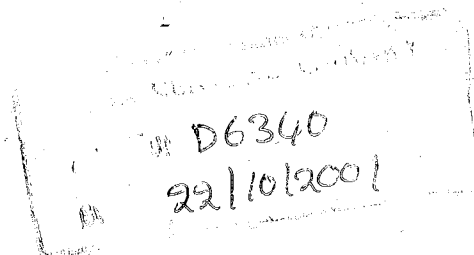


**GENETIC STUDIES ON DROUGHT TOLERANCE
IN RICE (*Oryza sativa* L.)**

By
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M.Sc. (Ag)



THESIS SUBMITTED TO THE
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IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE FACULTY OF AGRICULTURE



DEPARTMENT OF GENETICS AND PLANT BREEDING
SRI VENKATESWARA AGRICULTURAL COLLEGE
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DECEMBER, 2000

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Mr. Y. Suryanarayana has satisfactorily prosecuted the course of research and that the thesis entitled **GENETIC STUDIES ON DROUGHT TOLERANCE IN RICE (*Oryza sativa* L.)** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Date : 27-12-2000

Place :



Major Advisor

CERTIFICATE

This is to certify that the thesis entitled **GENETIC STUDIES ON DROUGHT TOLERANCE IN RICE (*Oryza sativa* L.)** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Acharya N.G.Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. Y. Suryanarayana** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.



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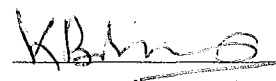
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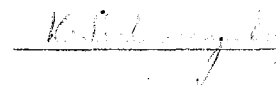
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(Y. SURYANARAYANA)

DECLARATION

I, Y. SURYANARAYANA, hereby declare that the thesis entitled "**GENETIC STUDIES ON DROUGHT TOLERANCE IN RICE (*Oryza sativa* L.)**" submitted to Acharya N.G. Ranga Agricultural University for the degree of **Doctor of Philosophy** in Agriculture is the result of original work done by me. I also declare that the materials contained in this thesis has not been published earlier.

Date : 27-12-2000


(Y. SURYANARAYANA)

ABSTRACT

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The present study was undertaken at Agricultural Research Station, Nellore during *rabi* 1996, 1997 and 1998 to conceptualize the genetic information on variation for drought tolerance, yield and its component traits, mode of inheritance and their interrelationships in rice crop under moisture stress as well as favourable environments.

The multivariate analysis revealed that the 60 genotypes studied have sufficient variability and could be grouped into nine distinct clusters cutting across the geographical boundaries, indicating that the geographic isolation is not the only factor causing genetic diversity. Further, it was observed that, the genotypes exhibited more variability under moisture stress condition than under favourable conditions. Hybridization between parents selected from distant clusters is suggested to get superior recombinants.

High genetic variation was recorded by root dry weight, plant height, number of ear bearing tillers per plant and grain yield per plant, indicating the existence of greater diversity for these traits in the genotypes studied.

High estimates of heritability with high genetic advance as percentage of mean were observed for number of days to 50% flowering, plant height and test weight, indicating the scope for further improvement of these traits.

Heterosis and combining ability effects were estimated by using eight parents and 28 hybrids. The magnitude of heterosis was high for number of filled grains per panicle, test weight and grain yield per plant under moisture stress situation. High heterobeltiosis was recorded for shoot dry weight, number of ear bearing tillers per plant and leaf area per plant under favourable environment. The cross Tulasi / CR 811-1 was found to be best heterotic combination under both unfavourable and favourable environments.

Combining ability analysis revealed the importance of both additive and non-additive gene actions. Bi-parental mating crossing *inter se* among the superior selects, followed by pedigree method of breeding will be profitable. The parents viz., CN 875-135-1-3, Tulasi and WGL 14280-1 were identified as the best general combiners under moisture stress as well as favourable environments.

Based on the correlation and path analysis of drought tolerance and yield contributing traits, the importance of root dry weight, root to shoot ratio, relative water content, number of ear bearing tillers and spikelet fertility per cent will serve as selection criteria for isolating superior genotypes under moisture stress conditions. Seedling growth under simulated drought conditions induced by polyethylene glycol, indicated that the parents CN 875-135-1-3 and CR 811-1 and hybrids NLR 33899 / Tulasi and WGL 14280-1 / NLR 30491 can withstand drought situation effectively. Combining ability analysis revealed the importance of both additive and non-additive gene actions for the seedling growth under simulated drought conditions.

SYMBOLS AND ABBREVIATIONS

Abscisic Acid	:	ABA
Better parent	:	BP
Centimetre	:	cm
Days after sowing	:	DAS
Coefficient of variation	:	CV
Degrees of freedom	:	df
General combining ability	:	gca
Genetic advance	:	GA
Genetic Advance as per cent of mean	:	GAM
Genotypic coefficient of variation	:	GCV
Gram	:	g
Hectare	:	ha
Heritability in broad sense	:	$h^2(b)$
Heterosis over mid parent	:	H_1
Heterosis over better parent	:	H_2
Kilogram	:	Kg
Mean	:	$\bar{X}$, μ
Million	:	m
Mid parent	:	MP
Per cent	:	%
Phenotypic coefficient of variation	:	PCV
Polyethylene glycol	:	PEG
Randomized block design	:	RBD
Relative water content	:	RWC
Specific combining ability	:	sca
Specific leaf weight	:	SLW
Square centimetre	:	cm^2
Tonnes	:	t

Introduction

CHAPTER I

INTRODUCTION

Rice is grown in a wide range of environments ranging from the wettest areas to the driest deserts in the world. One of the most important causes of yield instability in rice under rainfed agriculture is erratic rainfall distribution, resulting in drought or excess moisture.

Consequent upon the introduction of dwarf rices into India in mid sixties, there was a phenomenal increase in rice productivity and production. The rice production raised from 40 million tonnes in mid-sixties to 88.74 million tonnes during 1999-2000. The genetic potential of high yielding dwarf varieties is fully realised only under favourable environments. In India, upland rice is grown in an area of about 6.15 million hectares which produce 4.0 million tonnes of rice only. The average productivity in upland situation is only 0.6t/ha, compared to 7.5t/ha productivity potential of existing high yielding varieties. Thus rice cultivation under water stress situations is one of the areas bypassed by the green revolution.

In Andhra Pradesh sizeable area (0.21 m.ha) is prone to moisture stress which normally coincides with the maximum tillering to maturity stage of crop growth. The production assumes more serious in the years of uneven distribution of rainfall or failure of monsoons as evidenced by

the total failure of North East monsoon in South coastal and Rayalaseema regions of Andhra Pradesh during 1995.

In the absence of scope for the expansion of area under rice and near plateauing of rice productivity under favourable irrigated ecosystems, there is imperative need to enhance productivity levels of unexploited unfavourable rice growing situations like rainfed ecosystems, where the productivity is very low due to moisture stress. In India the loss of *Kharif* food grain alone during 1979 was estimated at more than 10 million tonnes due to moisture stress.

One of the major challenges confronting Indian rice breeders is the development of rice varieties suitable for abiotic stresses like drought. It is under these circumstances the research on drought tolerance in rice has acquired greater significance. Keeping this in view the present study has been taken up at Agricultural Research Station, Nellore with the following objectives.

- i. To study the nature and magnitude of genetic variability heritability and genetic advance for yield and component traits for drought tolerance.

- ii. To assess the genetic divergence among different genotypes for yield, yield components and component traits for drought tolerance. 3
- iii. To study the inter-relationships and relative contribution of component traits for drought and yield.
- iv. To study the gene action and combining ability for yield components and other component traits for drought tolerance.
- v. To study the hybrid vigour in different cross combinations for yield and component characters for drought tolerance.

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

The present study was taken up with the following objectives.

1. To study the nature and magnitude of genetic variability, heritability and genetic advance for yield and component traits for drought tolerance.
2. To assess the genetic divergence among the different genotypes for yield, yield components and component traits for drought tolerance.
3. To study the inter relationships and relative contribution of component traits for drought and yield.
4. To study the gene actions and combining ability for yield and other component traits for drought tolerance.
5. To study the hybrid vigour in different cross combinations for yield and component characters for drought tolerance.

Keeping the above objectives in view the relevant available literature on rice crop are reviewed hereunder.

Rice is the principle food crop grown more extensively in the tropical and sub tropical regions of the world. Over 85% of rice is grown and consumed in the densely populated regions of the South and South

East Asia. Rice grows in a wider range of complex environments than any other crop (Swaminathan, 1979). It grows mainly in five different ecosystems viz., upland, rainfed low land, irrigated, deep water and tidal wet lands.

Drought can be defined as the inadequacy of water availability including precipitation and soil moisture storage capacity in quality and distribution during the life cycle of the crop to restrict expression of its full genetic yield potential. Drought resistance, according to Passioura (1983) is a nebulous term that appears to become more nebulous, the more closely examined. There are a large number of morphological and physiological traits associated with plants growing naturally in arid environments is believed to confer drought resistance. In terms of plant physiologist, drought resistance is the maintenance of growth during water stress and its accelerated resumption on termination of water stress.

Breeding for drought tolerance is more complex than development of varieties for favourable irrigated lands. Frequency of drought occurrence, its intensity and duration in relation to growth stage of the crop varietal tolerance, soil factor and atmospheric temperature all influence the crop in the upland. Studies at IRRI indicated that yield reduction or sensitivity to water stress at reproductive stages can be

ranked as flowering > gametogenesis > panicle initiation > grain filling ("O" Toole, 1982). According to Rao *et. al.* (1971) an ideal plant type suitable for drought should possess the following characters.

- Early duration (85-100 days)
- Deep root system with maximum ramification of roots at deeper zones (25 cm).
- Early vigour with moderate tillering (6-8 tillers) and synchronous flowering.
- Medium height of nearly 100 cm with erect and less number of leaves and thick stem.
- Good expression of the panicle at the optimum density (about 400 panicles for square meter).
- Panicle weight type with high grain number per panicle.
- Moderate seed dormancy
- Low requirement for iron and manganese and
- Resistance to diseases like blast and Helminthosporium.

Blum (1979) and "O" Toole and Chang (1979) felt that before further progress can be made in utilizing morphologically and physiologically based adaptations to drought, suitable screening methods must be developed. Lack of proper screening method is a constraint and often delays attainment of breeding objectives.

2.1. GERMPLASM SCREENING FOR DROUGHT TOLERANCE

Screening methods developed by different workers are briefly reviewed hereunder.

2.1.1 Screening for absolute yield under stress

Maurya *et. al.* (1986) suggested that screening for yield can be made both under natural drought situations during the wet season as well as under artificially created drought during the dry season. The problem of testing under natural drought conditions is uncertain because of erratic rainfall distribution. It is always safe to screen under dry season with restricted and controlled irrigation supply to create specific desired conditions at any stage of plant growth.

2.1.2 Line Source sprinkler technique

This method was originally proposed by Hanks *et. al.* (1976) and improved subsequently by Puckridge and "O" Toole (1981). This line source sprinkler system efficiently creates a continuously variable water regime during the dry season. By sampling at several places across the supply gradient, growth and yield of varieties in terms of stability can be assessed with minimum variation in soil and climate.

2.1.3 Screening for earliness

Earliness is highly heritable character and easily identifiable (early maturity) either in germplasm or in segregating complex populations. Maurya *et. al.* (1986) gave first priority for earliness because of its simplicity and high heritability. This trait was used as the base trait for development of drought resistant varieties.

2.1.4 Screening for seedling vigour

Seedling vigour was generally considered essential in upland rice for good stand establishment and ability to compete with weed growth (Chang *et. al.* 1972 ; Chaudhary *et. al.* 1982 ; De Datta *et. al.* 1972 ; De Datta *et. al.* 1982 and Krishna Murthy *et. al.* 1973). Significant variation for this trait was noted among 100 genotypes.

2.1.5 Screening for plant height

Appropriate height for varieties suited to rainfed upland conditions is in question (Chang *et. al.* 1972 and Rao *et al.* 1971). However medium height of 80-100 cm was suggested by Maurya *et al.* (1986) for upland situations.

2.1.6 Screening for root characteristics

Deep root system is an important component of drought resistance because it enables the plant to exploit water in the deep soil layers. Of all the attributes, root length density is probably the major operative factor that largely determines the extent to which roots can extract water from adjacent soil (Newman, 1972). Several workers developed a variety of technique for root studies like Root box techniques (IRRI, 1980 and Yoshida *et. al.* 1982); Hydroponic culture technique (Ekanayake *et. al.* 1984), Root pulling force ("O" Toole *et. al.* 1981 and IRRI, 1977) and Root characterization *in situ* using ^{32}P (Reyniers *et. al.* 1972 and Truong Binh, 1977).

2.1.7 Screening for leaf rolling

Field screening method has been devised to evaluate reactions of large number of cultivars to drought at vegetative and reproductive phases as well as their ability to recover (Loresto *et. al.* 1976). Irrigation was withheld at 40 days after sowing ; for 20 days until the plants showed distinct signs of internal water deficit. The stress treatment and continuous scoring by a decimal system usually extends over 15-20 days until the soil moisture content reaches 13% and is no longer differentiated by soil tensiometers.

2.1.8 Crop canopy temperature technique

Water deficits induce stomatal closure, consequently, leaf temperatures usually raise. Leaf canopy temperature measurement by infrared thermometry may be used as an indicator of plant water stress.

2.1.9 Screening for leaf water potential

Leaf water potential as an integrator of soil and atmosphere conditions is related to drought in rice. Variations in leaf water potential among cultivars or strains under moisture stress upto 10-13 bars between extreme rice genotypes have been found ("O" Toole *et. al.* 1980 and "O" Toole *et. al.* 1978). They noticed significant differences among the genotypes for maintenance of relatively high leaf water potential.

2.1.10 Screening for osmotic adjustment

Osmotic adjustment, generally considered as the net increased in intracellular solutes, usually occurs in response to various environmental stresses (Steponkus, 1980). 60

2.1.11 Screening for amino acid accumulations

Certain amino acids increase dramatically under stress and screening for them has been suggested as a means of evaluating drought resistance (Maurya *et. al.* 1986). Observations suggest that proline could provide metabolic advantages within limits of water stress. Depending upon the plants growth stage and the chance of recovery from the water stress, the advantage may or may not be reflected in source or yield components. The degree of variation for proline accumulation as an adaptive mechanism in rice is still unknown.

2.2 GENETIC DIVERGENCE

Knowledge of nature and magnitude of existing variability in crop species plays an important role in formulating successful breeding programme. The importance of genetic diversity for successful selection of parents for hybridization has been emphasized in rice by several workers (Singh, 1983; De and Rao, 1987; Roy and Panwar, 1993).

Multivariate analysis by means of Mahalanobis D^2 statistic is a powerful tool in quantifying the degree of divergence among biological populations. Kotaiah *et. al.* (1986) studied Mahalanobis D^2 and metroglyph analysis in mid-duration genotypes of rice and concluded that the former method is the more precise and refined for studying germplasm collections while, the latter method is more suited for preliminary work prior to D^2 analysis. But the clustering pattern under varying environments generally differ due to environmental interactions with genotypes (Singh and Gill, 1984). So to get a proper picture of genetic divergence for any stress situation, it is better to conduct the experiment under that specific environment. There are several reports on genetic divergence on different plant characters in rice grown under normal irrigated conditions (Ratho, 1983, De and Suriya Rao, 1988). But it is limited in rice grown under upland conditions.

Genetic divergence was assessed separately by using Mahalanobis D^2 statistic on data on eight yield components from 40 drought tolerant rice genotypes planted simultaneously under semi dry conditions at two different locations (Rao and Gomathinayagam, 1997). They observed that genetic divergence was not related to geographic diversity. Differential response of the genotypes to the environments has altered the clustering pattern between environments. Further, they reported that favourable environment yielded in lesser number of clusters by exploiting high genetic potential of different traits expressed by genotypes. These results

confirm the earlier findings of Bhatt (1970) and Raut *et. al.* (1985) who suggested that genetic drift and human selection could cause great diversity than the geographic distance. Sterility percentage, ear bearing tillers per hill; yield per m² and grain length were major variables that influenced genetic divergence.

Arunachalam (1981) commenting on genetic distance in plant breeding observed that probability of realising fruitful crosses can be increased by selecting parents with a divergent range of "medium to high" in a low to high classification. Rao and Gomathinayagam (1997) studied 40 drought tolerant rice genotypes and suggested that stable genotypes with higher order of genetic divergence will provide best breeding material for the exploitation of heterosis and high degree of variability in segregating generations.

In selecting varieties from the already choosen groups, other important characters like disease resistance, earliness, quality or even performance of particular character should also be considered (Chaudhary *et. al.* 1975). Selecting one variety from each other group and testing them by a diallel analysis may prove to be highly fruitful (Singh and Chaudhary, 1977).

Review of research results in respect of genetic divergence are presented in table 1

Table 1 : Review of Research results in respect of Genetic divergence

S. No.	Material Studied	No. of clusters formed	Factors contributed to diversity	Authors
1	32 rice varieties	9	Plant height, sterile grains per panicle and grains per panicle	Singh, 1983
2	30 rice genotypes	10	Morphological components of grain yield	De and Rao, 1987
3	75 rice genotypes	13	Test weight, number of grains per panicle	De <i>et. al.</i> 1988
4	36 rice cultures	10	Days to 50% flowering and test weight	Kotaiah <i>et. al.</i> 1988
5	25 rice cultures	6	Test weight	Pradban and Roy, 1990
6	61 rice genotypes	17	Grains per panicle, panicle length harvest index and yield	Prasanthi, 1993
7	44 rice genotypes	12	Test weight, days to 50% flowering, panicle weight, spikelets per panicle	Chauhan ~~et. al.~~ 1994
8	30 rice cultivars	6	Tiller survival, elongation ability and nitrogen reduction percentage	Sankar Rao, 1994
9	37 rice cultures	5	Number of fertile grains per panicle, number of sterile grains per panicle and plant weight	Mishra <i>et. al.</i> 1994.
10	144 rice varieties	55	Days to 50% flowering, plant height, ear bearing tillers per hill, test weight and grain yield	Baruah, <i>et. al.</i> 1994.
11	94 rice geno types	18	Plant height, days to 50% flowering, fertile spikelets per panicle and fertility percentage	Kaw, 1995
12	40 rice genotypes	6	Grain yield and plant height	Singh <i>et. al.</i> 1996
13	72 rice genotypes	6	Grain yield, panicle exertion and plant height	Usha Kumari <i>et. al.</i> 1997
14	82 rice varieties	18	Number of grains per panicle, leaf area, grain weight per panicle and ear bearing tillers	Sardana <i>et. al.</i> 1997
15	52 rice cultivars	8	Spikelet sterility, straw yield, ear bearing tillers per plant and grain yield	Bhuyan <i>et. al.</i> 1997
16	33 rice genotypes	7	Test weight, protein and grain yield	Srinivasa Rao, 1989
17	50 rice genotypes	6	Days to 50% flowering, gelatinization temperature and water uptake	Ramesh Babu, 1999
18	132 genotypes	10	Quality traits	Soni <i>et. al.</i> 1999

2.3 VARIABILITY

Knowledge of the nature and magnitude of genotypic and phenotypic variability present in crop species is of immense utility in formulating a successful breeding programme for developing high yielding varieties. The rice plant offer a wealth of variability for different physiological and agronomic characters because of its wide ecological distribution and enormous number of variations encountered in its make up. Estimation of genetic variability does not give a clear indication of the possible improvement that can be achieved through selection and it should be used in association with heritability and genetic advance.

The magnitude of heritable variation, more particularly its genetic component, is the most important aspect of the genetic constitution of the breeding material which has a close bearing on its response to selection (Panse, 1957).

Plant height is greatly affected by environmental conditions. Maurya *et. al.* (1986) suggested a medium height (80-100 cm) is suitable for moisture stress situations. However, they added that dwarf height may not be undesirable or unfavourable for drought conditions. Plant height could be a useful selection criterion for drought resistance (Zuno *et. al.* 1990). High range of variability was reported for plant height by

Bhatt (1976), Deosarkar *et. al.* (1989) and Srinivasa Rao (1989), thereby indicating good scope for genetic improvement. Jangale *et. al.* (1985) observed that the magnitude of the PCV and GCV was moderate for plant height.

With regard to crop duration, rice varieties vary from 60 to 210 days. Crop duration in rice depends on its flowering duration. Rice plant is generally a short day plant, however, most of the modern varieties are photoperiod insensitive. Most traditional rices are photoperiod sensitive (Anwarthan *et al.*, 1979). Crop duration is an important character under water stress situations. The drought escape mechanism facilitated by growth adjustment, is a first line of defence and a most successful form of resistance. When drought develops during late growth stages, earliness is an important trait to escape moisture stress (Maurya *et. al.* 1986). The studies from 162 drought tolerant rice genotypes revealed that there was high values of GCV and PCV (Amirthadevarathinam, 1983). Maurya *et. al.* (1986) and Unnikrishnan (1982) reported a wide range of GCV and PCV for days to 50% flowering.

In respect of ear bearing tillers per plant, Balakrishna Rao *et al.*, (1971) suggested that an ideal plant type for drought situations is early vigour with moderate tillering (6-8 tillers) and synchronous flowering.

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Ear bearing tillers is one of the yield parameters significantly affected by moisture regimes (Pereira, 1994). High amount of variability was reported by Singh (1980), Unnikrishnan (1982) Amirthadevarathinam (1983), Deosarkar *et. al.* (1983). DeoSarkar *et. al.* (1989), Marimuthu *et. al.* (1990) and Chookar *et. al.* (1994). However, Jangale *et. al.* (1985) observed moderate range of PCV and GCV values for ear bearing tillers.

Variation for panicle length plays an important role for developing high yielding varieties. Chooker *et. al.* (1994) observed wide range of variation for panicle length and reported moderate GCV. While, Rama Rao (1990) observed low GCV and PCV values for panicle length in F₂ generation of three rice crosses. Prasanthi (1993) obtained moderate PCV and GCV values of 13.78 and 13.23 respectively in the variability study involving 51 rice genotypes.

Number of filled grains per panicle is one of the most vital traits to be considered for drought tolerance. Kim *et. al.* (1988) and Pereira *et. al.* (1994) observed that number of spikelets per panicle decreased with increasing drought stress. Several workers recorded high values of PCV and GCV for number of filled grains per panicle. Deo Sarkar *et. al.* (1989), Srinivasa Rao (1989), Chookar *et. al.* (1994), Shukla *et. al.* (1972), Chaudhary *et. al.* (1973), Jangale *et. al.* (1985) and Amirthadevarathinam (1990). However Reddy *et. al.* (1988) noticed low values of variability for number of filled grains per panicle.

In respect of 1000-grain weight; Pereira *et. al.* (1994) evaluated rice germplasm for drought tolerance and reported that test weight did not affected by moisture stress. High estimates of PCV and GCV were noticed by Pathak and Patel (1989) for test weight. Contrary to these results Ganesan and Subramanian (1990); Rama Rao (1990) and Mahammed Aziz Ahammed (1991) observed low values of PCV and GCV for test weight.

Harvest Index (HI) is the ratio between the economic yield (rice grain) and the total biological yield produced is the important yield contributing character. Pereira *et. al.* (1994) reported that drought has no influence on harvest index. Sarkarung *et. al.* (1996) attempted to increase productivity in water limiting rice environments by designing and developing new plant types that can raise the harvest index to 0.4. Roi and Smetamin (1994) observed that selection for harvest index would be effective due to its high coefficient of genotypic variation. Bhatt (1976) reported high variability for harvest index. While, Chauhan *et al.*, (1993) recorded high phenotypic coefficient of variation, for biological yield followed by harvest index in rice.

The yield potential of a given variety may vary considerably according to the environment. Even if it has a good yield potential that potential can not be expressed if constraint occur. So, under moisture

stress conditions, the yield potential is frequently repressed by environmentally hostile conditions. Hence, the objective of the plant breeder working for drought tolerant varieties is not the highest yield, but the best yield stability is required. Several workers studied yield variability in rice. Pathak and Patel (1989) observed higher GCV and PCV for grain yield in their studies conducted on 18 diverse early genotypes of upland rices. Ganesan and Subramanian (1990) Chookar *et. al.* (1994) and Rama Rao (1990) studied the segregating generations of rice crosses and observed very high values of variability in both the parents and crosses. However, Remabai *et. al.* (1992) from their studies reported high PCV than GCV values for grain yield.

Drought tolerance is conferred by a root system which is more effective in extracting water from a soil layer or more capable of extracting water from deeper layers of the profile not previously explored. The important root traits include root length, hard pan penetration capacity, root density, more root dry weight, root pulling force and root, shoot ratio. Gomathinayagam *et. al.* (1992) evaluated 18 genotypes of diverse geographical origin for drought tolerance in relation to root length and concluded that the longest root length varieties had good drought tolerance.

Lilley *et. al.* (1994) studied the rooting pattern and soil water extraction in four diverse rice cultivars. Moisture stress was imposed at reproductive stage. They observed cultivar differences for inherent rooting pattern, with total root length ranging from 1.3 to 33.7 km/m². Root length density was larger in the surface soil layers and declined with depth and suggested that selection for deeper roots and large root length density would assist in developing cultivars which extract more soil water and therefore, are more drought resistant in moisture stress conditions. Cruz and "O" Toole (1985) observed a higher mid day leaf water potential in a native upland culture than the exotic cultivars due to its higher root length density and depth and capability to extract stressed soil moisture from greater depths during the stress period. ADT 31 (drought tolerant variety) and IR 50 (drought susceptible) varieties were compared under three water regimes (Vijaya Lakshmi and Nagarajan, 1994). Through their studies with ³²P, it was revealed that ADT 31 had a higher absorption at 40 cm depth showing greater root density in deeper soil layers. Under water stress grain yields of IR50 were decreased by over 75% when compared to 50% in ADT 31.

Gomathinayagam *et. al.* (1988) recorded seminal root lengths seven days after seed germination for diverse rice genotypes and reported that long seminal roots were associated with drought tolerance. One hundred and eighteen upland rice genotypes were studied for root length and

weight and found that there was high genetic variability for root length and root weight (Awasti *et. al.* 1996). Contrary to these observations Shahid *et. al.* (1994) recorded the lowest PCV and GCV values for root dry weight. Price *et. al.* (1992) studied root dry weight and shoot dry weight and reported that root dry weight and shoot dry weight were the most useful criteria for drought tolerance. These results were confirmed by Kobata *et. al.* (1996).

Root volume is another root trait having drought tolerance at reproductive stage (Zuno *et. al.* 1990). Sunchuanqing *et. al.* (1995) through their rice root studies observed that root base thickness was found to be good index for drought resistance. Root pulling force was another important criteria suggested by Price *et. al.* (1992) for selecting drought tolerant varieties in rice. Lu Fengshen *et. al.* (1994) and Souframanien *et. al.* (1998) studied the main drought resistance indices for rice cultivars and observed that root, shoot ratio could indicate drought resistance of rice under moisture stress.

Relative water content is one of the traits to know the water retention capacity of the plants under moisture stress conditions. Rao and Venkateswarlu (1989) subjected 24 rice cultivars for water stress at flowering to know its influence on relative water content. Akomeah *et. al.* (1995) screened upland rice germplasm for moisture stress by

utilizing relative water content as one of the drought tolerant characters. Relative water content decreased when rice plants were subjected to drought at tillering and flowering stages. Under these stress conditions the genotype Annada had high relative water content in leaves (Saxena *et. al.* 1996).

Leaf rolling is another vital physiological mechanism to conserve moisture under drought conditions. Price *et. al.* (1997) studied leaf rolling character in 12 rice varieties. The varieties IR 20 and Bala were identified as slow at rolling. Although the variety 'Azucena' rolled its leaves much faster than Bala upon excision, stomatal resistance rose more rapidly in Bala resulting in a lower rate of water loss. These observations were confirmed by Dingkuhn *et. al.* (1989). They reported that stomatal closure and leaf rolling were more sensitive to water deficit in Azucena variety which maintained higher leaf water potential through the stress cycle. Ekanayake *et. al.* (1993) observed decreased transpiration losses in flag leaves due to leaf rolling.

Certain amino acids like proline accumulates under moisture stress conditions. Proline content was much higher in the drought resistant cultivars (Liu *et. al.* 1993) and suggested this factor may be adopted as one of the indicators in the identification of drought tolerance in rice. Kim and Yuk (1992) Zhang *et. al.* (1997) reported that the

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proline content increased the most in water stress resistant cultures and least in stress susceptible cultivars. However, Maurya *et. al.* (1986) felt that the degree of variation for proline accumulation under moisture stress conditions as an adaptive mechanism in rice is still unknown. Water stress can be created by using osmoticum solution of polyethylene glycol (PEG). Singh *et. al.* (1983) subjected three rice varieties to different external water potentials ranging from 0.0 bars to -10.0 bars and observed the retardation of shoot and root growths at moisture stresses of higher order. According to Reddy *et al.*, (1983) seed germination of the variety Rasi was higher than other rice varieties under osmotic stress induced by PEG Rice clones resistant to PEG had a high morphogenetic potential (Belyanskaya *et. al.* 1994).

Peric and Zaric (1985) studied extensively the role of hormones in the reaction of plants to drought. The physiological effects of Absciscic acid (ABA) and its interactions with other hormones were observed in crops like maize and sorghum. Resistant varieties exhibited higher capacity for ABA accumulation during stress but they recorded negative results in rice. However, contrary to these observations Yang Jianchang and Yang (1995) and Bilsborrow (1986) reported rapid increase of ABA content in water stressed rice leaves and also suggested greater allelic variation in genes affecting ABA accumulation.

2.4 HERITABILITY AND GENETIC ADVANCE

Heritability is defined as the ratio of genotypic variance to phenotypic variance and it is the measure of transmission of characters from generation to generation. The consistency of the performance of selection in succeeding generations depends on the magnitude of heritable variation present in relation to the observed variation. Heritability measures the relative amount of the heritable portion of variability, while the genetic advance helps to measure the amount of progress that could be expected with selection in a character. High heritability is not always an indication of higher genetic gain (Vishnuswarup and Chagle, 1962). Whereas high heritability coupled with high genetic advance could successfully be improved by direct selection (Paul, 1978). Therefore it is quite evident that information on these genetic parameters is of immense utility for crop improvement.

In respect of plant height; several workers viz., Kaul (1982) Krishna Kumari (1983), Chauhan *et. al.* (1984), Maurya *et. al.* (1986), Deo Sarkar *et. al.* (1989) and Pathak and Patel (1989) observed high heritability and high genetic advance. High heritability coupled with moderate expected genetic advance was reported by Ramesh Kumar (1989), Chauhan *et. al.* (1993) and Rama Rao (1990). However, Rema bai *et. al.* (1992) in their studies observed moderate to high estimates of heritability and genetic advance for plant height in rice.

With regard to growth duration, high heritability coupled with high genetic advance was reported for days to 50% flowering in rice by Dhanraj *et. al.* (1987), Ravindranath *et. al.* (1983), Amirthadevarathinam (1983) and Ganesan *et. al.* (1995). Thereby indicating scope for varietal improvement through phenotypic selection. Maurya *et. al.* (1986) also observed that the crop duration was one of the highly heritable characters which can be easily improved. However, Marimuthu *et. al.* (1990) reported high heritability estimates with genetic advance for this trait.

For ear bearing tillers per plant, high values of heritability coupled with high estimates of genetic advance was recorded by Amirthadevarathinam (1983) and Paramasivan (1980). Jangale *et. al.* (1985) observed high heritability with moderate genetic advance for this trait. But, low heritability with very low genotypic advance was observed by Ramesh Kumar (1989) while, Srinivasa Rao (1989) and Rama Rao (1990) reported high heritability along with low expected genetic advance for number of productive tillers per plant.

Several workers reported high heritability with high genetic advance for the character of panicle length (Ravindranath *et. al.* 1983, Sukanya Subramanian *et. al.* 1984, Maurya *et. al.* 1986, Singh 1980 and Ramalingam *et. al.* 1994). Panicle length exhibited high heritability with

low magnitude of genetic advance (Paramasivan 1980, Ramesh Kumar 1989, Srinivasa Rao 1989 and Rama Rao 1990).

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Total number of spikelets per panicle was evaluated by Amirthadevarathinam (1983) and recorded high heritability and high genetic advance. These results were confirmed by Maurya *et. al.* (1986), Paramasivan (1980), Reddy *et. al.* (1986), Pathak and Patel (1989), Chaubey and Richharia (1993) and Ganesan *et. al.* (1995). The trait, number of filled grains per panicle has direct impact on grain yield. Gomathinayagam *et. al.* (1990) worked on drought tolerant rice varieties and revealed that high heritability and moderate genetic advance for number of filled grains per panicle, whereas Paramasivan (1980) reported high estimates for both heritability and genetic advance. Chauhan *et al.*, (1993) observed high expected genetic advance and high heritability for percent filled grains per panicle. Medium to high estimates of heritability as well as genetic advance was reported by Shukla *et. al.* (1972) and Chaudhary *et. al.* (1973).

Test weight (1000-grain weight) is also one of the yield contributing traits in rice. Several workers viz., Maurya *et. al.* (1986), Pathak and Patel (1989) and Deosarkar *et. al.* (1989) observed high values of heritability and expected genetic advance for this character. But, Ganesan *et. al.* (1995) reported the existence of high heritability along with medium estimates of genetic advance for test weight.

Donald (1962) defined harvest index as the ratio of yield of the primary economic product to the biological yield. Paroda and Tomar (1997) suggested that the grain yield of rice can be increased beyond the current level by increasing the total dry matter and harvest index. Existence of high heritability along with high values of genetic advance was reported by Roi and Smetanin (1994) Sukanya Subramanian *et. al.* (1984), Yadav (1992) Chauhan *et. al.* (1993) and Ganesan *et. al.* (1995) while low estimates of heritability and genetic advance for harvest index was observed by Chaubey and Richharia (1993).

The ultimate objective of any plant breeder is to enhance the economic yield potential of the crop plants for which high estimates of heritability coupled with high values of genetic advance are very much desirable for crop improvement. Rema bai *et. al.* (1992) and Ganesan *et. al.* (1995) reported the existence of high heritability and high genetic advance. But, Ramesh Kumar (1989) observed high heritability with very low expected genetic advance. Medium heritability and low expected genetic advance were reported by Srinivasa Rao (1989) and Rama Rao (1990) while, Wilfred Manuel and Prasad (1993) indicated high heritability with medium genetic advance for grain yield per plant.

Among the various traits studied for drought tolerance, the root pattern serves as a more reliable measure on account of its high

correlation with resistance mechanism Chang *et. al.* (1974). Shahid *et. al.* (1994) through their genetic studies on drought tolerance in rice revealed the highest heritability value of 81 per cent for root dry weight and high heritability combined with high genetic advance expressed as percentage of the mean for root length, root dry weight, shoot dry weight thereby providing scope for crop improvement through selection. In addition to the above root characters, Shahid *et. al.* (1994) also reported high values of heritability and genetic advance for stomata frequency.

2.5 COMBINING ABILITY

Meaningful genetic analysis of quantitative traits have been initiated with the works of Fisher (1918) who has demonstrated that continuously varying characters are governed by genes with small individual effects which obey the Mendelian laws of inheritance. The genetic variance for such characters can be partitioned into additive dominance and epistatic components.

Griffings (1956) and Gardner and Eberhart (1966) developed the theory of diallel to estimate various components of hereditary variance. Diallel analysis provides information on (i) the nature and amount of genetic parameters and (ii) general and specific combining ability of parents and their crosses respectively. Combining ability is the ability of an inbred line to transmit desirable performance to its hybrid

progenies. General combining ability (gca) is the average performance of a parent in a series of hybrid combinations, whereas, specific combining ability (sca) is a deviation and to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of parents involved (Sprague and Tatum, 1942). While, gca was attributed to additive gene effects, sca was attributed to dominant deviation and epistatic interactions.

According to Sharma (1990) and Singh *et. al.* (1990) non additive gene action was responsible for plant height. Similar observation was also noted by Suprio Chakraborty *et. al.* (1994) and Ramalingam *et. al.* (1993), while both additive and non additive gene actions were recorded by Singh and Richharia (1980), and Ganesan *et. al.* (1997). With regard to days to 50 per cent flowering, additive gene action was observed by Sardana and Borthakur (1987). Sankar Rao (1994) and Singh *et. al.* (1996). But, Haque *et. al.* (1981) and Agarwal and Sharma (1985) recorded non-additive gene action; while both additive and non additive gene effects were found to be important for days to flowering (Virmani, 1990). In respect of ear bearing tillers per plant, Sankar Rao (1994) and Ganesan (1997) reported additive gene action. While Rama Rao *et. al.* (1989), Supriyo Chakraborty *et. al.* (1994) observed that the trait was conditioned by non additive gene action. However, Sardana and

Borthakur (1987) and Lavanya *et. al.* (1997) noticed both additive and non additive effects of gene action. Predominant role of non additive gene action for panicle length was observed by Ajmer Singh (1991) and Ramalingam *et al.*, (1994). However, the importance of additive and non additive gene action effects for this trait was noticed by Sardana and Borthakur (1987) and Lavanya *et. al.* (1997). With regard to number of filled grains per panicle, Sardana and Borthakur (1987) Ganesan *et. al.* (1997) observed additive gene action. Ram *et. al.* (1991) and Singh *et. al.* (1996) observed dominant gene action. On the other hand Ajmer Singh *et. al.* (1993) and Lavanya *et. al.* (1997) found the existence of both additive and non additive effects for this trait. Test weight (1000-grain weight) is one of the important yield contributing traits. According to Sardana and Borthakur (1987), Supriyo Chakraborty *et. al.* (1994) Sankar Rao (1994) and Ganesan *et. al.* (1997) additive gene effects were responsible to control this characters Ram *et. al.* (1991) and Singh *et. al.* (1996) have reported dominant gene action to govern the expression of test weight. However, Ravikumar (1987) and Lavanya *et. al.* (1997) found the importance of both additive and non additive gene actions for the inheritance of 1000-grain weight.

According to Kumar and Saini (1983) and Sharma *et. al.* (1984) grain yield was controlled by non additive gene effects. Similar results were also reported by Sardana and Borthakur (1987), Ram *et. al.* (1989),

Dhaliwal and Sharma (1990); Ram *et al.*, (1991).and Singh *et al.*, (1996).

On the other side Haque *et. al.* (1981) and Ganesan *et. al.* (1998)

observed additive gene action. However, the role of both additive and non additive gene action was emphasized by several workers (Ravikumar, 1987, Virmani, 1990, Wilfred Manuel *et. al.* 1992, Ajmir Singh, 1993 and Lavanya *et. al.* 1997). Although both additive and non additive components appeared to be significant for grain yield, the additive gene action was found to be predominant for grain yield character in rice. Sufficient work has not been done to understand the genetics of harvest index in rice. The role of additive gene action to control harvest index was reported by Bhatt (1976). However, Reddy (1981) and Rattan Singh and Ajmer Singh (1991) found the importance of both the components of variance for the inheritance of harvest index but predominant role was played by non additive gene action.

Knowledge on the inheritance pattern of root and its characters is of immense utility for drought tolerant research in rice. According to Sunchuan Quing *et. al.* (1995) all the root characters except root dry weight were controlled both by additive and dominance components with predominance of dominance effects. Similar results were observed by price and Tomos (1997) and price *et. al.* (1992). The predominance of additive gene effects were observed in respect of root dry weight, shoot dry weight and root to shoot ratio (Shahid *et. al.* 1994).

Review of literature on gene action for various characters in rice are presented in a tabular form here under

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Character (1)		Authors (2)
Plant height	A	Lokaprakash <i>et. al.</i> 1991; Ghosh 1993; Dushantha Kumar and Chandrappa, 1994; Geetha <i>et. al.</i> 1994, Vijayakumar <i>et. al.</i> 1994, Singh and Choudhury 1995; Manuel and Rangasamy, 1995.
	NA	Paramasivan, 1990 ; Ananda Kumar and Subramanian, 1994; Suprio Chakraborty and Hazarika, 1994. Rattan Singh <i>et. al.</i> 1996. Sharma <i>et. al.</i> 1996; Padmavathi <i>et. al.</i> 1997.
	A & NA	Singh and Richharia 1980; Peng and Virmani, 1990, Ganesan <i>et al.</i> , 1997.
Number of days to 50% flowering	A	Sardana and Borthakur, 1987; Sankar Rao, 1994; Suprio Chakrabarthy, 1994, Sharma and Koranne 1995, Singh and Choudhury 1995, Varma <i>et. al.</i> 1995; Singh <i>et. al.</i> 1996. Padmavathi <i>et. al.</i> 1997, Ganesan and Rangasamy, 1998.
	NA	Haque <i>et.al.</i> 1981. Agarwal and Sharma, 1985, Dhaliwal and Sharma, 1990; Supriochakraborty and Hazarika, 1994. Manuel and Rangasamy, 1995; Rattan Singh <i>et. al.</i> 1996, Ramalingam <i>et. al.</i> 1997; Anand <i>et. al.</i> 1999; Selvarani and Rangasamy, 1999.
	A & NA	Virmani 1990. Rattan Singh <i>et. al.</i> 1996.

Number of ear bearing tillers per plant.	A	Sankar Rao 1994; Dushyanth Kumar and Chandrappa 1994; Vijaya Kumar <i>et. al.</i> 1994 Sharma <i>et. al.</i> 1996, Ganesan <i>et al.</i> 1997
	NA	Suprio Chakraborty <i>et. al.</i> 1994, Sharma and Koranne 1995, Varma <i>et. al.</i> 1995, Ramalingam <i>et. al.</i> 1997, Ram <i>et. al.</i> 1998, Anand <i>et. al.</i> 1999.
	A&NA	Sardana and Borthakur, 1987, Lavanya <i>et. al.</i> 1997, Meenakshi and Amirtha-devarathinam, 1999.
Panicle length	A	Ghosh 1993, Singh and Choudhary, 1995
	NA	Ramalingam, 1993, Anandakumar and Subramaniam, 1994, Vijayakumar <i>et. al.</i> 1994, Ganesan <i>et. al.</i> 1997, Padmavathi <i>et. al.</i> 1997, Ganesan and Rangasamy, 1998, Ram <i>et. al.</i> 1998, Anand <i>et. al.</i> 1999
	A&NA	Sardana and Borthakur, 1987, Bobby and Nandarajan, 1994, Lavanya <i>et. al.</i> 1997.
Number of filled grains per panicle	A	Sardana and Borthakur, 1987; Prasad and Sastry, 1987; Bobby and Nadarajan, 1994 Vijayakumar <i>et. al.</i> 1994; Singh and Choudhary, 1995, Varma <i>et. al.</i> 1995, Ganesan <i>et. al.</i> 1997.
	NA	Ramalingam <i>et. al.</i> 1993, Dhanakodi and Subramaniam, 1994, Manuel and Rangasamy, 1995, Padmavathi <i>et. al.</i> 1997, Ram <i>et. al.</i> 1998, Anand <i>et. al.</i> 1999.
	A & NA	Ajmer Singh <i>et. al.</i> 1993 and Lavanya <i>et. al.</i> 1997.

1000-grain weight	A	Sardana and Borthakur, 1987, Prasad and Sastry 1987, Sankar Rao, 1994, Sprio Chakraborty <i>et al.</i> 1994, Geetha <i>et al.</i> 1994, Vijayakumar <i>et al.</i> 1994, Varma <i>et al.</i> 1995; Ganesan <i>et al.</i> 1997, Dwivedi <i>et al.</i> 1999. 33
	NA	Dhaliwal and Sharma, 1990, Ram <i>et al.</i> 1991, Siddiq <i>et al.</i> 1992, Dhankodi and Subramanian, 1994, Suprio Chakraborty and Hazarika, 1994, Singh <i>et al.</i> 1996; Ganesan <i>et al.</i> 1997, Ramalingam <i>et al.</i> 1997, Anand <i>et al.</i> 1999, Meenakshi and Amirthadevarathinam, 1999.
	A & NA	Ravikumar, 1987, Ramalingam <i>et al.</i> 1993, Lavanya 1994.
Grain yield per plant	A	Haque <i>et al.</i> 1981, Ramalingam <i>et al.</i> 1995, Bobby and Nandarajan, 1994, Vijayakumar <i>et al.</i> 1994, Singh and Chaudhary, 1995, Verma <i>et al.</i> 1995, Ganesan <i>et al.</i> 1998, Meenakshi and Amirthadevarathinam 1999.
	NA	Kumar and Saini, 1983, Sharma <i>et al.</i> 1984, Sardana and Borthakur, 1987, Prasad and Sastry, 1987, Ram <i>et al.</i> 1989, Dhaliwal and Sharma, 1990, Siddiq <i>et al.</i> 1992, Ghosh, 1993, Ananda Kumar and Subramanian, 1994, Dhankodi and Subramanian, 1994, Suprio Chakraborty <i>et al.</i> 1994, Manuel and Rangasamy, 1995, Sharma and Koranne, 1995, Rattan Singh <i>et al.</i> 1996, Sharma <i>et al.</i> 1996, Ganesan <i>et al.</i> 1997, Padmavathi <i>et al.</i> 1997, Ramalingam <i>et al.</i> 1997, Vivekanandan and Giridharan, 1997, Ganesan and Rangasamy, 1998, Ram <i>et al.</i> 1998, Anand <i>et al.</i> 1999.
	A & NA	Ravikumar, 1987; Virmani, 1990, Wilfred Manual <i>et al.</i> 1992, Ajmir Singh, 1993, Lavanya <i>et al.</i> 1997.

Harvest Index	A NA	Lawrence 1974, Bhatt, 1976, Reddy, 1981, Rattan Singh and Ajmer Singh, 1991

Root length	A&NA	SunchuanQuing <i>et. al.</i> 1995, Price and Tomos, 1997, Price <i>et. al.</i> 1997.
Root dry Weight	A	Shahid <i>et. al.</i> 1994
Shoot dry Weight		
Root to Shoot Ratio		

A : Additive gene action
 NA : Non additive gene action
 A & NA : Additive and non additive gene action.

2.6 CHARACTER ASSOCIATION

Study of character association helps the breeder in fixing selection criteria for grain yield in parental lines and segregating populations, such that the selection will possess the desired combination of characters. The different characters are often correlated with one another by Pleiotrophy or linkage (Harland, 1939). If the correlations are due to genetic linkage it is possible to reverse the correlations if so desired unless the linkage is very closer. Undesirable associations between desired attributes under selection may limit genetic advance. Hence, knowledge of association between different characters is highly essential for planning a sound breeding programme. The literature related to interrelationship studies in rice is reviewed below:

Correlation studies by Kawai and Sato (1967) reported a positive and significant association between plant height and days to 50% flowering. Wang (1965) found positive relationship between plant height and yield. Significant positive relationship between these traits was also reported by several workers. (Paramasivan, 1980, Kaul and Kumar, 1982, Krishnakumari 1983, Remabai *et. al.* 1992, Suprio Chakraborty and Hazarika 1994 and Sarwagi *et. al.* 1997). However, Tahir *et al.*, (1988) reported negative correlation between these characters. According to Palit (1976), plant height was negatively associated with 1000-grain weight. Positive association between plant height and days to maturity was noted by Singh *et. al.* (1984) and Marimuthu *et. al.* (1990).

Several workers reported positive association between days to 50% flowering and grain yield (Gomathinayagam *et. al.* 1988, Yadav 1992 and Chauhan *et. al.* 1993). But, Dhanraj *et. al.* (1987) noticed negative correlation between days to maturity and grain yield. Prasad *et. al.* (1988) observed that plant height was positively and significantly correlated with days to 50% flowering.

Number of ear bearing tillers per plant is an important yield contributing character as evident from its strong and significant association with grain yield in several studies. This was reported by Hegde (1987), Kalaimani and Kadambavanasundaram (1988). Similar

type of relationship between these two characters was also found by Reddy *et. al.* (1989), Rao (1990), Singh *et. al.* (1994) and Varma *et. al.* (1997). However, Mishra *et. al.* (1973) and Nakayama and Saito (1976) in their independent studies revealed negative association of number of panicles with grain number per panicle and 1000-grain weight. Similar negative association of panicle number with days to flowering was recorded by Saini and Ganeja (1975).

