0 101	-0 224	0 385*	0 599**
RGR	-0 700**	-0 801**	0 155	0 775**	1 000	0 215	0 281	-0 767**	-0 355*	-0 106	-0 004	0 552**	-0 252	-0 471**	0 096	-0 084	0 134
Adaxial stomatal density	-0 345*	-0 196	0 130	0 288	0 205	1 000	0 783**	-0 475**	0 211	0 085	0 234	-0 211	0 146	0 048	0 140	-0 453**	0 318*
Abaxial stomatal density	-0 391*	-0 361*	-0 057	0 214	0 264	0 744**	1 000	-0 587**	-0 145	-0 287	0 468**	-0 213	-0 112	-0 060	0 557**	0 104	0 314**
Days to stigma emergence	0 771**	0 736**	-0 049	-0 613**	-0 759**	-0 449**	-0 571**	1 000	0 486**	0 391*	-0 382*	-0 433**	0 220	0 312*	-0 282	-0 012	-0 326*
Plant height	0 593**	0 738**	0 679**	0 159	-0 350*	0 203	-0 141	0 484**	1 000	0 901**	-0 413**	-0 398**	0 785**	0 686**	-0 532**	0 601**	0 311*
Fodder yield/plant	0 608**	0 667**	0 828**	0 372*	-0 153	0 080	-0 271	0 382*	0 893**	1 000	-0 428**	-0 205	0 815**	0 586**	-0 594**	0 643**	0 459**
Harvest index	-0 078	-0 170	-0 184	-0 066	-0 009	0 230	0 437**	-0 374*	-0 406**	-0 419**	1 000	0 063	-0 189	-0 164	0 773**	-0 198	0 480**
Effective tillers/plant	-0 302	-0 465**	-0 080	0 269	0 534**	-0 209	-0 208	-0 431**	-0 388*	-0 191	0 063	1 000	-0 322*	-0 545**	0 091	-0 502**	-0 043
Ear length	0 502**	0 686**	0 843**	0 374*	-0 248	0 137	-0 113	0 215	0 782**	0 804**	-0 184	-0 319*	1 000	0 824**	-0 581**	0 706**	0 620**
Ear girth	0 445**	0 704**	0 600**	0 102	-0 463**	0 051	-0 059	0 305*	0 677**	0 581**	-0 154	-0 529**	0 816**	1 000	-0 533**	0 643**	0 466**
No of grains/cm^2	-0 112	-0 356*	-0 463**	-0 221	0 092	0 128	0 543**	-0 279	-0 529**	-0 586**	0 748**	0 084	-0 581**	-0 529**	1 000	-0 542**	0 084
1000 grain weight	0 123	0 365*	0 615**	0 376*	-0 070	0 410**	0 094	-0 013	0 578**	0 622**	-0 176	-0 489**	0 678**	0 628**	-0 530**	1 000	0 470**
Grain yield/plant	0 241	0 259	0 744**	0 594**	0 132	0 288	0 291	-0 325*	0 305*	0 452**	0 479**	-0 028	0 614**	0 467**	0 074	0 466**	1 000

*, ** significant at P = 0 05 and P = 0 01, respectively



VITA

9. VITA

PRAMOD LAXMAN BADHE

A candidate for the degree
of
DOCTOR OF PHILOSOPHY (AGRICULTURE)

---

of the thesis	.	Phenotypic stability and association of morpho-physiological characters in pearl millet [*Pennisetum* glaucum (L.) R. Br.]
field	:	Agricultural Botany (Cytogenetices and Plant Breeding)
aphical information		
onal	·	Born at Chinawal, Tal Raver, Dist Jalgaon on Nov 18th, 1961. Son of Late Shri. Laxman Vithal Badhe, Married with Kalpana Patil on May 7th, 1987, having one son Chi. Pushkar and one daughter Ku. Kajal
cation		Attended Primary education at Chinawal, Dist. Jalgaon and Secondary education at Kalyan, Dist Thane. Received Bachelor of Science (Agriculture), First class with distinction (1982) and Master of Science (Agriculture), First class with distinction (1984) in Cytogenetics and Plant Breeding from Punjabrao Krishi Vidyapeeth, Akola Recipient of P.K.V Merit Scholarship during the period of M.Sc.(Agri.) degree course. Awarded two Silver Medals, for standing first at University level in Cytogenetics and Plant Breeding
		Completed requirement of Ph.D degree course work and being submitted thesis for Doctor of Philosophy in Agricultural Botany (Cytogenetics and Plant Breeding) at Post

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		Presently working at All India Co-ordinated Pearl millet Improvement Porject, College of Agriculture, Dhule, Since 1st July 1998
		Associated in the development of sesamum varieties Tapi (JLT-7) and Padma (JLT-26) and wheat variety NIAW-34
blications		Published eight research papers in recognized journals.
		Published three popular articles (Marathi) and delivered fifteen radio talk in All India Radio, Jalgaon

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