In correlation studies by Dhanraj *et. al.* (1987) Remabai *et. al.* (1992) and Supriyo Chakraborty and Hazarika (1994) observed a positive and highly significant correlation between panicle length and grain yield per plant. Prasad *et. al.* (1988) reported a positive relationship between panicle length and plant height. Contrary to these observations Ananda Kumar (1992) noticed a negative association between these two traits in upland rice cultivars.

In an experiment conducted by Zhang *et. al.* (1987) found a positive association between total number of spikelets per panicle and grain yield. Similar results were observed by Chaubey and Richharia (1993) and Supriyo Chakraborty and Hazarika (1994). In a study of nine rice varieties Huang (1984) and Remabai *et al.*, (1992) reported a close positive correlation between number of filled grains per panicle and yield. On the other hand an uncommon negative association between

number of filled grains and grain yield was reported by Wilfred manuel and Rangasamy (1993). Correlation studies for test weight (Mohanty and Singh 1969 and Chaudhary *et. al.* 1973) revealed positive association between 1000-grain weight and grain yield. Similar trend was observed by Chen *et. al.* (1986), Supriyo Chakraborty and Hazarika (1994). Based on correlation studies, Zhang *et. al.* (1987) and Wilfred Manuel and Rangaswamy (1993) revealed negative association of test weight and grain yield.

Strong positive correlation between harvest index and grain yield was recorded by several workers viz., Siddiq and Reddy (1984) Hegde (1987), Cheng *et. al.* (1988) and Chauhan *et. al.* (1993). Studies by Xiang *et. al.* (1986) revealed that grain yield had positive association with biological yield, grains per panicle, harvest index and 1000-grain weight. Similar relation between grain yield and grains per panicle and test weight were also noted by Chen *et. al.* (1986). Marimuthu *et. al.* (1990) and Remabai *et. al.* (1992). Dhanraj *et. al.* (1987) observed that grain yield was significantly correlated with plant height, ear bearing tillers per plant and test weight but had negative association with panicle length. Jangale *et. al.* (1987) also recorded similar trend.

Shahid *et al.* (1994) reported positive correlation between root length, root dry weight, shoot dry weight, stomata frequency and drought

tolerance. On the other hand they observed negative correlation between shoot length and stomata frequency. Namuco *et. al.* (1993) reported significant correlation ($r = 0.97$) between root thickness and drought tolerance thereby, indicating that root diameter may be of use in selecting drought tolerant genotypes.

2.7 PATH COEFFICIENT ANALYSIS

Wright (1921) developed path coefficient analysis and later Dewey and Lu (1959) used this technique in plant breeding. Correlation coefficients indicate the relationship between the characters. From correlations alone one cannot get adequate information on the nature of association along with the order of their relative contribution to dependent variables like economic yield. Path coefficient is a standardized partial regression coefficient and as such, measures the direct influence of one variable upon another variable and permits the separation of correlation coefficients into components of direct and indirect effects. Summary of review of results with respect to path coefficient analysis is furnished in Table 2.

2.8 HETEROSIS

Heterosis may be regarded as the converse of the deterioration that accompanies inbreeding in out breeding systems. According to Allard (1960) hybrid vigour may be defined as the phenomenon by which

F_1 hybrid falls outside the range of the parents with respect to some character or characters, usually applied to size, rate of growth or general fitness. The term "Heterosis" was coined by Shull (1908) and it is usually referred to relative heterosis.

Heterosis in rice was first reported by Jones (1926) and he observed that some F_1 hybrids had more culms and higher yield than their parents. Subsequently other workers have reported the occurrence of this phenomenon in various agronomic traits of rice, such as yield, grain weight, number of grains per panicle, number of panicles per plant, plant height, number of days to flowering and general plant vigour. Since, the suggestions for commercial exploitation of heterosis by way of producing hybrid rice varieties have been made from time to time and the rice breeders have been showing interest in heterosis breeding in rice. According to Swaminathan *et. al.* (1972) hybrid vigour in a self pollinated crop to be economically advantageous, must give 25 per cent more yield than the best commercial variety. The literature pertaining to heterosis in rice is reviewed hereunder.

In rice, number of studies have shown that heterosis for plant height is highly cross specific (Namboodri 1963, Sivasubramanian and Menon, 1973) and significant positive as well as negative heterosis has been reported. In rice shorter height of F_1 hybrids may be attributed to

the higher photoperiod sensitivity of some hybrids in comparison to their parents. Mandal (1982) observed positive and significant heterosis of 17.4 percent for plant height. But Julfikar *et. al.* (1994) noted varying degrees of positive and negative heterosis for plant height. With regard to growth duration, several workers observed that rice hybrids were shorter than the mid parent value and in some cases, shorter than that of the early parent. Chang *et. al.* (1973) Bardhan Roy *et. al.* (1975). Maurya and Singh (1978) and Dwivedi (1985) recorded significant positive heterosis for days to heading and days to maturity. Contrary to these observations Zen and Bahar (1993) observed negative heterosis for growth duration. With respect to ear bearing tillers Namboodri (1963) reported 9.1 to 122.8 per cent heterosis. Saini and Ishkumar (1973) reported positive heterosis in the F_1 hybrids for this character. Heterosis over mid parent varying from 14.7 to 84.8 per cent for panicle number was observed by Sivasubramanian and Madhava Menon (1973). Significant and positive heterosis was also reported by Ananda Kumar and Sreerangaswamy (1984). Dwivedi (1985) and Pandey *et. al.* (1995).

With regard to panicle characters like panicle length, number of grains per panicle and 1000-grain weight, several workers, reported heterosis. Heterosis over mid parent ranging from – 35.5 to 43.2 per cent for grains per panicle was found by Sivasubramanian and Madhava Menon (1973). High degree of heterosis for number of grains per panicle

was shown by Murayama (1973). According to Saini and Ishkumar (1973) high heterosis for grain yield in rice is mainly due to grains per panicle. While, Srivatsava and Seshu (1982) observed 10.48 per cent Mohanty and Mahapatra (1973) noted non-significant heterosis for this trait. However, Ghorai and Pandey (1982) recorded negative heterosis of -161.5 per cent for number of grains per panicle. Standard heterosis for spikelet sterility ranging from 3 to 17 per cent was observed by Virmani *et. al.* (1982) in 73 hybrids. Nijaguna and Mahadevappa (1983) recorded maximum heterosis of 87 per cent in the cross IR36/MTU3 and negative heterosis of 25.9 per cent in the cross IR36/Y4 for spikelet sterility. High positive standard heterosis and heterobeltiosis were recorded for spikelet sterility in a number of rice hybrids (Rao *et. al.* 1985, Rangaswamy and Natarajamurthy, 1998 and Biraj *et. al.* 1989). However Suhuman (1989) observed no significant difference with respect to sterility in rice hybrids.

With regard to heterosis for test weight, Mohanty and Mahapatra (1973) Virmani (1994) and Pandey *et. al.* (1995) found significant and high heterosis. Srivatsava and Seshu (1982) recorded moderate (less than 7%) heterosis for test weight, whereas Nijaguna and Mahadevappa (1983) noted significant positive heterosis and heterobeltiosis for this character. Dwivedi (1985) observed heterosis over mid parent, better parent and also over standard check for 1000-grain weight. Singh and

Singh (1978) and Ghorai and Pandey (1982) recorded negative heterosis for this character. Both positive and negative heterosis as well as heterobeltiosis was observed (Satyanarayana 1992) in different cross combinations for 1000-grain weight. 42

Reports in the literature have provided ample evidence of significant positive mid and high percent heterosis for yield ranging from 1.9 to 368.9 per cent in rice (Virmani *et. al.* 1981). Carnahan *et. al.* (1972) reported high level of heterosis for grain yield over better parent (210%) and best parent (122%). Maurya and Singh (1978) and Singh and Singh (1978) reported high heterotic effects for grain yield. Saini and Ishkumar (1973) and Paramasivan (1979) have however observed positive heterosis for grain yield. In their heterosis studies, Shanmugasundaram and Sivasubramanian (1983) revealed that high heterosis for grain yield is due to simultaneous heterosis for number of effective tillers per plant. They also emphasized the necessity to identify the hybrids exhibiting simultaneous heterosis for more than one yield component. Kaushik and Sharma (1986) recorded highest heterotic effects for grain yield which were 60.4 per cent over mid parent, 38.81 per cent over better parent and 32.3 per cent over the standard variety in rice. From their studies in rice, Sampath *et. al.* (1989) recorded high heterosis for grain yield due to ear bearing tillers and number of grains per panicle. Based on their study Liang *et. al.* (1986) revealed that decrease in

number of panicles per plant was the primary cause of the reduction in yield for heterosis. According to Virmani *et. al.* (1982) and Kim (1988) high yielding hybrids had significant heterosis and heterobeltiosis for harvest index.

The foregoing review indicates that in most of the cases heterosis was found to be cross specific and hybrid vigour has been recorded for grain yield or for one or more yield components. Negative heterosis for yield is usually compensated by positive heterosis for other yield components indicating that yield in hybrids was the result of increased size. However, difficulties in hybrid seed production discouraged most of the researchers from continuing their vigorous efforts.

Table 2 : Review of results published with respect to path coefficient analysis

Direct effects on grain yield

Character showing direct effect on yield	Direction of the effect	Authors
Plant height	Positive	Sri Rangaswamy and Murugesan (1973)
	Negative	Amirthadevarathnam (1983)
	Positive	Sinha and Banerjee (1987)
	Positive	Ramakrishnayya <i>et. al.</i> (1991)
	Positive	Chaubey and Singh (1994)
	Positive	Sardana <i>et. al.</i> (1994)
Days to 50%flowering	Positive	Amirthadevarthinam (1983)
	Negative	Soundara Pandian (1990)
	Positive	Gomathi nayagam (1988)
	Positive	Sardana <i>et. al.</i> (1989)

	Positive	Ibrahim <i>et. al.</i> (1990)
	Positive	Dash <i>et. al.</i> (1996)
Ear bearing tillers per plant	Positive	Hegde (1987)
	Positive	Murthy and Venkatesh Babu (1992)
	Negative	Rajamani (1993)
	Positive	Knneth <i>et. al.</i> (1993)
	Positive	Chaubey and Singh (1994)
	Positive	Babu (1996)
	Positive	Basavaraja <i>et. al.</i> (1997)
	Positive	Anand <i>et. al.</i> (1998)
Panicle length	Positive	Nandarajan and Kumaravelu (1994)
	Positive	Sawant <i>et. al.</i> (1994)
	Positive	Feng <i>et. al.</i> (1995)
Number of spikelets per panicle	Positive	Sinha and Banerjee (1987)
	Negative	Amrithalingam (1988)
	Positive	Reuben and Kisanga (1989)
	Positive	Rajamani (1993)
	Positive	Chauhan <i>et. al.</i> (1993)
Number of filled grains per panicle	Positive	Mishra <i>et. al.</i> (1973)
	Positive	Rao <i>et. al.</i> (1980)
	Positive	Ismail and Alvarez (1986)
	Positive	Ramlingam <i>et. al.</i> (1994)
	Positive	Sundaram and Palaniswamy (1994)
	Positive	Babu (1996)
	Positive	Sinha and Banerjee (1987)
1000 grain weight	Positive	Soares <i>et. al.</i> (1990)
	Positive	Padhi and Singh (1991)
	Positive	Rajamani (1993)
	Positive	Sawant (1994)
	Positive	Chaubey and Singh (1994)
	Positive	Satpute (1996)
Harvest Index	Positive	Lin and Wu (1981)
	Positive	Siddiq and Reddy (1984)

Indirect effects on yield

Character showing indirect effect on yield	Direction of the effect	Character through Which effect is Expressed	Authors
Plant height	Negative	Ear bearing tillers per plant	Singh (1980)
	Positive	Days to 50% flowering	Gomathinayagam <i>et al.</i> (1990)
	Positive	Panicle length	-do-
	Positive	No. of grains per panicle	-do-
	Positive	Ear bearing tillers	-do-
	Positive	Panicle length	Pathak and Patel (1989)
	Positive	Dry matter production	Wilfred Manuel and Rangaswamy (1993)
Days to 50% flowering	Positive	Plant height	Amirthadevarathinam (1983)
	Negative	Ear bearing tillers	Soundarapandian (1990)
	Negative	Test weight	Rajamani (1993)
Number of productive tillers per plant	Positive	Grain numbers per panicle	Geetha <i>et. al.</i> (1994)
	Negative	Grain number per panicle	Sawant <i>et. al.</i> (1994)
Panicle length	Positive	Grain number per panicle	Ramalingam <i>et. al.</i> (1994)
	Positive	Spikelet number	Panwar <i>et. al.</i> (1989)
	Negative	Test weight	Sukanya Subramanian and Rathinam (1984)
Number of spikelets per panicle	Positive	Gram number per panicle, Panicle length	Rajamani (1993)
	Negative	Productive tillers, test weight	Sri Krishna Devarayalu (1993)
	Negative	Plant height, Days to 50% flowering, productive tillers per plant	Rajamani (1993)

Filled grains per panicle	Positive	Spikelet number	Panwar <i>et. al.</i> (1989)
	Positive	Plant height, panicle length	Paramasivam and Srirangaswamy (1988)
	Negative	Plant height Tillers per plant	Reuben and Katuli (1989)
	Positive	Productive tiller test weight	Sundaram and Palaniswamy (1994)
	Positive	Tiller number panicle length	Ganapthy <i>et. al.</i> (1994)
Test weight	Negative	Plant height Ear length	Paramasivam and Sree Rangaswamy (1988)
	Negative	Panicle length Grain number per panicle	Rajamani (1993)
	Positive	Plant height Days to 50% flowering productive tillers	Rajamani (1993)
Harvest Index	Positive	Panicle size	Siddiq and Reddy (1984)

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Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present study was taken up as two separate experiments in accordance with the objectives.

3.1 LOCATION

The present investigation was carried out at Agricultural Research Station, Nellore, Andhra Pradesh, situated at an altitude of 20 meters above mean sea level, 14.21° N latitude and 79.59° E longitude and 20 km away from Bay of Bengal. The experiment was conducted during *rabi* seasons of 1996, 1997 and 1998.

3.2. MATERIAL

The experimental material used in the present investigation was consisted of 60 genotypes of rice obtained from Directorate of Rice Research, Rajendranagar, Hyderabad, Agricultural Research Stations, Nellore, Maruteru and Warangal. Source of origin and other important characters of the genotypes are presented in Table 3.

Table 3 : Source and the salient features of the material used in the experiments

S.No	Name	Source	Salient features
1.	MTU 17	Maruteru A.P.	It is a pure line selection from land races. Short duration suitable for upland cultivation. Red Kernal.
2.	MTU 7014	Maruteru A.P.	It is a cross derivative of IET 1444 and IET 7332 semi dwarf plant with short duration. Resistant to blast and bacterial leaf blight. Straw glume with fine grain.
3.	WGL 14280-1	Warangal A.P.	It is a cross combination of WGL 20471 and CR 5441-2 semi dwarf, early duration. Dark brown glume having long slender grain, resistant to gallmidge.
4.	NLR 33771	Nellore A.P.	It is a single cross derivative of NLR 31109 / IET 7230. Semi dwarf and early duration straw glume and medium slender grain.
5.	Bharani	Nellore A.P.	It is a cross derivative of IR 36 and IET 2508. Semidwarf plant with short duration. Straw glume with fine quality grain. Resistant to Rice Tungro Virus.
6.	WGL 3825	Warangal A.P.	It is developed by crossing WGL 28712 and IR 36. Semidwarf plant type with short duration. Long slender grain, resistant to biotype 1 gall midge.
7.	NLR 33634	Nellore A.P.	Dwarf and early duration. A cross derivative of NLR 30250 / IR 62. Straw glume and fine grain.
8.	M.S. Vari	Maruteru A.P.	It is a pure line selection from land races. Short duration, suitable for upland conditions. Fine quality grain.

Table 3 (Contd....)

9.	NLR 26706	Nellore A.P.	Dwarf and early maturing erect in habit with green leaves. Straw glume with medium slender grain.
10.	Swathi	Nellore A.P.	It is a cross between IR 36 / MTU 4569. It has sturdy culms and dark green, broad and upright leaves. Erect plant type with short duration. Fine quality grain.
11.	WGL 19299	Warangal A.P.	It is a single cross between C10754 and C13709. Short duration and Semidwarf plant type.
12.	WGL 14399-1	Warangal A.P.	It is a cross combination of WGL 20471 and CR 544-1-1-2. Erect plant type with short duration. Dark brown glume with long slender grain.
13.	N22	Nagina U.P.	It is a local selection from Rajbhog in Pilibhit, medium tall with short duration. Resistant to BPH. Short bold grains, suitable for upland conditions.
14.	NLR 13969	Nellore A.P.	A dwarf derivative of the cross between Sona and Kakatiya. It is early maturing and fine grain type.
15.	WGL 18011-15	Warangal A.P.	It is a single cross combination of CR44 and C 12708. Erect plant type with early duration. Straw glume with short bold grain.
16.	NLR 33633	Nellore A.P.	Semi dwarf and early maturing. Stiff culms and erect foliage. Tolerant to blast and BPH. A cross derivative of NLR 30250 / MTU 4870.
17.	Sravani	Nellore A.P.	It is a selection from IR 50. Superfine grain with good cooking quality, early maturing and tolerant to blast.

Table 3 (Contd....)

18.	Srinivas	DRR Hydera- bad	Short statured, profuse tillering erect plant type with upright and green leaves. It is a cross between IR8 and Latisail.
19.	NLR 33356	Nellore A.P.	Dwarf and short duration variety. Straw glume with short bold grain. Tolerant to cold.
20.	IR 64	IRRI Philli- ppines	Dwarf, erect plant type with dark green leaves. It is a cross derivative of IR5657-33-2-1/IR 2061-465-1-55 with superfine grain. Resistant to blast.
21.	NLR 33358	Nellore A.P.	Dwarf and short duration. Straw glume and extra long grain. Suitable for export under non-basmathi quality.
22.	IET 9994	DRR Hydera- bad	It is a single cross derivative of Sona / ARC 14529. Superfine grain, early maturing variety with tolerance to Rice Tungro Virus.
23.	NLR 33635	Nellore A.P.	It is a single cross combination of NLR 145 / IET 7332. Short duration with erect leaves. Straw glume and fine quality grain.
24.	NLR 30674	Nellore A.P.	Dwarf, erect and dark green foliage. Early maturing. Straw glume with medium slender grain quality.
25.	Rasi	DRR Hydera- bad	Semi dwarf and short duration variety. A cross derivative of T(N)1/C029. Straw glume, short bold grain, with purple tip. Tolerant to moisture stress and blast resistant.
26.	NLR 30426	Nellore A.P.	A single cross derivative of IR 36 and IET 2508. Leaves are erect and short duration. Straw glume with fine quality grain.

Table 3 (Contd....)

27.	NLR 33899	Nellore A.P.	It is a selection from IR50, early maturing and tolerant to blast. Straw glume, long slender and quality grain.
28.	RRB 63-2	Bans- wara Rajas- than	It is a cross derivative of CR 199-1 / Mahsuri. Dwarf plant type and early maturing. Straw glume and long bold grain type.
29.	Pusa - 836-202-208- 207-7	IARI New Delhi	It is a double cross combination among parents of IR50/P3//P312/TKM9. Semidwarf with erect leaves. Short duration. Straw glume with long slender grain.
30.	RP 1579- 1219-MRST 27	DRR Hydera- bad	Semi dwarf and early maturing. Purple leaf sheath. Straw glume with short bold grain type. Purple tip is present on grain.
31.	NDR 1038-1	Faizabad U.P.	It is a cross combination of Bagired / IR 1568-173 / 1 // IR 6228-1-3-5. Dwarf and erect leaves, straw glume with long slender grain type.
32.	NDR 1041-2	Faizabad U.P.	Semi dwarf and early maturing variety. A cross combination of Bagired / IR 15448-193-3 // IR 6228-4-3-4. Straw glume with long slender grain.
33.	NDR 1048-3	Faizabad U.P.	A dwarf derivative of IR 10068-11-1 / IR 10058-107-1 // IR 4563-5-1-36. Early maturing with erect flag leaf. Straw glume with long slender grain type.
34.	KMJ 10-1-3	Karim- ganj Assam	A cross combination of Pusa 2-21 / CH 631. Dwarf and early maturing. Straw glume and medium slender grain.
35.	KMJ 10-1-4	Karim- ganj Assam	Semi dwarf and short duration. A cross derivative of Pusa 2-21 / CH 631. Medium slender grain.

Table 3 (Contd....)

36.	KMJ 10-2-2	Karim-ganj Assam	A cross derivative of Pusa 2-21 / CH 631. Dwarf and short duration. Straw glume with medium slender grain type.
37.	OR 1401-3	Bhuba- neswar Orissa	Dwarf, Uniform flowering and early maturing. A cross derivative of ORS 14-15 / DR 83-1. Medium slender grain.
38.	OR 1507-6	Bhuba- neswar Orissa	Dwarf with short duration. Broad and erect foliage. A cross combination of OR 924-25 / Pathara.
39.	OR 1513-3	Bhuba- neswar Orissa	Semi dwarf, early maturing. A cross combination of OR 1045-1-10/ Pathara. Straw glume with medium slender grain.
40.	OR 1590-1	Bhuba- neswar Orissa	Semi dwarf with short duration. A cross derivative of Suphala / OR 1029-5-4. Medium slender grain.
41.	RP 3740- 1460-1784	DRR Hydera- bad	Dwarf and early maturing. A single cross derivative of IET 7654/IET 7946. Medium slender grain.
42.	Rewa 103-70-26	Rewa M.P.	Dwarf and early maturing. A single cross combination of GMS 47 / Ratna. Straw glume with long slender grain.
43.	Rewa 107-73-28	Rewa M.P.	It is a cross derivative of Sabri / ARC 10372. Dwarf uniform height. Erect leaves and long slender grain type.
44.	Rewa 205-66-22	Rewa M.P.	Dwarf, Uniform and early maturing. A cross combination of UPR 103-8 / IR 25588. Long slender grain type.

Table 3 (Contd...)

45.	OR 1432-10	Bhuba- neswar Orissa	A single cross derivative of Sankar / Heera. Dwarf, early maturing. Uniform height, Medium, bold grain.
46.	OR 1507-3	Bhuba- neswar Orissa	It is a cross combination of OR 924-2-5 / Pathara. Short duration and medium bold grain.
47.	OR 1502-2	Bhuba- neswar Orissa	Dwarf and early maturing. It was developed by crossing OR 924-2-5 / OR 482-19. Straw glume with medium slender grain.
48.	OR 1509-7	Bhuba- neswar Orissa	Semi dwarf and early maturing. A cross derivative of OR 924-2-5 / OR 1045-1-10. Medium bold grain.
49.	ORS 102-4	Bhuba- neswar Orissa	It is a cross combination of Jajati / Annapurna. Semidwarf, Uniform height, Medium bold grain.
50.	CR 691-47	CRRI Cuttack	Dwarf and early maturing. A cross combination of C 1046 / Dular. Straw glume and fine grain.
51.	CR 691-48	CRRI Cuttack	This variety is a cross combination of C 1046 / Dular. Short duration with long slender grain. Erect and dark green foliage.
52.	CR 679-2	CRRI Cuttack	Dwarf stature with short duration. Erect and dark green foliage. A cross derivative of CR 628-2 / IR 36. Medium slender grain.
53.	CR 811-1	CRRI Cuttack	It is a cross combination of CR 635-49 / Lalnakanda 41. Semi dwarf. Short duration broad and droopy leaves. Medium slender grain.
54.	RR 168-1	Hazari- bhag Bihar	Dwarf, uniform height and short duration. Cross combination of C22 / CH 45.

Table 3 (Contd....)

55.	CN 875-135-1-3	Chinsura W.B.	It was developed from the cross Panke / HPU-741. Dwarf and early duration. Fine quality grain.
56.	PSR 1344-4-1	Kanpur U.P.	It is a single cross derivative of ES 1-2-3 / IR 36. Dwarf and early maturing, uniform height. Straw glume and fine grain.
57.	PASR 1345-1	Kanpur U.P.	Dwarf and short duration. A cross combination of IET 7564 / Pusa 33 straw glume with long slender grain.
58.	SBR 34-69-1	Kanpur U.P.	Dwarf and Uniform height. A single cross derivative of IET 14189 / Pusa 33. Fine grain.
59.	Tulasi	DRR Hyderaba d	Dwarf, erect plant type with short duration, resistant to blast and tolerant to drought. It is a cross between Rasi / Fine gora.
60.	Annada	CRRI Cuttack	Dwarf, uniform height, erect and dark green foliage. Early maturing. Suitable for upland conditions.

3.3 METHODS

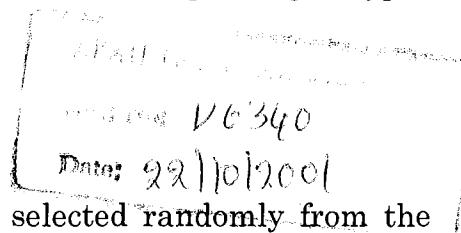
3.3.1 Experiment I

This experiment was taken up to screen the germplasm for yield and component traits for drought tolerance. The experiment was conducted during Rabi 1996 at Agricultural Research Station, Nellore and the material was sown on 12-11-1996.

The experiment was laid out in a randomised block design with three replications. Twenty five days old seedlings were transplanted at

the rate of two seedlings per hill adopting an uniform spacing of 15 x 10 cm, as the entries were of early duration group. Each plot consisted of 4 rows of 5 meter length. The crop was provided with recommended doses of fertilizers and attended to normal cultural operations.

When the crop was 70 days old, artificial moisture stress was created by withholding irrigation for 15 days. The susceptible genotypes exhibited severe wilting symptoms.



Ten plants from each genotype were selected randomly from the two central rows for recording data on characters like root dry weight, shoot dry weight, relative water content, days to 50% flowering, plant height, number of ear bearing tillers per plant, panicle length, number of spikelets per panicle, spikelet fertility per cent, test weight, harvest index and grain yield per plant.

The data collected from experimental material were subjected to statistical analysis to estimate variability, heritability, genetic advance and the same data were subjected to D^2 statistic (Mahalanobis 1936). Based on D^2 statistic eight genotypes viz., NLR 33899 (P_1); WGL 14280-1 (P_2); NLR 30491 (P_3); N22 (P_4); KMJ 10-2-2 (P_5); Tulasi (P_6); CN 875-135-1-3 (P_7) and CR 811-1 (P_8) falling in different clusters were selected as parents. These parents were crossed in all possible

combinations under 8 x 8 diallel mating system, excluding reciprocals.

The eight parents were transplanted at different dates with an interval of 15 days to ensure synchrony in flowering to produce adequate crossed seed.

3.3.2. Experiment II

This experiment was taken up to study heterosis, combining ability gene action and inter relationship between drought tolerance, yield and its components through character association.

Material

The material for this experiment consists of eight parents (NLR 338899, WGL 14280-1, NLR 30491, N22, KMJ 10-2-2, Tulasi, CN 875-135-1-3 and CR 811-1 selected based on D^2 analysis and $28F_1^s$ involving these parents in diallel mating system without reciprocals.

3.3.3 Hybridization Programme

The crossing programme was taken up during Rabi, 1997. The crossing was started with the emergence of panicles. Plants with 50 to 60 per cent emerged panicles were selected. The florets that have completed anthesis from the top and the young florets from bottom of the panicle were removed. The remaining florets of the panicle, which are expected to open within one or two days are emasculated by using

scissors and forceps. The six anthers present in each spikelet were carefully removed with the help of forceps without causing injury to stigma and ovary. The emasculated florets were covered with butter paper bags and labelled. On the next day morning panicles from healthy and representative male parents having more florets were cut to the bottom and kept in conical flasks containing water. After the extrusion of anthers, paper bag from emasculated female panicle was removed and the blooming panicle of the male parent was taken out from the water and pollen was dusted gently over the female parent and immediately the panicle was again covered with butter paper bag. This process of pollination was repeated for three days to have good seed setting. Care has been taken to cover the emasculated panicles with butter paper bags from emasculation to seed setting so as to avoid cross pollination. The fully matured crossed seed was harvested and sun dried for raising in F_1 generation.

During the off season (early kharif, 1998), again fresh crosses were effected to produce adequate crossed seed for inheritance studies.

3.3.3.1 Study of F_1^s and parents

The seed of resultant $28F_1^s$, and eight parents were partitioned into 2 sets and sown on 18-11-98. These two sets were conducted as two separate experiments one under moisture stress conditions and the other

under normal favourable condition. These two experiments were planted adopting randomized block design with three replications at two different blocks of Agricultural Research Station, Nellore.

3.3.3.2 Nursery

The F_1 seeds and parents were germinated first in petridishes on 18-11-98. All the F_1 seeds and parents had good germination. Three days after germination they were transferred to a raised and well prepared nursery bed at Agricultural Research Station, Nellore. Vigorous and robust seedlings were obtained from these seeds.

3.3.3.3 Main field preparation and planting

Main field was dry ploughed twice with tractor drawn cultivator during October, 1998. Water was let into the field and the field was puddled twice with tractor in November, 1998. Finally, the field was levelled and laid out into plots as per the field design.

Twenty five day's old seedlings were transplanted on well prepared and levelled field with single seedling per hill adopting 15 x 10 cm spacing. The plot size of F_1 progenies and parents was two rows of 3 meter length. Recommended package of practices were followed in growing the crop. Need based plant protection was given.

A thin film of water (2-3 cm) was maintained at planting time in the main field for both the experiments. Later on an uniform water depth of about 5 cm was maintained upto panicle initiation stage. Subsequently in one experiment the water was maintained normally upto ripening stage. The seedlings of this experiment were raised under favourable conditions. For another experiment which was located relatively on high piece of land, moisture stress was created by withholding irrigation for 15 days during reproductive stage.

3.4 OBSERVATIONS

The following data were collected replication and treatment wise from 10 randomly selected plants for parents and F_1^s . Data were collected separately for each experiment.

3.4.1. Preharvest observations

3.4.1.1. Plant height (cm)

Plant height was measured from ground level to tip of the panicle and expressed in centimetres

3.4.1.2: Number of ear bearing tillers per plant

Total number of panicle bearing tillers were counted in each of the selected plants at maturity and mean was computed.

3.4.1.3. Days to 50 per cent flowering

Period from the date of sowing to date of 50 per cent plants in 60 panicle emergence stage.

3.4.1.4 Root and shoot dry weights (g)

Plants were dug out carefully with the help of crow bar without causing damage to root portion. Roots were washed thoroughly with tap water and the root and shoot portions were separated. These root and shoot parts were allowed to dry in an oven at 80°C till constant dry weights were obtained. Root to shoot ratio was calculated by utilizing the data.

3.4.1.5 Relative water content (RWC)

Relative water content of leaves was estimated at the end of stress period. Rice leaves were collected treatment wise from each replication in a butter paper cover and the fresh weight of these samples was recorded without loss of time and then soaked in water for about eight hours. Then the leaves were taken out from water, gently pressed with a filter paper to remove superficial moisture and recorded turgidity weights in grams. These samples were dried in an oven at 80 °C for 48 hours till constant dry weights were recorded. Relative water content in per cent was calculated by using the formula.

$$\text{RWC} = \frac{\text{Fresh weight} - \text{oven dry weight}}{\text{Turgid weight} - \text{oven dry weight}} \times 100$$

3.4.1.6. Leaf rolling

Leaf rolling score was recorded under stress using the 10 point scale of standard evaluation system for rice (1996) devised by International Rice Research Institute, Philippines. 61

Scale	Leaf Symptoms
0	Leaves healthy
1	Leaves start to fold shallow V shape
3	Leaves folding (deep V shape)
5	Leaves fully cupped (U shape)
7	Leaf margins touching (O shape)
9	Leaves tightly rolled

3.4.1.7 Leaf area per plant

Leaf area was measured by length x breadth method using a constant factor 0.69 at reproductive stage.

3.4.1.8 Specific leaf weight

Leaf samples were collected randomly from each treatment. The leaf area in Sq.cm. was measured on a graph paper, then the leaf samples were dried in hot air oven at 80°C for 48 hours and the weight was recorded in milligrams. Specific leaf weight was calculated by using the formula.

$$\text{Specific leaf weight (mg/sq.cm)} = \frac{\text{Dry weight of the leaf in milligrams}}{\text{Area of the leaf in sq. cm.}}$$

3.4.2 Post harvest observations

3.4.2.1 Panicle length

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The length from base of the panicle to the tip was measured in centimetres.

3.4.2.2. Number of spikelets per panicle

Number of total spikelets including filled and unfilled for each panicle were counted. The same sample of ten panicles used for recording panicle length was utilized for this trait.

3.4.2.3. Spikelet fertility percent

The number of well filled grains in the 10 panicles chosen randomly were counted and the spikelet fertility percent was calculated.

3.4.2.4. Test weight

Random sample of 1000 grain in each treatment was taken and weight recorded in grams.

3.4.2.5. Harvest index

Harvest index was calculated as per the following formula.

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Total biological yield}} \times 100$$

3.4.2.6. Grain yield

Weight of grain from single plant was recorded in grams after sun drying, at 14 per cent grain moisture content. 63

3.5 SIMULATION OF DROUGHT BY POLYETHYLENE GLYCOL SOLUTIONS ON SEEDLING GROWTH

Drought conditions were simulated in the laboratory by using aqueous solutions having osmotic pressures of 0.00, 3.00; 6.00 and 10.0 bars.

Aqueous solutions of 0.00; 3.00, 6.00 and 10.00 bars were obtained by dissolving 0,; 172; 230 and 294 grams of polyethylene glycol (PEG) in one litre of distilled water respectively (Pamar and Moore, 1966). Well filled and uniform seeds were collected and these seeds were placed on moistened filter paper in glass petridishes and the filter papers were moistened in the beginning and at regular intervals with the above mentioned solutions. On 6th day after soaking, the shoot and root lengths were recorded in centimetres.

3.6 STATISTICAL ANALYSES

Means based on 10 single plant observations for F_1 s and parents of the two experiments were used for statistical analysis separately.

3.6.1 Analysis of variance

Analysis of variance was computed based on randomized block design for each of the character separately as per standard statistical procedure (Panse and Sukhatme, 1978). The significance was tested by referring to the values of "F" table (Fisher and Yates, 1963).

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

Where:

$$\begin{aligned} Y_{ij} &= \text{phenotypic observation of } i^{\text{th}} \text{ genotype and } j^{\text{th}} \text{ replication} \\ m &= \text{general mean} \\ g_i &= \text{effect of } i^{\text{th}} \text{ genotype} \\ r_j &= \text{effect of } j^{\text{th}} \text{ replication} \\ e_{ij} &= \text{random error associated with } i^{\text{th}} \text{ genotype and } j^{\text{th}} \text{ replication} \end{aligned}$$

The structure of the analysis of variance

Source	d.f.	S.S.	M.S.S.	"F"-ratio
Replications	(r-1)	M_s	M'_s	M'_s / M'_e
Treatments	(t-1)	M_t	M'_t	M'_t / M'_e
Error	(r-1) (t-1)	M_e	M'_e	
Total	(tr-1)			

Where, r and t : number of replications and treatments respectively

M'_s , M'_t and M'_e stand for mean sum of squares due to replications, treatments and error respectively

3.6.2. Multivariate analysis through D^2 statistic

A measure for group distance based on multiple characters was given by Mahalanobis (1936) using D^2 statistic. With the help of this, genetic divergence between genotypes was estimated.

D^2 value between i^{th} and j^{th} genotypes for "P" characters was calculated as

$$D_{ij}^2 = \sum_{t=1}^p (\bar{Y}_{it} - \bar{Y}_{jt})^2$$

where:

Y_{it} = Uncorrelated mean values of i^{th} genotype for "t" character

Y_{jt} = Uncorrelated mean value of j^{th} genotype for "t" character.

D_{ij}^2 = D^2 between i^{th} and j^{th} genotype.

The various steps involved in estimation of D^2 values are given below.

3.6.2.1 Test of significance

After testing the differences between genotypes for each of the characters, a simultaneous test of significance for differences in the mean values of a number of correlated variables with regard to the pooled effect of characters was carried out by using "V" statistic which in turn utilizes Wilks " Λ " criterion. The sum of squares and sum of products of error + genotype were used for this purpose. The estimation of " Λ " (Wilks criterion) was done using the following relationship.

$$"\Lambda" = \frac{W}{S}$$

Where,

" Λ " = Wilk's criterion

W = Determinant of error matrix

S = Determinant of error variety matrix

$$V(stat) = -m \log_e \Lambda' = - \left(n - \frac{P + Q + 1}{2} \right) \log_e \Lambda' \quad (66)$$

Where,

$$m = n - (P+Q+1)/2$$

$$P = \text{Number of variables or characters}$$

$$Q = \text{number of variables} - 1 \text{ (or d.f. for population)}$$

$$n = \text{degrees of freedom for error t varieties}$$

$$\text{Log}_e \Lambda = 2.3026 \log_{10} \Lambda$$

V (stat) is distributed as χ^2 with PQ (13 x 60 = 780) degrees of freedom

3.6.2.2. Transformation of correlated variables

In the present model, computation of D^2 values were reduced to simple summation of the differences in mean values of various characters of the two genotypes i.e., d_i^2 . Therefore, transformation of correlated variables to uncorrelated one was done before working out the D^2 values. Transformation was done by using pivotal condensation method.

3.6.2.3. Computation of D^2 values

For a given combination of 'i' and 'j' genotype the mean deviation i.e., $\bar{Y}_{it} - \bar{Y}_{jt}$ for $t = 1, 2, \dots, P$ variables were computed and D^2 values were calculated as sum of squares deviations

$$= \sum_{t=1}^P (\bar{Y}_{it} - \bar{Y}_{jt})^2$$

3.6.2.4. Testing of significance of D^2 values

The D^2 value obtained for a pair of populations is taken as the calculated value of χ^2 and is tested against the tabulated value of χ^2 for P degrees of freedom, where P is the number of characters considered.

3.6.2.5 Contribution of individual characters towards divergence:

In all the combinations each character was ranked on the basis of their combination towards divergence between two entries ($d_i = r_t^i \cdot r_t^j$) Rank 1 is given to the highest mean difference and rank P to the lowest difference, where P is the total number of characters. Percentage contribution of each character towards genetic divergence was calculated using the formula.

$$\text{Percentage contribution of character } X = \frac{N \times 100}{M}$$

Where :

N = number of genotype contribution where the character was ranked first

M = All possible combinations of number of genotypes considered

3.6.2.6 Grouping of genotypes into various clusters:

Grouping of populations into different clusters was done using Tocher's method as described by Rao (1952). The criterion used in clustering by this method is that any two varieties belonging to the same cluster should atleast on an average show a smaller D^2 value than those

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 belonging to different clusters. For this purpose D^2 values of all combinations of each genotype were arranged in increasing order of magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with two populations having the smallest distance from each other were considered to which a third population having the smallest D^2 value from the first two populations was added. Similarly next nearest fourth population was considered and this procedure was continued. At certain stage where it was felt that after adding a particular population there was abrupt increase in the average D^2 value, that population was not considered for including in that cluster. The group of the first cluster was then omitted, and the rest was treated in a similar way. This process was continued till the genotypes were included into one or the other clusters.

3.6.2.7 Average intra cluster distance

For the measurement of intra cluster distance, the formula used was $\sum D_i^2 / n$

Where

$\sum D_i^2$ = sum of distance between all possible combinations (n) of the populations included in a cluster

n = number of clusters

3.6.2.8 Average inter-cluster distance

Clusters were taken one by one and their distance from other clusters were calculated. The distance between two clusters was the sum

of the D^2 values between the numbers of one cluster to each of the numbers of the other cluster divided by the product of number of genotypes in both the clusters under consideration.

3.6.3. Genetic variability

The genotypic and phenotypic coefficients of variabilities were calculated according to the formulae given by Falconer (1981)

$$\text{Genotypic coefficient of variability (GCV)} = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

$$\text{Phenotypic coefficient of variability (PCV)} = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

Categorisation of the range of variation was effected as proposed by Sivasubramanian and Menon (1973).

Less than 10%	—	Low
10 - 20%	—	Moderate
More than 20%	—	High

3.6.4. Heritability

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability (h^2) in the broad sense was calculated according to the formula given by Burton (1952)

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

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σ_g^2 = genotypic variance

σ_p^2 = phenotypic variance

As suggested by Johnson *et al.*, (1955) h^2 estimates were categorised as:

Low	=	0 – 30%
Medium	=	30 – 60%
High	=	61% and above

3.6.5 Genetic advance

Genetic advance refers to the expected gain or improvement in the next generation by selecting the superior individuals under certain amount of selection pressure. From the heritability estimates the genetic advance was estimated by the following formula given by Burton (1952).

$$GA = K \cdot h^2_{(b)} \cdot \sigma_p$$

Where:

GA = expected genetic advance

K = 2.06 at 5 per cent selection intensity

σ_p = Phenotypic standard deviation

$h^2_{(b)}$ = heritability in broad sense

In order to visualize the relative utility of genetic advance among the characters, genetic advance as per cent of mean was computed.

$$\text{Genetic advance as per cent of mean} = \frac{GA}{\text{Grand mean}} \times 100$$

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et. al.* (1955).

Low	=	Less than 10%
Moderate	=	10 – 20%
High	=	More than 20%

3.6.6 HETEROSIS

The magnitude of heterosis was estimated in relation to mid parent as well as better parent values. Both were calculated as percentage increase or decrease of F_1 s, over the mid parent (MP) and better parent (BP) values.

a) Heterosis over mid parent (H_1)

$$\text{Mid parent value } (\overline{MP}) = \frac{\overline{P}_1 + \overline{P}_2}{2}$$

$$\text{Percent } F_1 \text{ heterosis over MP } = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

(% H_1)

$$\text{SE } (H_1) = \sqrt{\frac{3}{2} \cdot \frac{V_e}{r}}$$

b) Heterosis over better parent (H_2)

$$\text{Percent } F_1 \text{ heterosis over BP } = \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

(H_2)

$$\text{SE } (H_2) = \sqrt{2 \cdot \frac{V_e}{r}}$$

Where:

V_e = error mean square obtained from simple RRD analysis of variance

$\bar{F}_1$ = mean of F_1

$\overline{MP}$ = mean of the two parents

$\overline{BP}$ = mean of the better parent

SE = standard error

The significance of heterosis was tested for both the situations by calculating the critical difference (CD) at 5 and 1 per cent levels of probability at error degrees of freedom.

$$CD = SE \times t \text{ error d.f.}$$

3.6.7 Combining ability analysis

Estimation of combining ability variance and effects from diallel crosses were calculated following Model I and Method II of Griffings (1956). This method was considered more appropriate since, the study was restricted to the parents and single set of crosses. Model I assumes that variety and block effects are constant but environmental effect is variable and the experimental material is the population about which inferences are to be made. The method helps to compare combining ability of parents when parents themselves are used as testers. Error is independently and distributed with mean zero and variance as σ_e^2 .

The mathematical model for the combining ability in Model I is assumed to be

$$X_{ij} = \mu + g_i + g_j + S_{ij} + 1/bc + \sum_k \sum_l e_{ijkl}$$

$$\begin{aligned} i, j &= 1, \dots, p \\ k &= 1, \dots, b \\ l &= 1, \dots, c \end{aligned}$$

Where :

- p = number of varieties
- b = number of blocks
- c = number of observations for each of the plots
- μ = population mean
- g_i = general combining ability of i th parent
- g_j = general combining ability of the j th parent
- S_{ij} = Specific combining ability effect such that $S_{ij} = S_{ji}$
and
- e_{ijkl} = environmental effect pertaining to the $ijkl$ th observation

The restrictions imposed on this model are

$$\sum g_i = 0 \text{ and } \sum S_{ij} + \sum S_{ji} = 0 \text{ (for each } i \text{)}$$

3.6.7.1 Estimation of combining ability variances

The general and specific combining ability variances were estimated by the following formulae

$$S_g = \frac{1}{(P+2)} \left[\sum (x_i + x_{ii})^2 - \frac{4}{\rho} x_{..}^2 \right]$$

$$S_s = \left[\sum \sum x_{ij}^2 - \frac{1}{P+2} (x_i + x_{ii})^2 + \frac{2}{(P+1)(P+2)} x_{...}^2 \right]$$

Where,

- Sg = sum of squares due to general combining ability
 Ss = sum of squares due to specific combining ability
 P = number of parents
 xi = total array of ith parent
 xii = mean value of ith parent
 x... = grand total of $\frac{1}{2} P (P+1)$ progenies and parental values
 xij = mean value in the diallel table

Analysis of variance table for combining ability was further partitioned into gca and sca as furnished below:

Source	d.f	M.S	Expectation of mean square
gca	P-1	Mg	$\sigma_e^2 + \frac{P+2}{P-1} \sum gi^2$
sca	$\frac{P(P-1)}{2}$	Ms	$\sigma_e^2 + \frac{2}{P(P-1)} \sum_{i < j} S_{ij}^2$
Error		Me	σ_e^2

The mean squares for general and specific combining ability were obtained by dividing their sum of squares by respective degrees of freedom. The error mean square (M'e) for combining ability analysis was obtained by dividing error mean square obtained from simple RBD analysis of variance for the experiment by number of replications. For "F" test each mean square was tested against M'e.

3.6.7.2 Estimation of gca and sca effects

The gca and sca effects were obtained as follows:

General combining ability (gca) of ith parent

$$\hat{g}_i = \frac{1}{P+2} \left[\sum (x_{i.} + x_{ii}) - \frac{2}{P} x_{..} \right]$$

Specific combining ability (sca) effects of the jth cross

$$\hat{s}_{ij} = \left[x_{ij} - \frac{1}{P+2} \left(x_{i.} + x_{.j} + x_{ij} + \frac{2}{(P+1)(P+2)} x_{..} \right) \right]$$

Standard error of an estimate was calculated as the square root of the variance of the estimate. The variances of various estimates were calculated as follows:

$$\text{Variance } (\hat{g}_i) = \frac{P-1}{P(P+2)} \sigma_e^2$$

$$\text{Variance } (\hat{s}_{ij}) = \frac{P^2 + P + 2}{(P+1)(P+2)} \sigma_e^2 \quad (i = j)$$

3.6.7.3 Test of significance of gca and sca effects

Each gca and sca value was tested for its significance by "t" test.

$$t = \frac{\hat{g}_i}{SE(\hat{g}_i)} \text{ and } t = \frac{\hat{s}_{ij}}{SE(\hat{s}_{ij})} \text{ respectively}$$

The 't' values thus obtained were compared at error degrees of freedom. The significance of differences between two estimates was tested by comparing them with critical difference (CD).

$$\text{CD} = \frac{\text{S.E of difference between two estimates}}{X} \quad t \text{ at } 0.05 \text{ at error degrees of freedom}$$

Thus, SE of difference of two estimates was taken as the square root of the variance of the difference of two estimates. The variance of the differences of the two estimates was calculated as follows:

$$\text{Var } (\hat{g}_i - \hat{g}_j) = \frac{2}{P+2} \sigma_e^2 \quad i \neq j$$

$$\text{Var } (\hat{s}_{ij} - \hat{s}_{ik}) = \frac{2(P+1)}{P+2} \sigma_e^2 \quad (i \neq j, k, j \neq k)$$

for sca estimates in one array

$$\text{Var } (\hat{s}_{ij} - \hat{s}_{kl}) = \frac{2P}{P+2} \sigma_e^2 \quad (i \neq j, k, l, j \neq k, l; k \neq l)$$

for any two specific combining ability estimates.

Where,

P = number of parents

σ_e^2 = error mean square

3.6.8 Correlation coefficient (r)

The correlation coefficients were calculated by using the following formulae :

$$r_{XY} = \frac{(\text{COV} \cdot X \cdot Y)}{\sqrt{V(X) \cdot V(Y)}}$$

Where

r_{XY} = Correlation coefficient between X and Y

CoV (X, Y) = Covariance between X and Y

V (X) = Variance of X

V (Y) = Variance of Y

X and Y = two related variables

Similarly

$$\text{Phenotypic } r(p) = \frac{\text{Covariance of XY (Phenotypical)}}{\sqrt{\text{Variance of } V_x, V_y \text{ (Phenotypical)}}}$$

$$\text{Genotypic } r(g) = \frac{\text{Covariance of XY (Genotypical)}}{\sqrt{\text{Variance of } V_x \cdot V_y \text{ (Genotypical)}}}$$

The significance of r was tested by 't' test at $(n-2)$ degrees of freedom using the 't' table of Fisher and Yates (1963) at $P = 0.05$ and $P = 0.01$, where n is the number of genotypes tested.

3.6.9 Path coefficient Analysis

The path coefficient were obtained by solving the following simultaneous equations as suggested by Dewey and Lu (1959).

Where:

r_{1y} = simple correlation coefficient between X_1 and Y the dependent character

P_{1y} = direct effect of X_1 on Y the dependent character

$r_{12} P_{2y}$ = indirect effect of X_1 on Y through X_2

r_{12} = Correlation coefficient between X_1 and X_2

$r_{1k} P_{ky}$ = indirect effect of X_1 on Y through K variables

In the same way equations for r_{2y} , r_{3y} , upto r_{11y} , were written and path coefficient viz., direct and indirect effects were calculated by solving the simultaneous equations. Besides the direct and indirect effects the residual effect was computed by using the formula.

$$P_{Ry} = 1 - (P_{1y} r_{1y} + P_{2y} r_{2y} + P_{3y} r_{3y} \dots)^2$$

Where:

P_{Ry} = residual effect

P_{1y} = direct effect of X_1 on Y

r_{1y} = correlation coefficient of X_1 and Y

Results

CHAPTER - IV

RESULTS

The data collected on thirteen characters viz., root dry weight, shoot dry weight, relative water content, days to 50% flowering, plant height, ear bearing tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility per cent, harvest index, test weight and grain yield per plant from 60 genotypes were used for estimating means, variability, heritability; genetic advance and genetic divergence studies.

4.1 ANALYSIS OF VARIANCE

Analysis of variance were carried out for all the thirteen characters studied and the difference among the genotypes were highly significant for the characters studied. The results of analysis of variance are presented in Table 4.

4.2 MEANS, VARIABILITY, HERITABILITY AND GENETIC ADVANCE

4.2.1 Root dry weight per plant

The root dry weight per plant varied from 2.23 g (PASR1345-1) to 7.33 g (NLR33356) per plant. Twenty two genotypes exceeded the general mean of 4.34 g per plant (Table 5).

Table 4 : Analysis of variance for thirteen characters in 60 rice genotypes under moisture stress conditions

Character	Mean sum of squares		
	Replications d.f : 2	Treatments d.f : 59	Error d.f 118
Root dry weight	3.33	3.52**	1.77
Shoot dry weight	23.32	53.55**	26.97
Relative water content	260.81	161.38**	61.42
Days to 50% flowering	1.31	60.00**	1.25
Plant height	170.45	227.40**	16.59
Ear bearing tillers per plant	33.71	15.05**	7.54
Panicle length	9.21	8.66**	4.92
Number of filled grains per panicle	2563.47	1298.60**	536.89
Number of unfilled grains per panicle	2079.20	658.71**	277.10
Spikelet fertility percentage	240.55	166.32**	69.98
Harvest index	96.81	81.15**	29.68
Test weight	11.77	8.08**	0.78
Grain yield per plant	58.02	28.57**	15.17

Table 5 : Mean values of characters contributing to genetic divergence in 60 genotypes of rice under moisture stress conditions

Sl. No.	Genotype	Root dry weight (g)	Shoot dry weight (g)	Relative water content (%)	Days to 50% flowering	Plant height (cm)	Ear bearing tiller per plant	Panicle length (cm)	Filled grain per panicle (no.)	Unfilled grain per panicle (no.)	Spikelet fertility per cent	Harvest index (%)	Test weight (g)	Grain yield per plant (g)
1.	MTU 17	7.00	22.66	75.66	94.00	83.33	13.00	21.00	92.66	29.33	75.33	43.66	26.00	14.66
2.	MTU 7014	4.66	29.00	80.00	99.66	64.66	10.33	21.66	91.66	70.66	63.00	40.66	22.33	12.33
3.	WGL 14280-1	4.33	27.66	62.66	96.66	65.33	12.00	22.33	108.00	43.00	70.66	54.00	21.33	19.66
4.	NLR 33771	5.00	26.33	74.00	100.00	72.33	12.00	20.66	116.66	33.33	78.66	44.00	19.10	13.33
5.	NLR 30491	3.66	25.33	87.00	97.00	68.00	15.00	21.00	117.33	63.66	68.00	52.66	17.13	15.33
6.	WGL 3825	4.00	28.00	79.33	92.66	65.33	13.00	21.00	119.33	35.33	77.00	50.00	21.00	14.33
7.	NLR 33634	4.33	28.00	80.66	99.00	77.00	9.66	22.00	140.66	23.33	85.66	48.33	20.66	15.66
8.	M.S.Vari	3.33	23.00	84.00	94.00	85.33	8.00	21.66	96.33	25.00	79.00	42.66	23.10	12.00
9.	NLR 26706	6.00	26.00	76.33	94.33	71.00	9.00	21.33	134.33	28.33	82.66	48.00	20.16	15.33
10.	NLR 33057	6.00	28.00	75.66	100.00	83.66	8.33	23.00	143.00	69.00	67.66	43.33	20.66	11.66
11.	WGL 19299	4.00	26.00	82.66	91.33	71.00	8.66	24.33	134.66	59.66	69.00	46.33	18.33	14.00
12.	WGL 14399-1	5.33	31.33	77.33	90.00	80.33	9.66	21.66	129.66	45.33	75.33	51.33	19.53	17.00
13.	N22	5.66	27.66	74.66	90.00	89.66	12.33	19.00	68.33	55.33	55.66	48.66	17.00	21.66
14.	NLR 13969	3.66	25.33	74.00	96.00	72.00	11.00	22.00	119.66	15.00	88.53	47.00	21.33	16.66
15.	WGL 180-11-15	3.00	20.66	76.33	87.00	66.66	10.00	21.33	92.33	46.00	70.33	49.00	21.33	11.00
16.	NLR 33633	7.00	35.33	79.33	98.33	78.66	9.66	23.00	91.00	29.66	65.33	48.66	18.33	18.00
17.	NLR 33359	5.66	28.00	37.00	98.00	67.33	10.66	23.00	102.33	34.66	73.33	44.33	20.00	13.00
18.	IET 2508	5.00	29.33	81.00	95.66	72.33	10.66	20.00	98.00	13.00	88.00	47.00	21.00	16.00
19.	NLR 33356	7.33	32.66	81.33	96.00	70.33	17.00	20.00	94.66	36.66	72.66	40.33	19.23	15.33

Sc

Table 5 (Contd....)

20.	IR 64	4.66	23.66	82.00	99.00	68.66	10.66	22.66	109.33	24.33	81.00	41.33	22.16	13.66
21.	NLR 33358	4.50	26.33	74.66	87.00	68.66	12.33	22.00	104.00	38.33	71.00	47.33	19.60	13.33
22.	IET 9994	5.00	27.66	83.33	100.00	73.66	9.00	23.66	115.00	44.00	73.33	39.00	19.36	14.33
23.	NLR 33635	5.00	27.66	89.66	96.00	74.33	10.00	23.66	128.00	44.33	70.00	43.33	13.86	14.66
24.	NLR 30674	4.33	28.00	80.33	99.66	75.00	10.00	22.33	99.66	28.00	78.00	45.00	21.16	15.00
25.	IET 1444	3.33	26.66	78.66	94.00	74.66	12.66	21.00	144.66	25.00	85.33	49.33	20.26	22.33
26.	NLR 30426	4.00	19.00	79.00	97.00	63.00	10.66	20.33	109.33	18.66	85.33	45.33	21.13	15.00
27.	NLR 33899	4.00	22.00	74.66	94.00	72.00	11.33	21.66	113.33	42.33	80.66	52.33	21.56	18.33
28.	RRB 63-2	3.50	22.00	69.66	92.00	71.00	8.00	23.00	142.33	45.00	75.33	50.00	19.00	17.00
29.	PUSA 836-202-208-207-7	3.50	22.33	63.66	100.00	71.66	11.00	21.33	103.33	36.00	73.66	53.00	19.93	20.66
30.	RP 1579-1219-MRST27	3.53	23.33	78.00	94.00	66.66	12.00	22.33	61.66	29.66	62.33	56.66	21.53	18.66
31.	NDR 1038-1	3.83	24.33	70.33	97.00	65.00	10.66	20.00	67.33	23.33	73.66	50.33	22.06	18.33
32.	NDR 1041-2	5.86	26.66	78.33	98.00	86.66	10.33	23.33	95.33	40.66	69.06	49.33	22.53	16.66
33.	NDR 1048-3	3.93	17.33	70.33	87.00	65.66	12.33	20.33	93.66	39.66	80.00	52.33	21.16	16.66
34.	KMJ 10-1-3	3.20	27.33	74.66	94.00	70.00	9.33	22.00	117.33	51.33	68.66	45.33	22.03	17.33
35.	KMJ 10-1-4	5.70	27.00	72.33	86.00	61.33	9.33	27.66	97.33	31.33	75.66	60.66	21.86	17.66
36.	KMJ 10-2-2	3.90	22.66	67.66	84.00	61.33	11.66	20.00	109.00	46.33	73.00	65.33	18.86	15.00
37.	OR 1401-3	3.93	22.00	71.33	97.00	59.33	9.66	20.66	109.33	35.33	75.33	54.66	22.70	16.66
38.	OR 1507-6	3.70	21.00	79.00	94.00	69.00	9.66	19.00	108.33	20.33	83.66	59.33	21.33	17.33
39.	OR 1513-13	3.93	27.00	71.33	90.00	74.00	11.00	21.33	112.00	37.33	74.66	55.33	23.26	18.00
40.	OR 1590-1	4.50	24.00	70.66	97.00	71.00	8.66	22.33	147.66	52.66	74.33	49.66	20.30	15.00
41.	RP 3470-1460-1784	4.13	21.33	74.00	94.00	71.33	9.00	20.33	103.66	16.33	86.00	49.66	21.46	17.33

Table 5 (Contd....)

42.	Rewa 103-70-26	3.33	21.83	76.00	95.00	88.66	8.00	24.33	119.33	40.66	75.00	49.33	23.90	17.66
43.	Rewa 107-73-28	5.56	30.00	68.33	95.00	69.00	10.66	20.66	78.66	31.00	71.66	48.66	22.93	15.00
44.	Rewa 205-66-22	4.06	22.00	74.00	95.33	61.66	11.00	20.33	90.33	31.66	74.00	52.00	17.73	15.66
45.	OR 1432-10	3.80	25.00	68.66	100.00	76.00	11.00	23.33	86.66	45.66	65.33	40.00	24.70	14.00
46.	OR 1507-3	3.50	23.33	72.33	94.00	66.66	11.66	22.66	127.00	42.00	74.00	40.00	19.10	17.33
47.	OR 1502-2	2.90	22.00	62.66	94.00	79.33	9.66	23.33	119.66	36.66	78.33	49.33	20.16	17.00
48.	OR 1509-7	4.60	25.33	73.33	97.00	64.00	10.33	21.66	96.33	83.33	53.00	46.66	20.50	15.66
49.	ORS 102-4	3.00	23.00	75.00	83.66	69.00	11.66	19.00	130.33	42.00	75.33	53.00	16.70	15.66
50.	CR 691-47	3.23	22.00	75.66	92.00	81.00	9.00	23.33	93.66	27.66	76.66	53.66	22.36	17.00
51.	CR 691-48	3.40	22.33	77.66	88.00	84.33	8.33	25.33	97.00	46.33	67.66	43.33	22.23	13.66
52.	CR 679-2	3.83	32.66	77.00	100.00	70.66	11.66	22.66	103.33	32.33	76.33	43.33	20.60	19.00
53.	CR 811-1	5.60	39.00	79.66	87.66	98.33	9.00	25.66	139.33	63.66	68.66	50.00	21.83	24.00
54.	RR 168-1	4.30	22.33	77.33	92.66	82.66	12.00	22.66	73.66	37.66	66.33	49.66	21.66	17.00
55.	CN 875-135-1-3	3.86	26.00	69.66	97.00	95.00	8.66	24.66	146.33	67.00	68.66	51.00	19.50	23.33
56.	PSR 1344-4-1	3.60	19.93	71.00	93.00	74.33	12.33	21.66	107.00	35.66	74.33	49.66	20.06	21.00
57.	PASR 1345-1	2.23	17.00	72.00	82.33	55.66	15.33	20.00	64.66	39.00	62.00	49.33	20.30	11.33
58.	SBR 34-69-1	2.86	17.00	80.66	93.00	61.33	12.66	19.33	115.33	62.33	63.00	49.33	23.06	15.00
59.	Tulasi	4.93	29.00	74.00	92.00	71.00	16.00	22.33	109.66	21.66	81.33	49.66	22.13	25.00
60.	Annada	5.20	23.66	73.33	97.00	73.00	19.66	22.00	107.66	23.66	81.33	55.33	19.66	22.33
	General Mean	4.34	25.30	74.85	94.15	72.66	10.96	21.93	108.13	38.94	73.82	48.80	20.75	16.54
	SEm ($\pm$)	0.76	2.97	4.48	0.64	2.33	1.57	1.27	13.26	9.53	4.78	3.11	0.50	2.23
	CD at 0.05% level	2.15	8.39	12.67	1.81	6.58	4.44	3.58	37.46	26.91	13.52	8.80	1.43	6.29

Table 6 : Mean, range, genotypic (GCV), Phenotypic (PCV) coefficients of variation, heritability (broad sense) and genetic advance for different characters.

Character	Mean	Range	Heritability (h ²)	Genotypic coefficient of variation	Phenotypic coefficient of variation	Genetic advance	Genetic advance as per cent of mean
Root dry weight	4.34	2.23-7.33	24.6	17.53	35.32	0.77	17.92
Shoot dry weight	25.30	17.00-39.00	24.7	11.76	23.65	3.04	12.05
Relative water content	74.85	37.00-89.66	35.17	7.71	13.00	7.05	9.42
Days to 50% flowering	94.15	82.33-100.00	93.98	4.70	4.84	8.83	9.38
Plant height	72.66	55.66-98.33	80.89	11.53	12.82	15.53	21.37
Ear bearing tillers per plant	10.96	8.00-19.66	24.94	14.43	28.90	1.62	14.84
Panicle length	21.93	19.00-27.66	20.17	5.08	11.32	1.03	4.70
Number of filled grains per panicle	108.13	61.66-147.66	32.11	14.73	26.00	18.59	17.19
Number of unfilled grains per panicle	38.94	13.00-83.33	31.46	28.96	51.63	13.03	33.46
Spikelet fertility percent	73.82	63.00-88.33	31.40	7.67	13.68	6.54	8.86
Harvest index	48.80	40.00-65.00	36.62	8.48	14.02	5.16	10.58
Test weight	20.75	16.70-23.26	75.51	7.51	8.64	2.79	13.45
Grain yield per plant	16.54	11.00-25.00	22.74	12.77	26.78	2.07	12.55

Genotypic and phenotypic coefficients of variation were 17.53 per cent and 35.52 per cent respectively. This character exhibited low heritability (24.6) and moderate genetic advance in terms of percentage of mean (17.92) (Table 6).

4.2.2 Shoot dry weight

Shoot dry weight among the genotypes ranged from 17.0 g in PASR1345-1 to 39.0 g in CR 811-1 indicating considerable variation for this character (Table 6). Twenty nine genotypes exhibited superior performance over the mean shoot dry weight of 25.30 g (Table 5).

The phenotypic and genotypic coefficients of variation were 23.65 and 11.76 respectively. Low estimates of heritability (24.70 per cent) and genetic advance expressed as percentage of mean (12.05) were observed for this trait (Table 6).

4.2.3 Relative water content

Maximum relative water content under moisture stress condition was recorded by NLR33635 (89.66%), while NLR33359 had shown the lowest relative water content (37.00). Thirty one cultures excelled the mean relative water content of 74.85% (Table 5).

Though medium heritability of 35.17 per cent recorded by this trait, the genetic advance expressed as percentage of mean was low (9.42). The PCV and GCV for this character were 13.00 and 7.71 respectively (Table 6).

4.2.4 Days to 50% flowering

This character varied from 82.33 to 100.00 days showing high variability (Table 6). NLR 33771 ; NLR 33057 ; IET 9994, PUSA 836-202-208-207-7 ; OR 1432-10 and CR 679-2 had the highest flowering duration of 100 days ; while the genotype PASR 1345-1 had the shortest duration of 82.33 days. Thirty three genotypes exceeded the general mean of 94.15 days (Table 5).

High heritability (93.98 per cent) and low genetic advance as percentage of mean (9.38) were noticed for this trait. Genotypic (4.70) and phenotypic (4.84) coefficients of variation were low (Table 6).

4.2.5 Plant height

Plant height among the genotypes ranged from 55.66 cm to 98.33 cm exhibiting high variability for this character (Table 6). The culture PASR 1345-1 was the shortest (55.66 cm) among the genotypes studied, while the culture CR 811-1 was the tallest (98.33 cm). Twenty two entries surpassed the general mean of 72.66 cm plant height.

Plant height exhibited high heritability (80.89 per cent) and medium values for genetic advance as percentage of mean (21.37). The GCV and PCV estimates of 11.53 and 12.82 respectively were moderate (Table 6).

4.2.6 Ear bearing tillers per plant

Among the genotypes tested for drought tolerance, the variety Annada recorded the highest number of ear bearing tillers per plant (19.66). While, M.S.vari had the lowest number of 8.0 (Table 5). This wide range indicated high variability for this trait. Twenty seven entries among the genotypes excelled the general mean of 10.96 ear bearing tillers per plant.

Low estimates of heritability (24.94 per cent) and moderate genetic advance as percentage of mean (14.84) were observed for this trait. GCV and PCV values were 14.43 per cent and 28.90 per cent respectively (Table 6).

4.2.7 Panicle length

This trait varied from 19.00 cm (N 22) to 27.66 cm (KMJ 10-1-4) indicating considerable variability among the genotypes (Table 5). The twenty seven genotypes indicated better performance compared to general mean of 21.93 cm for this character.

The genotypic and phenotypic coefficients of variation were 5.08 and 11.32 respectively. The character exhibited low heritability of 20.17 per cent as well as low genetic advance in terms of percentage of mean 4.70 (Table 6).

4.2.8 Number of filled grains per panicle

Number of filled grains per panicle ranged from 61.66 (RP1579-1219-MRST27) to 147.66 (OR 1590-1) showing high variability (Table 6). Twenty eight genotypes had higher value over the general mean of 108.13 grains per panicle. The estimates of heritability (32.11 per cent) and genetic advance (17.19) were observed to be medium level for this character. Genotypic (18.59) and phenotypic (26.0) coefficients of variation were high (Table 6).

4.2.9 Number of unfilled grains per panicle

This undesirable trait varied from 13.0 to 83.33, showing very high variability existing among genotypes. The highest number of unfilled grains (83.33) was recorded by the culture OR 1059-7 (Table 5). While, the lowest number (13.0) was noticed in IET 2508. Twenty seven cultures exceeded the general mean value of 38.4 unfilled grains per panicle.

High estimates of genotypic (28.96) and phenotypic (51.63) coefficients of variation were observed for this trait. Medium heritability (31.46) and high genetic advance with percent mean of 33.46 were exhibited by this character (Table 6).

4.2.10 Spikelet fertility percent

Under moisture stress conditions, NLR 13969 revealed the highest fertility percent of 83.33 (Table 5) among the genotypes tested. The genotype OR 1509-7 had the minimum spikelet percent of 63.00. Twenty four genotypes exhibited better performance over the general mean of 73.82 per cent.

Genotypic and Phenotypic coefficients of variation were low / moderate 7.67 and 13.68 respectively. Moderate heritability (31.4 per cent) coupled with low estimates of genetic advance (8.86) were recorded by this trait (Table 6).

4.2.11 Harvest index

Harvest index among genotypes varied from 40.00 per cent in OR 1432-10 to 65.00 per cent in KMJ 10-2-2 (Table 6). Thirty two entries surpassed the general mean of 48.80 per cent.

Moderate levels of heritability (36.62 per cent) and genetic advance (10.58) were revealed by this character. Genotypic (8.48) and phenotypic (14.02) coefficients of variation were observed for the character harvest index (Table 6). 89

4.2.12 Test weight

Data on test weight showed significant differences among the 60 genotypes evaluated and it ranged from 16.7 g in ORS 102-4 to 23.26 g in the culture OR1513-13 (Table 6). Twenty nine genotypes exhibited higher test weights compared to the general mean of 20.75 (Table 5).

High heritability (75.51 per cent) and moderate genetic advance (13.45) were recorded for this trait. Low genotypic (7.51) and phenotypic (8.64) coefficients of variation were (Table 6) observed for this trait.

4.2.13 Grain yield per plant

Grain yield per plant ranged from 11.00 g in WGL 180-11-15 to 25.00 g in Tulasi exhibiting high variability for this important quantitative character (Table 6). Thirty genotypes exhibited better performance over the mean 16.54 g of grain yield per plant (Table 5).

Lower estimates of heritability (22.74 per cent) as well as genetic advance (12.55) were observed for this character. Genotypic (12.77) and

Phenotypic (26.78) co-efficients of variation were recorded for this trait (Table 6).

4.3 D² ANALYSIS :

The quantitative assessment of genetic divergence has been taken up utilising Mahalanobis D² statistic based upon the thirteen characters studied.

4.3.1 Test with wilk's criterion

The significant differences among the genotypes for individual characters were first determined and later the statistical significant differences between the genotypes based on the pooled effects of all the characters studied were done using the Wilk's " Λ " criterion.

The "V" statistic was highly significant

4.3.2 Mahalanobis's D² values

The contribution of different quantitative characters towards genetic divergence (D²) in 60 genotypes of rice under moisture stress conditions are presented in Table 7.

Table 7 : Contribution of different quantitative characters towards genetic divergence (D^2) in 60 genotypes of rice under moisture stress conditions

Character	Percentage contribution towards divergence	Rank	No. of times ranked first
Root dry weight	0.79	11	14
Shoot dry weight	0.17	13	3
Relative water content	2.94	4	52
Days to 50% flowering	53.56	1	948
Plant height	16.44	2	291
Ear bearing tillers per plant	1.75	8	31
Panicle length	0.28	12	5
Filled grain per panicle	2.03	7	36
Unfilled grain per panicle	2.54	5	45
Spikelet fertility percentage	1.64	9	29
Harvest index	2.20	6	39
Test weight	14.80	3	262
Grain yield per plant	0.85	10	15

From the total 1770 combinations of contributions of different parameters, the contribution of days to 50% flowering was maximum (53.56%), followed by plant height (16.44%), test weight (14.80%) ; relative water content (2.94%), number of unfilled grains per panicle (2.54%), harvest index (2.20%), number of filled grains per panicle (2.03%), ear bearing tillers per plant (1.75%), fertility percentage (1.64%),

grain yield per plant (0.85%), root dry weight (0.79%), panicle length (0.28%), and shoot dry weight (0.17%).

4.3.3 Grouping of genotypes into various clusters

The 60 genotypes were grouped into nine clusters using the Tocher's procedure (Singh and Chaudhary, 1977). The distribution of genotypes into various clusters are presented in Table 8.

Table 8 : Distribution of 60 genotypes of rice in different clusters under moisture stress conditions

Cluster	Number of Genotypes	Identity of genotypes
I	46	NLR 13969 ; IET 2508 ;RP 3740-1460-1748 ; NLR 33899, NLR 26706, OR 1507-6 ; Rewa 107-73-28 ; NLR 30426 ; NDR 1038-1 ; WGL 14280-1, OR 1590-1 ; OR 1401-3 ; KMJ 10-1-13, RP 1579-1219-MRST 27 ; WGL 3825 ; PSR 1344-4-1 ; IET 1444 ; OR 1502-2 ; OR 1507-3 ; OR 1509-7 ; Tulasi ; NLR 33635 ; CR 691-47 ; RRB 63-2 ; RR 168-1 ; Rewa 205-66-22 ; Ananda ; NLR 33356 ; IR 64 ; WGL 33634 ; M.S.Vari, NLR 30674 ; Rewa 103-70-26 ; PUSA 836-22-208-207-7 ; NLR 33771 ; IET 9994 ; MTU 7014 ; CR 679-2 ; ND 1041-2 ; MTU 17 ; NLR 33359, WGL 19299, NLR 33057 ; NLR 33633 ; WGL 14399-1 and SBR 34-69-1
II	7	WGL 180-11-15, NDR 1048-3 ; NLR 33358 ; KMJ 10-1-4; KMJ 10-2-2 ; PASR 1345-1, ORS 102-4
III	1	OR 1513-13
IV	1	CN 875-135-1-3
V	1	NLR 30491
VI	1	CR 691-48
VII	1	OR 1432-10
VIII	1	N22
IX	1	CR 811-1

4.3.4 Inter and intra cluster D^2 values

The intra and inter cluster D^2 values were calculated as per the procedure given by Singh and Chaudhary (1977) and are presented in Table 9.

Intra cluster average D^2 values ranged from zero to 38.56. Cluster I had the maximum intra cluster distance. The average inter cluster D^2 values varied from 24.40 to 270.60. The average inter cluster D^2 value between II and VII was maximum (270.60), while, the minimum divergence was found between clusters III and VI (24.40).

Cluster	Genotypes
I	NLR 13969, IET 2508 ; RP 3740-1460-1784 ; NLR 33899; NLR 26706 ; OR 1507-6 ; Rewa 107 73-28 ; NLR 30426 ; NDR 1038-1 ; WGL 14280-1, OR1590-1 ; OR 1401-3 ; KMJ 10-1-3, RP 1579-1219-MRST 27 ; WGL 3825 ; PSR 1344-4-1 ; IET 1444 ; OR 1502-2 ; OR 1507-3 ; OR 1509-7 ; Tulasi ; NLR 33635 ; CR 691-47 ; RRB 63-2 ; RR 168-1 ; Rewas 205-66-22 Annada, NLR 33356 ; IR 64 ; WGL 33634 ; M.S. Vari ; NLR 30674; Rewa 70-26 ; PUSA 836-22-208-207-7 ; NLR 33771, IET 9994, MTU 7014, CR 679-2 ; NDR 1041-2; MTU 17, NLR 33359 ; WGL 19299 ; NLR 33057; NLR 33633 ; WGL 14399-1 and SBR 34-6-9-1.
II	WGL 180-11-15 ; NDR 1048-3 ; NLR 33358 ; KMJ 10-1-4, KMJ 10-2-2 ; PASR 1345-1 ; ORS 102-4.
III	OR 1513-13
IV	CN 875-135-1-3
V	NLR 30491
VI	CR 691-48
VII	OR 1432-10
VIII	N22
IX	CR811-1

Table 9 : Intra and inter cluster average distance D^2 values of nine clusters from 60 genotypes of rice under moisture stress conditions

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	38.56 (6.21)	145.92 (12.08)	58.98 (7.68)	76.03 (8.72)	57.76 (7.60)	84.64 (9.20)	61.93 (7.87)	95.84 (9.79)	133.40 (11.55)
II		34.93 (5.91)	63.52 (7.97)	244.6 (15.64)	162.05 (12.73)	70.53 (8.40)	270.60 (16.45)	124.32 (11.15)	146.89 (12.12)
III			0.00	112.15 (10.59)	113.42 (10.65)	24.40 (4.94)	105.67 (10.82)	92.16 (9.60)	64.00 (8.00)
IV				0.00	93.31 (9.66)	109.20 (10.45)	86.86 (9.32)	74.13 (8.61)	87.23 (9.34)
V					0.00	142.32 (11.93)	122.10 (11.05)	90.82 (9.53)	196.56 (14.02)
VI						0.00	139.47 (11.81)	68.89 (8.30)	40.57 (6.37)
VII							0.00	185.23 (13.61)	189.61 (13.77)
VIII								0.00	80.82 (8.99)
IX									0.00

Square root of D^2 values are given in parenthesis

Table 9A : Mean values of clusters from 60 genotypes of rice for thirteen characters under moisture stress conditions

Character / Cluster	Root dry weight (g)	Shoot dry weight (g)	Relative water content	Days to 50% flowering	Plant height (cm)	Ear bearing tillers per plant (no.)	Panicle length (cm)	Filled grains per panicle (no.)	Unfilled grains per panicle (no.)	Spikelet fertility (%)	Harvest index	Test weight (g)	Grain yield per plant (g)
I	4.45	25.47	75.08	95.70	72.31	10.87	21.85	109.34	36.41	75.07	48.04	20.86	16.56
II	3.75	22.00	72.61	85.28	64.04	11.81	21.47	98.76	40.38	72.47	53.85	19.97	14.38
III	3.93	27.00	71.33	90.00	74.00	11.00	21.33	112.00	37.33	74.66	55.33	23.26	18.00
IV	3.86	26.00	69.66	97.00	95.00	8.66	24.66	146.33	67.00	68.66	51.00	19.50	23.33
V	3.66	25.33	87.00	97.00	68.00	15.00	21.00	117.33	63.66	68.00	52.66	17.13	15.33
VI	3.40	22.33	77.66	88.00	84.33	8.33	25.33	97.00	46.33	67.66	43.33	22.23	13.66
VII	3.80	25.00	68.66	100.00	76.00	11.00	25.33	86.66	45.66	65.33	40.00	24.70	14.00
VIII	5.66	27.66	74.66	90.00	89.66	12.33	19.00	68.33	55.33	55.66	48.66	17.00	21.66
IX	5.60	39.00	79.66	87.66	93.33	9.00	25.66	139.33	63.66	68.66	50.00	21.83	24.00

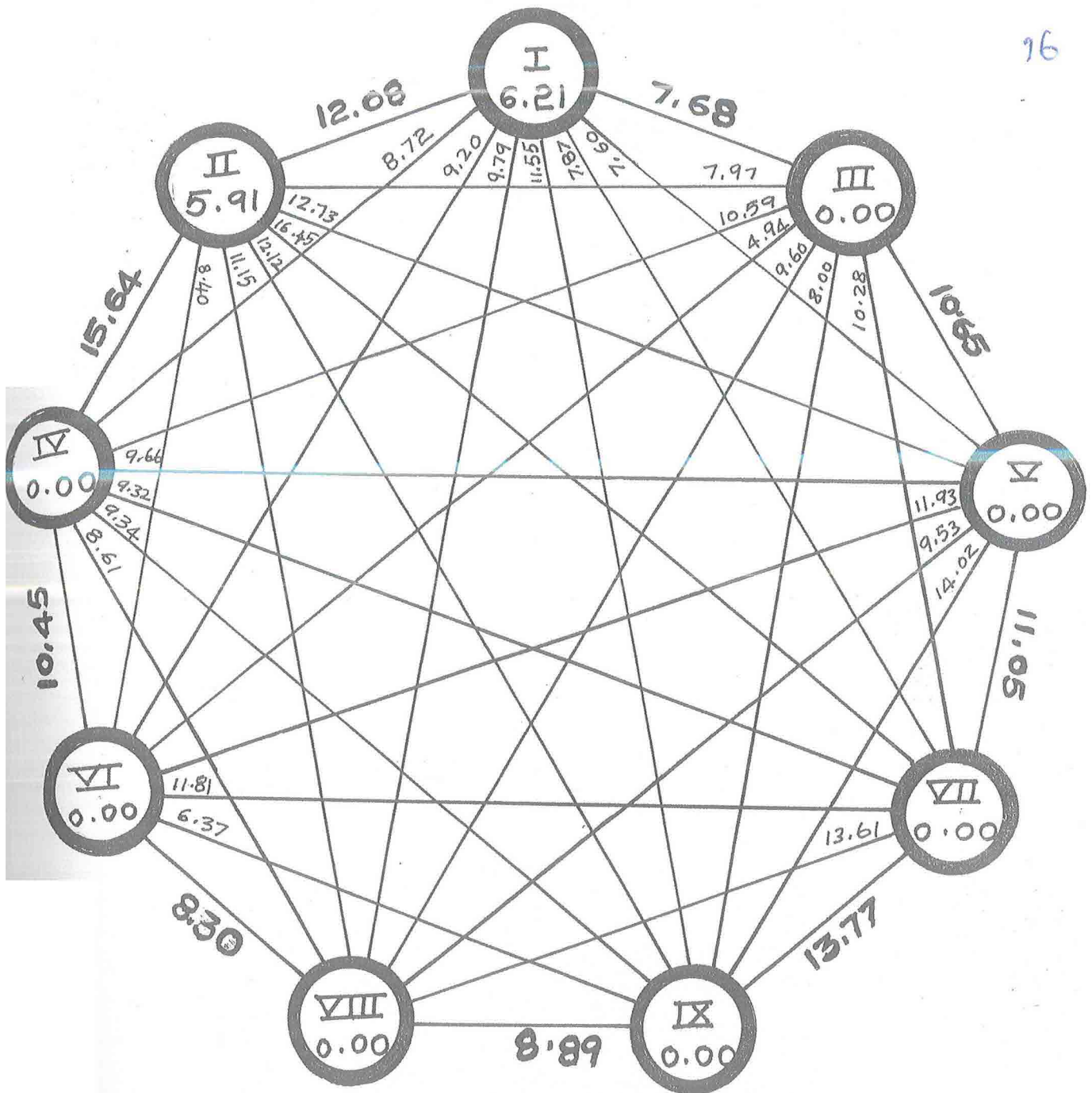


Figure 1 : Configuration of clusters and their relationship



Figure 2 : Screening of 60 rice genotypes for drought tolerance under moisture stress condition.

Cluster I was the largest with 46 genotypes, which were developed in Andhra Pradesh, Orissa, Madhya Pradesh, Uttar Pradesh, Rajasthan, Bihar and Assam. One culture IR 64 is exotic (Philippines). Cluster I was closest to cluster V and cluster II was farthest from cluster I.

Cluster II consisted of seven genotypes. Intra cluster distance was 5.9%. Cluster II was more divergent to cluster VII followed by cluster IV and nearest to cluster III.

Cluster III had only one genotype i.e OR 1513-13 originated from Orissa. Cluster III was farthest from cluster V and nearest to Cluster VI.

Cluster IV with only one genotype CN 875-135-1-3 (West Bengal) was more divergent to cluster II and nearest to cluster VIII.

Cluster V had one variety Bharani (NLR 30491) and was closer to Cluster V and farthest from Cluster IX.

Cluster VI with single genotype CR 691-48 developed at CRRI, Cuttack was more divergent to cluster V and nearest to Cluster III.

Cluster VII had one entry OR 1507-3 which was nearer to Cluster I and far away from Cluster II.

Cluster VIII with one genotype N22 was more divergent to Cluster VII and closer to Cluster VI.

Cluster IX with one genotype CR811-4 was nearest to Cluster VI and farthest to Cluster V.

The mutual relationship between clusters were diagrammatically represented in Figure 1 by taking the square root of the average of intra and inter cluster D^2 values.

4.5. DIALLEL ANALYSIS

The data on quantitative characters viz. root dry weight (g), shoot dry weight (g), root to shoot ratio, relative water content (%), days to 50% flowering, plant height (cm), number of ear bearing tillers per plant, panicle length (cm), number of spikelets per panicle, number of filled grains per panicle, spikelet fertility per cent; harvest index(%), test weight (g) specific leaf weight (mg/cm^2), leaf area per plant (cm^2), grain yield per plant (g) and leaf rolling (0-9 scale) from a diallel set of $28F_1$ s along with eight parents both under moisture stress and favourable situations were subjected to statistical analyses to understand the nature of various genetic parameters at the two environments.

Data on shoot length and root length of 6-day old seedlings under simulated drought by polyethylene glycol 6000 at different osmotic pressures viz. 0.00; 3.00; 6.00 and 10.00 bars were recorded. The data of 28 F_1 s and eight parents were also subjected to statistical analysis.

4.5.1. Analysis of variance

The analysis of variance of eight parental diallel experiments for the characters studied under moisture stress, favourable situations and seedling growth under simulated drought conditions are presented in tables 10, 11 and 12 respectively.

Under moisture stress situation significant differences were found among genotypes for all the characters in F_1 generation. The treatment sum of squares was further partitioned into parents, crosses and interaction effects i.e. parents Vs crosses. The parents differed significantly except for ear bearing tillers per plant and test weight indicating the diversity among parents. The differences between the crosses were also significant.

Under favourable environment, treatmental differences were significant for all the characters except for leaf area per plant in F_1 generation. The treatment sum of squares was partitioned into parents, crosses and interaction effects of parents Vs crosses. Significant

Table 10 : Analysis of variance for 17 characters studied from 8 parents and 28 crosses under moisture stress situation

Source of variation	d.f	Mean sum of squares																
		Root dry weight (g)	Shoot dry weight (g)	Root / shoot ratio	Rel. active water content (%)	No. of days to 50% flowering	Plant height (cm)	No. of ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spi- kelet fertility (%)	Harvest index (%)	Test weig ht (g)	Specific leaf weight (mg / cm2)	Leaf area per plant (cm2)	Grain yield per plant (g)	Leaf rolling (0-9 scale)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Replications	2	7.409	84.46	0.018	3.45	0.25	18.89	50.19	0.58	549.0	31.17	190.5	65.5	31.7	8.77	967216.0	62.69	1.33
Treatments	35	13.611**	268.73**	0.06**	69.41**	9.31**	429.19**	9.57*	6.09**	650.6**	530.13**	144.3**	107.8**	36.0*	2.75**	262069.6**	66.91**	12.53**
Parents	7	13.031**	300.53**	0.042**	50.38	11.56**	303.08**	12.64**	3.52*	1109.0**	891.7**	167.9*	145.9**	11.0	3.30**	267850.7**	28.02*	8.76**
Crosses	27	14.186**	269.29**	0.059**	76.92**	5.29**	453.14**	9.12*	6.23**	494.7**	430.1**	143.4**	70.4**	40.6**	2.63**	247700.2**	77.32**	12.26**
Parents vs Crosses	1	2.148	31.12	0.091**	26.45	102.15**	665.34**	0.24	20.25	1653.1**	697.5*	1.16	850.5**	86.1	2.32	609560.1**	58.01*	46.09*
Error	70	3.073	76.33	0.017	31.97	0.40	30.39	6.71	1.38	234.1	117.2	76.0	19.4	24.8	1.10	87513.9	11.10	0.65
SE ±		1.431	7.13	0.336	4.61	0.51	4.50	2.11	0.96	12.4	8.8	7.1	3.60	4.0	0.85	241.50	2.72	0.65
C.D (5%)		2.80	13.97	0.65	9.03	0.99	8.82	4.13	1.88	23.30	17.26	13.91	7.05	7.84	1.66	473.30	5.33	1.27
CV %		30.0	25.0	28.0	7.40	0.70	7.60	2.20	5.51	13.66	14.50	13.70	9.50	25.2	19.9	27.8	30.8	15.5

Significant at 5% level
Significant at 1% level

Table 12 : Analysis of variance for seedling growth studied under simulated drought by different osmotic pressures of polyethylene glycol solutions (Parents and F₁ generation)

Source of variation	d.f	Mean sum of squares									
		0.00 bars		3.00 bars		6.00 bars		10.00 bars			
		Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
Replications	2	0.209	0.212	0.065	0.010	0.076	0.009	0.003	0.001		
Treatments	35	4.303**	8.054**	5.186**	5.296**	1.820**	1.398**	0.487**	3.223**		
Parents	7	0.439**	2.368**	2.832**	0.718**	1.775**	0.348**	0.005	1.407**		
Crosses	27	5.013**	6.648**	3.992**	5.006**	1.264**	1.463**	0.599**	3.442**		
Parents vs Crosses	1	12.179**	85.810**	53.909**	45.192**	17.165**	6.976**	1.894**	10.006**		
Error	70	0.087	0.100	0.100	0.063	0.046	0.059	0.004	0.022		
SE $\pm$		0.240	0.258	0.258	0.204	0.175	0.198	0.051	0.121		
C.D (5%)		0.472	0.506	0.506	0.401	0.343	0.388	0.101	0.237		
CV %		6.2	7.1	8.9	6.8	10.9	9.1	17.0	10.4		

* Significant at 5% level

** Significant at 1% level

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differences were noticed among parents except for number of ear bearing tillers per plant, specific leaf weight, shoot dry weight and leaf area per plant. Significant differences were also observed among crosses indicating wide variation among hybrids.

Under simulated drought studies by PEG for seedling growth highly significant differences were noticed among treatments in F_1 generation. The treatment sum of squares was partitioned into parents, crosses and interaction effects of parents Vs hybrids. Significant differences were noticed among parents except for shoot growth at 10.00 bars of osmotic pressure. The hybrids were also significantly differed for shoot and root growths indicating wide differences among cross combinations.

4.5.2 Mean performance of parents and hybrids

The mean performance of parents and crosses under moisture stress and favourable environments as well as seedling growth under simulated drought conditions are presented in tables 13, 14 and 15 respectively.

4.5.2.1 Root dry weight

Under moisture stress situation, the root dry weight among parents ranged from 3.46 g to 8.97 g (Table 13). NLR33899 had

Table 13 : Mean values of 17 quantitative characters in eight parental lines and 28 hybrids under moisture stress situation

Sl. No.	Genotype	Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Rel. active water content (%)	No. of days to 50% flowering	Plant height (cm)	No. of bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of grains per panicle	Spl. kernel fertility (%)	Harvest index (%)	Test weight (g)	Specific weight (mg/cm ³)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Leaf rolling scale
PARENTS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	NLR 33899	8.97	43.18	0.20	71	94	71.0	12.0	20.86	119.3	81.3	67.3	43	18.9	5.95	1032.0	12.3	4
2.	WGL 14280-1	3.46	23.22	0.15	75	92	55.0	14.0	20.80	99.6	61.3	62.0	43	19.5	4.87	945.4	9.5	7
3.	NLR 30491	7.84	45.73	0.16	74	93	60.0	11.0	20.20	130.6	91.0	70.0	48	16.9	7.80	1736.2	10.2	3
4.	N22	4.38	27.98	0.18	78	91	72.0	10.0	19.00	81.3	51.3	64.3	34	15.8	4.44	1092.7	4.4	7
5.	KMJ 10-2-2	4.50	29.14	0.16	71	88	60.0	14.0	20.00	103.6	64.0	60.3	41	16.5	5.88	945.0	8.7	6
6.	Tulasi	8.06	32.20	0.25	80	91	69.0	12.0	21.30	103.3	78.0	76.3	51	19.9	5.39	1286.6	14.1	4
7.	CN 875-135-1-3	6.66	46.93	0.13	82	93	87.0	9.0	22.50	132.0	86.6	66.00	38	21.3	4.95	1511.8	10.0	7
8.	CR 811-1	4.53	22.47	0.19	81	94	66.0	10.0	19.60	84.3	43.3	50.6	30	19.6	5.00	1048.7	6.5	7
F ₁ GENERATION																		
9.	NLR 33899 / WGL 14280-1	4.44	29.41	0.15	71	88	64.6	10.6	20.10	102.6	60.3	60.3	50	20.5	5.23	856.5	13.0	7
10.	NLR 33899 / NLR 30491	6.19	45.60	0.13	72	90	67.3	12.6	21.70	137.6	91.3	66.6	49	16.5	6.02	1384.1	15.7	5
11.	NLR 33899 / N22	5.19	37.18	0.13	74	91	85.3	12.6	20.30	113.6	69.0	61.6	44	20.2	5.90	1013.1	11.7	6
12.	NLR 33899 / KMJ 10-2-2	5.45	35.43	0.15	87	92	66.0	10.3	20.60	116.0	76.0	65.6	45	16.3	5.10	737.8	9.13	4
13.	NLR 33899 / Tulasi	7.47	31.97	0.22	81	89	85.0	10.0	21.00	107.3	67.6	61.3	50	18.5	4.45	1246.0	14.4	5
14.	NLR 33899 / CN 875-135-1-3	11.57	51.22	0.22	81	90	95.3	12.0	23.10	113.6	85.6	75.0	47	20.4	3.72	1485.5	22.3	7
15.	NLR 33899 / CR 811-1	6.11	30.05	0.20	80	92	71.3	12.0	20.90	107.6	72.6	67.2	48	20.1	4.88	1348.1	14.2	2
16.	WGL 14280-1 / NLR 30491	2.41	21.53	0.11	77	89	62.0	11.0	23.80	109.6	82.3	74.6	52	20.3	5.99	1211.7	9.9	3
17.	WGL 14280-1 / N22	4.49	32.24	0.13	70	88	86.3	13.6	23.16	89.0	56.0	63.0	40	21.7	5.55	803.0	12.9	2
18.	WGL 14280-1 / KMJ 10-2-2	6.19	36.75	0.16	69	89	54.6	12.6	21.30	109.0	54.0	51.3	52	21.5	4.91	986.8	10.7	6
19.	WGL 14280-1 / Tulasi	8.16	36.24	0.24	79	88	54.3	13.0	21.60	107.6	74.6	59.0	54	22.0	5.06	930.6	17.0	6

Table 13 Contd.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
20. WGL 14280-1 / CN 875-135-1-3	7.97	38.43	0.20	83	88	94.3	8.6	25.90	140.0	101.0	72.6	53	21.6	6.90	1364.4	16.7	3
21. WGL 14280-1 / CR 811-1	6.51	38.34	0.16	72	89	64.0	11.6	22.10	118.3	75.3	64.0	54	21.8	5.21	1106.3	13.0	3
22. NLR 30491 / N22	5.47	35.58	0.15	84	89	85.3	13.0	21.70	122.6	87.3	70.6	48	18.3	5.67	777.5	13.0	2
23. NLR 30491 / CN 875-135-1-3	5.16	48.62	0.10	74	91	72.3	11.0	22.20	87.6	85.3	61.3	48	20.5	5.01	1326.9	5.1	3
24. NLR 30491 / Tulasi	4.33	35.60	0.12	74	91	72.6	10.0	20.50	114.3	72.0	63.6	49	18.5	4.11	804.2	4.0	4
25. NLR 30491 / CN 875-135-1-3	4.18	50.80	0.08	82	90	90.6	11.3	22.00	133.6	86.6	64.6	48	18.8	7.15	1061.1	3.7	7
26. NLR 30491/CR 811-1	4.62	41.24	0.11	76	87	67.0	9.0	21.13	122.6	97.6	78.3	52	21.4	6.66	580.3	4.3	2
27. N22 / KMJ 10-2-2	4.70	38.27	0.12	71	89	55.0	13.0	21.00	114.0	68.3	60.0	48	20.2	5.88	701.1	4.38	3
28. N22 / Tulasi	9.32	52.59	0.17	76	88	91.0	11.0	23.00	122.3	76.0	63.0	47	21.1	3.38	1141.8	12.6	1
29. N22 / CN 875-135-1-3	1.80	18.61	0.09	68	91	68.0	14.0	22.00	90.3	70.6	52.0	34	17.0	3.17	655.8	2.5	6
30. N22 / CR 811-1	3.03	27.52	0.13	76	90	71.3	8.3	18.00	113.0	55.0	52.3	43	20.2	4.76	591.7	6.00	7
31. KMJ 10-2-2 / Tulasi	4.90	25.70	0.19	77	90	68.0	9.6	21.2	116.3	91.0	75.6	50.0	20.0	4.830	788.60	10.4	4
32. KMJ 10-2-2 / CN 875-135-1-3	5.29	28.40	0.18	80	89	71.0	9.0	20.8	109.0	73.0	66.6	48.3	19.9	5.914	675.5	10.7	3
33. KMJ 10-2-2/CR 811-1	4.62	11.50	0.18	74	89	64.3	14.0	20.1	105.6	61.3	57.6	49.6	21.3	4.830	1081.7	11.7	8
34. Tulasi/CN 875-135-1-3	3.69	18.60	0.18	74	92	83.0	9.6	22.0	135.3	87.0	64.6	42.0	20.6	5.409	1051.0	12.5	4
35. Tulasi / CR811-1	9.12	37.40	0.24	88	90	84.6	10.3	21.1	126.0	74.0	69.3	47.0	22.1	4.967	1587.3	21.0	2
36. CN 875-135-1-3 / CR 811-1	7.33	40.80	0.17	74	91	64.0	14.3	21.7	112.6	72.6	64.3	49.6	22.7	4.564	1277.6	11.9	1
General Mean	5.78	34.62	0.17	76	90.0	72.3	11.38	21.3	112	74.4	63.3	46.3	19.7	5.27	1061	10.7	5.21
SEM ±	1.43	7.13	0.33	4.61	0.51	4.50	2.11	0.96	12.4	8.81	7.10	3.60	4.0	0.85	241.5	2.7	0.65
CD at 0.05	2.80	13.97	0.65	9.03	0.99	8.82	4.13	1.88	23.30	17.26	13.91	7.05	7.8	1.66	473.3	5.3	1.27
CV (%)	30.0	25.0	28.0	7.4	7.0	7.60	2.2	5.51	13.66	14.5	13.7	9.50	25.2	19.9	27.8	30.8	15.5

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Table 14 : Mean values of 16 quantitative characters in eight parental lines and 28 hybrids under favourable environment

Sl. No.	Genotype	Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Relative content (%)	Days to 50% flowering	Plant height (cm)	Ear bearing tillers/plant	Panicle length (cm)	No. of spikelets/panicle	No. of grains/panicle	Spikelet fertility (%)	Harvest index (%)	Test weight (g)	Specific weight (mg/cm ³)	Leaf area per plant (g)	Grain yield per plant (g)
PARENTS		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	NLR 33899	2.50	32.01	0.07	69.0	95	84	10.0	22.0	114	89.3	81.0	49.3	23.6	5.87	1990.5	21.36
2.	WGL 14280-1	3.53	23.70	0.15	67.3	90	75	11.3	23.5	135	100.0	73.6	46.6	21.6	6.59	1450.7	15.36
3.	NLR 30491	5.91	35.66	0.16	72.0	91	81	10.6	22.3	159	110.0	69.3	38.6	18.8	6.01	1883.9	11.23
4.	N22	5.08	31.03	0.16	70.0	89	92	7.6	18.6	109	72.3	66.3	43.6	19.3	6.57	1650.6	10.13
5.	KML 10-2-2	4.71	35.16	0.12	78.6	90	74	10.0	20.3	138	90.0	66.6	39.0	18.6	5.39	1450.0	8.73
6.	Tulasi	4.92	45.70	0.11	77.0	90	83	9.6	23.2	122	88.3	73.0	47.3	23.2	6.43	1592.8	13.50
7.	CN 875-135-1-3	7.03	35.43	0.19	71.0	92	114	8.6	25.1	155	121.6	78.0	44.6	24.7	5.05	2392.5	21.90
8.	CR 811-1	5.81	31.82	0.17	69.0	91	90	8.3	22.1	132	86.0	64.0	39.3	25.5	6.13	1947.40	12.06
F ₁ GENERATION																	
9.	NLR 33899 / WGL 14280-1	4.54	36.39	0.12	65.0	88	79	10.0	23.8	124	90.6	72.6	53.6	24.03	6.05	2148.6	18.00
10.	NLR 33899 / NLR 30491	3.20	34.40	0.09	62.6	90	78	11.6	21.7	95	64.3	68.0	49.3	19.56	6.72	1958.3	18.40
11.	NLR 33899 / N22	4.70	36.16	0.13	64.3	86	102	12.0	22.2	148	81.0	55.0	45.6	23.23	5.10	2536.0	20.50
12.	NLR 33899 / KML 10-2-2	2.32	23.86	0.10	65.0	86	80	12.0	22.8	134	87.0	74.3	50.3	20.30	5.39	1671.5	13.90
13.	NLR 33899 / Tulasi	6.08	42.40	0.14	63.0	89	86	13.0	22.5	120	72.6	66.3	50.6	20.26	5.55	2033.8	19.23
14.	NLR 33899 / CN 875-135-1-3	5.43	45.25	0.11	75.0	88	106	9.6	24.4	152	121.0	78.0	46.6	23.03	5.99	1379.0	19.70
15.	NLR 33899 / CR 811-1	4.51	18.95	0.18	63.0	88	95	12.0	23.4	131	99.0	75.0	46.0	24.46	7.65	1438.0	22.40
16.	WGL 14280-1 / NLR 30491	4.13	33.76	0.12	77.0	88	80	13.3	22.7	149	110.0	74.0	43.6	20.80	5.81	1607.6	18.90
17.	WGL 14280-1 / N22	3.45	41.56	0.08	65.0	88	104	11.0	23.5	121	75.0	62.3	44.6	22.30	3.94	2403.7	18.10
18.	WGL 14280-1 / KML 10-2-2	5.20	48.70	0.10	74.0	89	75	11.3	23.5	109	88.0	80.3	52.3	21.30	6.56	2395.9	24.50

Table 14 (Contd...)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
19. WGL 14280-1 / Tulasi	6.27	43.60	0.14	73.6	88	79	11.0	29.0	113	68.0	61.3	49.0	21.70	6.51	1675.4	15.18
20. WGL 14280-1 / CN 875-135-1-3	5.43	33.60	0.16	63.0	88	110	8.6	25.1	158	120.0	77.6	73.6	24.50	5.97	951.6	16.20
21. WGL 14280-1 / CR 811-1	6.26	47.50	0.13	72.6	89	89	11.3	24.3	135	95.3	71.6	44.3	24.80	5.66	1510.6	14.90
22. NLR 30491 / Tulasi	4.42	29.80	0.15	76.3	86	98	10.3	20.8	136	79.6	53.0	38.3	22.30	5.58	1349.4	14.36
23. NLR 30491 / KMJ 10-2-2	4.79	53.50	0.09	64.6	86	102	10.0	23.3	96	68.6	72.0	45.6	20.20	5.80	1759.7	13.20
24. NLR 30491 / Tulasi	5.24	48.80	0.10	68.0	89	98	13.0	24.6	103	80.0	71.0	50.3	19.50	5.04	1563.5	12.60
25. NLR 30491 / CN 875-135-1-3	10.75	91.10	0.12	74.0	89	89	9.3	24.2	125	92.6	77.6	50.3	18.50	6.96	2550.9	26.00
26. NLR 30491 / CR 811-1	3.52	33.10	0.10	67.6	89	89	13.0	21.8	94	71.6	76.0	47.3	22.00	6.15	1939.6	17.70
27. N22 / KMJ 10-2-2	4.66	42.10	0.11	63.0	89	90	7.6	17.6	97	63.0	65.3	44.6	21.00	6.21	1810.3	13.30
28. N22 / Tulasi	7.36	57.90	0.12	70.6	85	94	9.6	22.0	107	76.3	71.3	47.0	19.00	3.76	1774.5	23.20
29. N22 / CN 875-135-1-3	6.30	33.90	0.19	72.0	86	109	11.0	24.9	157	82.3	51.3	36.0	19.10	5.48	1790.4	10.60
30. N22 / CR 811-1	4.63	38.6	0.12	79.6	86	85	9.6	17.2	96.0	69.0	71.0	41.3	20.80	5.92	1491.7	15.80
31. KMJ 10-2-2 / Tulasi	5.66	51.1	0.11	68.3	86	95	13.6	22.8	120.0	98.0	81.3	48.3	21.0	6.80	1691.9	20.30
32. KMJ 10-2-2 / CN 875-135-1-3	8.56	69.7	0.12	73.0	86	80.0	14.3	23.6	96.3	71.3	74.6	46.0	21.7	6.10	1551.9	19.20
33. KMJ 10-2-2 / CR 811-1	8.83	66.8	0.13	72.0	90	79.0	16.0	21.9	77.0	52.0	67.6	45.3	25.6	5.15	1474.3	12.50
34. Tulasi / CN 875-135-1-3	4.36	40.7	0.10	66.0	91	90.0	12.0	23.5	113.6	82.0	75.3	42.6	22.0	6.11	1434.6	12.00
35. Tulasi / CR 811-1	6.90	40.5	0.17	80.6	91	85.0	20.0	25.0	151.6	126.0	83.6	51.6	25.8	7.82	2240.9	24.60
36. CN 875-135-1-3 / CR 811-1	9.62	55.1	0.17	72.6	89	104.0	16.6	24.6	155.0	135.6	87.3	50.3	26.0	7.64	2040.1	28.10
General Mean	5.46	41.9	0.10	70.1	88.6	90.0	11.35	22.8	124.3	88.2	71.2	46.7	21.9	5.96	1817.0	17.15
SEM ±	1.07	7.93	0.02	3.06	0.13	3.25	1.65	1.07	17.17	114.0	5.40	3.17	0.66	0.74	390.8	2.82
CD at 0.05	2.10	15.54	0.05	6.01	0.26	6.38	3.24	2.10	33.66	223.0	10.59	6.21	1.30	1.45	765.9	5.54
CV %	24.0	23.1	31.0	5.30	4.0	4.4	17.80	5.78	16.9	148.3	9.29	8.32	3.73	15.23	28.3	20.27

Table 15 : Mean values of shoot growth and root growth of eight parents and 28 crosses of F₁ under simulated drought induced by different osmotic pressures of polyethylene glycol

S. No.	Genotype	0.00 bars		3.00 bars		6.00 bars		10.00 bars	
		Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
		1	2	3	4	5	6	7	8
PARENTS									
1.	NLR 33899	3.50	2.56	3.10	2.20	2.56	1.80	0.10	1.00
2.	WGL 14280-1	3.80	3.20	2.73	3.16	1.80	2.10	0.10	0.80
3.	NLR 30491	4.46	1.80	1.46	2.03	0.50	1.83	0.18	0.46
4.	N22	4.70	3.86	2.63	3.13	1.90	2.20	0.10	0.10
5.	KMJ 10-2-2	4.00	3.90	2.90	2.43	0.83	2.76	0.10	0.10
6.	Tulasi	4.06	2.30	0.88	2.66	0.56	2.56	0.10	0.10
7.	CN 875-135-1-3	4.43	1.63	0.86	2.50	0.70	1.96	0.13	1.70
8.	CR 811-1	4.03	3.40	3.03	1.80	0.86	2.20	0.20	1.73
F ₁ GENERATION									
9.	NLR 33899 / WGL 14280-1	2.03	5.00	2.96	1.80	2.23	2.80	0.10	0.10
10.	NLR 33899 / NLR30491	5.13	6.56	5.06	4.73	2.16	2.23	0.56	1.90
11.	NLR 33899 / N22	6.10	3.36	5.83	2.93	1.63	3.46	0.53	2.83
12.	NLR 33899 / KMJ 10-2-2	4.96	5.16	4.26	5.93	0.90	2.76	0.40	1.60
13.	NLR 33899 / Tulasi	5.86	7.86	3.20	5.86	2.40	3.60	1.03	4.00
14.	NLR 33899 / CN 875-135-1-3	2.63	3.56	4.10	5.50	3.22	3.10	0.13	1.10
15.	NLR 33899 / CR 811-1	4.03	5.03	5.16	3.03	2.56	2.33	1.90	2.36
16.	WGL 14280-1 / NLR 30491	2.56	4.70	1.73	5.10	1.16	4.20	0.30	3.16
17.	WGL 14280-1 / N22	4.36	6.50	4.50	4.13	2.23	3.50	0.36	1.46

Table 15 (Contd....)

	1	2	3	4	5	6	7	8
18.	WGL 14280-1 / KMJ 10-2-2	5.03	6.36	3.90	5.20	3.06	3.53	3.06
19.	WGL 14280-1 / Tulasi	3.06	5.23	3.83	2.56	2.00	2.10	1.00
20.	WGL 14280-1 / CN 875-135-1-3	6.33	5.06	4.20	3.33	1.10	1.90	1.66
21.	WGL 14280-1 / CR 811-1	5.50	6.43	5.50	4.96	2.36	3.63	2.00
22.	NLR 30491 / N22	2.76	3.36	2.43	2.00	1.26	1.80	1.36
23.	NLR 30491 / KMJ 10-2-2	4.63	5.50	1.50	5.80	2.70	2.36	1.13
24.	NLR 30491 / Tulasi	5.03	5.96	4.76	3.60	2.36	2.76	0.10
25.	NLR 30491 / CN 875-135-1-3	6.06	4.83	5.36	4.93	2.76	3.93	1.20
26.	NLR 30491 / CR 811-1	5.46	3.06	4.03	2.96	2.06	2.23	0.10
27.	N22 / KMJ 10-2-2	6.00	3.20	5.16	3.13	2.96	1.86	0.10
28.	N22 / Tulasi	5.96	4.10	3.46	3.86	2.98	2.73	0.10
29.	N22 / CN 875-135-1-3	5.16	6.33	2.50	5.16	1.90	2.36	0.10
30.	N22 / CR 811-1	4.26	4.03	3.36	3.63	3.20	3.46	2.23
31.	KMJ 10-2-2 / Tulasi	5.63	6.00	4.20	6.10	1.96	1.60	2.03
32.	KMJ 10-2-2 / CN 875-135-1-3	6.34	3.60	2.33	3.13	2.03	2.90	0.50
33.	KMJ 10-2-2 / CR 811-1	5.13	2.46	4.10	2.13	2.23	3.30	1.40
34.	Tulasi / CN 875-135-1-3	5.00	4.53	3.03	4.63	1.13	2.30	1.93
35.	Tulasi / CR 811-1	7.96	8.30	5.03	2.96	1.96	2.30	0.56
36.	CN 875-135-1-3 / CR 811-1	4.56	3.21	4.06	4.06	2.46	3.00	2.46
	General Mean	4.73	4.44	3.53	3.69	1.96	2.65	1.42
	SE _m ±	0.240	0.258	0.258	0.204	0.175	0.198	0.121
	CD at 0.05	0.472	0.506	0.506	0.401	0.343	0.388	0.237
	CV %	6.2	7.1	8.9	6.8	10.9	9.1	10.4

maximum root dry weight of 8.97g, followed by Tulasi (8.06 g) and NLR 30491 (7.84 g). The lowest dry weight was recorded by WGL 14280-1 (3.46g) followed by KMJ 10-2-2 (4.50 g) and CR 811-1 (4.53 g). Among hybrids, root dry weight varied from 1.80 g in N22 / CN 875-135-1-3 to 11.57 g in the hybrid NLR 33899/CN 875-135-1-3 (Table 13).

Under favourable environment the variation for root dry weight among parents was from 2.50 g to 7.03 g (Table 14). CN 875-135-1-3 (7.03 g) followed by NLR 30491 (5.91 g) and CR 811-1 (5.81 g) recorded the higher root dry weights. In hybrids the values varied from 2.32 g to 10.75 g. The hybrid combination NLR 30491/CN 875-135-1-3 had 10.75g followed by CN 875-135-1-3/CR 811-1 (9.62 g), KMJ 10-2-2/CR 811-1 (9.62g) and KMJ 10-2-2/CN 875-135-1-3 (8.56 g). While, the lesser root dry weights were observed in NLR 33899/KMJ 10-2-2 (2.32 g), NLR 33899 / NLR 30491 (3.20 g) and WGL14280-1/N22 (3.45 g) hybrid combination.

4.5.2.2 Shoot dry weight

Under moisture stress situation shoot dry weight ranged from 22.47 g to 46.93 g among parents and 11.5 g to 52.59 g among hybrids (table 13). Among the parents the highest shoot dry weight was observed in CN 875-135-1-3 (46.93g); followed by NLR 30491 (45.18 g) and NLR 33899 (43.18 g), while the lowest shoot dry weights were noticed in

CR811-1 (22.47 g), WGL 14280-1 (23.22 g) and N22 (27.98 g). Among hybrids N22 / Tulasi gave the highest shoot dry weight of 52.59g followed by NLR 33899 / CN 875-135-1-3 (51.22 g) ; NLR 30491 / CN 875-135-1-3 (50.80 g) and NLR 30491/KMJ 10-2-2 (48.62 g); while the lowest shoot dry weights were recorded by KMJ 10-2-2-/CR 811-1 (11.5g) followed by Tulasi / CN 875-135-1-3 (18.6 g) and N22/CN 875-135-1-3 (18.61 g).

In respect of favourable environment, the shoot dry weight varied from 23.70 g to 45.70 g among parents and from 18.95 g to 91.1 g among hybrids (table 14). The maximum shoot dry weight was observed in Tulasi (45.70g) followed by NLR 30491 (35.66 g), CN 875-135-1-3 (35.43 g) and KMJ 10-2-2 (35.16 g). The lowest weights among parents were found in WGL 14280-1 (23.70g) followed by NLR 33899 (32.01 g) and N22 (31.03 g). In the case of hybrids the highest shoot dry weight was observed in cross combination of NLR 30491/CN 875-135-1-3 (91.1g) followed by KMJ 10-2-2/CN 875-135-1-3 (69.7 g) KMJ 10-2-2/CR 811-1 (66.8 g) and N22 / Tulasi (57.9 g). The lowest shoot dry weight was recorded by NLR 33899/CR 811-1 (18.95g) followed by NLR 33899 / KMJ 10-2-2 (23.86 g) and NLR 30491 / N22 (29.8 g).

4.5.2.3 Root to shoot ratio

The character root to shoot ratio ranged from 0.25 to 0.13 among parents and from 0.08 to 0.24 among hybrids under moisture stress environment (Table 13). The parent Tulasi recorded the highest root to shoot ratio of 0.25 followed by NLR 33899 (0.20) and CR 811-1 (0.19). The lowest ratio was observed in the parent CN 875-135-1-3 (0.13) followed by WGL 14280-1 (0.15) NLR 30491 (0.16) and KMJ 10-2-2 (0.16). With regard to hybrids, two cross combinations of Tulasi/CR 811-1 and WGL 14280-1/Tulasi recorded the maximum root to shoot ratio of 0.24 followed by NLR 33899/Tulasi (0.22), NLR 33899/CN 875-135-1-3 (0.22), NLR 33899/CR 811-1 (0.20) and WGL 14280-1/CN 875-135-1-3 (0.20). The minimum values were observed in NLR 30491/CN 875-135-1-3 (0.08) closely followed by N22/CN 875-135-1-3 (0.09) and NLR 30491/KMJ 10-2-2 (0.10).

The variation for root to shoot ratio in favourable environment was from 0.07 to 0.19 among parents and from 0.08 to 0.19 among hybrids. (Table 14). The parent CN 875-135-1-3 recorded the highest ratio of 0.19 followed by NLR 30491 (0.16) and N22 (0.16), while the lowest ratio was found in the parent NLR 33899 (0.07) followed by Tulasi (0.11) and KMJ 10-2-2 (0.12). Among hybrids the cross combination of N22/CN 875-135-1-3 recorded the highest ratio of 0.19 followed by NLR 33899/CR811-1 (0.18), Tulasi/CR 811-1 (0.17) and CN 875-135-1-3 / CR 811-1 (0.17). The

minimum ratio of 0.08 was expressed by the cross combination of WGL 14280-1 / N22 followed by NLR 33899 / NLR 30491 (0.09) and NLR 30491/KMJ 10-2-2 (0.09). (114)

4.5.2.4 Relative water content

Relative water content among parents varied from 71 to 82% and from 68 to 88% among hybrids under moisture stress situation (Table 13). The maximum relative water content of 82% was noticed in the parent CN875-135-1-3 followed by CR 811-1 (81%) and Tulasi (80%). The minimum relative water content of 71% was expressed by two parents NLR 33899 and KMJ 10-2-2. In the case of hybrids Tulasi/CR 811-1 recorded the highest value of 88% followed by NLR 33899/KMJ 10-2-2 (87%) and NLR 30491/N22 (84%). The minimum of 68 % relative water content was exhibited by the hybrid N22/CN 875-135-1-3 followed by WGL 14280-1/KMJ 10-2-2 (69%) and WGL 14280-1/N22 (70%).

Under favourable environment KMJ 10-2-2 recorded the highest relative water content of 78% among parents followed by Tulasi (77%) NLR30491 (72%) and CN 875-135-1-3 (71%). The minimum relative water content observed in WGL 14280-1 (67%) followed by NLR 33899 (69%) and CR 811-1 (69%). In the case of hybrids the variation for relative water content was from 62% to 80%. The maximum value was shown by the hybrid Tulasi / CR811-1 (80%) followed by N22 / CR 811-1

(79%) ; WGL 14280-1/NLR 30491 (77%) and NLR 30491/N22 (76%).

While the minimum relative water content was expressed by NLR 33899/
NLR 30491 (62%) followed by 63% by NLR 33899 / Tulasi ; NLR33899/
CR811-1, WGL 14280 / Tulasi and N22 / KMJ 10-2-2 (Table 14).

4.5.2.5 Number of days to 50% flowering

Number of days to 50% flowering varied from 91 to 94 days among parents and 87 to 92 days among hybrids under moisture stress situation (Table 13). Two parents NLR 33899 and CR 811-1 had 94 days to 50% flowering where as the other parents N22 and Tulasi had 91 days to 50% flowering. In the case of hybrids, two cross combinations NLR 33899/KMJ10-2-2 and NLR 33899/CR 811-1 took 92 days to flower, while the other hybrid NLR 30491/CR 811-1 had 87 days to 50% flowering.

Under favourable environment, number of days to 50% flowering varied from 89 to 95 days among parents and 85 to 91 days among hybrids (table 14). NLR 33899 was the latest to flower (95 days), while, N22 was the earliest to flower (89 days) among parents. Two hybrids Tulasi/CN 875-135-1-3 and Tulasi /CR 811-1 took 91 days to flower, while N22 / Tulasi had only 85 days to 50% flowering.

4.5.2.6 Plant height

Under moisture stress situation, the plant height ranged from 55 cm to 87 cm among parents and 75 cm to 110 cm among hybrids (Table 13). Among the parents the tallest was CN 875-135-1-3 (87 cm) followed by N22 (72 cm) and NLR 33899 (71 cm), while the shortest was WGL 14280-1 (55 cm) followed by NLR 30491 (60 cm). In the case of hybrids, the tallest was the hybrid NLR 33899/CN875-135-1-3 (95.3 cm) followed by that of WGL 142-80-1 / CN 875-135-1-3 (94.3 cm) and N22/Tulasi (91.0 cm). The shortest was the hybrid WGL 14280-1/Tulasi 10-2-2 (54.3 cm) followed by that of WGL 142-80-1 / KMJ 10-2-2 (84.6 cm).

Under favourable environment, plant height varied from 74 cm to 114 cm among parents and from 75 cm to 110 cm among hybrids. (Table 14). Among the parents tallest was CN 875-135-1-3 (114cm) followed by N22 (92 cm) and CR 311-1 (90 cm). However, dwarfest parent was KMJ 10-2-2 (74 cm). Among hybrids, WGL 14280-1/CN 875-135-1-3 recorded the highest height of 110 cm closely followed by N22/ CN 875-135-1-3 (109 cm) and NLR 33899 / CN 875-135-1-3 (106 cm), while the minimum height was expressed by the hybrid WGL 14280-1/ KMJ 10-2-2 (75 cm) followed by NLR 33899/NLR 30491 (78 cm).

4.5.2.7 Number of ear bearing tillers per plant

Under moisture stress environment, number of tillers per plant ranged from 9.0 to 14.0 among parents and 8.3 to 14.3 among hybrids (table 13). Among parents maximum number of tillers was observed in KMJ 10-2-2 (14.0) and WGL 14280-1(14.0) followed by Tulasi (12 .0) and NLR 33899 (12.0). The lowest number was observed in N22 (10.0) and CR 811-1 (10.0). Among hybrids, CN 875-135-1-3/CR 811-1 was having the more number of tillers (14.3) followed by N22 / CN 875-135-1-3 (14.0) and WGL 14280-1 / N22 (13.6). Number of tillers was the least in the cross N22 / CR 811-1 (8.3).

Under favourable situation, the variation was from 7.6 to 11.3 among parents, from 8.6 to 20.0 among hybrids (table 14). In the case of parents highest number of tillers was recorded in WGL 14280-1 (11.3) followed by NLR 30491 (10.0) and KMJ 10-2-2 (10.0). Among hybrids maximum number of tillers per plant was noticed in the cross combination of Tulasi / CR811-1 (20.0), CN 875-135-1-3/CR 811-1 (16.6) and KMJ 10-2-2 / CR 811-1 (16.0).

4.5.2.8 Panicle Length

Panicle length ranged from 19.0 cm to 22.5 cm and from 18.0 cm to 25.9 cm among parents and hybrids respectively (table 13) under moisture stress situation. The maximum length was observed in the

parent CN 875-135-1-3 (22.5 cm) followed by Tulasi (21.3 cm), NLR 33899 (20.86 cm) and WGL 14280-1 (20.8 cm). Among hybrids WGL 14280-1 / CN 875-135-1-3 recorded the highest length of 25.9 cm, followed by that of WGL 14280-1 / NLR 30491 (23.8 cm), WGL 14280-1/ N22 (23.16) and NLR 33899 / CN 875-135-1-3 (23.10 cm).

Panicle length varied from 18.6 cm to 25.1 cm among parents and from 17.2 cm to 29.0 cm among hybrids under favourable environment (Table 14). The parent CN 875-135-1-3 recorded the maximum length of 25.1 cm followed by WGL 14280-1 (23.5 cm), Tulasi (23.2 cm) and NLR 30491 (22.3 cm). Where as the lowest panicle length of 18.6 cm was noticed in the parent N22 followed by KMJ 10-2-2 (20.3 cm) and NLR 33899 (22.0 cm). In the case of hybrids WGL 14280-1/Tulasi has 29.0 cm followed by that of WGL 14280-1/CN 875-135-1-3 (25.1 cm), Tulasi / CR 811-1 (25.0 cm) and N22 / CN 875-135-1-3 (24.9 cm).

4.5.2.9 Number of spikelets per panicle

The number of spikelets per panicle in moisture stress situation among parents ranged from 81.3 to 132.0 and among hybrids from 87.6 to 140.0 (table 13). Highest number of spikelets per panicle was produced by CN 875-135-1-3 (132.0) and NLR 30491 (130.0); while the lowest number was produced by N22 (81.3) and CR 811-1 (84.3). In

respect of hybrids maximum number of spikelets per panicle was produced by WGL 14280-1/CN 875-135-1-3 (140.0) followed by WGL 14280-1 / NLR 30491 (137.6) and Tulasi / CN 875-135-1-3 (135.3). Whereas minimum number was produced by NLR 30491 / KMJ 10-2-2 (87.6) followed by WGL 14280-1 / N22 (89.0) and N22 / CN 875-135-1-3 (90.3).

Under favourable environment, the number of spikelets per panicle showed variation from 109 to 159 among parents and from 77 to 158 among hybrids (table 14). In the case of parents maximum number of spikelets per panicle was counted in NLR 30491 (159.0) followed by CN 875-135-1-3 (155.0), KMJ 10-2-2 (138.0) and WGL 14280-1 (135). Whereas minimum number was found in N22 (109), NLR 33899 (114) and Tulasi (122). In the case of hybrids more spikelets were recorded in WGL 14280-1/CN 875-135-1-3 (158), N22 / CN 875-135-1-3 (157) and CN 875-135-1-3/CR 811-1 (155).

4.5.2.10 Number of filled grains per panicle

Under moisture stress environment, number of filled grains per panicle varied from 51.3 to 91.0 among parents and from 54.0 to 101.0 among hybrids. Highest number of filled grains per panicle was produced by NLR 30491 (91.0) followed by CN 875-135-1-3 (86.6), NLR 33899 (81.3) and Tulasi (78.0). The lowest number of filled grains was found in CR 811-1 (43.3) followed by N22 (51.3) and WGL 14280-1 (61.3). In

the case of hybrids maximum number of filled grains per panicle was observed in WGL 14280-1/CN 875-135-1-3 (101.0) followed by NLR 30491 (91.3) and KMJ 10-2-2 / Tulasi (91.0) as against WGL 14280-1 / KMJ 10-2-2 (54.0), WGL 14280-1 / N22 (56.0) and N22 / CR 811-1 (58.0) having minimum number of grains per panicle.

In respect of favourable environment, the highest number of grains was observed in the parent CN 875-135-1-3 (121.6) followed by NLR 30491 (110.0), WGL 14280-1 (100.0) and KMJ 10-2-2 (90.0). The lowest number was found in N22 (72.3). Among hybrids maximum number of filled grains per panicle was recorded in CN 875-135-1-3/CR 811-1 (135.6) followed by Tulasi / CR 811-1 (126.0) and WGL 14280-1 / CN 875-135-1-3 (120.0), while minimum number was found in the cross combination of KMJ 10-2-2 / NLR 33899 (52.0) followed by N22 / KMJ 10-2-2 (63.0) and NLR 33899 / NLR 30491 (64.0).

4.5.2.11 Spikelet fertility per cent

Spikelet fertility ranged from 50.6 to 76.3 per cent and from 51.3 to 78.3 percent among parents and hybrids respectively (table 13). In the case of parents, highest fertility was observed in Tulasi (76.3%) followed by NLR 30491 (70.0%) and NLR 33899 (67.3%), while lowest fertility was found in CR 811-1 (50.6%), KMJ 10-2-2 (60.3%) and NLR 14280-1 (62.0%). In the case of hybrids, maximum fertility was recorded in NLR

30491/CR 811-1 (78.3%) followed by KMJ 10-2-2/Tulasi (75.6%) and NLR33899/CN 875-135-1-3 (75.0%). Lowest fertility was observed in WGL 14280-1 / KMJ 10-2-2 (51.3%) followed by N22 / CN875-135-1-3 (52.0%) and N22 / CR 811-1 (52.3%).

Under favourable environment, spikelet fertility varied from 64.6 to 81.0 percent and from 51.3 to 87.3 percent among parents and hybrids respectively (table 14). In the case of parents NLR 33899 recorded the maximum spikelet fertility of 81.0 percent followed by CN 875-135-1-3 (78.0%). WGL 14280-1 (73.6%) and Tulasi (73.0%). The lowest was observed in N22 (66.3%). Among hybrids the highest fertility percent of 87.3 was found in CN 875-135-1-3 / CR 811-1, followed by Tulasi / CR 811-1 (83.6%), KMJ 10-2-2/Tulasi (81.3%) and WGL 14280-1/KMJ 10-2-2 (80.3%), while the minimum spikelet fertility was observed in N22/CN 875-135-1-3 (51.3%), NLR 30491 / N22 (53.0%) and NLR 33899 / N22 (55.0%).

4.5.2.12 Harvest index

The variation for harvest index ranged from 30 to 51% and from 33.6 to 54.0% among parents and hybrids respectively under moisture stress situation (Table 13). The highest harvest index was observed in the parent Tulasi (51%) followed by NLR 30491 (48%) NLR 33899 (43%) and WGL 14280-1 (43%). The lowest was found in CR 811-1 (30%).

Among hybrids the maximum percent of harvest index was found in the cross combination of WGL 14280-1 / Tulasi and WGL 14280-1 / N22 (54.0%), while the lowest was found in N22 / CN 875-135-1-3 (33.6%).

Under favourable environment harvest index varied from 38.6% to 49.3% and from 36.0% to 73.6% among parents and hybrids respectively (Table 14). Maximum harvest index was observed in NLR 33899 (49.3%), while the lowest was found in the parent NLR 30491 (38.6%). In the case of hybrids the highest percent of harvest index 73.6% was recorded by WGL 14280-1 / CN 875-135-1-3 and the minimum of 36.0% was noticed in the cross combination of N22 / CN 875-135-1-3.

4.5.2.13 Test weight

Under stress situation, variation for test weight ranged from 15.8 g to 21.3 g and from 16.3 g to 22.7 g among parents and hybrids respectively (Table 13). Among parents, CN 875-135-1-3 (21.3 g) Tulasi (19.9 g) and CR 811-1 (19.6 g) recorded high test weights and N22 (16.5 g), KMJ 10-2-2 (16.5) and NLR 30491-1 (16.9 g) had low test weights. In the case of hybrids CN 875-135-1-3 / CR 811-1 (22.7 g), Tulasi / CR 811-1 (22.1 g) and WGL 14280-1 / Tulasi (22.0 g) had high test weights, while NLR 33899 / KMJ 10-2-2 (16.3 g), NLR 33899 / NLR 30491 (16.5 g) and N22 /CN 875-135-1-3 (17.0 g) had low test weights.

Test weight varied from 18.6 to 24.7 g and from 19.0 g to 26.0 g among parents and hybrids respectively under favourable environment (Table 14). Highest test weight was observed in CR 811-1 (25.5 g) followed by CN 875-135-1-3 (24.7 g) and NLR 33899 (23.6 g), while lowest test weight was recorded in KMJ 10-2-2 (18.6 g) followed by NLR 30491 (18.8 g) and N22 (19.3 g). In the case of hybrids, high test weights were observed in CN 875-135-1-3 / CR 811-1 (26.0 g), Tulasi / CR 811-1 (25.8 g) and KMJ 10-2-2 / CR 811-1 (25.6 g) and low test weights were observed in N22 / Tulasi (19.0 g), N22 / CN 875-1-135-1-3 (19.1 g) and NLR33899 / NLR30491 (19.56 g).

4.5.2.14 Specific leaf weight

The variation for specific leaf weight ranged from 4.87 mg/cm² to 7.80 mg/cm² among parents and from 3.175 mg/cm² to 7.156 mg/cm² among hybrids respectively under moisture stress situation (table 13). The highest specific leaf weight was observed in NLR 30491 (7.80 mg/cm²) followed by NLR 33899 (5.95 mg/cm²) and KMJ 10-2-2 (5.88 mg/cm²). While low specific leaf weight was estimated in N22 (4.44 mg/cm²) and WGL 14280-1 (4.87 mg/cm²). With regard to F₁ hybrids NLR 30491 / CN 875-135-1-3 had 7.156 mg/cm², followed by WGL 14280-1 / CN 875-135-1-3 (6.90 mg/cm²) and NLR 30491/CR 811-1 (6.66 mg/cm²). The lowest estimates were observed in N22 / CN 875-135-1-3 (3.17 mg/cm²), N22 / Tulasi (3.38 mg/cm²) and NLR 33899 / CN 875-135-1-3 (3.72 mg/cm²).

Under favourable environment, specific leaf weight ranged from 5.05 mg/cm² to 6.59 mg/cm² among parents and from 3.94 mg / cm² to 7.82 mg/cm² among hybrids respectively (Table 14). WGL 14280-1 recorded the highest specific leaf weight of 6.59 mg/cm² followed by N22 (6.57 mg/cm²) and Tulasi (6.43 mg/cm²), while the lowest values were noticed in CN 875-135-1-3 (5.05 mg/cm²), KMJ 10-2-2 (5.39 mg/cm²) and NLR 33899 (5.87 mg/cm²). In the case of hybrids the cross combination Tulasi / CR 811-1 recorded the highest value of 7.82 mg/cm², followed by NLR 33899/CR 811-1 (7.65 mg/cm²) and CN 875-135-1-3/CR811-1 (7.64 mg/cm²). The lowest estimates were observed in N22 / Tulasi (3.76 mg/cm²) WGL 14280-1 / N22 (3.94 mg/cm²) and NLR 33899 / N22 (5.10 mg/cm²).

4.5.2.15 Leaf area per plant

Leaf area per plant among parents ranged from 945.0 cm² to 1763.2 cm² and from 580.3 cm² to 1787.7 cm² among parents and hybrids respectively under moisture stress environment (Table 13). NLR 30491 recorded the highest leaf area per plant (1763.2 cm²), followed by CN875-135-1-3 (1511.8 cm²) and Tulasi (1286.6 cm²), while KMJ 10-2-2 showed the lowest leaf area per plant of 945.0 cm² followed by WGL 14280-1 (945.4 cm²), NLR 33899 (1032.0cm²) and CR 811-1 (1048.7cm²). Among the hybrids the largest leaf area of 1587.7 cm² was recorded in The hybrid Tulasi/CR 811-1 followed by NLR 33899/CN875-135-1-3

(1485.5 cm²), NLR 33899/NLR 30491 (1384.1 cm²) and WGL 14280-1/CN 875-135-13 (1364.4cm²), where as the minimum leaf area per plant of 580.3cm² was recorded in the hybrid of NLR 30491 / CR811-1 followed by N22 / CR811-1 (591.76 cm²) and N22 / CN 875-135-1-3 (655.86 cm²). Among the hybrids NLR 33899 / N22 had the largest leaf area of 2566.0 cm² followed by NLR 30491 / CN 875-135-1-3 (2550.9 cm²) and WGL 14280-1 / N22 (2408.7 cm²) where as WGL 14280-1 /CN 875-135-1-3 (951.6 cm²), NLR 33899 / CN 875-135-1-3 (1349.0cm²) and NLR 33899/ CR 811-1 (1438.0 cm²) showed the lowest leaf area per plant.

4.5.2.16 Grain yield per plant

Under moisture stress environment, grain yield per plant ranged from 4.4 g to 14.1 g among parents and from 2.48 g to 22.3 g among hybrids (Table 13). Among parents Tulasi (14.1 g) recorded the highest grain yield per plant, followed by NLR 33899 (12.3 g) and NLR 30491 (10.2 g), while N22 (4.4 g) followed by CR811-1 (6.5 g) and KMJ 10-2-2 (8.7 g) gave lowest grain yield. In the case of hybrids highest grain yield per plant was recorded in NLR 33899/CN 875-135-1-3 (22.3g) followed by Tulasi / CR 811-1 (21.0g) and WGL 14280-1 / Tulasi (17.0 g) where as the lowest grain yield per plant was observed in N22 / CN 875-135-1-3 (2.48 g), NLR 30491 / CN 875-135-1-3 (3.74 g) and NLR 30491 / Tulasi (3.95 g).

Under favourable environment, grain yield per plant varied from 8.73 g to 21.90 g and from 10.6 g to 28.1 g among parents and hybrids respectively (Table 14). In the case of parents, CN 875-135-1-3 (21.90 g), NLR 33899 (21.36 g) and WGL 14280-1 (15.36 g) showed high single plant grain yield and KMJ 10-2-2 (8.73g) N22 (10.13 g) and NLR 30491 (11.73 g) exhibited low yields. Among hybrids, CN 875-135-1-3/CR 811-1 recorded maximum single plant grain yield (28.1 g) followed by NLR 30491 / CN 875-13-1-3 (26.0 g) and Tulasi / CN 875-135-1-3 (24.6 g). While N22 / CN 875-135-1-3 had lowest grain yield of 10.6 g followed by Tulasi / CN 875-135-1-3 (12.0 g) and KMJ 10-2-2 /CR 811-1 (12.5 g).

4.5.2.17 Leaf rolling (0-9 scale)

Under moisture stress situation, leaf rolling score ranged from 3 to 7 among parents and from 1 to 8 among hybrids (Table 14). Among parents lowest score was noticed in NLR 30491 (3) followed by Tulasi (4) and NLR 33899(4). Where as highest score was observed in WGL 14280-1 (7) N22 (7) CN 875-135-1-3 (7) and CR 811-1 (7). Among hybrids least score was recorded in N22 / Tulasi (1), CN 875-135-1-3/CR 811-1 (1) while highest score was observed in the cross combination of KMJ 10-2-2 / CR 811-1 (8).

4.5.2.18 Shoot and root growths of 6 day old seedlings under simulated drought conditions induced by polyethylene glycol.

Shoot and root lengths of 6 day old seedlings were recorded under different osmotic pressures. (0.00 ; 3.00 ; 6.00 and 10.00 bars) induced by polyethylene glycol.

4.5.2.18.1 0.00 bars (control)

Shoot length at 0.00 bars varied from 3.50 cm to 4.70 cm and from 2.03 cm to 7.96 cm among parents and hybrids respectively (Table 15). Among parents N22 recorded highest shoot length of 4.70 cm followed by NLR 30491 (4.46 cm) and CN 875-135-1-3 (4.43 cm), while the lowest shoot lengths were observed in NLR 33899 (3.50 cm), WGL 14280-1 (3.80 cm) and KMJ 10-2-2 (4.00 cm). In the case of hybrids, the highest length was shown by Tulasi / CR811-1 (7.96 cm), KMJ 10-2-2 / CN 875-135-1-3 (6.34 cm) and WGL14280-1 / CN875-135-1-3 (6.33 cm). Where as the lowest values were observed in NLR 33899 / WGL14280-1 (2.03 cm) followed by WGL 14280-1 / NLR 30491 (2.56 cm) and NLR 30491/N22 (2.76 cm).

Variation for root length ranged from 1.63 cm to 1.80 cm among parents and from 2.46 cm to 8.30 cm among hybrids. the parent KMJ 10-2-2 had maximum root length of 3.90 cm followed by N22 (3.86 cm)

and CR 811-1 (3.40 cm) while the minimum length was produced by CN 875-135-1-3 (1.63 cm) followed by NLR 30491 (1.80 cm) and Tulasi (2.30 cm). In the case of hybrids highest root length was recorded by the hybrid Tulasi / CR811-1 (8.30 cm) followed by NLR 33899 / Tulasi (7.86 cm), NLR 33899 / NLR 30491 (6.56 cm) and WGL 14280-1 / N22 (6.50 cm). The lowest root length was shown by KMJ 10-2-2/CR 811-1 (2.46 cm), NLR 30491 / CR811-1 (3.06 cm) and NLR 33899 / Tulasi (3.20 cm).

4.5.2.18.2 3.00 bars of osmotic pressure

Variation for shoot growth ranged from 0.86 cm to 3.10 cm and from 1.50 cm to 5.83 cm among parents and hybrids respectively (Table 15). In the case of parents NLR33899 (3.10 cm) CR 811-1 (3.03 cm) and KMJ 10-2-2 (2.90 cm) recorded highest shoot length, while the lowest shoot length was shown by CN 875-135-1-3 (0.86 cm), Tulasi (0.88 cm) and NLR 30491 (1.46 cm). Among hybrids NLR 33899 / N22 (5.83 cm), WGL 14280-1/CR811-1(5.50 cm) and NLR 30491/CN875-135-1-3 (5.36 cm) showed high shoot length, where as NLR 30491/KMJ 10-2-2 (1.50 cm) followed by WGL 14280-1/NLR 30491 (1.73 cm) and KMJ 10-2-2 / CN 875-135-1-3 (2.33 cm) exhibited minimum shoot length.

Root length of 6 day old seedling at 3.00 bars ranged from 1.80 cm to 3.16 cm among parents and from 1.80 cm to 6.10 cm among F_1

hybrids (Table 15). Highest root length was observed in WGL 14280-1 (3.16 cm) followed by N22 (3.13 cm) and Tulasi (2.66 cm). Of the hybrids the cross combination KMJ 10-2-2 / Tulasi recorded the maximum root length of 16.10 cm followed by NLR 33899 / KMJ10-2-2 (5.93 cm) and NLR33899 / Tulasi (5.86 cm). While, the minimum root length was observed in NLR 33899 / WGL 14280-1 (1.80 cm), NLR 30491 / N22 (2.00 cm) and KMJ 10-2-2 / CR 811-1 (2.13 cm).

4.5.2.18.3 6.00 bars of osmotic pressure

Shoot length at 6.00 bars varied from 0.50 cm to 2.56 cm among parents and from 0.90 cm to 3.22 cm among hybrids (Table 15). Among the parents NLR33899 had maximum shoot length of 2.56 cm followed by N22 (1.90 cm) and WGL 14280-1 (1.80 cm), while the lowest shoot lengths were observed in NLR30491 (0.50 cm), CN 875-135-1-3 (0.70 cm) and KMJ 10-2-2 (0.83 cm). Among hybrids highest shoot length was noticed in NLR 33899/CN875-135-1-3 (3.22 cm), N22 / CR811-1 (3.20 cm) and N22/Tulasi (2.98 cm). Where as the lowest shoot lengths were observed in NLR 33899/KMJ 10-2-2 (0.90 cm), WGL 14280-1/CN 875-135-1-3 (1.10 cm) and WGL 14280-1/NLR 30491 (1.16 cm).

In respect of variation for root length at 6.00 bars ranged from 1.80 cm to 2.76 cm and from 1.60 cm to 4.20 cm among parents and hybrids respectively (Table 15). Among parents KMJ 10-2-2 recorded the

highest root length of 2.76 cm followed by Tulasi (2.56 cm) and N22 (2.20 cm) and the lowest root length was observed in NLR 33899 (1.80 cm) NLR 30491 (1.83 cm) and CN875-135-1-3 (1.96 cm). In the case of hybrids the cross combination WGL 14280-1/NLR 30491 (4.20 cm) had recorded highest root length followed by NLR 30491/CN 875-135-1-3 (3.93 cm) and WGL 14280-1/CR 811-1 (3.63 cm), whereas the minimum estimates were shown by KMJ 10-2-2 / Tulasi (1.60 cm), NLR 30491/N22 (1.80 cm) and N22 / KMJ 10-2-2 (1.86 cm), followed by N22 (3.13 cm) and Tulasi (2.66 cm). Of the hybrids the cross combination KMJ 10-2-2/Tulasi recorded the maximum root length of 6.10 cm followed by NLR 33899 / KMJ 10-2-2 (5.93 cm). While, the minimum root length was observed in NLR 33899 / WGL 14280-1 (1.80 cm), NLR 30491 / N22 (2.00 cm) and KMJ 10-2-2/CR 811-1 (2.13 cm).

4.5.2.18.4 10.00 bars of osmotic pressure

Shoot length ranged from 0.10 cm to 0.20 cm among parents and from 0.10 cm to 1.90 cm among hybrids (Table 15). The parent CR811-1 had highest shoot length of 0.20 cm, while five parents viz. NLR 33899, WGL 14280-1, N22, KMJ 10-2-2 and Tulasi showed minimum shoot length of 0.10 cm.

With regard to root length the variation was from 0.10 cm to 1.73 cm among parents and from 0.10 cm to 4.00 cm among hybrids

(Table 15). Out of the eight parents CR 811-1 (1.73 cm) recorded highest root length followed by CN 875-135-1-3 (1.70 cm) and NLR 33899 (1.0 cm). The minimum root length of 0.10 cm was shown by three parents viz. N22, KMJ 10-2-2 and Tulasi. In the case of hybrids NLR 33899 / Tulasi recorded the highest length of 4.00 cm followed by WGL 14280-1 / NLR30491 (3.16 cm) and WGL14280-1 / KMJ 10-2-2 (3.06 cm).

4.5.3 HETEROSIS

The percent heterosis estimated over mid and better parents for the characters studied under moisture stress and favourable environments as well as under stimulated drought by polyethylene glycol are furnished in Tables 16, 17 and 18 respectively.

4.5.3.1 Root dry weight (g)

Under moisture stress situation heterosis varied from -67.40 to 62.59 per cent over mid parent and from -73.00 to 101.47 per cent over better parent for root dry weight (Table 16). Among the 28 hybrids, positive and significant heterosis was observed in 10 hybrids over mid parent and in 13 hybrids over better parent. The hybrid Tulasi / CR 811-1 exhibited the highest heterosis over better parent (101.47 per cent) followed by NLR 33899 / CN 875-135-1-3 (73.60%) and CN 875-135-1-3/ CR 811-1 (61.96%). Significant and negative heterosis observed in 17 hybrids over mid parent and 11 hybrids over better parent.

Table 16 : Percent heterosis for various characters over mid and better parental values under moisture stress

S. No.	Cross	Root dry weight		Shoot dry weight		Root / shoot ratio		Relative water content		Days to 50% flowering	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	-28.51**	28.39**	-11.41	26.67**	-12.15**	4.44**	-2.74	-5.33	-5.35**	-4.69**
2.	NLR 33899 / NLR30491	-26.38**	-21.05**	2.72	-0.15	-28.57**	20.00**	-0.69	-3.12	-3.39**	-2.87**
3.	NLR 33899 / N22	-22.17**	18.74**	4.52	32.90**	-31.62**	-27.27**	-0.67	-5.13	-1.80*	-0.36
4.	NLR 33899 / KMJ 10-2-2	-19.02**	21.96**	-2.01	21.58**	-16.07**	6.00**	22.25**	21.96**	1.10	4.55**
5.	NLR 33899 / Tulasi	-11.15**	-6.12**	-15.18*	0.72	-2.16**	-11.69**	7.28	1.25	-3.78**	-2.20**
6.	NLR 33899 / CN 875-135-1-3	47.97**	73.60**	13.68*	9.14	30.10**	63.41**	6.58	0.00	-3.57**	-2.88**
7.	NLR 33899 / CR 811-1	-9.48**	34.95**	-8.45	33.73**	0.00	3.45**	4.82	-1.65	-2.13**	-2.13**
8.	WGL 14280-1 / NLR 30491	-57.36**	-69.26**	-37.54**	-52.91**	-30.53**	-54.00**	3.34	3.57	-3.96**	-4.30**
9.	WGL 14280-1 / N22	14.63**	2.67**	25.96**	15.25**	-22.00**	-29.09**	-8.50*	-10.26*	-4.17**	-3.65**
10.	WGL 14280-1 / KMJ 10-2-2	55.55**	37.63**	40.38**	26.11**	3.16**	2.00**	-5.69	-3.27	-1.29	1.14
11.	WGL 14280-1 / Tulasi	41.64**	1.24	30.78**	12.53	18.03**	-5.49**	2.37	-0.83	-4.00**	-3.30**
12.	WGL 14280-1 / CN 875-135-1-3	57.35**	19.55**	9.57	-18.10*	44.19**	51.22**	6.41	2.47	-4.83**	-5.04**
13.	WGL 14280-1 / CR 811-1	62.89**	43.71**	67.86**	70.66**	-4.85**	-15.52	-7.69	-11.11*	-4.47**	-5.32**
14.	NLR 30491 / N22	-10.65**	-24.98**	-3.47	27.16**	-14.20**	-13.18**	2.18	0.00	-3.07**	-2.19
15.	NLR 30491 / KMJ 10-2-2	-16.26**	14.81**	29.81**	66.76**	-36.00**	-35.00**	1.83	4.21	0.55	3.41**
16.	NLR 30491 / Tulasi	-45.50**	-46.26**	-8.63	10.57	-43.61**	-53.25**	-3.88	-7.08	-1.09	0.00
17.	NLR 30491 / CN 875-135-1-3	-42.33**	-37.25**	9.65	8.25	-47.25**	-41.46**	5.78	1.65	-2.65**	-2.52**
18.	NLR 30491 / CR 811-1	-25.30**	1.99	21.19**	83.93**	-38.89**	-43.10**	-1.50	-5.35	-6.24**	-6.74**
19.	N22 / KMJ 10-2-2	5.97**	4.52**	33.96**	31.28**	-31.43**	-25.00**	-4.46	0.00	-0.74	1.14
20.	N22 / Tulasi	50.91**	16.41**	74.77**	63.31**	-21.21**	-32.47**	-3.38	-4.58	-3.47**	-3.30**
21.	N22 / CN 875-135-1-3	-67.40**	-73.00**	-50.30**	-60.34**	-39.58**	-26.67**	-14.47**	-16.05**	-1.03	-1.80**
22.	N22 / CR 811-1	-31.96**	-33.11**	-6.75	4.69	-30.97**	-32.76**	-4.40	-6.17	-2.88**	-4.26**
23.	KMJ 10-2-2 / Tulasi	-21.89**	-39.15**	-16.00**	-19.99**	-10.24**	-22.97**	1.76	-3.75	0.56	-1.10
24.	KMJ 10-2-2 / CN 875-135-1-3	-5.25**	-20.65**	-25.16**	-39.34**	20.88**	34.15**	4.60	-1.65	-1.48	-3.96**
25.	KMJ 10-2-2 / CR 811-1	2.47	2.13	-8.72	4.84	1.85**	-5.17**	-2.41	-8.23	-2.20**	-5.32**
26.	Tulasi / CN 875-135-1-3	-49.85**	-44.60**	-52.78**	-60.19**	-6.78**	34.5**	-7.66	-8.23	0.18	-0.72
27.	Tulasi / CR 811-1	44.94**	101.47**	37.03**	66.71**	8.15**	25.86**	9.73*	9.05	-2.70*	-4.26**
28.	CN 875-135-1-3 / CR 811-1	31.05**	61.96**	17.70**	81.77**	7.07**	-8.32**	-7.82	-7.82	-2.50*	-3.19**

Table 16 (Contd....)

S. No.	Cross	Plant height		No. of ear bearing tillers per plant		Panicle length		No. of spikelets per panicle		No. of filled grains per panicle	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	2.92	18.29**	-17.95**	-23.81**	-3.60**	-3.52**	-6.24	3.01	-15.42	-1.63
2.	NLR 33899 / NLR 30491	3.06	12.85**	11.76**	18.75**	5.67**	7.24**	10.13	5.36	4.45	-1.10
3.	NLR 33899 / N22	19.07**	17.97**	16.92**	31.03**	2.09**	7.01**	13.29	39.75**	4.02	34.42**
4.	NLR 33899 / KMJ 10-2-2	0.25	8.79**	-20.51**	-26.19**	1.14	3.33**	4.04	11.90	4.59	18.75*
5.	NLR 33899 / Tulasi	21.62**	23.08**	-18.92**	-21.05**	-0.25	1.28*	-3.59	3.87	-15.06	-13.25
6.	NLR 33899 / CN 875-135-1-3	19.58**	8.40*	16.13**	38.46**	6.45**	4.20**	-9.55	-13.89	1.59	-1.54
7.	NLR 33899 / CR 811-1	4.14	8.08*	10.77**	24.14**	3.37**	5.62**	5.73	27.67	16.53	67.69**
8.	WGL 14280-1 / NLR 30491	8.45*	3.91	-10.81**	3.12	15.82**	17.43**	-4.78	-16.07	6.35	-10.99
9.	WGL 14280-1 / N22	35.96**	19.35**	15.49**	41.38**	16.22**	21.72**	-1.66	9.43	-0.59	9.09
10.	WGL 14280-1 / KMJ 10-2-2	-5.20	-9.89*	-9.52**	-9.52**	4.33**	6.50**	7.21	5.14	-13.83	-15.62
11.	WGL 14280-1 / Tulasi	-12.37**	-21.63**	-2.50	2.63	2.83**	1.69	6.08	4.19	7.18	-4.27
12.	WGL 14280-1 / CN 875-135-1-3	32.86**	8.02*	-23.83**	0.00	19.75**	15.24**	20.86	6.06	31.53**	12.31
13.	WGL 14280-1 / CR 811-1	6.08	-3.03	-1.41	20.69**	9.39**	12.73**	28.62*	40.32**	43.95**	73.85**
14.	NLR 30491 / N22	29.29**	17.97**	27.87**	34.48**	10.60**	14.19**	16.04	51.23**	21.31	68.18**
15.	NLR 30491 / KMJ 10-2-2	20.22**	19.23**	-10.81**	-21.43**	10.26**	11.00**	3.27	16.72	10.11	33.33**
16.	NLR 30491 / Tulasi	12.66**	4.81	-14.29**	-21.05**	-1.38	-3.79**	-2.28	10.65	-14.79	-7.69
17.	NLR 30491 / CN 875-135-1-3	23.36**	3.82	17.24**	30.77**	3.12**	-2.07*	1.78	1.26	-2.44	0.00
18.	NLR 30491 / CR 811-1	6.63	1.52	-11.48**	-6.90**	5.93**	7.54**	14.11	45.45**	47.39**	128.46**
19.	N22 / KMJ 10-2-2	-17.29**	-9.34*	9.86**	-7.14**	7.60**	5.00**	47.03**	31.19*	18.50	6.77
20.	N22 / Tulasi	28.47**	31.25**	-1.49	-13.16**	15.35**	9.20**	32.49**	18.39	17.58	-2.56
21.	N22 / CN 875-135-1-3	-14.82**	-22.14**	52.73**	61.54**	5.85**	-2.37**	-15.31	-31.57*	2.42	-18.46*
22.	N22 / CR 811-1	3.13	8.08*	-13.79**	-13.79**	-6.90**	-8.32**	36.42**	33.99**	22.54**	33.85**
23.	KMJ 10-2-2 / Tulasi	4.62	-1.92	-27.50**	-23.68**	1.79*	-1.33	12.40	12.58	28.17**	16.67
24.	KMJ 10-2-2 / CN 875-135-1-3	-4.05	-18.70**	-20.59**	3.85	-1.88**	-7.40**	-7.50	-17.42	-3.10	-15.77
25.	KMJ 10-2-2 / CR 811-1	1.58	-2.53	18.31**	44.83**	1.60	2.55**	12.41	25.30*	14.25	41.54**
26.	Tulasi / CN 875-135-1-3	8.51**	-2.67	-9.38**	11.54**	0.36	-2.37**	15.01	2.53	5.67	0.38
27.	Tulasi / CR 811-1	25.12**	28.28**	-7.46**	6.90**	3.40**	7.31**	34.28**	49.41**	21.98*	70.77**
28.	CN 875-135-1-3 / CR 811-1	-16.52**	-3.03	56.36**	42.28	3.24**	10.87**	4.16	33.60**	11.75	67.69**

Table 16 (Contd....)

S. No.	Cross	Spikelet fertility (%)		Harvest Index		Test Weight		Specific leaf weight		Leaf area per plant	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	-6.70	-2.69	14.62**	13.74**	6.85**	5.30	-3.27**	7.53**	-12.51	-7.47
2.	NLR 33899 / NLR 30491	-2.68	-4.31	6.57	0.69	-17.29**	-12.40**	-12.46**	-22.82**	-0.97	-21.50
3.	NLR 33899 / N22	-6.33	-4.15	13.30**	26.92**	16.31**	27.85**	13.60**	32.95**	-4.63	-7.28
4.	NLR 33899 / KMJ 10-2-2	2.87	8.84	6.30	8.00*	-7.79*	-1.21	-13.85**	-13.36**	-25.36	21.92
5.	NLR 33899 / Tulasi	-14.62*	-19.65**	6.34	-2.58	-4.63	-7.02*	-21.48**	-17.38**	7.47	-3.17
6.	NLR 33899 / CN 875-135-1-3	12.50	13.64	16.87**	24.56**	1.41	-4.23	-31.50**	-24.61**	16.80	-1.74
7.	NLR 33899 / CR 811-1	14.12*	32.89**	30.91**	58.24**	4.42	2.73	-10.89**	-2.40**	29.58	28.55
8.	WGL 14280-1 / NLR 30491	13.42	7.18	26.81**	20.69**	103.11**	118.50**	-5.47**	-23.25**	-9.36	-31.28
9.	WGL 14280-1 / N22	-0.26	-2.07	1.28	14.42**	23.14**	37.55**	19.34**	25.08**	-20.37	-26.47
10.	WGL 14280-1 / KMJ 10-2-2	-16.08*	-14.92*	21.09*	24.00**	19.22**	29.78**	-8.62**	-16.53**	5.52	4.43
11.	WGL 14280-1 / Tulasi	-0.24	-9.61	15.38**	6.45*	11.92**	10.70**	-1.20	-6.00**	-17.37	-28.97
12.	WGL 14280-1 / CN 875-135-1-3	12.50	9.09	28.98**	38.60**	6.05	1.56	40.62**	39.34**	11.97	-9.75
13.	WGL 14280-1 / CR 811-1	11.83	24.34**	45.95**	78.02**	11.77**	11.58**	5.61**	4.20**	12.05	5.46
14.	NLR 30491 / N22	5.47	9.84	15.66**	38.46**	12.22**	13.24**	-7.19**	27.93**	-45.35	-28.85
15.	NLR 30491 / KMJ 10-2-2	-5.64	1.66	7.41*	16.00**	22.59**	23.94**	-26.74**	-14.84**	-2.01	40.41
16.	NLR 30491 / Tulasi	-12.79	-16.59**	-2.00	-5.16	0.72	-5.86*	-37.68**	-23.75**	-47.27	-37.50
17.	NLR 30491 / CN 875-135-1-3	-4.67	-2.02	11.20**	26.32**	-1.66	-11.74**	12.46**	44.72**	-35.20	-29.81
18.	NLR 30491 / CR 811-1	30.75**	55.26**	33.90**	73.63**	17.63**	9.71**	3.75**	32.80**	-58.73	-44.67
19.	N22 / KMJ 10-2-2	-3.74	-0.55	26.64**	16.00**	25.23**	22.33**	3.49**	-9.23**	-31.19	-25.81
20.	N22 / Tulasi	-10.90	-17.90**	8.88**	-9.03**	18.47**	6.19	-31.16**	-37.23**	-4.03	-11.26
21.	N22 / CN 875-135-1-3	-20.20**	-21.21**	-7.34	-11.40**	-8.36*	-20.19**	-32.46**	-35.98**	-49.64	-56.62
22.	N22 / CR 811-1	-8.99	3.29	31.28**	40.66**	14.23**	3.24	0.92	-4.73**	-44.73	-43.57
23.	KMJ 10-2-2 / Tulasi	10.73	-0.87	7.14	-3.23	9.59**	9.33	-14.34**	-10.39**	-29.33	-38.71
24.	KMJ 10-2-2 / CN 875-135-1-3	5.54	1.01	21.34**	27.19**	5.28	-6.42	9.01**	19.23**	-45.01	-55.32
25.	KMJ 10-2-2 / CR 811-1	3.90	13.82*	37.96**	63.74**	18.08**	9.03*	-11.21**	-3.33**	8.51	3.15
26.	Tulasi / CN 875-135-1-3	-9.13	-2.02	-6.32	10.53**	0.89	-2.35	4.45**	9.01**	-24.89	-30.48
27.	Tulasi / CR 811-1	9.19	36.84**	14.63**	54.95**	12.24**	13.29**	-4.46**	-0.73	35.96	51.39
28.	CN 875-135-1-3 / CR 811-1	10.29	26.97**	45.37**	63.74**	11.09**	16.01**	-0.44	-0.87	-0.21	21.83

Table 16 (Contd...)

S. No.	Cross	Grain yield per plant		Lear rolling (0-9 scale)	
		Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	-18.90**	36.36**	23.83**	0.00
2.	NLR 33899 / NLR30491	38.73**	54.07**	36.36**	66.67**
3.	NLR 33899 / N22	36.78**	158.65**	11.76**	-9.52**
4.	NLR 33899 / KMJ 10-2-2	-13.15**	4.98*	-31.25**	-42.11**
5.	NLR 33899 / Tulasi	9.07**	2.12	25.00**	36.36**
6.	NLR 33899 / CN 875-135-1-3	100.00**	123.33**	23.53**	0.00
7.	NLR 33899 / CR 811-1	49.12**	115.31**	-70.59**	-76.19**
8.	WGL 14280-1 / NLR 30491	0.51	-2.93	-40.00**	0.00
9.	WGL 14280-1 / N22	85.68**	192.48**	-36.67**	-66.67**
10.	WGL 14280-1 / KMJ 10-2-2	17.73**	23.37**	-15.00**	-10.53**
11.	WGL 14280-1 / Tulasi	46.48**	22.64**	3.75**	54.55**
12.	WGL 14280-1 / CN 875-135-1-3	72.70**	68.67**	-57.14**	-57.14**
13.	WGL 14280-1 / CR 811-1	60.58**	97.45**	-57.14**	-57.14**
14.	NLR 30491 / N22	78.18**	194.74**	-53.33**	-66.67**
15.	NLR 30491 / KMJ 10-2-2	-45.42**	-40.61**	-33.71**	-52.63**
16.	NLR 30491 / Tulasi	-67.55**	-72.03**	30.00**	18.00**
17.	NLR 30491 / CN 875-135-1-3	-62.97**	-62.53**	40.00**	0.00
18.	NLR 30491 / CR 811-1	-49.11**	-34.69**	-53.33**	-66.67**
19.	N22 / KMJ 10-2-2	-34.01**	-50.19**	-55.00**	-52.63**
20.	N22 / Tulasi	35.73**	-10.85**	-81.25**	-72.73**
21.	N22 / CN 875-135-1-3	-65.68**	-75.23**	-19.05**	-19.05**
22.	N22 / CR 811-1	9.42**	-8.16**	0.00	0.00
23.	KMJ 10-2-2 / Tulasi	-6.86**	-24.76**	-28.67**	0.00
24.	KMJ 10-2-2 / CN 875-135-1-3	14.44**	7.00**	-65.00**	-66.67**
25.	KMJ 10-2-2 / CR 811-1	53.61**	79.08**	15.00**	9.52**
26.	Tulasi / CN 875-135-1-3	3.59	25.00**	-18.75**	-38.10**
27.	Tulasi / CR 811-1	103.23**	221.43**	-68.75**	-76.19**
28.	CN 875-135-1-3 / CR 811-1	44.35**	82.65**	-85.71	-85.73**

Table 17 : Percent heterosis for various characters over mid and better parental values under normal situation

S. No.	Cross	Root dry weight		Shoot dry weight		Root / shoot ratio		Relative water content		Days to 50% flowering	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	50.80	28.80	30.56	13.55	8.82	-19.57	-4.65	-5.80	-4.36**	-7.37
2.	NLR 33899 / NLR 30491	-23.96	-45.92	1.60	-3.55	21.13	-42.86	-11.11**	-12.96	-3.23**	-5.26
3.	NLR 33899 / N22	24.19	-7.35	14.85	12.84	11.43	-18.75	-7.43	-8.10	-6.52**	-9.47
4.	NLR 33899 / KMJ 10-2-2	-33.90	-48.67	-28.99	-3.12	0.00	-21.05	-11.96**	-17.37	-7.03**	-9.47
5.	NLR 33899 / Tulasi	63.82**	23.48	9.07	-7.22	56.36**	30.30	-13.70**	-18.18	-3.78**	-6.32
6.	NLR 33899 / CN 875-135-1-3	13.83	-22.89	-32.13	27.72	-16.05	-42.37	7.14	5.63	-5.88**	-7.37
7.	NLR 33899 / CR 811-1	8.62	-22.35	13.76	-0.99	49.33**	5.66	-8.70	-8.70	-5.88**	-7.37
8.	WGL 14280-1 / NLR 30491	-12.49	-30.14	52.17	-5.33	-24.21	-26.53	10.53**	6.94	-2.76**	-3.30
9.	WGL 14280-1 / N22	-19.71	-31.96	65.46**	34.37	-46.81**	-47.92	-5.34	-7.14	-1.68**	-2.22
10.	WGL 14280-1 / KMJ 10-2-2	29.36	15.19	25.65	38.48	-26.19	-32.61	1.37	-5.93	-1.11**	-1.11
11.	WGL 14280-1 / Tulasi	48.44	27.40	13.75	-4.60	8.86	-6.52	2.08	-4.33	-2.22**	-2.22
12.	WGL 14280-1 / CN 875-135-1-3	2.68	-22.94	71.09**	-5.08	-8.57	-18.64	-9.88**	12.21	-3.30**	-4.35
13.	WGL 14280-1 / CR 811-1	33.95	7.62	71.09**	49.25	-21.21	-26.42	6.60	5.31	-1.66**	-2.20
14.	NLR 30491 / N22	-19.55	-25.24	10.48	-16.42	-3.09	-4.08	7.51	6.02	-4.44**	-5.49
15.	NLR 30491 / KMJ 10-2-2	-8.53	-19.32	51.25**	50.19**	-37.93**	-44.90	-14.16**	-17.80	-4.97**	-5.49
16.	NLR 30491 / Tulasi	-3.23	-11.32	20.11	6.93	-21.95	-34.69	-8.72**	-11.69	-1.66**	-2.20
17.	NLR 30491 / CN 875-135-1-3	65.90**	52.60**	156.26**	155.42**	-33.33**	-38.98	3.50	2.78	-2.73**	-3.26
18.	NLR 30491 / CR 811-1	-39.89**	-40.39	-1.69	-6.98	-39.22**	-41.51	-4.02	-6.02	-2.20**	-2.20
19.	N22 / KMJ 10-2-2	-2.78	-8.14	27.45*	19.81	-23.26	-31.25	-15.25**	19.92	0.56**	-1.11
20.	N22 / Tulasi	43.24**	41.08**	51.28**	26.84	-8.64	-22.92	-3.85	-8.23	-3.91**	-4.44
21.	N22 / CN 875-135-1-3	4.01	-10.05	2.25	-4.24	6.54	-3.89	2.13	1.41	-4.97**	-6.52
22.	N22 / CR 811-1	-15.02	-20.40	23.86	22.12	-28.71**	-32.08	14.63**	13.81**	-4.44**	-5.49
23.	KMJ 10-2-2 / Tulasi	19.97	15.02	26.38	11.82	-7.04	-33.16	-12.21**	-13.14	-4.44**	-4.44
24.	KMJ 10-2-2 / CN 875-135-1-3	48.13**	21.57	97.54**	96.80**	-23.71	-37.29	-2.45	-7.20	-5.49**	-6.52
25.	KMJ 10-2-2 / CR 811-1	70.91**	51.86**	99.42**	89.95**	-12.09	-24.53	-2.48	-8.47	-0.55**	-1.10
26.	Tulasi / CN 875-135-1-3	-27.12	-38.08	0.33	-10.94	-30.43	-45.76	-10.81**	-14.29	0.00	-1.09
27.	Tulasi / CR 811-1	29.38	19.48	4.48	-11.14	20.93	-1.89	10.53**	4.76	0.55**	0.00
28.	CN 875-135-1-3 / CR 811-1	49.68**	36.61**	65.25**	54.94**	-7.14	-11.86	3.81	2.35	-2.73**	-3.26

Table 17 Contd...

S. No.	Cross	Plant height		Ear bearing tillers per plant		Panicle length		No. of spikelets per panicle		No. of filled grains per panicle	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	0.0	-5.16	-6.25	-11.76	4.54	1.13	0.13	-7.90	-4.23	-9.33
2.	NLR 33899 / NLR 30491	-5.03	-6.35	12.90	9.38	-1.73	-2.39	-30.40**	-40.38	-35.45**	-41.52
3.	NLR 33899 / N22	16.23**	19.79**	35.85	20.00	9.69	1.21	32.54**	29.82	0.21	-2.33
4.	NLR 33899 / KMJ 10-2-2	1.05	-4.76	20.00	20.00	7.87	3.79	6.47	-2.89	-9.27	-3.33
5.	NLR 33899 / Tulasi	1.57	0.78	32.20	30.00	-0.29	-2.87	1.83	-1.63	-18.20	-16.66
6.	NLR 33899 / CN 875-135-1-3	7.07**	-7.02	3.57	-3.33	3.46	3.05	12.95	-2.35	14.69	-8.55
7.	NLR 33899 / CR 811-1	8.16**	3.64	30.91	20.00	6.19	5.87	6.90	-0.50	12.93	10.82
8.	WGL 14280-1 / NLR 30491	1.91	-2.04	21.21	17.65	6.62	3.82	1.47	-6.28	5.08	9.30
9.	WGL 14280-1 / N22	23.81**	12.23**	15.79	-2.94	11.87**	0.14	13.23	2.47	-12.19	-24.33
10.	WGL 14280-1 / KMJ 10-2-2	0.22	0.44	6.25	0.00	7.29	0.00	-19.76	-20.72	-7.02	-11.67
11.	WGL 14280-1 / Tulasi	-0.83	-6.64	4.76	-2.94	24.11**	23.23**	-11.92	-16.05	-26.02**	-30.33
12.	WGL 14280-1 / CN 875-135-1-3	16.90**	-2.92	-13.33	-23.53	3.22	-0.13	-12.13	-18.12	8.27	-1.37
13.	WGL 14280-1 / CR 811-1	6.99	2.55	15.25	0.00	6.57	3.40	1.00	0.00	2.51	-4.57
14.	NLR 30491 / N22	13.19**	6.47	12.73	-3.13	2.04	-6.43	1.49	-14.44	-12.61	-27.58
15.	NLR 30491 / KMJ 10-2-2	30.77**	24.90**	-3.23	-6.25	9.30	4.48	-35.50**	-39.75	-31.33**	-37.58
16.	NLR 30491 / Tulasi	17.37**	14.84	27.87	21.87	8.28	6.18	-26.63**	-35.15	-19.33	-27.27
17.	NLR 30491 / CN 875-135-1-3	-8.69**	-21.64	-3.45	-12.50	2.25	-3.58	-20.59	-21.34	-15.68	-19.73
18.	NLR 30491 / CR 811-1	3.46	-2.18	36.84**	21.87	-1.73	-2.09	-35.09**	-40.59	-26.87**	-34.85
19.	N22 / KMJ 10-2-2	8.18	-2.52	-13.21	-23.33	-9.25	-13.11	-21.67	-29.88	-22.38	-38.60
20.	N22 / Tulasi	5.62	1.44	11.54	0.00	5.58	-4.39	-7.34	-12.26	-4.98	-13.58
21.	N22 / CN 875-135-1-3	5.48	-4.39	34.69	26.92	13.79**	-1.36	18.70	0.85	-15.12	-28.33
22.	N22 / CR 811-1	-7.78**	-8.27**	20.83	16.00	-15.38**	-22.14	-20.00	-26.95	-12.84	-28.77
23.	KMJ 10-2-2 / Tulasi	19.00**	11.33**	38.98**	36.67**	4.90	-1.58	-7.42	-12.77	9.91	8.89
24.	KMJ 10-2-2 / CN 875-135-1-3	-15.04**	-29.82	53.57**	43.33**	4.03	-5.96	-34.62	-38.38	-32.60**	-41.37
25.	KMJ 10-2-2 / CR 811-1	-4.02	-13.09	74.55**	60.00**	3.45	-0.75	-43.10	44.34	-60.91**	-42.22
26.	Tulasi / CN 875-135-1-3	-9.70	-21.05	30.91	24.14	-2.69	-6.49	-18.42	-27.29	-21.90**	-32.60
27.	Tulasi / CR 811-1	-4.71	-8.00	122.22**	106.90**	10.74**	8.15	19.11	14.61	44.93**	43.67**
28.	CN 875-135-1-3 / CR 811-1	1.78	-8.19	96.08**	92.31**	4.30	-1.89	7.39	-0.85	38.66**	11.51

Table 17 Contd...

S. No.	Cross	Spikelet fertility percentage		Harvest index		Test weight		Specific leaf weight		Leaf area per plant	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	-6.03	-10.29	9.90	5.23	6.19**	1.84	-8.02	-8.19	24.88	7.95
2.	NLR 33899 / NLR30491	-9.53	-16.05	10.04	-3.27	-7.85**	-17.09	13.03	11.87	1.09	-1.62
3.	NLR 33899 / N22	-25.34**	-32.10	-3.52	-10.46	8.23**	-1.55	-18.11	-22.40	-0.95	28.92
4.	NLR 33899 / KMJ 10-2-2	0.68	-8.23	11.85	-1.31	-3.7	-13.84	-4.34	-8.32	-2.85	-16.02
5.	NLR 33899 / Tulasi	-13.85	-18.11	3.05	-0.65	-13.45**	-14.12	-9.74	-13.58	8.98	3.18
6.	NLR 33899 / CN 875-135-1-3	-1.47	-3.29	-2.44	-8.50	-4.69	-6.87	9.57	1.81	-38.44	-43.62
7.	NLR 33899 / CR 811-1	2.97	-7.41	1.85	-9.80	-0.34	-4.05	27.27**	24.74**	-26.81	-27.60
8.	WGL 14280-1 / NLR 30491	3.50	0.45	2.34	-6.43	2.80	-3.85	-7.72	-11.79	-3.58	-14.67
9.	WGL 14280-1 / N22	-10.95	-15.38	-1.11	-4.29	9.11**	3.23	-40.15**	-40.21	53.33	45.93
10.	WGL 14280-1 / KMJ 10-2-2	14.49	9.05	22.18**	12.14	5.87	-1.54	9.57	-0.35	65.15	65.15
11.	WGL 14280-1 / Tulasi	-16.36**	-16.74	4.26	3.52	-3.19	-6.46	0.08	-1.11	3.76	-5.80
12.	WGL 14280-1 / CN 875-135-1-3	2.42	-0.43	61.31**	57.87**	5.75**	-0.81	2.72	-9.26	-50.48	-60.23
13.	WGL 14280-1 / CR 811-1	3.61	-2.71	3.10	-5.00	5.16	-2.75	-11.01	-14.11	-11.10	-22.44
14.	NLR 30491 / N22	-21.87**	-23.56	-6.88	-12.21	16.75**	15.34**	-11.33	3.14	4.65	-1.83
15.	NLR 30491 / KMJ 10-2-2	5.88	3.85	17.60**	17.09**	7.91**	7.24**	1.75	-15.5	5.54	-6.59
16.	NLR 30491 / Tulasi	-0.23	-2.74	17.05**	6.34	-7.21**	-15.93	-18.94	-3.44	1.76	-1.08
17.	NLR 30491 / CN 875-135-1-3	5.43	-0.43	20.80**	12.69	-15.14**	-25.20	25.94	0.61	15.30	6.62
18.	NLR 30491 / CR 811-1	13.43	9.62	21.37**	20.34**	-0.83	-13.73	1.32	15.80	-0.31	-1.94
19.	N22 / KMJ 10-2-2	-1.75	-2.00	8.06	2.29	10.62**	8.62**	2.62	-6.59	16.74	9.68
20.	N22 / Tulasi	2.39	-2.28	3.30	-0.70	-10.73**	-18.22	-42.10**	-42.73	3.50	-0.23
21.	N22 / CN 875-135-1-3	-28.57**	-34.19	-18.49**	-19.40	-13.77	-23.18	-5.65	-16.57	-11.43	-25.16
22.	N22 / CR 811-1	8.40	7.04	0.40	-5.34	-6.91**	-18.17	-10.02	-13.08	-17.08	-23.40
23.	KMJ 10-2-2 / Tulasi	16.47**	11.42	11.97	2.11	0.32	-9.61	15.07	5.80**	316.51**	278.12**
24.	KMJ 10-2-2 / CN 875-135-1-3	3.23	-4.27	9.96	2.99	0.08	-12.26	16.81	13.09	-15.24	-35.14
25.	KMJ 10-2-2 / CR 811-1	3.05	1.50	15.74	15.25	17.22**	1.44	-10.53	-15.93	-13.23	-24.29
26.	Tulasi / CN 875-135-1-3	-0.22	-3.42	-7.25	-9.86	-8.27**	-11.05	6.38	-5.03	-31.22	-40.05
27.	Tulasi / CR 811-1	21.55**	14.61	19.231**	9.15	6.02**	1.31	24.54**	21.61	20.28	15.07
28.	CN 875-135-1-3 / CR 811-1	22.43**	11.97	19.84**	12.69	3.52	1.96	36.69**	24.09**	-5.39	-14.73

Table 17 Contd...

S. No.	Cross	Grain yield per plant	
		Mid parent	Better parent
1.	NLR 33899 / WGL 14280-1	-2.00	-15.76
2.	NLR 33899 / NLR 30491	13.09	-13.73
3.	NLR 33899 / N22	29.41	-3.90
4.	NLR 33899 / KMJ 10-2-2	-8.31	-35.41
5.	NLR 33899 / Tulasi	11.66	-8.89
6.	NLR 33899 / CN 875-135-1-3	-9.08	-10.32
7.	NLR 33899 / CR 811-1	34.20**	4.99
8.	WGL 14280-1 / NLR 30491	42.61**	23.43
9.	WGL 14280-1 / N22	40.67	17.79
10.	WGL 14280-1 / KMJ 10-2-2	103.60**	59.65**
11.	WGL 14280-1 / Tulasi	5.22	-1.17
12.	WGL 14280-1 / CN 875-135-1-3	-12.86	-25.95
13.	WGL 14280-1 / CR 811-1	9.11	-2.60
14.	NLR 30491 / N22	33.02	27.89
15.	NLR 30491 / KMJ 10-2-2	32.55	17.80
16.	NLR 30491 / Tulasi	2.16	-6.42
17.	NLR 30491 / CN 875-135-1-3	56.63**	18.36
18.	NLR 30491 / CR 811-1	51.93**	46.69
19.	N22 / KMJ 10-2-2	39.27	28.30
20.	N22 / Tulasi	94.41**	71.85**
21.	N22 / CN 875-135-1-3	-34.23	-51.59
22.	N22 / CR 811-1	40.86	30.94
23.	KMJ 10-2-2 / Tulasi	82.61**	50.37**
24.	KMJ 10-2-2 / CN 875-135-1-3	25.60	-2.44
25.	KMJ 10-2-2 / CR 811-1	22.76	5.80
26.	Tulasi / CN 875-135-1-3	-31.20	-44.46
27.	Tulasi / CR 811-1	92.96**	82.72**
28.	CN 875-135-1-3 / CR 811-1	65.13*	27.92**

Table 18 : Percent heterosis for seedling growth under simulated drought conditions by polyethylene glycol over mid and better parental values

S. No.	Cross	4.00 bars						3.00 bars						6.00 bars						9.00 bars					
		1		2		3		4		5		6		7		8									
		Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent	Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent	Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent	Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent	Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent	Shoot length (cm)	Mid parent	Shoot length (cm)	Better parent
1.	NLR 33899 / WGL 14280-1	-17.27**	-20.18	73.41	56.25**	1.71	-4.30	-32.92**	-43.16	-12.99	43.59**	33.33**	33.33**	-3.23	-6.25	-100.00**	-100.00								
2.	NLR 33899 / NLR 30491	28.33**	14.93**	200.76	155.84**	121.90	63.46**	123.62**	115.15	-15.58	22.94**	21.89**	21.89**	300.00**	209.09**	159.09**	90.00**								
3.	NLR 33899 / N22	48.18**	29.79**	4.66	-12.93	103.40**	88.17**	10.00	-6.38	-26.87**	73.33**	57.58**	57.58**	433.33**	433.33**	415.15**	183.83**								
4.	NLR 33899 / KMJ 10-2-2	31.86**	24.17**	59.79**	32.48**	41.44**	37.63**	156.12**	143.84**	-47.06**	300.00**	0.00	0.00	300.00**	300.00**	190.91**	60.00**								
5.	NLR 33899 / Tulasi	54.39**	44.25**	223.29**	206.49**	61.34**	3.23	141.10**	120.00**	531.9**	64.89**	40.26**	40.26**	933.33**	933.33**	627.27**	300.00**								
6.	NLR 33899 / CN 875-135-1-3	-33.89**	-40.60	69.84**	68.72**	106.72**	32.25**	134.04**	120.00**	95.92**	64.80**	57.63**	57.63**	14.29	0.00	-18.52**	-35.29								
7.	NLR 33899 / CR 811-1	6.61	0.00	68.72**	48.04**	68.48**	66.67**	51.67**	37.88**	49.51**	16.67	6.06	6.06	1166.70**	850.00	73.17**	36.54**								
8.	WGL 14280-1 / NLR 30491	-37.90**	-42.54	88.00**	48.87**	-17.46	-36.59	96.15**	61.05**	0.00	-35.36	113.56**	101.00**	106.90	63.64**	400.00**	295.83**								
9.	WGL 14280-1 / N22	-5.10	-14.18	83.96**	68.10**	67.20**	64.63**	31.22**	30.53**	19.64**	62.79**	59.09**	59.09**	254.84**	243.75**	225.93**	83.33**								
10.	WGL 14280-1 / KMJ 10-2-2	29.06**	25.83**	79.34**	63.75**	37.65**	32.95**	85.71**	64.21**	130.00**	67.27**	45.21**	27.71**	996.77**	962.50**	581.48**	283.33**								
11.	WGL 14280-1 / Tulasi	-22.03**	-24.59	90.30**	63.54**	112.96**	40.24**	-12.00	-18.95	66.67**	9.89	-10.00	-18.18	-3.23	-6.25	122.22**	25.00								
12.	WGL 14280-1 / CN 875-135-1-3	58.35**	42.89**	109.66**	58.33**	133.33**	53.68**	17.65**	5.26	-13.86	-40.00	-6.56	-9.52	122.22**	100.00**	33.33**	-1.96								
13.	WGL 14280-1 / CR 811-1	40.43**	36.36**	94.95**	89.22**	90.75**	81.32**	100.00**	56.84**	75.31**	29.09**	68.99**	65.15**	95.65**	50.00	57.89**	15.38**								
14.	NLR 30491 / N22	-39.64**	-41.13	18.82**	-12.93	18.70	-7.59	-22.58**	-36.17	5.56	-33.33	-9.09	-16.67	229.41**	154.55**	382.35**	192.86**								
15.	NLR 30491 / KMJ 10-2-2	9.45	3.73	92.98**	41.03**	-31.82**	-48.86	164.18**	142.47**	305.00**	224.00	2.90	1.44	-29.41	-45.45	300.00**	142.86**								
16.	NLR 30491 / Tulasi	17.97**	12.69**	191.06**	159.42**	308.57**	225.80	53.19**	35.00	343.75**	317.65**	25.76**	7.79	-5.88	-27.27	-64.71	-78.57								
17.	NLR 30491 / CN 875-135-1-3	36.33**	35.82**	181.55**	168.52**	360.00**	265.93**	117.65**	97.33**	361.11**	295.24**	107.02**	100.00**	321.05	263.64**	10.77	-29.41								
18.	NLR 30491 / CR 811-1	28.63**	22.39**	17.95	-9.80	79.26**	32.97**	54.78**	45.90**	202.44**	138.46**	10.74	1.52	-47.83	-50.00	-90.91**	-94.23								
19.	N22 / KMJ 10-2-2	37.93	27.66**	-17.60**	-17.95	85.63**	76.14**	12.57	0.00	117.07**	56.14**	-24.83**	-32.53	0.00	0.00	0.00	0.00								
20.	N22 / Tulasi	36.12**	26.95**	32.97**	6.03	98.10**	31.62**	33.33**	23.40**	140.54**	56.14**	14.89	6.49	0.00	0.00	0.00	0.00								
21.	N22 / CN 875-135-1-3	13.14**	9.93	130.30**	63.79**	42.86**	-5.06	83.43**	64.89**	46.15**	0.00	13.60	7.58	-14.29	-25.00	-88.89**	-94.12								
22.	N22 / CR 811-1	-2.29	-9.22	11.01	4.31	7.06	0.00	47.30**	15.96**	131.33**	68.42**	57.58**	57.58**	522.22**	365.67**	143.64**	28.85**								
23.	KMJ 10-2-2 / Tulasi	39.67**	35.52**	93.55**	53.85**	121.05**	43.18**	139.22**	128.75**	180.95**	136.00**	-40.00	-42.17	466.67**	466.68**	1933.33**	1933.33**								
24.	KMJ 10-2-2 / CN 875-135-1-3	50.20**	42.86**	30.12**	-7.69	22.81	-20.45	27.03**	25.33**	165.22**	144.00**	22.54**	4.82	42.86	25.00	-44.44**	-70.59								
25.	KMJ 10-2-2 / CR 811-1	27.80**	27.27**	-32.42**	-36.75	37.43**	35.16**	0.79	-13.33	162.75**	157.69**	32.89**	19.25**	55.56	16.67	82.73**	-19.23								
26.	Tulasi / CN 875-135-1-3	17.65**	12.78**	130.51**	97.10**	250.00**	250.00	79.35**	73.75**	78.95**	61.90**	14.7	-10.39	214.29**	175.00**	114.81**	13.73								
27.	Tulasi / CR 811-1	96.71**	95.90**	191.23**	144.12**	158.12**	65.93**	32.84**	11.25	174.42**	259.22**	-3.50	-10.39	33.33	0.00	-38.18**	-67.31								
28.	CN 875-135-1-3 / CR 811-1	6.30	1.50	27.15**	-5.88	108.55**	24.87	89.15**	62.67**	214.89**	84.62**	44.00**	36.36**	580.00**	465.67**	43.69**	42.31**								

Under favourable environment heterosis for root dry weight ranged from -39.89 to 65.90 per cent over mid parent and from -48.67 to 52.60 per cent over better parent (Table 16). Six hybrids exhibited positive and significant heterosis over mid parent. Highest heterosis over better parent was recorded by NLR 30491 / CN 875-135-1-3 (52.60%) followed by KMJ 10-2-2 / CR 811-1 (51.86%) and N22 / Tulasi (41.08%).

Eleven and sixteen crosses out of 28 showed negative heterosis over mid and better parent respectively. The hybrid NLR30491/CR 811-1 recorded highest negative heterosis of -39.89 per cent followed by NLR 33899/KMJ 10-2-2 (-33.90 %) and Tulasi/CN 875-135-1-3 (-27.12%). Highest negative heterobeltiosis was observed in NLR 33899 / KMJ 10-2-2 (-48.67 %) followed by NLR 33899 / NLR 30491 (-45.92%) and NLR 30491 / CR 811-1 (-40.39%).

4.5.3.2 Shoot dry weight (g)

Eleven hybrids expressed positive and significant heterosis over midparent and fourteen hybrids over better parent for shoot dry weight under moisture stress environment (Table 16). The heterosis ranged from -52.78 to 74.77 per cent over mid-parent and from -60.84 to 83.93 per cent over better parent. The hybrid NLR 30491 / CR 811-1 displayed highest heterosis of 83.93 per cent over better parent followed by CN 875-135-1-3 / CR 811-1 (81.77%) and WGL 14280-1 / CR 811-1 (70.66%).

Crosses involving CR 811-1 as one of the parents produced heterotic hybrid for increased shoot dry weight. The hybrid Tulasi / CN 875-135-1-3 registered high significant negative heterosis of -52.78 per cent over mid parent, while N22 / CN 875-135-1-3 exhibited the maximum significant negative heterosis of -60.34 per cent over better parent.

Heterosis over mid parent varied from -28.89 to 156.26 per cent and from -32.13 to 155.42 per cent over better parent under favourable environment (Table 17). Among 28 hybrids, nine hybrids revealed significant and positive heterosis over mid-parent, while five hybrids showed positive and significant heterosis over better parent. Three hybrids over mid parent and 12 hybrids over better parent exhibited negative and non-significant heterosis.

4.5.3.3 Root / Shoot ratio

Variation for root to shoot ratio ranged from -47.25 to 44.19 over mid parent and from -53.25 to 63.41 per cent over better parent under moisture stress environment (Table 16). Among the 28 hybrids eight hybrids showed positive and significant heterosis over mid-parent and seven hybrids over better parent. The hybrid WGL 14280-1/CN 875-135-1-3 recorded highest heterosis of 44.19 per cent followed by NLR-33899/CN875-135-1-3 (30.10 %) and KMJ 10-2-2 / CN 875-135-1-3 (20.88%) over mid-parent. Significant negative heterosis was observed in 19 hybrids over mid-parent and 21 hybrids over better parent.

Under favourable environment heterosis for root to shoot ratio varied from -46.81 to 56.36 per cent over mid parent and from -47.92 to 30.30 per cent over better parent (Table 17). The hybrids NLR 33899 / Tulasi registered highest heterosis of 56.36 per cent followed by NLR 33899 / CR 811-1 (49.33 %) and NLR 33899 / NLR 30491 (21.13 %). Eight hybrids showed positive heterosis, while other 20 hybrids recorded negative heterosis over mid-parent. Positive heterosis observed only in two hybrids, while the rest of the hybrids exhibited negative heterosis over better parent.

4.5.3.4 Relative Water Content (%)

Significant positive heterosis was observed in two hybrids over mid parent for relative water content under moisture stress situation (Table 16). Heterosis varied from -14.47 to 22.25 per cent over mid-parent and from -16.05 to 21.96 per cent over better parent. Highest positive heterosis was displayed by the hybrid NLR 33899 / KMJ 10-2-2 (22.25%) over mid-parent; while significant negative heterosis was observed in the hybrid N22 / CN 875-135-1-3 (-14.47%). Only six hybrids displayed positive heterosis over better parent. The maximum positive heterosis of 21.96 per cent was noticed in Tulasi / CR 811-1, where as the maximum significant negative heterosis was recorded by N22 / CN 875-135-1-3 (-16.05%). Three hybrids recorded significant positive heterosis ranged from -15.25 to 14.63 per cent for relative water content

under moisture stress environment over mid parent (Table 17). The maximum heterosis was exhibited by the hybrid N22 / CR 811-1 (14.63%). Only one hybrid N22 / CR 811-1 recorded significant positive heterosis of 13.81 per cent over better parent.

4.5.3.5 Number of days to 50% flowering

Heterosis for number of days to 50% flowering under moisture stress situation showed variation from -6.24 to 1.10 per cent over better parent (Table 16). Nineteen hybrids exhibited negative significant heterosis over mid parent, while 21 hybrids revealed negative and significant heterosis over better parent. None of the hybrids showed significant positive heterosis both in mid parent as well as better parent.

Heterosis for number of days to 50% flowering under favourable environment varied from 0.56 to -7.03 per cent over mid parent (Table 17). Two hybrids exhibited positive significant heterosis, while 25 hybrids showed significant negative heterosis over mid-parent. Twenty seven hybrids recorded negative but non-significant heterosis over better parent.

4.5.3.6 Plant height (cm)

Heterosis varied from -17.29 to 35.96 per cent over mid parent and from -22.14 to 31.25 per cent over better parent for plant height under

moisture stress situation (Table 16). Among the 28 hybrids, positive and significant heterosis was observed in 13 hybrids over mid parent and in 14 hybrids over better parent. The hybrid WGL 14280-1 / N22 exhibited highest heterosis over mid parent (35.96 per cent), followed by WGL 14280-1 / CN 875-135-1-3 (32.86 %); NLR 30491/N22 (29.29%) and N22/Tulasi (28.47%). Maximum heterosis was observed in N22 / Tulasi (31.25%) over better parent. Negative values of heterosis and heterobeltiosis were considered desirable for plant height. The heterobeltiosis in desirable direction was revealed by N22 / CN 875-135-1-3 (-22.14%), WGL 14280-1 / Tulasi (-21.63%) and KMJ 10-2-2/CN 875-135-1-3 (-18.70%).

Heterosis for plant height ranged from -15.04 to 30.77 per cent over mid-parent and from -29.82 to 24.90 per cent over better parent under favourable environment (Table 17). Nine hybrids exhibited positive and significant heterosis. Out of which NLR 30491/ KMJ 10-2-2 recorded 30.77 per cent followed by WGL 14280-1 / N22 (23.81%), KMJ 10-2-2 / Tulasi (19.00%) and NLR 30491/N22 (17.37%). Maximum heterosis of 24.90 per cent was recorded by NLR 30491 / KMJ 10-2-2 over better parent.

The hybrid KMJ 10-2-2/CN875-135-1-3 recorded the highest significant negative heterosis of -15.04 per cent followed by NLR

30491/CN 875-135-1-3 (-8.69%) and N22 / CR-811-1 (-7.78%) over mid parent. Highest negative heterobeltiosis was observed in cross combination of KMJ 10-2-2/ CN 875-135-1-3 (-29.82%) followed by NLR 30491 / CN 875-135-1-3 (-2.64%) and Tulasi / CN 875-135-1-3 (-21.5%).

4.5.3.7 Number of ear bearing tillers per plant

Heterosis for number of panicles per plant in moisture stress situation had variation from -27.50 to 56.36 per cent over mid parent and from 26.19 to 61.54 per cent over better parent (Table 16). Eleven hybrids showed significant and positive heterosis over mid parent, while 13 hybrids over scored better parent for the character. Highest heterosis over mid parent was noted in CN 875-135-1-3 / CR 811-1 (56.36%) followed by N22/CN 875-135-1-3 (52.73%) and NLR 30491/N22 (27.87%), while the same over better parent was recorded in N22 / CN 875-135-1-3 (61.54%).

Under favourable environment, number of ear bearing tillers per plant ranged from -13.33 to 122.22 per cent over mid parent and from -23.53 to 106.90 per cent over better parent (Table 17). Significant and positive heterosis over mid parent was shown by 27 hybrids and over better parent by 25 hybrids. While, highest heterosis over mid parent was exhibited by Tulasi / CR 811-1 (122.22%) followed by CN 875-135-1-3 / CR 811-1 (96.98%) and KMJ-10-2-2 / CR 811-1 (74.55%), the same

over better parent was shown by Tulasi / CR 811-1 (106.90%), followed by CN 875-135-1-3 / CR 811-1 (92.31%) and KMJ 10-2-2 / CR 811-1 (60.00%) had heterotic hybrids for number of ear bearing tillers per plant.

4.5.3.8 Panicle length (cm)

Twenty hybrids exhibited positive heterosis over mid parent and 18 hybrids over better parent for panicle length in moisture stress situation (Table 16). Heterosis varied from -6.90 to 19.75 per cent over mid parent and from -8.32 to 21.72 per cent over better parent respectively. Highest heterosis was recorded over mid parent in WGL 14280-1 / CN 857-135-1-3 (19.75%) followed by WGL 14280-1 / N22 (16.22%) and WGL 14280-1 / NLR 30491 (15.82%). Maximum heterosis was observed over better parent in WGL 14280-1 / N22 (21.72%) followed by WGL 14280-1 / NLR 30491 (17.43%) and WGL 14280-1 / CN 875-135-1-3 (15.24%). Crosses involving WGL 14280-1 had heterotic hybrids for this character.

Under favourable environment, positive and significant heterosis was observed in four hybrids over mid-parent and in one hybrid over better parent (Table 17). Heterosis over mid parent ranged from -15.38 to 24.11 per cent and over better parent from -22.14 to 23.23 per cent. High heterotic values over mid parent were recorded in WGL 14280-1 /

Tulasi (24.11%), N22 / CN 875-135-13 (13.79%) and Tulasi / CR 811-1 (10.74%), whereas the same was observed over better parent in WGL 14280-1 / Tulasi (23.23%).

4.5.3.9 Number of spikelets per panicle

In moisture stress situation the range in heterosis over mid-parent was from -15.31 to 32.49 per cent, while it was from -31.57 to 51.23 per cent over better parent for number of spikelets per panicle (Table 16). Five hybrids exhibited significant positive heterosis over mid parent, while ten hybrids showed significant positive heterosis over better parent. Highest heterotic values were observed in N22 / KMJ 10-2-2 (47.03%), N22 / CR 811-1 (36.42%) and Tulasi / CR 811-1 (34.28%) over mid parent. With reference to the better parent, maximum heterosis was observed in NLR 30491 / N22 (51.23%), followed by Tulasi / CR 811-1 (49.41 %) and NLR 30491 / CR 811-1 (45.45 %). The range of heterosis for number of spikelets varied from -43.10 to 32.54 per cent over mid-parent under favourable environment, while it was from -44.34 to 29.82 per cent over better parent (Table 17). Only one F_1 hybrid displayed heterosis over mid-parent. High heterotic readings were noted over mid parent in NLR 33899 / N22 (29.82%) and Tulasi / CR 811-1 (14.61 %).

4.5.3.10 Number of filled grains per panicle

Heterosis for number of filled grains per panicle under moisture stress environment had variation from -15.42 to 47.39 per cent over mid-parent, while it varied from -15.77 to 128.46 per cent over better parent (Table 16). Significant positive heterosis over mid-parent was shown by six hybrids, while 11 hybrids exhibited over better parent. Highest heterosis over mid-parent was exhibited by hybrid combination NLR 30491 / CR 811-1 (47.39%), followed by WGL 14280-1 / CR 811-1 (43.95%) and WGL 14280-1 / CN 875-135-1-3 (31.53%), while the hybrid NLR 30491 / CR 811-1 (128.46%) followed by Tulasi / CR 811-1 (70.77%) and NLR 30491 / N22 (68.18%) exhibited heterosis over better parent.

Under favourable environment heterosis for number of filled grains per panicle ranged from -40.91 to 44.93 per cent over mid parent and from -42.22 to 43.02 per cent over better parent (Table 17). Two hybrids showed significant and positive heterosis over mid parent, while one hybrid over better parent for the character. Highest heterosis over mid parent was noted in Tulasi / CR 811-1 (44.93 %) and CN 875-135-1-3 / CR 811-1 (30.66%), while the same over better parent was recorded in Tulasi / CR 811-1 (43.02%).

4.5.3.11 Spikelet fertility (%)

Heterosis for spikelet fertility in moisture stress situation varied from -20.20 to 30.75 per cent over mid-parent and from -19.65 to 55.26 per cent over better parent (Table 16). Significant positive heterosis over mid-parent and better parent was expressed by two and seven crosses respectively. Highest positive significant heterosis over mid parent was noticed in NLR 30491 / CR 811-1 (30.75%) and NLR 33899 / CR 811-1 (14.12 %). Maximum significant heterosis over better parent was registered in NLR 30491 / CR 811-1 (55.26%) followed by 'Tulasi' / CR 811-1 (36.84%) and NLR 33899 / CR 811-1 (32.89%).

Under favourable environment, heterosis for spikelet fertility showed variability from -28.87 to 22.43 per cent over mid parent and from -34.19 to 14.61 per cent over better parent. Three hybrids exhibited significant positive heterosis over mid parent. CN 875-135-1-3 / CR 811-1 recorded highest heterosis of 22.43 per cent over mid parent followed by 'Tulasi' / CR 811-1 (21.55%) and KMJ 10-2-2 / 'Tulasi' (16.47%). None of the hybrids showed significant positive heterosis over better parent for this character.

4.5.3.12 Harvest Index

Twenty hybrids expressed positive and significant heterosis for harvest index over mid parent, while 22 hybrids out scored better parent

in moisture stress situation (Table 16). Heterosis varied from -7.34 to 45.95 per cent over mid-parent and from -11.40 to 78.02 per cent over better parent. WGL 14280-1 / CR 811-1 (78.02%) recorded highest heterosis over better parent followed by NLR 30491 / CR 811-1 (73.63%) and NLR 33899 / CR 811-1 (58.24%). None of the hybrids showed significant negative heterosis either over better parent or mid parent for this trait.

In favourable environment, eight hybrids exhibited positive and significant heterosis over mid parent and three hybrids over better parent (Table 17). The range in heterosis was from 18.49 to 61.31 per cent over mid-parent and from -19.40 to 57.86 per cent over better parent. WGL 14780-1 / CN 815-135-1-3 recorded highest heterosis (61.31%) over mid-parent followed by WGL 14280-1 / KMJ 10-2-2 (22.18%) and NLR 30491 / CR 811-1 (21.37%). Three hybrids viz. WGL 14280-1 / CN 875-135-1-3 (57.86%) NLR 30491/CR 811-1 and NLR 30491/KMJ 10-2-2 (17.09%) displayed positive significant heterosis over better parent.

4.5.3.13 Test weight (g)

Under moisture stress situation, variation in heterosis over mid parent was from -17.29 to 103.11 per cent and over better parent it was from -20.19 to 118.50 per cent (Table 16). Seventeen hybrids showed

positive and significant heterosis over mid-parent and thirteen hybrids out scored over better parent. Highest heterosis over mid-parent was noticed in WGL 14280-1 / NLR 30491 (103.11 %) followed by N22 / KMJ 10-2-2 (25.23 %) and WGL 14280-1 / N22 (23.14 %). Highest heterosis over better parent was observed in WGL 14280-1 / NLR 30491 (118.50 %) followed by WGL 14280-1 / N22 and WGL 14280-1 / KMJ 10-2-2 (29.78 %).

Under favourable environment, the range in heterosis for test weight was from -15.14 to 17.22 per cent over mid-parent and from -25.20 to 15.34 per cent over better parent (Table 17). Positive and significant heterosis over mid-parent was expressed by nine crosses and three crosses over better parent. Heterosis over mid parent was noted in KMJ 10-2-2 / CR 811-1 (17.22 %), NLR 30491 / N22 (16.75 %) and N22 / KMJ 10-2-2 (10.62 %). Only three hybrids out performed the better parent in respect of test weight viz. NLR 30491 / N22 (15.34%) ; N22 / KMJ 10-2-2 (8.62 %) and NLR 30491 / KMJ 10-2-2 (7.24 %).

4.5.3.14 Specific leaf weight (mg / cm²)

In moisture stress environment variation in heterosis for specific leaf weight ranged from -37.68 to 40.62 per cent over mid parent and from -37.23 to 44.32 per cent over better parent (Table 16). Positive heterosis was exhibited by nine hybrids over mid-parent and by 10

hybrids over better parent respectively. Significant negative heterosis over mid parent and better parent were exhibited by 16 crosses each. Over the mid parent WGL 14280-1 / CN 875-135-1-3 (40.62 %) recorded highest positive heterosis followed by WGL 14280-1 / N22 (19.34 %) and NLR 30491 / CN 875-135-1-3 (12.46 %). Over the better parent NLR 30491 / CN 875-135-1-3 (44.72 %) registered highest heterosis for specific leaf weight followed by WGL 14280-1 / CN 875-135-1-3 (39.34 %) and NLR 33899 / N22 (32.96 %).

Three and two crosses displayed positive and significant heterosis over mid parent and better parent respectively for the character specific leaf weight in favourable environment (Table 17). Heterosis over mid parent ranged from -42.10 to 36.69 per cent and from -42.73 to 24.74 per cent over better parent. Maximum heterosis over mid parent was observed in CN 875-135-1-3 / CR 811-1 (36.69 %) followed by NLR 33899 / CR 811-1 (27.27 %) and Tulasi / CR 811-1 (24.54 %).

4.5.3.15 Leaf area per plant (cm²)

Eight hybrids exhibited positive heterosis over mid-parent as well as better parent for leaf area per plant under moisture stress situation (Table 16). Heterosis varied from -49.64 to 35.96 per cent over mid-parent and from -56.67 to 51.39 per cent over better parent. Highest heterosis was recorded over mid-parent in Tulasi / CR 811-1 (35.96 %)

followed by NLR 33899 / CR 811-1 (28.58 %) and NLR 33899 / CN 875-135-1-3 (16.80 %). Maximum heterosis was observed over better parent in Tulasi / CR 811-1 (51.39 %) followed by NLR 30491 / KMJ 10-2-2 (40.41 %) and NLR 33899 / CR 811-1 (28.55 %). In favourable environment, positive heterosis was observed only in one cross over mid-parent and better parent. Heterosis over mid-parent ranged from -50.48 to 316.15 per cent and over better parent from -60.23 to 278.12 per cent. Over mid-parent high heterotic value was recorded in KMJ 10-2-2 / Tulasi (316.51 %). The same cross combination exhibited 278.12 per cent heterosis over better parent.

4.5.3.16 Grain yield per plant (g)

Variation in heterosis for grain yield per plant in moisture stress situation ranged from -65.68 to 103.23 per cent over mid-parent and from -75.23 to 221.43 per cent over better parent (Table 16). Positive heterosis over mid-parent and better parent was shown by 17 hybrids while highest heterosis over mid-parent was noted in Tulasi / CR 811-1 (103.23 %) followed by NLR 33899 / CN 857-135-1-3 (100.00 %) and WGL 14280-1 / N22 (85.68 %). Heterosis over better parent was recorded in Tulasi / CR 811-1 (221.43 %) followed by NLR 30491 / N 22 (194.74 %) and WGL 14280-1 / N22 (192.48 %).

Under favourable environment, heterosis for grain yield ranged from -34.23 to 103.60 per cent over mid-parent and from -51.59 to 82.72 per cent over better parent (Table 17). Significant positive heterosis was observed in nine F_1 s over mid-parent and five F_1 s over better parent. Highest heterosis over mid-parent was noticed in WGL 14280-1 / KMJ 10-2-2 (103.60 %) followed by N22 / Tulasi (94.41 %), Tulasi / CR 811-1 (92.96 %) and KMJ 10-2-2 / Tulasi (82.61 %), while it was recorded over better parent in Tulasi / CR 811-1 (82.72 %) followed by N22 / Tulasi (71.85 %) and WGL 14280-1 / KMJ 10-2-2 (59.65 %).

4.5.3.17 Leaf rolling (0-9 scale)

The character leaf rolling was studied under moisture stress situation. Heterosis over mid-parent ranged from -85.71 to 40.00 per cent and over better parent from -85.71 to 66.67 per cent (Table 16). Negative readings are desirable for this character. Significant negative heterosis over mid-parent and better parent were observed in 18 and 17 cross combinations respectively. Highest negative significant mid-parent heterosis was recorded in CN 875-135-1-3 / CR 811-1 (-85.71 %) and N22/Tulasi (-81.25 %). Highest significant negative better parent heterosis was observed in CN 875-135-1-3 / CR 811-1 (-85.75 %) followed by NLR 33899 / CR 811-1 (-76.69 %) and Tulasi / CR 811-1 (-76.19). Crosses involving CR 811-1 as one of the parents produced negative heterotic hybrids for increased leaf rolling.

4.5.3.18 Seedling growth under simulated drought conditions

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Heterosis was estimated for shoot and root growths of 6 day old seedlings under simulated drought conditions induced by different osmotic pressures of polyethylene glycol solutions.

4.5.3.18.1 0.00 bars (control)

Shoot length at 0.00 bars osmotic pressure ranged from -39.64 to 96.72 per cent over mid-parent and from -42.54 to 95.90 per cent over better parent respectively (Table 18). High heterotic values over mid parent for shoot length were expressed by Tulasi / CR 811-1 (96.71 %) followed by WGL 14280-1 / CN 875-135-1-3 (58.35 %) and NLR 33899/ Tulasi (54.39 %). The hybrid combinations viz., Tulasi / CR 811-1 (95.90 %), WGL 14280-1 / CN 875-135-1-3 (42.89 %) and KMJ 10-2-2 / CN 875-135-1-3 (42.86 %) showed significant positive heterosis over better parent.

In the case of root length 21 and 19 crosses showed positive heterosis over mid-parent and better parent respectively (Table 18). Heterosis over mid-parent varied from -32.42 to 223.29 per cent and over better parent from -36.75 to 206.49 per cent. High positive heterosis over mid-parent was noted in NLR 33899 / Tulasi (223.29 %) and in NLR 33899 / NLR 30491 (200.76 %). Higher level of heterosis was observed

in NLR 33899 / Tulasi (206.49 %) followed by NLR 30491 / CN 875-135-1-3 (168.52 %) and NLR 30491 / Tulasi (159.42 %).

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4.5.3.18.2 3.00 bars of osmotic pressure

Heterosis for shoot length showed variation from -31.82 to 360.00 per cent over mid-parent and from -48.86 to 265.59 per cent over better parent at 3.00 bars osmotic pressure (Table 18). Twenty one hybrids exhibited positive heterosis over mid-parent, the highest being NLR 30491 / CN 875-135-1-3 (360.00 %) followed by NLR 30491 / Tulasi (308.57 %) and Tulasi / CN 875-135-1-3 (250.00 %). While 17 hybrids over better parent the high heterotic combinations being NLR 30491 / CN 875-135-1-3 (265.91 %) and NLR 30491/Tulasi (225.00 %). Heterosis in root length over mid parent ranged from -32.97 to 164.18 per cent and over better parent from -43.16 to 143.84 per cent (Table 18). The hybrid NLR 30491/KMJ 10-2-2 recorded highest positive heterosis (164.18 %) followed by NLR 33899/KMJ 10-2-2 (156.12 %) and NLR 33899/Tulasi (141.10 %), while high positive heterobeltiosis was observed in NLR 33899/KMJ 10-2-2 (143.84 %) and NLR 30491/KMJ 10-2-2 (142.47 %). More number of hybrid combinations (22 & 18) recorded positive heterosis over mid-parent and better parent respectively.

4.5.3.18.3 6.00 bars

Variation in heterosis for shoot length at 6.00 bars osmotic pressure varied from -47.06 per cent in NLR 33899/KMJ 10-2-2 to 361.11 per cent in NLR 30491 / CN 875-135-1-3 over mid-parent, while the range was from -64.94 (NLR 30491 / Tulasi) to 317.65 per cent (NLR 30491/Tulasi) over better parent (Table 18). Many hybrids (22 & 16) showed positive heterosis over mid-parent and better parent respectively.

Heterosis readings for root length ranged from -24.33 (N22 / KMJ 10-2-2) to 113.56 per cent (WGL 14280-1 / NLR 30491) over mid-parent and from -42.17 (KMJ 10-2-2 / Tulasi) to 101.00 per cent (WGL 14280-1/ NLR 30491) over better parent (Table 18). Positive heterosis was expressed over mid-parent in 16F₁s, while 13 crosses displayed the same over better parent.

4.5.3.18.4 10.00 bars of osmotic pressure

Heterosis in shoot growth over mid parent ranged from -29.41 to 1166.70 per cent and over better parent from -50.00 to 962.50 per cent (Table 18). Highest positive heterosis over mid-parent was recorded in NLR 33899/CR 811-1 (1166.70 %) followed by WGL 14280-1/KMJ 10-2-2 (996.77 %) and NLR 33899/Tulasi (933.33 %), while the combinations WGL 14280-1/KMJ 10-2-2 (962.50 %) followed by NLR 33899/Tulasi (933.32 %) and NLR 33899/CR 811-1 (850.00 %) fared better over the better parent.

For root length at 10.00 bar osmotic pressure maximum crosses (16 and 14) registered positive heterosis over mid-parent and better parent respectively (Table 18). Heterosis over mid parent varied from -100.00 to 1933.33 per cent and over better parent form -100.00 to 1933.33 per cent. Highest mid parent positive heterosis was observed in KMJ 10-2-2 / Tulasi (1933.00 %), NLR 33899 / Tulasi (627.27 %) and NLR 33899 / N22 (415.15 %), while heterobeltiosis was observed in KMJ 10-2-2 / Tulasi (1933.33 %) followed by NLR 33899 / Tulasi (300.00 %) and WGL 14280-1 / NLR 30491 (295.83 %).

The heterosis studies in both the environments viz., favourable and unfavourable revealed that the cross combinations Tulasi / CR 811-1 expressed high magnitude of heterosis for grain yield per plant. The same trend was observed for other traits like number of spikelets per panicle, number of filled grains per panicle and spikelet fertility per cent.

The cross combinations involving the parent WGL 14280-1 specifically exhibited high per cent of heterosis over better parent for the important yield contributing characters like panicle length and test weight under moisture stress conditions, while in general the hybrids involving CR 811-1 as one of the parents expressed high per cent of heterosis for most of the characters in both the environments.

4.5.4 COMBINING ABILITY ANALYSIS

Analysis of variance for combining ability was done for all the characters studied in both under moisture stress and favourable situations and for seedling growth under simulated drought through different osmotic pressures of polyethylene glycol solutions. The results obtained there in are presented in Table 19, 20 and 21 respectively. Variances due to gca for all the characters except number of ear bearing tillers per plant and test weight in moisture stress situation, root to shoot ratio and leaf area per plant in favourable situation and shoot growth under simulated drought condition at 6.00 bars osmotic pressure were significant, indicating that all the eight parents differed significantly for their general combining ability for the characters studied. Sca variances were significant for all characters except root to shoot ratio and leaf area per plant under favourable environment and shoot growth under simulated drought created by polyethylene glycol at 6.00 bars osmotic pressure.

4.5.4.1 General combining ability effects

The estimates of general combining ability effects for characters studied under moisture stress; normal situation and seedling growth under simulated drought are presented in Table 22, 23 and 24 respectively.

Table 19 : Analysis of variance of combining ability of a 8 x 8 diallel under moisture stress situation

Source of variation	d.f	Mean sum of squares														Crain yield per plant (g)	Leaf rolling (0-9 scale)
		Root dry weight (g)	Shoot dry weight (g)	Root / shoot ratio	Rel. active water content (%)	No. of days to 50% flowering	Plant height (cm)	No. of bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest index (%)	Test weight (g)	Specific leaf weight (mg / cm ²)	Leaf area per plant (cm ²)	
gea	7	6.63**	118.15**	0.051**	26.00**	3.60**	318.06**	2.22	4.07**	370.77**	455.35**	75.37**	75.00**	14.03	1.75**	112870.1**	42.27**
sca	28	4.01**	82.43**	0.010**	22.42**	2.98**	99.31**	3.43**	1.51**	178.43**	37.05**	41.28**	26.19**	11.51*	7.12**	80977.8**	17.31**
Error	70	1.02	25.44	0.056	10.65	0.13	10.13	2.23	0.46	78.06	39.07	25.36	6.48	8.26	0.36	29171.5	3.70
$\frac{2\sigma_{gea}^2}{2\sigma_{gea}^2 + \sigma_{gea}^2}$		0.92	0.74	0.90	0.70	0.70	0.86	0.56	0.94	0.80	0.90	0.73	0.85	0.71	0.33	0.73	0.82
																	0.49

* Significant at 5% level

** Significant at 1% level

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Table 20 : Analysis of variance for combining ability of 8 x 8 diallel under normal situation

Source of variation	d.f	Mean sum of squares															
		Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Relative water content (%)	Days to 50% flowering	Plant height (cm)	Ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains panicle	Spikelet fertility (%)	Harvest Index (%)	Test weight (g)	Spec-ific leaf weight (mg / cm ²)	Leaf area per plant (cm ²)	Grain yield per plant (g)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
gca	7	7.561**	219.044**	0.002	25.268**	4.343**	284.467**	7.612**	15.035**	463.652**	737.974**	123.134**	57.964**	16.072**	0.634**	42332.58	25.116**
sca	28	2.452**	172.726**	0.001	27.941**	4.271**	73.667**	6.241**	2.286**	478.975**	381.495**	51.720**	34.918**	2.464**	0.791**	89360.79	23.016**
Error	70	0.576	31.440	0.001	4.708	0.009	5.299	1.375	0.579	147.499	57.047	14.600	5.036	0.223	0.275	74975.51	4.033
		0.85	0.71	0.80	0.64	0.66	0.88	0.71	0.92	0.65	0.83	0.82	0.76	0.92	0.61	0.48	0.68
		$\frac{2\sigma_{gca}^2}{2\sigma_{gca}^2 + \sigma_{sca}^2}$															

* Significant at 5% level

** Significant at 1% level

Table 21 : Analysis of variance of combining ability of a 8 x 8 diallel for seedling shoot and root growth in polyethylene glycol simulated drought conditions

Source of variation	d.f	Mean sum of squares							
		0.00 bars		3.00 bars		3.00 bars		10.00 bars	
		Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
gca	7	1.223**	1.662**	1.351**	0.844**	0.332	0.101**	0.106**	0.723**
sca	28	1.487**	2.940**	1.823**	1.996**	0.675	0.557**	0.176**	1.162**
Error	70	0.029	0.033	0.033	0.021	0.015	0.020	0.001	0.007
$\frac{2\sigma_{gca}^2}{2\sigma_{gca}^2 + \sigma_{gca}^2}$		0.62	0.53	0.60	0.45	0.49	0.26	0.54	0.55

* Significant at 5% level

** Significant at 1% level

Table 22 : General combining ability effects for different characters of the parents from a 8 x 8 diallel under moisture stress situation

SL No	Parent	Root dry weight (g)	Shoot dry weight (g)	Root / shoot ratio	Relative water content (%)	No. of days to 50% flowering	Plant height (cm)	No. of ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest index (%)	Test weight (g)	Specific leaf weight (mg / cm ²)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Leaf rolling (0-9 scale)
1.	NLR 33899	0.24	3.35	0.02**	-0.06	0.83**	2.62**	0.18	-0.27	1.03	1.43	0.97	-0.10	-1.33*	-0.01	59.36	2.71**	0.43*
2.	WGL 14280-1	-0.50	-3.44	0.00	-1.69**	-0.83**	-6.08**	0.68**	0.75**	-5.13	-4.81	-0.57	2.83**	2.32**	0.12	-44.78	1.51**	0.27
3.	NLR 30491	-0.40	5.88**	-0.03**	-0.38	0.27*	-1.38	-0.32	0.14	9.63	11.29**	3.67	2.97**	0.13	0.89**	113.06*	-2.14**	-0.70**
4.	N22	-0.93	-1.98	-0.02**	-1.89**	-0.30**	3.66**	0.25	-0.47	-7.70	-8.24*	-3.20	-4.73**	-1.16	-0.47	-167.13**	-2.60**	0.17
5.	KMJ 10-2-2	-0.68	-1.86	-0.01**	-1.32	-0.70**	-7.78**	0.52**	-0.51	-0.67	-3.24	-2.40	0.47	-0.91	0.04	-135.30**	-1.79**	0.17
6.	Tulasi	1.12	-1.10	0.04**	2.21*	-0.20	2.93**	-0.35	0.09	0.90	2.89	3.60	2.37**	0.10	-0.44	56.53	2.30**	-0.70**
7.	CN 875-135-1-3	0.31	2.72	-0.01**	1.64*	0.47**	9.19**	-0.62**	1.05**	7.17*	7.66*	0.83	-2.23**	0.17	-0.02	105.32*	0.28	0.43*
8.	CR 811-1	-0.17	-3.37	0.01**	1.51	0.47**	-3.17**	-0.35	-0.78*	-5.23	-6.98*	-2.90	-1.57**	0.68	-0.11	12.92	-0.28	-0.17
	S.E. (g) ±	0.89	2.22	0.0004	0.93	0.11	0.86	0.19	0.40	6.83	3.41	2.21	0.56	0.72	0.32	48.89	0.32	0.18
	S.E. (g·g) ±	0.20	5.08	0.001	2.13	0.27	2.02	0.44	0.92	15.61	7.81	5.07	1.29	1.65	0.73	73.91	0.74	0.43

* Significant at 5% level

** Significant at 1% level

Table 23 : General combining ability effects for different characters of the parents from a 8 x 8 diallel under normal situation

Sl. No	Parent	Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Relative water content (%)	Days to 50% flowering	Plant height (cm)	Ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest Index (%)	Test weight (g)	Specific leaf weight (mg/cm ²)	Leaf area per plant (cm ²)	Grain yield per plant (g)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	NLR 33899	-1.330**	-6.63**	-0.015	-3.533**	0.700**	-1.783**	-0.208	-0.167	1.542	-0.225	0.958	2.292**	0.440*	0.042**	-46.823	2.032**
2.	WGL 14280-1	-0.673**	-4.809**	-0.001	-0.700	0.001	-4.483**	-3.08	1.417**	4.908	5.32*	0.525	3.325**	0.523*	-0.012	-30.019	0.197
3.	NLR 30491	-0.121	1.537	-0.007	0.300	0.100**	-1.417	-0.042	-0.101	-0.025	-0.25	-1.175	-1.908**	-1.703**	0.027	-37.063	-1.098
4.	N22	-0.359	-3.835*	0.005	-0.033	-1.300**	5.517**	-1.575**	-2.094**	-1.892	-12.492**	-8.008**	-3.642**	-1.130**	-0.494**	-64.510	-1.811**
5.	KMJ 10-2-2	-0.403	4.558**	-0.016	0.600	-0.600**	-6.317**	0.258	-1.024**	-11.125**	-8.825**	0.692	-1.075	-0.900**	-0.106	265.284	-2.015**
6.	Tulasi	0.250	3.558*	-0.006	1.300*	0.200**	-1.617**	0.925**	0.939**	-4.392	-1.492	1.425	1.292*	-0.190	0.066	368.747*	-0.013
7.	CN 875-135-1-3	1.547**	5.947**	0.020*	0.567	0.300**	10.383**	-0.342	1.419**	12.242**	15.675**	3.625**	1.358**	0.650**	0.056	150.001	2.129**
8.	CR 811-1	0.687**	-0.352	0.019*	1.500*	0.600**	-0.283	1.292**	-0.387	-1.258	2.412	1.358	-1.642*	2.310**	0.422**	180.487	0.579
	S.E. (gt) ±	0.22	1.66	0.01	0.64	0.03	0.68	0.35	0.23	3.59	2.23	1.13	0.66	0.14	0.16	286.13	0.59
	S.E. (gt-gt) ±	0.34	2.51	0.01	0.97	0.04	1.03	0.52	0.34	5.43	3.38	1.71	1.00	0.21	0.23	387.24	0.90

* Significant at 5% level

** Significant at 1% level

Table 24 : General combining ability effects for seedling growth under simulated drought by different osmotic pressures of polyethylene glycol solutions

Sl. No	Parent	0.00 bars		3.00 bars		6.00 bars		10.00 bars	
		Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
1.	NLR 33899	-0.398**	0.119*	0.507**	0.008	0.0253**	0.001	0.149**	0.393**
2.	WGL 14280-1	-0.565**	0.519**	0.037	0.012	0.013	0.198**	-0.060**	0.209**
3.	NLR 30491	-0.222**	-0.291**	-0.390**	-0.002	-0.220**	-0.066	-0.068**	-0.197**
4.	N22	0.88**	-0.187**	0.047	-0.218**	0.227**	-0.026	-0.058**	-0.347**
5.	KMJ 10-2-2	0.292**	-0.041	-0.040	0.308**	-0.017	-0.002	-0.048**	-0.184**
6.	Tulasi	0.385**	0.609**	-0.247**	0.162**	-0.117**	-0.136**	-0.068**	-0.194**
7.	CN 875-135-1-3	0.208**	-0.611**	-0.440**	0.245**	-0.170**	-0.046	-0.028**	0.049
8.	CR 811-1	0.212**	-0.117*	0.527**	-0.595**	0.090	0.078*	0.182**	0.273**
	S.E. (gi) $\pm$	0.05	0.05	0.05	0.04	0.04	0.04	0.01	0.03
	S.E. (gi-gj) $\pm$	0.08	0.08	0.08	0.06	0.06	0.06	0.02	0.04

* Significant at 5% level

** Significant at 1% level

Under moisture stress situation

Among eight parents studied NLR 30491 exhibited positive and significant gca effects for shoot dry weight (Table 22). Positive and significant gca effects were noted for root to shoot ratio in NLR 33899 and Tulasi, for relative water content in Tulasi and CN 875-135-1-3, for number of days to 50% flowering in NLR 33899, NLR 30491, CN 875-135-1-3 and CR 811-1, for plant height in NLR 33899; N22, Tulasi and CN 875-135-1-3.

The genotypes viz., WGL 14280-1 and KMJ 10-2-2 showed positive and significant gca effects for number of ear bearing tillers per plant, while WGL 14280-1 and CN 875-135-1-3 exhibited the same for panicle length. For number of filled grains per panicle NLR 30491 and CN 875-135-1-3 displayed positive and significant gca effects. Significant and positive gca effects were observed in WGL 14280-1, NLR 30491 and Tulasi for harvest index, WGL 14280-1 for test weight. NLR 30491 for specific leaf weight, NLR 30491 and CN 875-135-1-3 for leaf area per plant. NLR 33899 and WGL 14280-1 and Tulasi for grain yield and NLR 33899 for leaf rolling character.

None of the parents showed significant gca effects for root dry weight, number of spikelets per panicle and spikelet fertility per cent.

Under favourable environment

Positive and significant gca effects were recorded for root dry weight in CN 875-135-1-3 and CR 811-1 (Table 23); for shoot dry weight KMJ 10-2-2, Tulasi and CN 875-135-1-3, for root to shoot ratio CN 875-135-1-3 and CR 811-1. For relative water content, Tulasi and CR 811-1. The genotypes NLR 33899, NLR 30491, Tulasi, CN 875-135-1-3 and CR 811-1 showed positive and significant gca effects for number of days to 50% flowering, while N22 and CN 875-135-1-3 for plant height. Similarly for number of ear bearing tillers per plant, Tulasi and CR 811-1 registered positive and significant gca effects. WGL 14280-1, Tulasi and CN 875-135-1-3 for panicle length, CN 857-135-1-3 for number of spikelets per panicle, WGL 14280-1 and CN 875-135-1-3 for number of filled grains per panicle. CN 875-135-1-3 for spikelet fertility per cent. NLR 33899, WGL 14280-1, Tulasi and CN 875-135-1-3 for harvest index. CN 875-135-1-3 and CR 811-1 for test weight, NLR 33899 and CR 811-1 for specific leaf weight, for leaf area per plant NLR 33899 and CN 875-135-1-3 for grain yield per plant observed significant and positive gca effects.

Under simulated drought conditions

Among the eight parents studied N22, KMJ 10-2-2, Tulasi, CN 875-135-1-3 and CR 811-1 expressed positive and significant gca effects for shoot length in control condition, while NLR 33899 and WGL 14280-1

showed the same for root length (Table 24). At 3.00 bars osmotic pressure NLR 33899 and CR 811-1 for shoot length and KMJ 10-2-2, 169 Tulasi and CN 875-135-1-3 for root length exhibited positive and significant gca effects.

The genotypes NLR 33899 and N22 for shoot length, WGL 14280-1 and CR 811-1 for root length displayed positive and significant gca effects at 6.00 bars of osmotic pressure. With regard to higher order of osmotic pressure (10.00 bars) NLR 33899 and CN 875-135-1-3 for shoot growth and NLR 33899, WGL 14280-1 and CR 811-1 for root length recorded significant and positive gca effects.

4.5.4.2 Specific combining ability effects

The estimates of specific combining ability effects for different characters studied under moisture stress situation, favourable environment and seedling growth under simulated drought conditions with polyethylene glycol solutions are presented in Table 25, 26 and 27 respectively.

4.5.4.2.1 Root dry weight

In moisture stress situation, sca effects for root dry weight per plant varied from -3.52 (Tulasi / CN 875-135-1-3) to 4.24 (NLR 33899 / CN 875-135-1-3) (Table 25). Positive and significant sca effects for the

Table 25 : Specific combining ability effects for different characters of 28F₁ hybrids from 8 x 8 diallel under moisture stress situation

Sl. No.	Cross	Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Relative water content (%)	No. of days to 50% flowering	Plant height (cm)	No. of ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest index (%)	Test weight (g)	Specific leaf weight (mg/cm ²)	Leaf area per plant (cm ²)	Grain yield per plant (g)	Leaf rolling (0-9 scale)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	NLR 33899 / WGL 14280-1	-2.08*	-5.37	-0.02**	-3.76	-2.22**	-4.15	-1.59	-1.75**	-7.34	-10.66**	-4.84	0.27	-0.69	-0.14	-218.43	-2.08	1.76**
2.	NLR 33899 / NLR 30491	-0.43	1.77	-0.01*	-3.73	-0.99**	-6.19*	1.41	0.49	12.89	2.90	2.74	-0.87	-4.20**	-0.12	151.48	4.33	0.82**
3.	NLR 33899 / N22	-0.91	0.95	0.03**	-0.56	0.24*	6.78*	0.84	-0.26	6.22	1.44	0.88	2.17	2.47**	1.12**	50.76	0.49	1.29**
4.	NLR 33899 / KMJ 10-2-2	-0.90	-0.92	-0.02**	11.57**	1.64**	-1.12	-1.76	0.08	1.52	3.44	2.32	-2.03	-1.63**	-0.19	-246.38	-2.65	-1.38**
5.	NLR 33899 / Tulasi	-0.58	-5.14	0.01*	2.34	-1.86**	7.51**	-1.22	-0.16	-8.71	-11.03*	-3.01*	1.40	-0.48	-0.36*	69.93	1.44	0.82**
6.	NLR 33899 / CN 875-135-1-3	4.24**	10.32	0.05**	2.91	-1.52**	10.58**	1.04	0.95**	-8.64	1.87	5.42*	3.00	1.32**	-1.49**	250.70*	8.48**	1.69**
7.	NLR 33899 / CR 811-1	-0.75	-4.80	0.01*	1.71	0.48**	-0.39	0.78	0.61	-2.24	3.84	5.49	3.00	0.51	-0.26	215.67	0.77	-3.04**
8.	WGL 14280-1 / NLR 30491	-2.48**	-15.57	-0.02*	2.51	-0.66**	-2.82	-0.76	1.55**	-8.94	0.14	5.79	5.87**	4.32**	-0.29	-83.29	-0.30	-1.11**
9.	WGL 14280-1 / N22	0.13	2.80	-0.01*	2.53	-1.09**	16.48**	1.34	1.52**	-12.28	-5.33	1.99	-5.10**	0.34	0.63*	-44.76	3.20	-2.64**
10.	WGL 14280-1 / KMJ 10-2-2	1.58	7.19	0.00	4.51*	0.31**	-3.75	0.08	-0.30	0.69	-12.33*	-16.48**	1.70	0.15	-0.51	106.76	0.16	0.69**
11.	WGL 14280-1 / Tulasi	1.75*	5.92	0.04**	2.31	-1.19**	-14.79**	1.28	-0.54	-2.21	2.20	1.19	3.13	-0.59	0.12	-157.93	2.67	1.56**
12.	WGL 14280-1 / CN 875-135-1-3	2.37**	4.29	0.05**	6.54**	-1.86**	-18.95**	-2.79*	2.80**	23.86**	20.10**	6.56*	5.40**	-1.09*	1.54**	243.73	4.22	-2.24**
13.	WGL 14280-1 / CR 811-1	1.39	10.29	-0.01*	-4.33	-0.86**	0.98	-0.06	0.80*	14.59	12.74*	1.19	6.07**	-1.40**	-0.07	77.72	0.91	-1.64**
14.	NLR 30491 / N22	1.01	-2.99	0.04**	2.77	-0.86**	10.78**	1.68	0.70	6.96	8.90	5.52	3.10	-0.84	0.00	-228.62	6.54*	-1.58**
15.	NLR 30491 / KMJ 10-2-2	0.46	9.92	-0.02**	-3.46	1.21**	9.21**	-0.59	1.21**	-2.08	2.90	-4.1	1.77	1.07*	-1.17**	288.94*	-1.76	-0.91**
16.	NLR 30491 / Tulasi	-2.17**	-3.84	-0.05**	-3.99	0.71**	-1.15	-0.72	-1.10**	-10.31	-16.56**	-8.33*	-3.00	-1.90**	-1.60**	-425.53**	-7.67*	1.29**

Table 25 (Contd....)

17.	NLR 30491 / CN 875-135-1-3	-1.51	7.54	-0.04*	4.57*	-0.62**	10.55**	0.88	-0.49	2.76	-6.66	-4.61	0.60	-1.74**	1.04**	-217.43	-5.26	2.82**
18.	NLR 30491 / CR 811-1	-0.60	4.16	-0.03**	-0.96	-3.29**	-0.72	-1.72	0.41	4.16	20.30**	-13.12**	4.60*	0.42	0.60*	-605.87**	-4.18	-1.24**
19.	N22 / KMJ 10-2-2	0.52	7.24	-0.02**	-1.96	-0.22*	-13.15**	0.84	0.62	30.26**	5.44	0.82	5.93**	2.10**	0.51	-56.65	-2.14	-1.78**
20.	N22 / Tulasi	3.40**	20.81	-0.01*	-0.49	-1.72**	12.15**	-0.29	2.28**	15.02	6.97	-2.51	2.70	1.99**	-0.97**	-192.26	2.04	-2.91**
21.	N22 / CN 875-135-1-3	-3.47**	-16.99	-0.04**	-8.26**	0.61**	-17.12**	2.58*	0.05	-23.24**	-3.13	-10.41**	-6.03**	-2.25**	-1.60**	-342.50*	-6.08*	0.62**
22.	N22 / CR 811-1	-1.67*	-5.99	-0.03**	-0.13	-0.39*	-1.42	-2.96*	-2.14**	11.82	-1.16	-6.34	2.30	0.44	0.08	-314.20*	-1.98	2.56**
23.	KMJ 10-2-2 / Tulasi	-1.33	-6.13	-0.01*	-0.39	0.65**	0.58	-1.89	0.07	1.99	16.97**	9.69**	0.50	0.57	-0.03	-192.81	-0.73	-0.24
24.	KMJ 10-2-2 / CN 875-135-1-3	-0.13	-7.25	0.03**	2.84	-0.99**	-2.69	-2.29	-1.04**	-11.61	-5.80	3.46	3.43	0.43	0.63*	-354.71*	1.35	-2.71**
25.	KMJ 10-2-2 / CR 811-1	-0.32	-6.07	0.01*	-2.36	-0.99**	3.01	2.44	0.06	-2.54	-2.83	-1.81	4.10*	1.32**	-0.33	143.96	2.91	3.22**
26.	Tulasi / CN 875-135-1-3	-3.52**	-17.79	-0.02**	-6.03**	1.51**	0.61	0.76	-0.51	13.16	2.07	-4.54	-4.80**	0.29	0.60*	-171.00	-0.94	0.16
27.	Tulasi / CR 811-1	2.38**	7.07	0.03**	8.11**	-0.49**	12.65**	-0.36	0.48	16.29*	3.70	3.86	-0.47	1.15**	0.25	458.07**	8.12**	-1.91**
28.	CN 875-135-1-3 / CR 811-1	1.41	6.64	0.01*	-4.99*	-0.16	-14.29**	3.91**	0.13	-3.38	-2.40	1.62	6.80**	1.61**	-0.18	99.21	1.07	-3.71**
	SE (Stj) ±	0.842	20.92	0.004	2.30	0.11	2.70	1.30	0.37	8.31	5.10	3.52	1.80	0.44	0.30	130.40	3.94	0.17
	SE (Stj) - SE ±	1.844	45.79	0.010	3.90	0.24	4.25	2.35	0.83	14.14	8.68	5.95	3.10	0.67	0.66	22.10	6.66	0.38

* Significant at 5% level

** Significant at 1% level

Table 26 : Specific combining ability effects for different characters of 28F₁ hybrids from 8 x 8 diallel under normal situation

Sl. No	Cross	Root dry weight (g)	Shoot dry weight (g)	Root/shoot ratio	Relative water content (%)	Days to 50% flowering	Plant height (cm)	Ear bearing tillers per plant	Panicle length (cm)	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest Index (%)	Test weight (g)	Specific weight (mg/cm ³)	Leaf area per plant (cm ²)	Grain yield per plant (g)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	NLR 33899 / WGL 14280-1	1.094	5.541	0.008	-0.935	-1.367**	-0.493*	-0.863	-0.616	-6.441	-2.559	-0.159	1.226	1.100**	0.040	439.512	-1.427
2.	NLR 33899 / NLR 30491	-0.805	-2.798	-0.017	-4.28*	0.533**	-8.559**	0.537	-0.933	-30.841**	-23.526**	-3.126	2.126	-1.140**	0.674	82.472	0.302
3.	NLR 33899 / N22	0.939	4.340	0.008	-2.243	-2.067**	8.507**	2.404**	1.561	24.026**	5.207	-9.293**	0.193	1.953**	-0.425	717.651	3.115*
4.	NLR 33899 / KMJ 10-2-2	-1.803**	-16.353**	-0.001	-2.215	-2.767**	-2.326	0.570	1.657	19.593*	7.541	1.341	2.293	-1.77**	-0.520	-506.575	-3.415*
5.	NLR 33899 / Tulasi	1.707**	3.151	0.032**	-4.913**	-0.567**	-1.026	0.904	-1.286	-1.141	-14.126*	-7.393*	0.259	-1.954**	-0.529	-227.905	0.250
6.	NLR 33899 / CN 875-135-1-3	-0.240	3.649	-0.023	7.819**	-1.667**	6.974**	-1.163	0.351	14.559	17.041**	2.407	-3.807*	-0.207	-0.085	-445.492	-1.658
7.	NLR 33899 / CR 811-1	-0.297	-3.576	0.051**	-5.113**	-1.967**	6.641**	-0.463	1.821	7.059	8.274	0.741	-1.474	-0.254	1.202**	-308.335	2.625
8.	WGL 14280-1 / NLR 30491	-0.528	-5.256	-0.004	7.233**	-0.767**	-4.526*	2.304*	0.151	20.126*	16.907**	3.307	-4.574**	0.043	0.182	-111.315	2.670
9.	WGL 14280-1 / N22	-0.967	7.916	-0.027**	-4.413**	0.633**	12.541**	1.504	1.277	10.993	-5.653	-1.526	-1.841	1.003**	-1.535**	717.298	2.516
10.	WGL 14280-1 / KMJ 10-2-2	0.427	6.656	-0.011	3.552*	0.933**	-4.626*	0.004	0.174	-8.441	3.307	7.774**	3.259	-0.260	0.704	374.638	9.153**
11.	WGL 14280-1 / Tulasi	1.244*	2.526	0.019*	2.979	-0.867**	-4.659*	-0.996	3.637	-11.507	-22.663**	-11.959**	-2.441	-0.570	0.482	-442.292	-2.196
12.	WGL 14280-1 / CN 875-135-1-3	-0.900	-9.799**	0.010	-7.631**	-0.967**	14.341**	-2.063*	-0.639	-13.474	10.474	2.174	22.159**	1.390**	-0.045	-685.345	-3.257*
13.	WGL 14280-1 / CR 811-1	0.790	10.367**	-0.019*	1.779	-0.267**	3.674**	-1.030	0.357	7.026	-0.959	-2.159	4.174*	-0.004	-0.731	-83.808	-3.007
14.	NLR 30491 / N22	-0.553	-10.187**	0.027**	5.919**	-1.467**	4.141*	0.570	0.054	13.926	4.074	-9.159**	2.941	3.163**	0.066	-8.786	0.078
15.	NLR 30491 / KMJ 10-2-2	-0.558	5.177	-0.019*	-6.381**	-2.167**	19.307**	-1.596	1.457	-17.174	-10.513	1.141	1.826	0.866**	-0.098	-425.202	-0.852

Table 26 (Contd....)

16.	NLR 30491 / Tulasi	-0.338	1.447	-0.013	-3.748*	0.033	10.607**	0.737	0.827	-16.574	-6.993	0.592	4.126*	-0.544	-1.031*	-427.865	-3.454*
17.	NLR 30491 / CN 875-135-1-3	3.872**	41.372**	0.000**	2.985	-0.067	-10.059**	-1.663	-0.019	-11.207	-6.993	3.574	4.059*	-2.417**	0.903	746.648	7.772**
18.	NLR 30491 / CR 811-1	-2.495**	-10.303**	0.001**	-4.281*	-0.367**	0.941	0.370	-0.646	-28.374**	-18.859**	3.574	4.059*	-0.577	-0.280	156.418	1.022
19.	N22 / KMJ 10-2-2	-0.428	-0.885	-0.011	-7.715**	2.233**	0.707	-2.936**	-2.183	-14.307	-4.193	1.307	2.559	1.060**	0.763	-350.188	-0.072
20.	N22 / Tulasi	1.819**	15.918**	-0.008	-0.748	-1.567**	-0.326	-1.063	0.254	-10.707	1.807	6.574**	2.526	-1.656	-1.787**	-489.418	7.826**
21.	N22 / CN 875-135-1-3	-0.338	-10.477**	0.004**	1.319	-1.667**	2.674	-1.537	2.607	22.993**	-9.359	-15.626**	-8.541**	-2.490**	-0.056	33.662	-6.882**
22.	N22 / CR 811-1	-1.155*	0.759	0.001	8.052**	-1.967**	-10.659**	-1.430	-3.253	-24.507**	-9.459	5.707	-0.207	-2.284**	-0.193	240.102	-0.165
23.	KMJ 10-2-2 / Tulasi	-0.037	0.659	0.001	-3.715*	-2.267**	12.507**	1.104	-0.409	11.859	19.80**	7.874**	1.293	0.120	0.866**	4331.521**	5.130**
24.	KMJ 10-2-2 / CN 875-135-1-3	1.567**	16.934**	-0.012	1.685	-2.362**	-14.493**	3.037**	0.304	-29.107**	-24.025**	-0.995	-1.107	-0.020	0.173	-554.698	1.922
25.	KMJ 10-2-2 / CR 811-1	2.693**	20.299**	-0.001	-0.248	1.333**	-4.159	3.070**	0.411	-34.941**	-30.126**	-6.326*	1.226	2.486**	-1.144**	-587.229	-2.995
26.	Tulasi / CN 875-135-1-3	-2.890**	-11.130	0.000**	-6.015**	1.833**	-9.193**	0.037	-1.793	-18.507	-20.695**	-1.059	-6.807**	-0.430	0.007	-735.695	-7.114**
27.	Tulasi/ CR 811-1	0.556	-5.031	0.008**	7.719**	1.533**	-4.193*	6.404**	1.581	32.993**	36.874**	8.941**	5.193**	1.743**	1.354**	33.875	6.903**
28.	CN875-135-1-3/ CR 811-1	1.936**	7.011	0.003	0.452	-0.567**	4.141*	4.337**	0.667	19.693*	29.041**	10.407**	3.793*	1.070*	1.184**	332.292	8.195**
	SE (Std) ±	0.60	4.42	0.01	1.71	0.08	1.82	0.92	0.60	9.58	5.96	3.01	1.77	0.37	0.41	653.02	1.58
	SE (Std) - Std ±	1.02	7.52	0.02	2.91	0.13	3.09	1.57	1.02	16.29	10.13	5.13	3.01	0.63	0.70	1361.71	2.69

Table 27 : Specific combining ability effects for seedling growth under simulated drought conditions by different osmotic pressures of polyethylene glycol

S. No.	Cross	0.00 bars		3.00 bars		6.00 bars		9.00 bars	
		Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
		1	2	3	4	5	6	7	8
1.	NLR 33899 / WGL 14280-1	-0.761**	0.139	-1.103**	-2.002**	0.001	-0.053	0.364**	1.921**
2.	NLR 33899 / NLR30491	0.996**	2.237**	1.424**	0.945**	0.167	-0.356**	0.111**	0.386**
3.	NLR 33899 / N22	1.653**	-1.066**	1.754**	-0.639**	-0.813**	0.837**	0.067*	1.469**
4.	NLR 33899 / KMJ 10-2-2	0.316*	0.587**	0.274*	1.835**	-1.303**	0.114	-0.076*	0.072
5.	NLR 33899 / Tulasi	1.123**	2.637**	-0.586**	1.915**	0.357	1.080**	0.577**	2.482**
6.	NLR 33899 / CN 875-135-1-3	-1.934**	-0.443**	0.507**	1.465**	1.150**	0.490**	-0.363**	-0.661**
7.	NLR 33899 / CR 811-1	-0.537**	0.531**	0.607**	-0.162	0.257**	-0.400**	1.194**	0.382**
8.	WGL 14280-1 / NLR 30491	-1.404**	-0.028	-1.439**	1.388**	-0.593**	-1.414**	0.053	1.836**
9.	WGL 14280-1 / N22	-0.247	1.667**	0.891**	0.638**	0.027	0.674**	0.109**	0.286**
10.	WGL 14280-1 / KMJ 10-2-2	0.549**	1.387**	0.377**	1.178**	1.103**	0.684**	0.866**	1.722**
11.	WGL 14280-1 / Tulasi	-1.511**	-0.396**	0.517**	-1.309**	0.197**	-0.616**	-0.147**	-0.334**
12.	WGL 14280-1 / CN 875-135-1-3	1.933**	0.657**	1.077**	-0.625**	-0.710**	-0.906**	-0.021	0.089
13.	WGL 14280-1 / CR 811-1	1.096**	1.531**	1.411**	1.848**	0.297**	0.704**	-0.197**	0.199**

Table 27 (Contd....)

14.	NLR 30491 / N22	-1.857**	-0.656**	-0.749**	-1.482**	-0.707**	-0.730**	0.217**	0.592**
15.	NLR 30491 / KMJ 10-2-2	-1.194**	1.331**	-1.596**	1.891**	0.970**	-0.220	-0.159**	0.196**
16.	NLR 30491 / Tulasi	0.113	1.147**	1.877**	-0.262**	0.797**	0.314**	-0.106**	-0.828**
17.	NLR 30491 / CN 875-135-1-3	1.323**	1.234**	2.671**	0.988**	1.190**	1.390**	0.387**	0.029
18.	NLR 30491 / CR 811-1	0.719**	-1.026**	0.371**	-0.139	0.230*	-0.433**	-0.389**	-1.294**
19.	N22 / KMJ 10-2-2	0.863**	-0.1073**	1.634**	-0.659**	0.790**	-0.760**	-0.169**	-0.688**
20.	N22 / Tulasi	0.736**	-0.823**	0.141	0.221*	0.950**	0.240*	0.149**	-0.678**
21.	N22 / CN 875-135-1-3	0.113	2.631**	-0.633**	1.438**	-0.123	-0.216*	-0.189**	-0.921**
22.	N22 / CR 811-1	-0.791**	-0.163	-1.066**	0.745**	0.917**	0.760**	0.434**	0.989**
23.	KMJ 10-2-2 / Tulasi	0.199	0.931**	0.961**	1.928**	0.193	0.916**	0.307**	1.092**
24.	KMJ 10-2-2 / CN 875-135-1-3	1.076**	-0.249	0.713**	-1.122**	0.253*	0.294**	-0.133**	-0.684**
25.	KMJ 10-2-2 / CR 811-1	-0.127	-1.876**	0.087	-1.282**	0.193	0.570**	-0.276**	-0.008
26.	Tulasi / CN 875-135-1-3	-0.351**	0.034	0.194	0.525**	-0.487**	-0.173	0.087**	0.759**
27.	Tulasi / CRS 11-1	2.613**	3.307**	1.227**	-0.302**	0.087	-0.296**	-0.289**	0.831**
28.	CN 875-135-1-3 / CR 811-1	-0.677**	-0.573**	0.454**	0.715**	0.580**	0.314**	0.604**	0.826**
	SE (Sij) ±	0.13	0.14	0.140	0.11	0.10	0.11	0.03	0.07
	SE (Sij - Sik) ±	0.23	0.24	0.340	0.19	0.17	0.19	0.05	0.12

* Significant at 5% level

** Significant at 1% level

character were noticed in four hybrids viz. NLR 33899 / CN 875-135-1-3; WGL 4280-1 / CN 875-135-1-3 ; N22 / Tulasi and Tulasi / CR 811-1. Significant negative effects were recorded in cross combinations Tulasi / CN 875-135-1-3 ; N22 / CN 875-135-1-3 ; NLR 30491 / Tulasi, WGL 14280-1 / NLR 30491 ; NLR 33899 / WGL 14280-1 and N22 / CR 811-1.

Under favourable situation, the range in sca effects for the trait was from -2.89 (Tulasi/CN 875-135-1-3) to 3.87 (NLR 30491/CN 875-135-1-3) (Table 26). The cross combinations viz. NLR 30491/CN 875-135-1-3; N22/Tulasi ; NLR 33899/Tulasi ; KMJ 10-2-2/CN 875-135-1-3 and WGL 14280-1 / Tulasi were considered good specific combinations for the character. Significant negative sca effects were noted in four crosses viz. Tulasi/CN 875-135-1-3 ; NLR 30491/CR 811-1 ; NLR 33899 / KMJ 10-2-2 and N22 / CR 811-1.

4.5.4.2.2 Shoot dry weight

The sca effects ranged from -17.79 (Tulasi / CN 875-135-1-3) to 20.81 (N22 / Tulasi) for shoot dry weight under moisture stress situation (Table 25). None of the hybrids showed significant effects for the character. However cross combinations N22 / Tulasi and NLR 33899 / CN 875-135-1-3 had positive sca effects.

Under favourable environment, the variation in sca effects for shoot dry weight was -16.35 (NLR 33899 / KMJ 10-2-2) to 41.32 (NLR 30491/CN 875-135-1-3) (Table 26). The cross combinations viz. NLR 30491 / CN 875-135-1-3 ; KMJ 10-2-2 / CR 811-1 and KMJ 10-2-2/ CN 875-13-1-3 had high sca effects for this trait.

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4.5.4.2.3 Root to shoot ratio

In moisture stress environment, the sca effects for root to shoot ratio varied from -0.05 (NLR 30491 / Tulasi) to 0.05 (NLR 33899 / CN 875-135-1-3). Ten hybrids displayed positive and significant effects for the character. WGL 14280-1 / CN 825-135-1-3 ; NLR 33899 / CN 875-135-1-3 ; WGL 14280-1 / Tulasi and NLR 30491 / N22 were the best specific combinations for the trait.

In favourable environment, the sca effects ranged from -0.052 (WGL 14280-1 / N22) to 0.051 (NLR 33899 / CR 811-1) (Table 26). The crosses NLR 33899 / CR 811-1 ; N22 / CN 875-135-1-3 and NLR 33899/ Tulasi were good specific combiners for root shoot ratio. Six hybrids exhibited positive and significant sca effects.

4.5.4.2.4 Relative water content

Specific combining ability effects for relative water content varied from -8.26 (N22 / CN 875-135-1-3) to 11.87 (NLR 33899 / KMJ 10-2-2)

in moisture stress environment (Table 25). Significant positive sca effects were obtained for relative water content in four hybrids viz. NLR 33899/ KMJ 10-2-2 ; Tulasi / CR 811-1 ; WGL 14280-1 / CN 875-135-1-3 and NLR 30491 / CN 875-135-1-3. Significant negative effects were observed in N22 / CN 875-135-1-3 ; Tulasi / CN 857-135-1-3 ; CN 875-135-1-3 / CR 811-1 and in WGL 14280-1 / KMJ 10-2-2.

Under favourable environment, the range in sca effects for relative water content was from -7.71 (N22 / KMJ 10-2-2) to 8.05 (N22 / CR 811-1). Six hybrids expressed positive and significant sca effects. The crosses N22 / CR 811-1, NLR 33899 / CN 875-135-1-3 and Tulasi / CR 811-1 were the best specific combiners. Significant negative sca effects were noted in ten crosses of which N22 / KMJ 10-2-2 ; WGL 14280-1 / CN 875-135-1-3 and Tulasi / CN 875-135-1-3 had higher values.

4.5.4.2.5 Number of days to 50% flowering

The sca effects ranged from -3.29 (NLR 30491 / CR 811-1) to 1.64 (NLR 33899 / KMJ 10-2-2) for number of days to 50% flowering under moisture stress situation (Table 25). Positive significant sca effects were observed in the hybrids viz., NLR 33899 / KMJ 10-2-2 ; Tulasi / CN 875-135-1-3 and NLR 30491 / KMJ 10-2-2. Significant negative sca effects were noted in cross combination viz., NLR 30491/CR 811-1; NLR 33899/ WGL 14280-1, NLR 33899 / Tulasi and WGL 14280-1 / CN 875-135-1-3.

Under favourable environment, the sca effects varied from -2.76 (NLR 33899 / KMJ 10-2-2) to 2.23 (N22 / KMJ 10-2-2) (Table 26). Seven hybrids exhibited significant and positive effects which included N22 / KMJ 10-2-2 ; Tulasi / CN 875-135-1-3 and Tulasi / CR 811-1. Significant negative sca effects were observed in 18 crosses of which NLR 33899 / KMJ 10-2-2 and KMJ 10-2-2 / Tulasi had higher values.

4.5.4.2.6 Plant height

Under moisture stress situation, the sca effects ranged from 18.95 (WGL 14280-1 / CN 875-135-1-3) to 16.48 (WGL 14280-1 / N22) for plant height (Table 25). Significant positive sca effects were obtained for plant height in nine crosses viz., WGL 14280-1 / N22 ; Tulasi / CR 811-1, N22/ Tulasi ; NLR 30491 / N22 ; NLR 3389 / CN 875-135-1-3 ; NLR 30491 / CN 875-135-1-3 ; NLR 30491 / KMJ 10-2-2 ; NLR 33899 / Tulasi and NLR 33899 / N22. Significant negative sca effects were recorded in WGL 14280-1 / CN 875-135-1-3 ; N22 / CN 875-131-1-3 ; WGL 14280-1 / Tulasi, CN 875-135-1-3 / CR 811-1 and NLR 33899 / NLR 30491.

The range in sca effects for plant height was from -14.49 (KMJ 10-2-2 / CN 875-135-1-3) to 19.70 (NLR 30491 / KMJ 10-2-2) in favourable environment (Table 26). Positive and significant sca effects were observed in 11 crosses. NLR 30491 / KMJ 10-2-2 ; WGL 14280-1 / CN 875-135-1-3 and WGL 14280-1 / N22 had high positive sca effects. Ten crosses had

significant negative sca effects which included KMJ 10-2-2 / CN 875-135-1-3, N22 / CR 811-1 and NLR 30491 / CN 875-135-1-3.

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4.5.4.2.7 Number of ear bearing tillers per plant

The sca effects for number of ear bearing tillers per plant showed variation from -2.96 (N22 / CR 811-1) to 3.91 (CN 875-135-1-3 / CR 811-1) under moisture stress situation (Table 25). Positive and significant sca effects for the character were noticed in only two hybrids. CN 875-135-1-3 / CR 811-1 and N22 / CN 875-135-1-3. Significant and negative sca effects were observed in N22 / CR 811-1 and WGL 14280-1 / CN 875-135-1-3.

Under favourable environment, the variation in sca effects for number of tillers per plant was noted from -2.39 (N22 / KMJ 10-2-2) to 6.40 (Tulasi / CR 811-1) (Table 26). Six hybrids expressed positive and significant sca effects of which Tulasi / CR 811-1 ; CN 875-135-1-3 / CR 811-1 and KMJ 10-2-2 / CR 811-1 had high magnitude of sca effects. Two crosses viz., N22 / KMJ 10-2-2 and WGL 14280-1 / CN 875-135-1-3 showed significant and negative sca effects.

4.5.4.2.8. Panicle length

The sca effects for panicle length in moisture stress situation showed variation from -2.14 (N22 / CR 811-1) to 2.80 (WGL 14280-1 /

CN 875-135-1-3) (Table 25). Significant positive sca effects were found in the crosses viz., WGL 14280-1 / CN 875-135-1-3 ; N22 / Tulasi, WGL 14280-1 / NLR 30491 ; WGL 14280-1 / N22, NLR 30491 / KMJ 10-2-2, NLR 33899 / CN 875-135-1-3 and WGL 14280-1 / CR 811-1.

Sca effects ranging from -3.25 (N22 / CR 811-1) to 3.67 (WGL 14280-1 / Tulasi) for panicle length were recorded under favourable environment (Table 26). None of the crosses exhibited significant sca effects for this trait.

4.5.4.2.9 Number of spikelets per panicle

The variation in sca effects for number of spikelets per panicle under moisture stress condition ranged from -23.24 (N22/CN 875-135-1-3) to 30.26 (N22/KMJ 10-2-2) (Table 25). Significant and positive sca effects were observed in three crosses N22/KMJ 10-2-2, WGL 14280-1/CN 875-135-1-3 and Tulasi/CR 811-1. Significant and negative sca effect was noticed in only one cross combination of N22/CN 875-135-1-3.

Under favourable environment, sca effects for number of spikelets per panicle varied from -34.94 (KMJ 10-2-2/CR 811-1) to 32.99 (Tulasi/CR 811-1) (Table 26). Tulasi/CR 811-1 and NLR 33899/N22 were the promising specific combiners for the character.

4.5.4.2.10 Number of filled grains per panicle

Under moisture stress situation, the sca effects for number of filled grains per plant showed variation from -16.56 (NLR 30491/Tulasi) to 20.30 (NLR 30491/CR 811-1) (Table 25). Four hybrids displayed positive and significant heterosis for the character. NLR 30491/CR 811-1, WGL 14280-1/CN 875-135-1-3, KMJ 10-2-2/Tulasi and WGL 14280-1/CR 811-1 were the best specific combiners for the character. 182

In favourable environment, the variation in sca effects for number of filled grains per panicle was noted from -30.12 (KMJ 10-2-2/CR 811-1) to 36.87 (Tulasi/CR 811-1) (Table 26). Five crosses expressed positive and significant sca effects of which Tulasi / CR 811-1; CN 875-135-1-3 / CR 811-1 and KMJ 10-2-2 / Tulasi had higher estimates.

4.5.4.2.11 Spikelet fertility per cent

Sca effects for spikelet fertility per cent under moisture stress situation ranged from -13.12 (NLR 30491/CR 811-1) to 9.69 (KMJ 10-2-2/Tulasi) (Table 25). Only three hybrids viz. KMJ 10-2-2/Tulasi; NLR 33899/CN 875-135-1-3 and WGL 14280-1/CN 875-135-1-3 displayed high positive sca effects for spikelet fertility in favourable environment varied from -15.62 (N22/CN 875-135-1-3) to 10.40 (CN 875-135-1-3/CR 811-1) (Table 26). Five F_1 s viz., CN 875-135-1-3/CR 811-1; Tulasi/CR 811-1; KMJ 10-2-2/Tulasi; WGL 14280-1/KMJ 10-2-2 and N22/Tulasi exhibited significant negative sca effects.

4.5.4.2.12 Harvest index

In moisture stress environment, sca effects for the character varied from -6.03 (N22 / CN 875-135-1-3) to 6.07 (WGL 14280-1 / CR 811-1) (Table 25). Seven crosses including CN 875-135-1-3 / CR 811-1 ; WGL 14280-1 / CR 811-1 and WGL 14280-1 / NLR 30491 displayed positive and significant sca effects for harvest index.

Under favourable environment, sca effects for harvest index ranged from -8.54 (N22 / CN 875-135-1-3) to 22.16 (WGL 14280-1 / CN 875-135-1-3) (Table 26). Six crosses WGL 14280-1 / CN 875-135-1-3 ; Tulasi/ CR 811-1 ; NLR 30491 / Tulasi ; NLR 30491 / CN 875-135-1-3 NLR 30491 / CR 811-1 and CN 875-135-1-3 / CR 811-1 displayed positive and significant sca effects for harvest index.

4.5.4.2.13 Test weight

The range in sca effects for test weight in moisture stress situation was from -2.25 (N22 / CN 875-135-1-3) to 4.32 (WGL 14280-1 / NLR 30491) (Table 25). WGL 14280-1 / NLR 34091 ; NLR 33899 / N22 and N22 / KMJ 10-2-2 were the best specific combiners for the trait.

The sca effects for test weight in favourable situation varied from -2.49 (N22 / CN 875-135-1-3) to 3.16 (NLR 30491 / N22) (Table 26). NLR 30491 / N22 ; KMJ 10-2-2 / CR 811-1 and NLR 33899 / N22 were considered good specific combiners for the character.

4.5.4.2.14 Specific leaf weight

In stress environment, the sca effects varied from -1.60 (NLR 30491 / Tulasi ; N22 / CN 875-135-1-3) to 1.54 (WGL 14280-1 / CN 875-135-1-3) (Table 25). Positive and significant sca effects were noted in seven crosses. WGL 14280-1 / CN 875-135-1-3 ; NLR 33899 / N22 and NLR 30491 / CN 875-135-1-3 had high positive sca effects. Five crosses had significant negative sca effects which included NLR 30491 / Tulasi; N22 / CN 875-135-1-3 and NLR 33899 / CN 875-135-1-3.

In favourable environment, the sca effects for specific leaf weight varied from -1.79 (N22 / Tulasi) to 1.35 (Tulasi / CR 811-1) (Table 26). Four crosses viz. Tulasi / CR 811-1 ; NLR 33899 / CR 811-1 ; CN 875-135-1-3 / CR 811-1 and KMJ 10-2-2 / Tulasi exhibited positive and significant sca effects. Four hybrids including N22 / Tulasi ; WGL 14280-1/N22 ; KMJ 10-2-2 / CR 811-1 and NLR 30491 / Tulasi registered significant negative sca effects for the character.

4.5.4.2.15 Leaf area per plant

The range in sca effects for leaf area per plant under moisture stress situation was from -605.87 (NLR 30491 / CR 811-1) to 458.07 (Tulasi / CR 811-1) (Table 25). The hybrids Tulasi / CR 811-1 ; NLR 30491 / KMJ 10-2-2 and NLR 33899 / CN 875-135-1-3 were good specific combiners for leaf area per plant.

The variation in sca effects for the character under favourable environment was from -775.69 (Tulasi / CN 875-135-1-3) to 4131.52 (KMJ 10-2-2 / Tulasi). Only one cross combination of KMJ 10-2-2 / Tulasi recorded significant and positive sca effect, while none of the hybrids showed significant sca effects.

4.5.4.2.16 Grain yield per plant

In moisture stress situation, sca effects for grain yield per plant ranged from -6.07 (N22 / CN 875-135-1-3) to 8.48 (NLR 33899 / CN 875-135-1-3) (Table 25). Three crosses viz., NLR 33899 / CN 875-135-1-3; Tulasi / CR 811-1 and NLR 30491 / N22 had high positive sca effects.

In favourable environment the sca effects for the grain yield varied from -7.11 (Tulasi / CN 875-135-1-3) to 9.15 (WGL 14280-1 / KMJ 10-2-2) (Table 26). WGL 14280-1 / KMJ 10-2-2 ; CN 875-135-1-3 / CR 811-1 and N22 / Tulasi were good specific combiners for grain yield per plant.

4.5.4.2.17 Leaf rolling (0-9 scale)

Under moisture stress conditions the sca effects for leaf rolling trait ranged from -3.71 (CN 875-135-1-3 / CR 811-1) to 3.22 (KMJ 10-2-2 / CR 811-1). Twelve hybrids including KMJ 10-2-2 / CR 811-1 ; NLR 30491 / CN 875-135-1-3 and N22 / CR 811-1 showed

positive and significant sca effects. Crosses viz., CN 875-135-1-3 / CR 811-1 ; NLR 33899 / CR 811-1 and N22 / Tulasi showed significant negative sca effects.

4.5.4.2.18

The estimates of specific combining ability effects for seedling growth under simulated drought created by different osmotic pressures of polyethylene glycol solutions are presented in Table 27.

4.5.4.2.18.1 Seedling growth at 0.00 bars (control)

The sca effects for shoot length in control conditions showed variation from -1.93 (NLR 33899 / CN 875-135-1-3) to 2.61 (Tulasi / CR 811-1). Thirteen crosses registered significant positive sca effects of which Tulasi / CR 811-1 ; WGL 14280-1 / CN 875-135-1-3 and NLR 33899 / N22 had higher values.

The range in sca effects for root length under control condition was from -1.87 (KMJ 10-2-2 / CR 811-1) to 3.30 (Tulasi / CR 811-1). Significant positive effects were observed in Tulasi / CR 811-1 ; NLR 33899 / Tulasi and N22 / CN 875-135-1-3.

4.5.4.2.18.2 Seedling growth at 3.00 bars

The sca effects for shoot length varied from -1.59 (NLR 30491 / KMJ 10-2-2) to 2.67 (NLR 30491 / CN 825-135-1-3). Eighteen hybrids showed positive and significant sca effects for this character, of which NLR 30491 / CN 875-135-1-3, NLR 30491 / Tulasi and NLR 33899 / N22 were the best specific combiners for the trait. (8)

The variation in sca effects for the character root length at 3.00 bars was noted from -2.00 (NLR 33899 / WGL 14280-1) to 1.93 (KMJ 10-2-2/Tulasi) of which KMJ 10-2-2/Tulasi ; NLR 33899/Tulasi and NLR 30491 / KMJ 10-2-2 had higher values for sca effects.

4.5.4.2.18.3 Seedling growth at 6.00 bars

At 6.00 bars of osmotic pressure, the range in sca effects was from -1.30 (NLR 33899 / KMJ 10-2-2) to 1.19 (NLR 30491 / CN 875-135-1-3). Positive and significant sca effects were observed in 14 crosses. Among them the cross combinations NLR 30491 / CN 875-135-1-3 ; NLR 33899/ CN 875-135-1-3 and WGL 14280-1 / N22 had high positive sca effects.

The variation in sca effects for the character root length was from -0.90 (WGL 14280-1 / CN 875-135-1-3) to 1.41 (WGL 14280-1 / NLR 30491). Among the fifteen crosses which exhibited positive and significant effects for root length at 6.00 bars of osmotic pressure, the

hybrids WGL 14280-1 / NLR 30491 ; NLR 30491 / CN 875-135-1-3 and NLR 33899 / Tulasi exhibited higher values.

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4.5.4.2.18.4 Seedling growth at 10.00 bars

The sca effects ranged from -0.39 (NLR 30491 / CR 811-1) to 1.19 (NLR 33899 / CR 811-1) for shoot length at -10.00 bars of osmotic pressure. Positive and significant sca effects were observed in the hybrids viz., NLR 33899 / CR 811-1 ; WGL 14280-1 / KMJ 10-2-2 and CN 875-135-1-3 / CR 811-1.

The sca effects varied from -1.92 (NLR 33899 / WGL 14280-1) to 2.48 (NLR 33899 / Tulasi). Fifteen hybrids exhibited positive and significant sca effects, which included NLR 33899 / Tulasi ; WGL 14280-1 / NLR 34091 and WGL 14280-1 / KMJ 10-2-2.

Among the eight parents studied, CN 875-135-1-3 expressed positive and significant gca effect for seven traits under moisture stress condition and for 12 traits under favourable environment. This parent is supposed to be good general combiner in both the environments.

The cross combination NLR 33899 / CN 875-135-1-3 was found to be best specific combiner which expressed positive and significant effect for nine traits under moisture stress condition, while Tulasi / CR 811-1

exhibited positive and significant sca effect for 11 traits under favourable environment.

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4.6 Correlation studies between character pairs

Correlation refers to the association of characters i.e., it measures the degree of relationship between two variables which may be independent of any other particular unit (Pearson, 1924).

The computed genotypic and phenotypic correlation coefficients in stress and favourable environments are presented in table 28 and 29 respectively.

4.6.1. Root dry weight

Under moisture stress condition, root dry weight was found to be positively correlated with shoot dry weight (rg:0.652 and rp:0.662) root to shoot ratio (rg: 0.738 and rp:0.629). Leaf area per plant (rg:0.843 and rp 0.379) and grain yield per plant (rg:0.819 and rp 0.631) at genotypic and phenotypic level, while negative correlation was observed with test weight (rg: -0.142 and rp: -0.061) and leaf rolling (rg -0.313 and rp -0.190). In favourable environment this trait showed positive correlation with shoot dry weight (rg:0.652 and rp: 0.662), root to shoot ratio (rg: 0.402 and rp: 0.378), relative water content (rg: 0.470 and rp: 0.333) and grain yield per plant (rg: 0.474 and rp: 0.365) at both genotypic and phenotypic level.

Table 28 : Genotypic and Phenotypic correlation coefficients among different characters in F₁ generation of :
8 x 8 diallel under moisture stress situation

Sl. No			Shoot dry weight	Root to shoot ratio	Relative water content	No. of days to 50% flowering	Plant height	No. of ear bearing tillers per plant	Panicle length	No. of spikelets per panicle	Spikelet fertility	Harvest index	Test weight	Specific weight	Leaf area per plant	Grain yield	Leaf rolling	
			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	Root dry weight	r_p	0.652**	0.638**	0.588** 0.187	-0.016	0.497* 0.141	-0.008	0.352*	0.392*	0.387*	0.395	-0.044	-0.000	0.843*	0.831**	-0.148	
2.	Shoot dry weight	r_y	—	-0.007	0.311	-0.033	0.419* 0.263	-0.008	0.456**	0.343*	0.596**	0.492**	-0.002	0.337	0.638** 0.272	0.348	0.348	-0.309
3.	Root to shoot ratio	r_{zy}	/	—	0.818**	0.024	0.441	-0.002	-0.025	-0.449	-0.092	0.455**	0.449	-0.031	-0.033	0.543**	0.835**	-0.093
4.	Relative water content	r_w			—	0.189	0.559** 0.292	-0.0157	0.112	0.368*	0.401*	0.327	0.421	0.206	0.084	0.567** 0.162	0.495**	-0.143
5.	No. of days to 50% flowering	r_f				—	-0.061	-0.033	-0.349*	-0.063	-0.042	-0.128	-0.543**	-0.016	-0.006	0.395*	-0.102	0.191
6.	Plant height	r_h					—	-0.749**	0.525**	0.390*	0.365*	0.328	-0.133	-0.002	-0.046	0.341	0.345**	-0.084
7.	No. of ear tillers per plant	r_t						—	0.035	-0.513**	-0.542**	-0.041	0.152	-0.256	-0.133	-0.092	0.193	0.094
8.	Panicle length	r_l							—	0.518**	0.648**	0.574*	0.385	0.993**	0.173	0.529**	0.462**	-0.468**
9.	No. of spike-panicle	r_s								—	0.929**	0.816**	0.626**	0.141	0.768**	0.479**	0.743	-0.366*
10.	No. of filled grains per panicle	r_g									—	0.595**	0.538*	0.273	0.581**	0.493**	0.743	-0.464*
11.	Spikelet fertility	r_{fg}										—	0.595**	0.705*	0.559**	0.741	0.536**	-0.546**
12.	Harvest index	r_i											—	0.203	0.374	0.485	0.326*	-0.342
13.	Test weight	r_w												—	0.009	0.471	0.355*	-0.457**
14.	Specific leaf weight	r_{sw}													—	0.029	0.602	-0.323
15.	Leaf area per plant	r_a														—	0.793**	-0.076
16.	Grain yield	r_y															—	-0.188
17.	Leaf rolling	r_r																—

* Significant at 5% level

** Significant at 1% level

Table 29 : Genotypic and Phenotypic correlation coefficients among different characters in F₁ generation of a 8 x 8 diallel under normal situation

Sl. No			Shoot dry weight	Root to shoot ratio	Relative water content	Plant height	No. of ear bearing tillers per plant	Panicle length	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility (%)	Harvest index	Test weight	Specific leaf weight	Leaf area per plant	Grain yield per plant
			2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Root dry weight	r_{12}	0.861** 0.805**	0.402* 0.378*	0.470** 0.333*	0.022 0.039	0.362* 0.245	0.290 0.243	-0.026 0.048	0.255 0.162	0.303 0.193	0.108 0.031	0.164 0.159	0.303 0.175	0.289 -0.106	0.474** 0.365*
2	Shoot dry weight	r_{21}	—	-0.140 -0.137	0.306 0.196	-0.125 -0.45	0.142 0.312	0.100 0.132	-0.490** -0.104	-0.099 -0.005	0.352* 0.204	0.025 0.007	-0.148 -0.079	0.059 0.052	0.463** 0.116	0.361* 0.319
3	Root to shoot ratio	r_{31}	—	—	0.244 0.239	0.342* 0.187	0.320* 0.262	0.350* 0.186	0.771** 0.222	0.605** 0.223	-0.126 -0.032	0.089 -0.016	0.499** 0.338*	0.515** 0.263	-0.341 -0.167	0.221 0.142
4	Relative water content	r_{41}	—	—	—	-0.238 -0.153	0.394* 0.234	0.107 0.114	0.299 0.116	0.335* 0.199	0.130 0.171	-0.365* 0.241	0.104 0.102	0.152 0.196	-0.261 0.014	0.205 0.236
5	Plant height	r_{51}	—	—	—	—	-0.288 -0.195	0.083 0.102	0.518** 0.373*	0.332* 0.327*	-0.203 -0.131	0.034 0.038	0.078 0.088	-0.215 -0.158	0.109 0.002	-0.082 -0.039
6	No. of ear bearing tillers per plant	r_{61}	—	—	—	—	—	0.322 0.191	0.254 0.039	0.375* 0.165	0.439** 0.258	-0.019 -0.026	0.516** 0.384*	0.538** 0.199	0.893** 0.036	0.349* 0.271
7	Panicle length	r_{71}	—	—	—	—	—	—	0.496** 0.323	0.465** 0.406*	0.123 0.210	0.380* 0.221	0.204 0.131	0.261 0.163	-0.474** 0.089	0.124 0.195
8	No. of spikelets per panicle	r_{81}	—	—	—	—	—	—	—	0.771** 0.728**	0.032 -0.073	-0.061 0.011	0.291 0.211	0.196 0.114	0.151 0.044	0.387* 0.220
9	No. of filled grains per panicle	r_{91}	—	—	—	—	—	—	—	—	0.658** 0.501**	0.398* 0.398*	0.464** 0.383*	0.611** 0.363**	0.219 0.064	0.615** 0.468**
10	Spikelet fertility (%)	r_{101}	—	—	—	—	—	—	—	—	—	0.522** 0.429**	0.321 0.207	0.639** 0.443**	0.667** 0.064	0.592** 0.510**
11	Harvest index	r_{111}	—	—	—	—	—	—	—	—	—	—	0.266 0.225	0.225 0.197	-0.137 -0.002	0.267 0.291
12	Test weight	r_{121}	—	—	—	—	—	—	—	—	—	—	—	0.398* 0.240	-0.482** -0.092	0.203 0.169
13	Specific leaf weight	r_{131}	—	—	—	—	—	—	—	—	—	—	—	—	0.729** 0.067	0.517** 0.366*
14	Leaf area per plant	r_{141}	—	—	—	—	—	—	—	—	—	—	—	—	—	0.811** 0.187
15	Grain yield per plant	r_{151}	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Significant at 5% level

** Significant at 1% level

4.6.2 Shoot dry weight

The character shoot dry weight under moisture stress environment had positive correlation with plant height (rg: 0.419), panicle length (rg: 0.456), number of spikelets per panicle (rg: 0.828 and rp:0.343), number of filled grains per panicle (rg: 0.596 and rp:0.376) spikelet fertility (rg:0.482) and leaf area per plant (rg: 0.638), while negative correlation was observed with root to shoot ratio (rg -0.007 and rp -0.107), number of days to 50% flowering (rg -0.037 and rp -0.048), number of ear bearing tillers per plant (rg: -0.056 and -0.003), test weight (rg: -0.309 and rp:-0.082) and leaf rolling (rg: -0.300 and rp: -0.151).

In favourable environment, shoot dry weight was positively correlated with spikelet fertility (rg:0.352), leaf area per plant (rg:0.463) and grain yield per plant (rg:0.361). Negative correlation was observed with number of spikelets per panicle (rg: -0.490).

4.6.3 Root to shoot ratio

Root to shoot ratio had positive correlation with root dry weight (rg:0.738 rp: 0.629) relative water content (rg: 0.818), spikelet fertility (rg:0.449) leaf area per plant (rg:0.543) and grain yield per plant (rg:0.0837 rp:0.599) under moisture stress environment. This trait had negative but non significant correlation with number of ear bearing tillers per plant, number of spikelets per panicle, test weight and specific

leaf weight. Under favourable environment, the character showed positive association with root dry weight (rg:0.470 and rp:0.333) plant height (rg:0.342) number of ear bearing tillers per plant (rg:0.329), panicle length (rg:0.359) number of spikelets per panicle (rg:0.771), number of filled grains per panicle (rg:0.605) test weight (rg:0.499 and rp:0.338) and specific leaf weight (rg:0.515). Shoot dry weight, spikelet fertility and leaf area per plant exhibited negative but non-significant relation with this trait.

4.6.4. Relative water content

Under stress condition, relative water content was positively correlated with root dry weight (rg:0.589) plant height (rg:0.559) number of spikelets per panicle (rg:0.368) number of filled grains per panicle (rg:0.403), spikelet fertility (rg:0.937), leaf area per plant (rg:0.567) and grain yield per plant (rg:0.495). Negative correlation had with number of ear bearing tillers per plant (rg:-0.890).

Under favourable conditions, relative water content had positive correlation with root dry weight (rg:0.470 and rp: 0.333) number of ear bearing tillers per plant (rg:0.394) and number of filled grains per panicle (rg:0.335), while this trait negatively correlated with harvest index (rg:-0.365)

4.6.5. Number of days to 50% flowering

Under moisture stress condition number of days to 50% flowering had positive association with leaf area per plant ($r_g : 0.395$), while negatively correlated with panicle length ($r_g : -0.349$), harvest index ($r_g : -0.563$ and $r_p : -0.473$) and test weight ($r_g : -0.511$).

4.6.6. Plant height

Plant height was found to be positively associated with panicle length ($r_g:0.527$ and $r_p:0.355$), number of spikelets per panicle ($r_g:0.390$) spikelet fertility ($r_g:0.338$) and grain yield per plant ($r_g:0.345$) under moisture stress situation. However the association of this trait with number of ear bearing tillers per plant ($r_g:-0.740$) was found to be negative.

Under favourable conditions plant height had positive and significant correlation with root to shoot ratio ($r_g:0.342$), number of spikelets per panicle ($r_g:0.518$ and $r_p:0.373$) and number of filled grains per panicle ($r_g:0.322$ and $r_p: 0.327$).

4.6.7 Number of ear bearing tillers per plant

Under moisture stress situation, panicle length was negatively associated with relative water content ($r_g:-0.890$), plant height ($r_g:-0.740$), number of spikelets per panicle ($r_g:-0.513$) number of filled grains per

panicle (rg:-0.542) and spikelet fertility (rg:-0.862). The traits panicle length and grain yield per plant had positive association.

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Under favourable condition, number of ear bearing tillers per plant had positive association with root weight (rg:0.362), root to shoot ratio (rg:0.329), relative water content (rg: 0.394) number of filled grains per panicle (rg: 0.375), spikelet fertility (rg: 0.439), test weight (rg:0.516 and rp 0.384) specific leaf weight (rg:0.538) leaf area per plant (rg:0.893) and grain yield per plant (rg:0.349). However, the association of this trait with shoot dry weight and plant height were negative but non-significant.

4.6.8. Panicle length

Studies for this character in moisture stress situation indicate positive correlation with root dry weight (rg:0.358), shoot dry weight (rg:0.456), panicle length (rg:0.516), number of filled grains per panicle (rg:0.648 and rp: 0.420) spikelet fertility (rg:0.570) harvest index (rg:0.398), panicle length (rg:0.993), leaf area per plant (rg:0.529) and grain yield per plant (rg:0.469). However this trait had negative correlation with leaf rolling (rg:-0.468).

Under normal environmental condition, the panicle length exhibited positive correlation with root to shoot ratio (rg:0.359), number

of spikelets per panicle (rg:0.496) number of filled grains per panicle (rg:0.465 and rp:0.406) and harvest index (rg:0.380). While, negative correlation was observed with leaf area per plant (rg:-0.474).

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4.6.9. Number of spikelets per panicle

Number of spikelets per panicle under moisture stress situation was positively correlated with shoot dry weight (rg:0.828 and rp:0.343), relative water content (rg:0.368), plant height (rg: 0.390) panicle length (rg:0.516) number of filled grains per panicle (rg:0.929 and rp:0.620), spikelet fertility (rg:0.812), harvest index (rg:0.626) specific leaf weight (rg: 0.768) and leaf area per plant (rg:0.479). Significant and negative correlation had with number of ear bearing tillers per plant (rg:-0.513) and leaf rolling (rg:-0.386).

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Number of spikelets per panicle under favourable environment, had positive correlation with root to shoot ratio (rg:0.771), plant height (rg:0.518 and rp:0.373) panicle length (rg:0.496) number of filled grains per panicle (rg:0.771 and rp:0.728) and grain yield per plant (rg:0.387). However negative association was observed with shoot dry weight (rg:-0.490) and grain yield per plant (rg:0.387).

4.6.10 Number of filled grains per panicle

Under moisture stress environment, number of filled grains per panicle, showed positive association with root dry weight (rg:0.337), shoot dry weight (rg:0.596 rp:0.376), relative water content (rg:0.403) plant height (rg:0.384), panicle length (rg:0.648 rp:0.420), number of spikelets per panicle (rg:0.929 rp:0.620), spikelet fertility (rg:0.912 rp:0.575), harvest index (rg:0.539 rp:0.358), specific leaf weight (rg:0.581) and leaf area per plant (rg:0.463). However, negative correlation was observed with number of ear bearing tillers per plant (rg:0.542) and leaf rolling (rg:-0.464).

Number of filled grains per panicle under favourable environment was positively correlated with root to shoot ratio (rg:0.605), panicle length (rg:0.465 rp:0.406), number of spikelets per panicle (rg:0.771 rp:0.728), spikelet fertility (rg:0.658 rp:0.501), harvest index (rg:0.398 rp:0.398) test weight (rg:0.464 rp:0.383), specific leaf weight (rg:0.611 rp:0.363) and grain yield per plant (rg:0.615 rp:0.468). None of the characters showed significant negative association with this trait.

4.6.11 Spikelet fertility per cent

The trait spikelet fertility percent exhibited positive correlation with harvest index (rg:0.768 and rp:0.343) number of filled grains per panicle (rg:0.912 rp:0.575) and grain yield per plant (rg:0.559 rp:0.306)

both at genotypic and phenotypic level. However negative association was noticed with number of days to 50% flowering under moisture stress situation. 190

Under normal environment spikelet fertility percent expressed positive association with number of filled grains per panicle (rg:0.658 rp:0.501), harvest index (rg:0.522 rp:0.428), specific leaf weight (rg:0.639 rp 0.443) and grain yield per plant (rg:0.592 rp: 0.510) at both genotypic and phenotypic level.

4.6.12 Harvest index

Under moisture stress condition, harvest index had positive correlation with number of filled grains per panicle (rg:0.559 rp 0.358), spikelet fertility percent (rg:0.768 rp:0.348) and grain yield per plant (rg:0.346 rp:0.357). However, negative association was observed with number of days to 50% flowering (rg:-0.563 rp: -0.473) and leaf rolling (rg:-0.440 rp:-0.332).

The character harvest index under favourable condition was positively and significantly associated with number of filled grains per panicle (rg: 0.398 rp: 0.398) and spikelet fertility percent (rg:0.522 rp: 0.429). Relative water content had significant and negative association (rg:-0.365) at genotypic level.

4.6.13 Test Weight

Test weight had positive and significant correlation in moisture stress situation with panicle length (rg:0.993), spikelet fertility percent (rg:0.791) and grain yield per plant at genotypic level. Negative and significant association at genotypic level was noticed with number of days to 50% flowering (rg:-0.511).

Under favourable environment, test weight had positive correlation at both genotypic and phenotypic levels with root to shoot ratio (rg:0.499 rp:0.338), number of ear bearing tillers per plant (rg:0.516 rp:0.384) and number of filled grains per panicle (rg:0.464 rp: 0.383) at both genotypic and phenotypic levels.

4.6.14 Specific leaf weight

The character specific leaf weight under moisture stress environment showed positive correlation with number of spikelets per panicle (rg:0.768), number of filled grains per panicle (rg:0.581) and harvest index (rg:0.387) at genotypic level only.

Under favourable environment, number of filled grains per panicle (rg:0.611 rp:0.383) spikelet fertility percent (rg:0.639 rp:0.443) had positive association both at genotypic and phenotypic levels.

4.6.15 Leaf area per plant

In moisture stress condition, leaf area per plant had positive association with root dry weight (rg:0.843 rp:0.379) shoot dry weight (rg:0.638) root to shoot ratio (rg:0.543) relative water content (rg:0.567) number of days to 50% flowering (rg:0.395) panicle length (rg:0.529) number of spikelets per panicle (0.479), number of filled grains per panicle (rg:0.463) spikelet fertility percent (rg:0.531) and grain yield per plant (rg:0.707 and rp:0.333). Negative association was observed with the trait leaf rolling.

Under favourable environment studies showed that leaf area per plant was positively correlated with shoot dry weight (rg:0.463), number of ear bearing tillers per plant (rg:0.893), spikelet fertility percent (rg:0.667), specific leaf weight (rg:0.729) and grain yield per plant (rg:0.811). This trait showed negative correlation with panicle length (rg:-0.474) and test weight (rg:-0.482).

4.6.16 Grain yield per plant

Grain yield per plant under moisture stress condition was positively associated with root dry weight (rg:0.810 rp:0.631), root to shoot ratio (rg:0.837 rp:0.599), relative water content (rg:0.495), plant height (rg:0.345), panicle length (0.469), spikelet fertility (rg:0.559 rp:0.306), harvest index (rg:0.346 rp:0.357) and test weight (rg:0.707

rp:0.333). However the traits number of days to 50% flowering and leaf rolling had negative association.

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In favourable environment, grain yield per plant was positively correlated with root dry weight (rg:0.474 rp:0.365), shoot dry weight (rg:0.361), number of ear bearing tillers per plant (rg:0.349), number of spikelets per panicle (rg:0.387), number of filled grains per panicle (rg:0.615 rp:0.468), spikelet fertility percent (rg:0.592 rp:0.510), specific leaf weight (rg:0.517 rp:0.366) and leaf area per plant (rg:0.811).

4.6.17 Leaf rolling

The character leaf rolling under moisture stress, though exhibited nonsignificant positive correlation with number of days to 50% flowering, it was negatively associated with panicle length (rg:-0.468), number of spikelets per panicle (rg:-0.386), number of filled grains per panicle (rg:-0.464), spikelet fertility percent (rg:-0.646), harvest index (rg:-0.440 and rp:-0.332) and test weight (rg:-0.457).

Under moisture stress condition the correlation studies revealed that the important trait grain yield per plant was strongly associated with root dry weight, root to shoot ratio, relative water content, plant height, panicle length, spikelet fertility, harvest index, test weight and leaf area per plant. Hence, these traits may be considered as selection

indices to isolate superior genotypes. However under favourable condition, leaf area per plant, specific leaf weight, ear bearing tillers per plant, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility percent, root dry weight and shoot dry weight were positively correlated with grain yield per plant. Therefore, these characters may be considered for isolation of genotypes.

4.7 Path coefficient analysis

Correlation coefficients do not project complete picture especially when the casual factors are inter-related. The correlation coefficients between grain yield and each of its component characters are partitioned into the corresponding direct and indirect effects through path coefficient analysis. The path coefficient analysis of different characters on yield, based on phenotypic and genotypic correlations in crosses both under moisture stress and normal environments were studied and presented in Table 30 and 31.

4.7.1 Root dry weight

Under moisture stress environment root dry weight recorded high positive direct effect (G: 1.546 and P: 0.991) on grain yield per plant along with positive indirect effects through plant height (G: 0.197 and P: 0.052) harvest index (G: 0.079 and P: 0.054) and leaf area per plant which indicated positive correlation (G: 0.240 and P: 0.041). The negative

Table 30 : Genotypic and Phenotypic (p) path coefficients in F₁ generation of a 8 x 8 diallel under moisture stress situation

Sl. No	Characters	Root dry weight	Shoot dry weight	Root to shoot ratio	Relative water content	No. of Days to 50% flowering	Plant height	No. of bearing tillers per plant	Panicle length	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility	Harvest index	Test weight	Specific leaf weight	Leaf area per plant	Leaf rolling	Correlation with grain yield
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Root dry weight	G 1.546 0.991	P -0.705 -0.439	-0.341 -0.093	-0.104 0.004	0.003 -0.001	0.197 0.052	-0.002 0.001	-0.041 -0.006	-0.075 0.028	0.018 -0.021	-0.021 0.028	0.079 0.054	-0.003 -0.001	-0.037 0.000	0.241 0.041	-0.034 -0.009	0.819** 0.631**
2	Shoot dry weight	GP 1.008 0.656	-1.081 -0.663	0.002 0.016	-0.036 0.002	0.006 0.004	0.302 0.057	-0.004 -0.001	-0.052 -0.005	-0.162 0.042	0.032 -0.029	-0.017 0.019	0.087 0.042	-0.007 -0.001	0.121 -0.002	0.181 0.002	-0.032 -0.007	0.248 0.161
3	Root to shoot ratio	G 1.141 0.623	P 0.008 0.071	-0.327 -0.147	-0.145 0.003	-0.004 -0.007	0.068 0.004	-0.005 -0.006	0.005 0.000	0.047 -0.005	-0.005 0.002	-0.016 0.018	0.040 0.021	-0.003 0.000	-0.112 0.001	0.154 0.027	-0.010 -0.004	0.837** 0.599**
4	Relative water content	GP 0.911 0.186	-0.217 -0.217	-0.267 -0.021	-0.177 0.022	-0.030 -0.007	0.270 0.063	-0.111 -0.025	-0.016 -0.002	-0.072 0.007	0.021 -0.008	-0.033 0.016	0.034 0.011	0.005 0.000	0.035 -0.001	0.161 0.016	-0.019 -0.002	0.495** 0.180
5	No. of days to 50% flowering	G -0.025 0.07	P 0.040 0.032	-0.008 -0.011	-0.032 0.002	-0.168 -0.093	-0.020 -0.014	-0.016 -0.006	0.040 0.005	0.013 -0.004	-0.002 0.002	0.007 -0.007	-0.151 -0.103	-0.012 -0.002	-0.007 0.000	0.112 0.019	0.021 0.008	-0.207 -0.165
6	Plant height	GP 0.630 0.238	-0.452 -0.175	-0.046 -0.002	-0.099 0.006	0.007 0.006	0.483 0.217	-0.019 0.080	-0.061 -0.008	-0.076 0.022	0.020 -0.017	-0.012 0.015	-0.049 -0.028	-0.003 0.000	-0.019 0.001	0.091 0.025	-0.010 -0.003	0.345** 0.278
7	No. of ear bearing tillers per plant	G -0.045 0.006	P 0.060 0.002	0.020 0.005	0.246 -0.003	0.034 0.003	-0.358 -0.026	0.080 0.161	-0.004 -0.001	0.100 -0.019	-0.029 0.008	0.030 0.004	0.045 -0.007	-0.006 0.000	-0.054 0.002	-0.025 -0.002	0.011 0.008	0.108 0.134
8	Panicle length	GP 0.553 0.250	-0.493 -0.161	0.015 -0.003	-0.024 0.002	0.059 0.023	0.255 0.077	0.003 0.009	-0.115 -0.022	-0.101 0.033	0.034 -0.032	-0.020 0.031	0.107 0.061	0.025 0.001	0.072 0.000	0.150 0.014	-0.051 -0.014	0.469** 0.269
9	No. of spikelets per panicle	GP 0.591 0.225	-0.894 -0.228	0.079 0.006	-0.065 0.001	0.011 0.003	0.188 0.038	-0.041 -0.025	-0.059 -0.006	-0.196 0.123	0.049 -0.047	-0.029 0.011	0.168 0.052	0.003 0.000	0.314 -0.003	0.136 0.018	-0.042 -0.011	0.213 0.158
10	No. of filled grains per panicle	GP 0.521 0.367	-0.644 -0.249	0.033 0.004	-0.071 0.002	0.008 0.002	0.185 0.050	-0.043 -0.016	-0.074 -0.009	-0.182 0.076	0.053 -0.0076	-0.036 0.059	0.144 0.078	0.006 0.000	-0.004 0.229	0.014 0.151	-0.014 -0.070	0.218 0.183
11	Spikelet fertility	G 0.938 0.369	P -0.521 -0.125	-0.147 -0.025	-0.166 0.003	0.033 0.006	0.163 0.032	-0.069 0.007	-0.066 -0.007	-0.159 0.013	0.054 -0.044	-0.035 0.183	0.206 0.074	0.018 0.001	0.229 -0.003	0.014 0.055	-0.013 -0.048	0.559** 0.306*
12	Harvest index	GP 0.457 0.248	-0.349 -0.128	-0.049 -0.014	-0.023 0.001	0.094 0.044	-0.088 -0.028	0.014 -0.005	-0.046 -0.006	-0.121 0.025	0.039 0.015	-0.027 0.035	0.268 0.217	0.023 0.002	0.158 -0.003	0.055 0.007	-0.048 -0.015	0.346* 0.337*
13	Test weight	GP 0.220 -0.061	0.334 0.054	0.040 0.005	-0.036 0.000	0.086 0.016	-0.063 0.001	-0.020 0.000	-0.126 -0.003	-0.023 -0.003	0.015 0.002	-0.028 0.006	0.272 0.045	0.023 0.010	0.082 0.000	0.020 0.013	-0.049 -0.007	0.305* 0.079
14	Specific leaf weight	GP 0.139 0.010	-0.321 -0.086	0.089 0.009	-0.015 0.001	0.003 0.001	-0.022 -0.014	0.000 -0.021	-0.020 -0.001	-0.150 0.027	0.031 -0.022	-0.020 0.026	0.104 0.046	0.005 0.000	0.449 -0.013	0.079 0.007	-0.024 -0.023	-0.002 -0.032
15	Leaf area per plant	GP 1.303 0.376	-0.689 -0.089	-0.177 -0.037	-0.100 0.003	-0.066 -0.017	0.154 0.051	-0.007 -0.002	-0.061 -0.003	-0.084 0.020	0.025 -0.010	-0.019 0.013	0.052 0.014	0.002 0.001	0.114 -0.001	0.248 0.108	-0.013 -0.003	0.707** 0.333*
16	Leaf rolling	GP -0.484 -0.188	0.324 0.100	0.030 0.011	0.031 -0.001	-0.032 -0.016	-0.045 -0.014	0.008 -0.001	0.054 0.007	0.075 -0.030	-0.025 0.024	0.023 -0.029	-0.118 -0.072	-0.010 -0.001	-0.092 0.001	-0.035 -0.008	0.108 0.046	-0.188 -0.170

Residual effect (P) : 0.330 (Bold are direct effects)

(G) : -0.021

Table 31 : Genotypic (G) and Phenotypic (P) path coefficients in F₁ generation of a 3 x 8 diallel under normal situation

Sl. No	Char-acters	Root dry weight	Shoot dry weight	Root to shoot ratio	Relative water content	Plant height	No. of ear bearing tillers per plant	Panicle length	No. of spikelets per panicle	No. of filled grains per panicle	Spikelet fertility	Harvest index	Test weight	Specific leaf weight	Leaf area per plant	Correlation with yield
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Root dry weight	G -12.885 P -0.275	9.979 0.409	3.423 0.106	-0.315 0.032	-0.025 -0.002	0.780 0.037	-0.251 -0.028	0.008 0.012	0.390 0.006	0.706 0.063	-0.009 0.006	-0.219 -0.012	-0.954 0.010	-0.155 -0.001	0.474** 0.365*
2	Shoot dry weight	G -11.092 P -0.222	11.592 0.509	-0.884 -0.044	-0.205 0.019	0.145 0.002	0.306 0.004	-0.087 -0.015	0.155 -0.027	-0.152 -0.031	0.822 0.067	-0.002 0.001	0.198 0.006	-0.186 0.003	-0.248 0.015	0.361* 0.319
3	Root to shoot ratio	G -5.187 P -0.104	-1.205 -0.080	8.504 0.281	-0.163 0.023	-0.397 -0.011	0.709 0.039	-0.312 -0.021	-0.244 0.059	0.924 0.068	-0.293 -0.017	-0.007 -0.003	-0.667 -0.025	-1.620 0.016	0.182 -0.021	0.221 0.142
4	Relative water content	G -6.052 P -0.091	3.548 0.099	2.074 0.067	-0.671 0.097	0.277 0.009	0.850 0.035	-0.093 -0.013	-0.095 0.030	0.512 0.007	0.303 0.056	0.029 -0.048	-0.140 -0.007	-0.479 0.012	0.140 -0.058	0.205 0.256
5	Plant height	G -0.2811 P -0.011	-14.53 -0.022	2.909 0.052	0.160 -0.015	-1.161 -0.062	-0.555 -0.029	-0.072 -0.012	-0.164 0.099	0.503 0.012	-0.480 -0.043	-0.002 0.007	-0.105 -0.006	0.677 -0.009	-0.058 0.001	-0.082 -0.039
6	No. of ear bearing tillers per plant	G -4.666 P -0.067	1.645 0.016	2.800 0.074	-0.264 0.022	0.299 0.012	2.155 0.152	-0.279 -0.022	-0.080 0.010	0.512 0.006	1.025 0.085	0.001 -0.005	-0.690 -0.028	-1.691 0.012	-0.418 0.004	0.349* 0.271
7	Panicle length	G -3.727 P -0.067	1.164 0.067	3.060 0.052	-0.072 0.011	-0.096 -0.006	0.694 0.029	-0.868 -0.118	-0.157 0.085	0.711 0.015	0.287 -0.069	-0.031 0.044	-0.272 -0.009	-0.822 0.010	0.253 0.011	0.124 0.195

Table 31 Contd....

8	No. of spikelets per panicle	G P	0.343 -0.013	-0.5680 -0.053	6.557 0.062	-0.201 0.011	-0.601 -0.023	0.547 0.005	-0.431 -0.038	-0.317 0.265	1.177 0.327	0.075 -0.024	0.005 0.002	-0.389 -0.015	-0.615 0.007	-0.081 0.005	0.387* 0.220
9	No. of filled grains per panicle	G P	-3.290 -0.044	-1.158 -0.002	5.147 0.062	-0.225 0.019	-0.023 -0.386	0.005 0.808	-0.038 -0.404	-0.244 0.193	1.527 0.337	1.536 0.165	-0.032 0.080	-0.621 -0.028	-1.922 0.022	-0.117 0.008	0.615** 0.468**
10	Spikelet fertility	G P	-3.902 -0.053	4.083 0.104	-1.609 -0.014	-0.087 0.016	0.239 0.008	0.947 0.039	-0.107 -0.024	-0.010 -0.019	1.005 0.018	2.333 0.328	-0.042 0.086	-0.430 -0.015	-2.009 0.027	-0.357 0.008	0.592** 0.510**
11	Harvest index	G P	-1.393 -0.008	0.249 0.004	0.759 -0.004	0.245 -0.023	-0.039 -0.002	-0.042 -0.004	-0.330 -0.026	0.019 0.003	0.608 0.044	1.218 0.141	-0.082 0.202	-0.355 -0.016	-0.708 0.012	0.073 -0.001	0.0267 0.291
12	Test weight	G P	-2.110 -0.004	-1.723 -0.040	4.247 0.095	-0.070 0.010	-0.091 -0.005	1.112 0.058	-0.177 -0.015	-0.092 0.056	0.709 0.014	0.750 0.068	-0.021 0.045	-1.337 -0.075	-1.251 0.014	0.258 -0.012	0.203 0.169
13	Specific leaf weight	G P	-3.913 -0.048	0.685 0.026	4.385 0.074	0.102 0.019	0.250 0.009	1.159 0.030	-0.227 -0.019	-0.062 0.030	0.934 0.013	1.491 0.145	-0.018 0.039	-0.532 -0.018	-3.148 0.061	-0.390 0.008	0.517** 0.366
14	Leaf area per plant	G P	-3.722 0.002	5.375 0.059	-2.899 -0.047	0.175 0.001	-0.126 -0.001	1.925 0.005	0.411 -0.010	-0.048 0.001	0.334 0.032	1.557 0.021	0.011 -0.001	0.644 0.006	-2.291 0.004	-0.536 0.130	0.811** 0.187

Residual effect (P) : (G) :

(Bold are direct effects)

indirect effects were expressed through shoot dry weight (G:-0.705 and P:-0.439) root to shoot ratio (G:-0.241 and P: -0.093), panicle length (G: -0.041 and P:-0.006), test weight (G: -0.003 and P: -0.001) and leaf rolling (G: -0.034 and P: -0.009) at both phenotypic and genotypic level.

The direction manifested by this trait was negative (G: -12.885 and P: -0.275) under favourable environment. The indirect effects through plant height (G: -0.025 and P: -0.002), panicle length (G:-0.251 and P: -0.028) test weight (G: -0.219 and P:-0.012) and leaf area per plant (G: -0.155 and P: -0.001) were negative. While indirect contribution through shoot dry weight (G:9.979 and P:0.409), root to shoot ratio (G:3.423 and P:0.106), number of ear bearing tillers per plant (G: 0.780 and P: 0.037), number of spikelets per panicle (G:0.008 and P:0.012), number of filled grains per panicle (G:0.390 and P: 0.006) and spikelet fertility (G:0.706 and P:0.063) were positive thus indicating positive correlation.

4.7.2 Shoot dry weight

The character shoot dry weight exhibited a negative direct effect (G: -0.081 and P: -0.663) on grain yield per plant in moisture stress condition and also negative indirect effects through number of ear bearing tillers per plant (G: -0.004 and : -0.001) panicle length (G: -0.052 and P: -0.005) test weight (G: -0.007 and P: -0.001 and leaf rolling (G: -0.032

and P: -0.007). The positive indirect effects were observed through root dry weight (G:1.008 and P: 0.656), root to shoot ratio (G: 0.002 and P: 0.016) number of days to 50% flowering (G:0.202 and P: 0.042) and leaf area per plant (G: 0.181 and P: 0.029).

The character shoot dry weight expressed a positive direct effect (G:11.592 and P: 0.509) on grain yield per plant in favourable environment and also positive indirect effects through shoot dry weight (G: 0.145 and P: 0.509) number of ear bearing tillers per plant (G:0.306 and P: 0.004), spikelet fertility (G:0.822 and P: 0.067) and test weight (G:0.198 and P: 0.006). The negative indirect effects were found through root dry weight (G:-11.092 and P: -0.222) root to shoot ratio (G: -0.884 and P:-0.044) panicle length (G: -0.087 and P: -0.015) and number of filled grains per panicle (G: -0.152 and P: -0.001).

4.7.3 Root to shoot ratio

Root to shoot ratio had a negative but low direct effect (G: -0.327 and P: -0.147) on grain yield per plant at both genotypic and phenotypic level under moisture stress environment, while positive indirect effects were expressed through root dry weight (G: 1.141 and P: 0.623), shoot dry weight (G: 0.008 and P: 0.071), plant height (G:0.068 and P: 0.004), harvest index (G:0.042 and P: 0.040) and leaf area per plant (G:0.029 and P: 0.154). The negative indirect effects were noticed through number

of days to 50% flowering (G: -0.004 and P: -0.007) number of ear bearing tillers per plant (G: -0.005 and P: -0.006) and leaf rolling (G: -0.010 and P: -0.004). The direct effect of this character was high and positive (G: 8.504 and P: 0.281) on grain yield per plant in favourable environment. The indirect effects through number of ear bearing tillers per plant (G: 0.709 and P: 0.039) and number of filled grains per panicle (G: 0.924 and P: 0.008) were positive and high at genotypic level and low at phenotypic level. However indirect and negative effects were observed through root dry weight (G: 5.187 and P: -0.104), shoot dry weight (G: -1.205 and P: -0.080), plant height (G: -0.397 and P: -0.011), panicle length (G: -0.312 and P: -0.021), harvest index (G: -0.007 and P: -0.003) and test weight (G: -0.667 and P: -0.025).

4.7.4 Relative water content

The direct contribution of this trait was low and positive at phenotypic level and negative at genotypic level (P: 0.022 and G: -0.177) under moisture stress environment. It had positive indirect effects through relative water content (G: 0.911 and P: 0.186) plant height (G: 0.270 and P: 0.063) harvest index (G: 0.034 and P: 0.011) and leaf area per plant (G: 0.161 and P: 0.016) thus resulting in positive correlation, while indirect but low negative effects were found through shoot dry weight (G: -0.217 and P: -0.074) root to shoot ratio (G: -0.267 and P: -0.021), number of days to 50% flowering (G: -0.030 and P: -0.007),

number of ear bearing tillers per plant (G: -0.111 and P: -0.025), panicle length (G:-0.016 and P: -0.002) and leaf rolling (G: -0.019 and P: -0.002).

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Under favourable environment the direct effect of relative water content was high and negative at genotypic level but low and positive at phenotypic level (G: -0.671 and P: 0.097). The indirect effects through root dry weight (G: -6.052 and P: -0.091), panicle length (G: -0.013 and P: -0.072), harvest index (G: -0.048 and P: -0.002) and test weight (G: -0.007 and P: -0.105) were negative, while indirect positive effects were noticed through shoot dry weight (G: 3.548 and P: 0.099), root to shoot ratio (G:2.074 and P: 0.067) plant height (G: 0.277 and P: 0.009), number of ear bearing tillers per plant (G: 0.850 and P: 0.035) number of filled grains per panicle (G: 0.512 and P: 0.007), spikelet fertility (G: 0.303 and P:0.056) and leaf area per plant (G:0.140 and P: 0.001).

4.7.5 Number of days to 50% flowering

This trait in moisture stress environment exhibited negative but low direct effect (G: -0.168 and P: -0.093) on grain yield per plant. Thus, resulting negative correlation. The indirect and negative effects were manifested through root to shoot ratio (G: -0.008 and P: -0.011), plant height (G: -0.020 and P: -0.014), number of ear bearing tillers per plant (G: -0.016 and P: -0.006), harvest index (G: -0.151 and P: -0.103) and test weight (G: -0.012 and P: -0.002). The indirect effects through shoot

dry weight (G: 0.040 and P: 0.032) panicle length (G:0.040 and P: 0.005),
leaf area per plant (G: 0.112 and P: 0.019) and leaf rolling (G: 0.021 and
P: 0.008) were negative but low.

4.7.6 Plant height

The direct effect of this trait on grain yield was high and positive (G: 0.483 and P: 0.217) both at genotypic and phenotypic level in moisture stress environment. The indirect effects through root dry weight (G: 0.630 and P: 0.238) number of days to 50% flowering (G:0.007 and P: 0.006) and leaf area per plant (G: 0.091 and P: 0.025) were low and positive. However negative indirect effects were observed through shoot dry weight (G: -0.452 and P: -0.0175), root to shoot ratio (G: -0.046 and P: -0.002) number of ear bearing tillers per plant (G: -0.059 and P: -0.019), panicle length (G: -0.061 and P: -0.008), harvest index (G: -0.049 and P: -0.028) leaf rolling (G: -0.010 and -0.003). Under favourable environment plant height exhibited direct negative effect on grain yield per plant (G: -1.161 and P: -0.062) at both genotypic and phenotypic level. Root to shoot ratio (G: 2.909 and P: 0.052) and number of filled grains per panicle (G: 0.506 and P: 0.012) expressed positive indirect effects on grain yield per plant.

4.7.7 Number of ear bearing tillers per plant

This trait exhibited positive but low direct effect (G: 0.080 and P: 0.161) on grain yield per plant under moisture stress environment. Shoot dry weight (G: 0.060 and P: 0.002), root to shoot ratio (G: 0.020 and P: 0.005), number of days to 50% flowering (G: 0.034 and P: 0.003) and spikelet fertility (G: 0.030 and P: 0.004) expressed low but positive indirect effect on grain yield per plant. The negative indirect effects were observed through plant height (G: -0.358 and P: -0.026), panicle length (G: -0.004 and P: -0.001) and leaf area per plant (G: -0.025 and P: -0.002).

Number of ear bearing tillers per plant had a positive direct effect (G: 2.155 and P: 0.152) on grain yield per plant under favourable environment. The positive indirect effects through shoot dry weight (G: 1.645 and P: 0.016), root to shoot ratio (G: 2.80 and P: 0.074), Plant height (G: 0.299 and P: 0.012), number of filled grains per panicle (G: 0.512 and P: 0.006) and spikelet fertility (G: 1.025 and P: 0.085) were noticed on grain yield per plant resulting high positive correlation. However, negative indirect effects were exhibited through root dry weight (G: -4.666 and P: -0.067) panicle length (G: -0.279 and P: -0.022) and test weight (G: -0.690 and P: -0.028).

4.7.8 Panicle length

Panicle length recorded a low negative direct effect (G: -0.115 and P: -0.022) on grain yield both at genotypic and phenotypic level. The indirect effects through root dry weight (G:0.553 and P: 0.250), number of days to 50% flowering (G: 0.059 P:0.023), plant height (G:0.255 and P: 0.077), number of ear bearing tillers per plant (G: 0.003 and P: 0.009), harvest index (G:0.107 and P: 0.001) and leaf area per plant (G:0.150 and P: 0.014) were positive but low both at genotypic and phenotypic levels. The negative indirect effects were observed through shoot dry weight (G: -0.493 and P:-0.161) and leaf rolling (G: -0.051 and P: -0.014).

Under favourable environment panicle length revealed negative and direct effect (G: -0.868 and P: -0.118) on grain yield per plant. It expressed positive indirect effect through shoot dry weight (G: 1.164 and P: 0.063), root to shoot ratio (G: 3.060 and P: 0.052), number of ear bearing tillers per plant (G: 0.694 and P:0.029), number of filled grains per panicle (G: 0.711 and P: 0.015) and leaf area per plant (G:0.253 and P: 0.011).

4.7.9 Number of spikelets per panicle

This trait showed negative direct effect at genotypic level and positive effect at phenotypic level (G: -0.196 and P: 0.123) on grain yield

under moisture stress situation. Root dry weight (G:0.591 and P: 0.225); root to shoot ratio (G:0.079 and P:0.006), number of days to 50% flowering (G: 0.011 and P: 0.003), plant height (G: 0.188 and P: 0.038), harvest index (G: 0.168 and P: 0.052) and leaf area per plant (G: 0.136 and P: 0.018) expressed indirect effects on grain yield per plant.

The character number of spikelets per panicle had direct negative effect at genotypic level and positive effect at phenotypic level (G: -0.317 and P: 0.265) on grain yield per plant under favourable environment it had positive indirect effects through root to shoot ratio (G: 6.557 and P: 0.062) number of ear bearing tillers per plant (G: 0.547 and P: 0.005), number of filled grains per panicle (G:1.777 and P: 0.0277) and harvest index (G:0.005 and P: 0.002).

4.7.10 Number of filled grains per panicle

The direct contribution expressed by the character was low and positive at genotypic and negative at phenotypic level (G:0.053 and P: 0.076) under moisture stress situation. The indirect effects through root dry weight (G:0.521d and P: 0.267), root to shoot ratio (G:0.033 and P: 0.004), number of days to 50% flowering (G: 0.008 and P:0.002) plant height (G: 0.185 and P: 0.050), harvest index (G:0.144 and P: 0.078) and leaf area per plant (G: 0.132 and P: 0.014) were positive. Under favourable environment, this trait exhibited positive direct effect

(G:1.527 and P:0.037) on grain yield per plant. However, indirect positive effects on grain yield were noted through root to shoot ratio (G:5.147 and P:0.062), number of ear bearing tillers per plant (G:0.808 and P: 0.025) and spikelet fertility (G: 1.536 and P: 0.165). resulting high level of positive correlation.

4.7.11 Spikelet fertility per cent

This character noticed a low direct negative effect at genotypic level and positive effect at phenotypic level, under moisture stress environment (G: -0.035 and P:0.103) on grain yield per plant and positive indirect effects through root dry weight (G:0.938 and P: 0.269), number of days to 50% flowering (G: 0.033 and P: 0.006), plant height (G:0.163 and P:0.032), harvest index (G: 0.206 and P: 0.074) and leaf area per plant (G:0.151 and P:0.014).

Spikelet fertility percent recorded direct positive effect (G:2.333 and P:0.328) on grain yield per plant under favourable environment. Positive indirect effects were observed through root to shoot ratio (G: 4.083 and P: 0.104) plant height (G:0.239 and P: 0.008), panicle length (G: 0.947 and P: 0.039) and number of filled grains per panicle (G: 1.005 and P: 0.018).

4.7.12 Harvest index

Harvest index exhibited a positive direct effect (G: 0.268 and P:0.217) on grain yield per plant under moisture stress situation and also positive indirect effects via root dry weight (G: 0.457 and P: 0.248), number of days to 50% flowering (G:0.094 and P:0.044), test weight (G:0.023 and P:0.002) and leaf area per plant (G: 0.055 and P:0.007). Negative indirect effects were noticed via root dry weight (G: -0.049 and P: -0.128), root to shoot ratio (G: -0.049 and P: -0.014) plant height (G: -0.033 and P: -0.028), panicle length (G: -0.046 and P: -0.006) and leaf rolling (G: -0.048 and P: -0.015). Under favourable environment, this trait showed negative direct effect at genotypic level and positive effect at phenotypic level (G: -0.082 and P: 0.202). Positive indirect effects were observed via root to shoot ratio (G: 0.294 and P: 0.004), number of spikelets per panicle (G:0.019 and P:0.003) number of filled grains per panicle (G: 0.608 and P:0.014) and spikelet fertility (G: 1.218 and P: 0.141) resulting positive correlation.

4.7.13 Test weight

The direct contribution of this trait on grain yield was low but positive (G: 0.023 and P:0.010) under moisture stress environment. Test weight had positive indirect effects through shoot dry weight (G: 0.334 and P: 0.054) root to shoot ratio (G:0.040 and P: 0.005), number of days to 50% flowering (G: 0.086 and P:0.016), number of filled grains per

panicle (G:0.015 and P: 0.002), harvest index (G: 0.272 and P: 0.045) and leaf area per plant (G: 0.020 and P:0.013).

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Under favourable environment, test weight manifested direct and negative effect (G: -1.337 and P: -0.075) on grain yield. It had positive indirect effects through root to shoot ratio (G: 4.247 and P:0.095), number of filled grains per panicle (G: 0.709 and P:0.014) and spikelet fertility (G: 0.750 and P:0.068), thus resulting high positive correlation.

4.7.14 Specific leaf weight

Specific leaf weight had positive direct effect at genotypic level and negative direct effect at phenotypic level on grain yield per plant under moisture stress situation (G:0.409 and P: -0.013). It exhibited positive indirect effects through root to shoot ratio (G: 0.089 and P: 0.009), harvest index (G: 0.104 and P: 0.046) and leaf area per plant (G: 0.079 and P:0.007).

This trait recorded negative as well as positive direct effects at genotypic and phenotypic levels respectively on grain yield under favourable environment (G: -3.148 and P:0.061) and also positive indirect effects were observed through shoot dry weight (G: 0.0685 and P:0.026) root to shoot ratio (G: 4.385 and P: 0.074), plant height (G: 0.250 and P:0.009), number of ear bearing tillers per plant (G: 1.159 and P:0.030),

number of filled grains per panicle (G:0.934 and P: 0.013) and spikelet fertility (G: 1.491 and P: 0.145). results high positive correlation. 217

4.7.15 Leaf area per plant

Leaf area per plant revealed a positive direct effect (G: 0.284 and P: 0.108) on grain yield per plant under moisture stress situation. This character noticed positive indirect effects via root dry weight (G: 1.303 and P: 0.376) plant height (G: 0.154 and P:0.051) harvest index (G:0.052 and P: 0.014).

Under favourable environment negative direct effect was observed at genotypic level where as positive direct effect was noticed at phenotypic level (G: -3.148 and P:0.061) and also positive indirect effects through shoot dry weight (G:0.685 and P:0.026) root to shoot ratio (G:4.385 and P: 0.074) and plant height (G: 0.250 and P:0.009), number of ear bearing tillers per plant (G: 1.159 and P:0.030) and spikelet fertility percent (G:1.491 and P:0.145).

4.7.16 Leaf rolling

This trait exhibited direct positive effect (G:0.108 and P: 0.046) on grain yield where as positive indirect effects were observed through shoot dry weight (G:0.324 and P: 0.100), root to shoot ratio (G: 0.030 and P:0.011) and panicle length (G:0.054 and P:0.007). Negative effects on

grain yield were found via root dry weight (G: 0.484 and P: -0.188), number of days to 50% flowering (G: -0.032 and P: -0.016), plant height (G: -0.045 and P:-0.014), test weight (G: -0.118 and P:-0.072) and leaf area per plant (G: -0.035 and P: -0.008).

Path coefficient studies under moisture stress conditions revealed that direct positive effect was showed by root dry weight, plant height, number of ear bearing tillers per plant, harvest index, test weight, leaf area per plant and leaf rolling character on grain yield per plant.

Root dry weight exerted a high positive and direct effect on grain yield per plant (G: 1.546 and P: 0.991). This is mainly due to its own strength and feebly supported by plant height (G: 0.197 and P:0.052), harvest index (G: 0.079 and 0.054) and leaf area per plant (G: 0.240 and P: 0.041), ultimately leading to a total positive effect (G: 0.819 and P: 0.631). Followed by root dry weight per plant, grain yield was positively and directly influenced by plant height (G: 0.483 and P: 0.217) with the support of root dry weight (G: 0.630 and P:0.238), number of days to 50% flowering (G:0.007 and P:0.006) finally to positive association with grain yield per plant (G:0.345 and P: 0.278). Similarly number of ear bearing tillers per plant exerted moderate positive direct effect on grain yield per plant (G: 0.080 and P:0.161), which was weakly supported by shoot dry weight (G: 0.060 and P:0.002), root to shoot ratio

(G:0.020 and P:0.005), number of days to 50% flowering (G: 0.034 and P: 0.003), spikelet fertility per cent (G: 0.030 and P: 0.004) and leaf rolling trait (G: 0.011 and 0.008), finally resulted in a total positive correlation (G: 0.108 and P: 0.134). 219

The positive and direct effect of harvest index (G: 0.268 and P:0.217) on grain yield per plant was indirectly supported by root dry weight (G: 0.457 and P:0.248), number of days to 50% flowering (G:0.094 and P:0.044), test weight (G: 0.023 and P:0.002) and leaf area per plant (G: 0.055 and P: 0.007) leading to positive correlation (G: 0.306 and P: 0.357). In the same way, a moderate direct effect was exerted by leaf area per plant (G: 0.284 and P:0.108) on grain yield per plant. However, it was strengthened by the positive indirect effects through root dry weight (G: 1.303 and P: 0.376), plant height (G: 0.154 and P: 0.051) and harvest index (G: 0.052 and P: 0.014), ultimately resulted a total positive association (G: 0.707 and 0.333) with grain yield per plant.

Under favourable environment maximum positive direct effect on grain yield per plant was exerted by shoot dry weight (G: 11.592 and P:0.509) followed by root to shoot ratio (G: 8.504 and P:0.281), number of ear bearing tillers per plant (G: 2.155 and P:0.152), number of filled grains per panicle (G: 1.527 and P: 0.037) and spikelet fertility per cent (G: 2.333 and P:0.328).

Shoot dry weight showed highest positive direct effect on grain yield per plant primarily on its own strength and was strengthened by indirect effects through plant height (G: 0.145 and P: 0.002), number of ear bearing tillers per plant (G: 0.306 and P: 0.004), spikelet fertility per cent (G: 0.822 and P:0.067) test weight (G: 0.198 and P:0.006) that ultimately resulted in a positive significant correlation.(G: 0.361 and P:0.319) with grain yield per plant.

Root to shoot ratio exerted a high positive direct effect (G:8.504 and P: 0.281) on grain yield per plant in its own strength and feebly supported by indirect effects through number of ear bearing tillers per plant (G: 0.039 and P:0.850), number of filled grains per panicle (G: 0.924 and P:0.008) which finally led to a total positive association (G: 0.221 and P:0.142).

Similarly number of ear bearing tillers per plant (G: 2.155 and P:0.152) expressed direct positive effect on grain yield per plant derived support to a major extent by its indirect effects through shoot dry weight (G: 1.645 and P:0.016), root to shoot ratio (G: 2.80 and P:0.074) plant height (G: 0.299 and P:0.012), number of filled grains per panicle (G: 0.517 and P: 0.006), spikelet fertility per cent (G: 1.025 and P:0.085) leading finally to positive correlation (G:0.349 and P:0.271) with grain yield per plant.

Number of filled grains per panicle, through itself exerting a positive direct effect (G: 1.577 and P:0.037) on grain yield per plant derived support from indirect effects via root to shoot ratio (G: 5.147 and P:0.063), number of ear bearing tillers per plant (G: 0.808 and P:0.025), spikelet fertility percent (G: 1.536 and P: 0.165) finally resulting with strong association (G: 0.615 and P: 0.468) with grain yield per plant.

Spikelet fertility percent exerted a high direct positive effect (G: 2.333 and P:0.329) on grain yield per plant which derived strong indirect effects through shoot dry weight per plant (G: 4.083 and P: 0.104), number of ear bearing tillers per plant (G: 0.947 and p: 0.039) and number of filled grains per panicle (G:1.005 and P: 0.081). These direct and indirect effects constitute a positive correlation (G: 0.597 and P:0.510) with grain yield per plant.

A high direct negative effect (G: -1.337 and P:-0.075) was exerted by test weight on grain yield per plant. The direct negative effect was neutralized by positive indirect effects through root to shoot ratio (G:4.247 and P:0.095), number of ear bearing tillers per plant (G:1.112 and P:0.058) number of filled grains per panicle (G: 0.014 and P: 0.709) and spikelet fertility per cent (G: 0.141 and P:0.750) that finally led to a positive non significant correlation (G: 0.203 and P:0.169) with grain yield per plant.

Correlation and path coefficient studies in moisture stress as well as favourable environments revealed that ear bearing tillers per plant had direct positive effects on grain yield per plant in both the environments, while root dryweight per plant, plant height, harvest index, test weight, leaf area per plant and leaf rolling traits had positive direct effects on grain yield in moisture stress condition. Shoot dry weight, root to shoot ratio, number of filled grains per panicle and spikelet fertility exerted direct effects under favourable environment.

Number of days to 50% flowering, specific leaf weight and leaf rolling had negative association with grain yield per plant under stress condition where as plant height showed negative correlation with grain yield in favourable environment.

Discussion

CHAPTER - V

DISCUSSION

The main job of the plant breeder is to develop superior new varieties with desirable characters. Success of any breeding programme largely depends upon the presence of sufficient genetic variability in a given crop species of the character under improvement vis-a-vis its mode of inheritance as well as inter relationships among the traits. In rice drought tolerance, though an important desirable character, is dependent on a number of component characters, that are largely polygenic in nature. As such before launching any breeding programme, it is necessary to have a thorough knowledge on genetic variability present in the available genetic material, the extent of association among the component traits related to drought tolerance and in turn with yield. The correlation and path analysis will further help in identifying some of these parameters to serve as additional indices for selection. Keeping the above in view the present investigation was taken up with the following objectives

- (1) to study the nature and magnitude of genetic variability, heritability and genetic advance for yield and component traits for drought tolerance.
- (2) To assess the genetic divergence among the different genotypes for yield components and component traits for drought tolerance.

- (3) To study the inter-relationships and relative contribution of component traits for drought and yield. 224
- (4) To study the nature of gene action and combining ability for yield and other component traits for drought tolerance.
- (5) To study the hybrid vigour in different cross combinations for yield and component traits for drought tolerance.

The results obtained through these studies are discussed separately under different items.

5.1 GENETIC DIVERGENCE

The importance of genetic diversity for successful selection of diverse parents to get desirable recombinants has been stressed by many workers (Murthy 1965, Murthy and Arunachalam 1966; Bhatt 1970 and Anand and Rewat, 1984). Multivariate analysis by means of Mahalanobis D^2 statistic is a powerful tool in quantifying the degree of divergence existing among the populations. Clustering pattern of genotypes based on their characters under study generally differ due to their genetic make up as well as genotype-environmental interactions (Singh and Gill 1984 and Raut et al.1985). Through the use of genetic diversity major advances in crop improvement have been made over the last three decades. In order to get detailed information about the genetic divergence under a given situation, it is better to conduct the experiment

under that specific environment. Though rice crop has been subjected to considerable improvement through different breeding methods by several researchers for a long time in respect of yield and its components, much work was not done on genetic divergence studies particularly for drought tolerance. The available literature on this aspect is relatively limited in rice.

Accordingly, the present investigation was aimed at in ascertaining the nature and magnitude of divergence for drought tolerance and the characters contributing to such genetic diversity under induced drought conditions during panicle initiation stage for two weeks. The material for the present study consisted of 60 genotypes of rice obtained from different ecogeographical regions. The data collected on the thirteen quantitative characters from 60 genotypes of rice, were subjected to multivariate analysis using D^2 statistic to assess the distance among the 60 genotypes studied and to identify promising genotypes to initiate crossing programme for evolving drought tolerant rice varieties.

Based on the relative magnitude of the D^2 values all the 60 genotypes were grouped into nine clusters (Table 8). Forty six genotypes were accommodated in cluster I. Seven genotypes in cluster II and one genotype each in cluster III, IV, V, VI, VII, VIII, and IX. An examination of the varietal composition of the clusters indicated that the

clustering of the varieties did not follow their geographic distribution as varieties from diverse sources were grouped into different clusters viz., 226 I and II comprising 88 percent of the total number of varieties studied. Similar observations of non-correspondence of genetic and geographic diversity have been reported by Murthy and Arunachalam (1966), Ratho (1983), Rao and Gomathinayagam (1997). The genotypes of common geographic origin or same location also were grouped into different clusters as evidenced by the distribution of genotypes developed at Agricultural Research Station, Nellore itself into different clusters. NLR 13969, NLR 33899; NLR 26706, NLR 30426; NLR 33635; NLR 33356, NLR 30674, NLR 33359; NLR 33057 and NLR 33633 were included in cluster I ; NLR 33358 in cluster II and NLR 30491 in cluster V respectively. Similarly genotypes evolved at CRRI, Cuttack were accommodated in cluster I (CR 691-4; CR 679-2), cluster VI (CR 691-48) and in cluster IX (CR 811-1). These results confirm the earlier findings of Bhatt (1970) and Raut et al. (1985) who have suggested that genetic drift and human selection could cause greater diversity than the geographic distance.

Cluster means for thirteen quantitative traits are presented in Table 9A. The cluster I had high mean value for spikelet fertility per cent (75.07%), cluster III for harvest index (55.33), cluster IV for number of filled grains per panicle (146.33) and number of unfilled

grains per panicle (67.00), cluster V for relative water content (87.00%) and number of ear bearing tillers per plant (15.00), cluster VII for number of days to 50% flowering and for test weight (214.7g), cluster VIII for root dry weight (5.66g) and cluster IX for shoot dry weight (39.00g), plant height (98.33cm) and grain yield per plant (24.00g). On the other hand cluster VI exhibited the lowest mean value for grain yield per plant (13.66g). Genetic differences among clusters were also reflected in the cluster means (Sankar Rao, 1994).

Number of days to 50% flowering (53.56%), plant height (16.44%), test weight (14.80%) and relative water content (2.94%) were the major contributing characters for the genetic divergence among the genotypes under study which may be used as parameters in selecting genetically diverse parents. On the other hand, shoot dry weight and panicle length had very low contribution to genetic divergence. The inter cluster distance (Table 9) was maximum between clusters II and VII (16.45) followed by that between II and IV. The minimum distance was observed between clusters III and IV (4.94) and VI and IX (6.37). The maximum intra cluster distance was observed in cluster I (6.21) and cluster II (5.91). Cluster I consists of 46 genotypes from different geographical origins, while cluster II had seven genotypes from Andhra Pradesh, Uttar Pradesh, Assam and Orrissa. Varieties belonging to the clusters with maximum inter cluster distance are obviously genetically more divergent.

It is well established by several workers (Chaudhary et al, 1975; Arunachalam, 1981 and Rao and Gomathinayagam, 1997) that inter cluster distance in D^2 analysis play the key role for selection of genotypes as parents for hybridization. For successful breeding programme for drought tolerance in rice, hybridization has to be effected between genotypes of clusters II and VII and between varieties of clusters II and IV, considering inter cluster distance and characters with higher contribution to D^2 values. The present investigation, quite clearly indicated the presence of considerable diversity in the material studied and this variability is useful to exploit heterosis and to obtain transgressive segregants through hybridization programme. Accordingly, mean performance of cluster and cluster distances were taken into criteria for selecting eight genotypes i.e., three from cluster I and one each from cluster II, IV, V, VIII and IX. These eight genotypes were crossed in diallel fashion (without reciprocals) to evaluate the potentialities of the parents in their specific combinations as hybrids and to understand the gene action governing various components related to drought tolerance and other attributes contributing to yield.

5.2 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any plant breeding programme largely depends upon the quantum of variability available for exploitation. Knowledge on nature and magnitude of genetic variation governing the inheritance of

quantitative characters like yield and its attributes helps in genetic improvement.

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Mean, range and coefficient of variation (CV) were calculated to express the extent of variation for each character. The estimate of heritability of a character provides a measure of the effectiveness of selection for that character. Heritability is the ratio of genetic variance to phenotypic variance. Heritability alone may be misleading during selection, therefore genetic advance (as percent of mean) and heritability should be taken into consideration during selection programme (Johnson et al, 1955). Genetic advance is the improvement in the performance of selected lines over the original population. Root is one of the important parts of the plant to absorb nutrients and also moisture from lower layers of the soil and to withstand moisture stress during drought periods. In the present study, wide range of variability for root dry weight was observed from 2.23g to 7.33g . Among 60 genotypes evaluated NLR 33356 recorded the highest root dry weight though it had low heritability with moderate genetic advance. Higher magnitudes of genotypic and phenotypic coefficients of variation were observed in the present study which is in contrast to the observations made by Shahid et al (1994). This could be due to the genetic make up of the genotypes under study.

Shoot dry weight that is shoot portion of the plant decides the amount of transpiration. Less number of leaves as well as narrow and erect foliage reduce transpiration and ultimately determines water requirement of plant during moisture stress conditions. Rao *et. al.* (1981), Lu Fengshen *et. al.* (1994) and Souframanien *et. al.* (1998) emphasized the importance of root, shoot ratio in drought tolerance. Shoot dry weight ranged from 17.0g to 39.0g and the genotype CR 811-1 recorded the highest shoot dry weight. This trait showed relatively low GCV indicating the presence of significant influence of environment. Low heritability and moderate genetic advance were observed. Therefore, population improvement approach of breeding could be used to improve this character and selection for this trait should be postponed to the advanced generations.

Relative water content is one of the vital physiological traits to know the water retention capacity of the plants under water limited conditions (Rao and Venkateswarlu 1989). Wide range of variability was observed for relative water content from 37.0% to 89.0%. Under moisture stress conditions the genotype NLR 33635 had high relative water content in leaves. On the other hand the variety Sravani retained the lowest water content; thus the genotype NLR 33635 may be utilized as donor in hybridization programme. Moderate heritability and low amount of genetic advance as percent of mean offered scope to improve this important physiological character.

Number of days to 50% flowering which determines the crop duration is one of the primary objectives in rice breeding programme, as varieties with varied growth durations are required to suit different agro-climatic regions. From physiological point of view, total biomass production by any genotype is known to depend largely on growth duration. Varieties with shorter duration can complete its life cycle early and thus escape stress situations (Rao et al, 1971). In the present study, lower magnitude of GCV as well as PCV, high heritability and low genetic advance as percent of mean were observed for this trait; which are in conformity with the results reported by Roy and Kar (1992). The genotype PASR 1345-1 had the shortest duration of 82 days to 50% flowering. Thus, this genotype could be recommended for water scarcity areas of rice cultivation. Heritability of this trait was found to be high, thus indicating scope for improving this character through selection.

Based on the experimental results, many workers (Rao *et. al.* 1971; Chang et al, 1972 and Maurya et al, 1986) opined that under moisture stress situations, generally varieties with medium height (80-100cm) are desirable because crop duration and plant height are correlated. Varieties with earliness and short stature are suitable to escape moisture stress. In the present investigation though the plant height varied from 55.6 cm to 98.3 cm, all the sixty genotypes are of medium plant height only. Plant height expressed not only higher heritability but also higher

genetic advance as percent of mean thus offering good scope for improving this vital physiological attribute through simple selection. 232

Number of ear bearing tillers per plant is one of the yield parameters significantly affect by moisture regimes (Pereira, 1994). Balakrishana Rao (1971) suggested that an ideal plant type for drought situations should have early vigour with moderate tillering (6-8 tillers). In the present study, number of panicles per plant differed widely among genotypes. Similar results were reported by Singh (1980). According to Johnson *et. al.* (1955) and Ramanujam and Tirumalachary (1967), high heritability estimates along with high genetic gain were more useful in predicting the resulted effect for selecting the best single plants. Contrary to these observations, low heritability coupled with low estimates of genetic advance were recorded in the present investigation, which is attributed to the genetic material under study. However moderate estimates of GCV and PCV values were noticed.

Panicle length, an important yield component varied from 19 cm (N22; OR 1507-6 and ORS 102-4) to 27.6 cm (KMJ 10-1-4). In the present investigation genotypic and phenotypic coefficients of variation were found to be lower as reflected by low estimates of GCV and PCV, which are in conformity with the results of Rama Rao (1990). Likewise low heritability and genetic advance as percent of mean, indicated that much efforts are needed to improve this character.

Presence of full spikelet fertility as reflected in number of filled grains per panicle to realize higher productivity is very important. Wider variation for this trait was observed as reflected by higher GCV and PCV. Moderate heritability and genetic advance as percent of mean were also observed for this character in the present study. Deosarkar et al (1989); Srinivasa Rao (1989) and Chookar *et. al.* (1994) also reported high values of GCV and PCV which are in conformity with the present investigation. The culture OR 1590-1 recorded highest number of filled grains per panicle. Sufficient variability among genotypes for spikelet fertility percent was observed in the present investigation, which varied from 63.0 to 88.3 percent. The genotypes viz. NLR 13969 and IET 2508 exhibited high percent of spikelet fertility, a desirable feature required under moisture stress conditions. The spikelet fertility exhibited moderate heritability with low genetic advance.

Harvest index is defined as the ratio of economic yield (grain yield) to biological yield. As high harvest index is considered to represent increased physiological capacity to mobilise photosynthesis and translocate them into organs of economic value, it has been suggested as a reliable selection criterion for improving the grain yield in cereal crops. In the present study, harvest index was found to vary from 40 to 65 per cent. Good variation for this trait as reflected by high coefficient of variation which are in conformity with the results of Chauhan *et. al.*

(1993). Further, the heritability and genetic advance were found to be moderate for harvest index.

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Test weight among different genotypes reflects the effective translocation of photosynthesis. Pereira *et. al.* (1994) evaluated rice germplasm for drought tolerance and reported that test weight was not affected by moisture stress. Similarly in the present investigation also, the test weight was not affected by moisture stress situation as revealed by the range of 16.7 to 23.2g. However, low estimates of GCV and PCV indicated limited variability. Such results were also reported by other workers viz. Ganesan and Subramanian (1990); Rama Rao (1990) and Mohammed Aziz Ahammed (1991). It was interesting to observe that the heritability estimate was found to be high with moderate genetic advance, thus offering scope for improving this trait to a moderate extent.

Grain yield is the ultimate goal of any breeding program and the presence of wide variability as in the present investigation is a desirable feature under moisture stress environment. The grain yield of a given variety may vary considerably due to the hostile environmental conditions. Under such conditions, the emphasis should be for stability of yield i.e. for stable performance of a variety with reasonable yield level. In the present investigation also the true reflection of the

environmental situation has been revealed by the high PCV than GCV, which are in agreement with the results reported by Remabai *et. al.* (1992). 236

5.3 HETEROSIS

Heterosis, the superiority of F_1 hybrid over the parents in terms of yield or some other character is one of the successful methods of plant breeding programmes. Heterosis provide an opportunity to assess the extent of hybrid vigour present in the F_1 hybrids over the parents and to ascertain the possibility of exploring the same depending upon the biological feasibility (Dubey and Singh, 1968). Knowledge on the nature and extent of hybrid vigour and gene action through heterosis and combining ability respectively, will help us in formulating effective breeding strategies and choice of suitable parents for effecting crosses for the successful breeding programme.

Keeping this in view heterosis was calculated as percent increase or decrease over mid-parent as well as corresponding better parent. The results of studies on heterosis and heterobeltiosis are briefly discussed here under.

Moisture stress situation

In the present study, heterosis in F_1 hybrids from 8x8 diallel set of the crosses (Table 16) indicated high heterobeltiosis (>50%) for root dry weight (101.47%), shoot dry weight (83.93%), root to shoot ratio (63.41%), number of ear bearing tillers per plant (61.54%), number of spikelet per panicle (51.23%), number of filled grains per panicle (128.46) spikelet fertility percent (55.26%), harvest index (78.02%), test weight (118.50%), leaf area per plant (51.39%), grain yield per plant (221.43%) and leaf rolling (66.67%). Moderate better parent heterosis (20 to 50%) was noticed for specific leaf weight (44.72%), panicle length (21.72%), plant height (31.25%), relative water content (21.96%) and low better parent heterosis (<20%) was observed for number of days to 50% flowering (4.55%). However, when mid parent heterosis was considered, it was high (>50%) for root dry weight (62.89%), shoot dry weight (74.77%), number of ear bearing tillers per plant (52.73%), test weight (103.11%) and grain yield per plant (103.23%). Moderate (20 to 50%) heterosis was observed for leaf rolling (40.00%), leaf area per plant (29.58%), specific leaf weight (40.62%), harvest index (45.95%), spikelet fertility per cent (30.75%), number of filled grains per panicle (47.39%), number of spikelets per panicle (47.03%), plant height (35.96%) relative water content and root to shoot ratio (44.19%). Low (<20%) for number of days to 50% flowering (1.10) and panicle length (19.75%). Heterosis over better parent (heterobeltiosis) could be a better measure of hybrid vigour for breeding purpose (Vandenberg and Matzinger, 1970).

Among the twenty eight cross combinations, positive and significant heterosis was observed in ten hybrids and heterobeltiosis in fourteen hybrids for root dry weight. The hybrid Tulasi/CR 811-1 with high x low parental combinations recorded the highest heterobeltiosis. Other cross combinations with considerable heterobeltiosis were NLR 33899/CN 875-135-1-3 (high x low) and CN 875-135-1-3/CR 811-1 (high x low). Significant positive heterosis and heterobeltiosis was exhibited by eleven and fourteen hybrids respectively for shoot dry weight. Among the parents, NLR 30491 and CN 875-135-1-3 were recorded highest shoot dry weight. The hybrid combinations involving these parents resulted in high mean performance and heterobeltiosis. Two hybrids viz. NLR 30491/CR 811-1 and CN 875-135-1-3/CR 811-1 exhibited high magnitude of heterobeltiosis. Root to shoot ratio is an important physiological trait for drought tolerance of rice genotypes Shahid *et al.* (1994). The present investigation with respect to root to shoot ratio revealed considerable variation for heterosis. Among the, hybrids significant and positive heterosis and heterobeltiosis was recorded by eight and seven hybrids respectively. Similar results were obtained by Souframanien *et. al.* (1998). The highest heterobeltiosis was noticed in the hybrid NLR 33899/CN 875-135-1-3 involving parents with high x low gca effects.

Relative water content is one of the important traits to know the water retention capacity of the plants under moisture stress situation.

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Maintaining high leaf water potential, particularly during the reproductive stage is important to reduce the effect of drought. Heterobeltiosis for relative water content was of lower magnitude as only one single cross NLR 33899/KMJ 10-2-2 exhibited positive significant heterosis and two crosses viz. NLR 33899/KMJ 10-2-2 and Tulasi /CR 811-1 showed mid parental heterosis. Heterosis for relative water content was also reported by Thangaraj and Sivasubramanian (1990).

Among the twenty eight cross combinations, positive and significant heterosis was observed in thirteen hybrids and heterobeltiosis in fourteen hybrids for plant height. The hybrid N22/Tulasi with high x high parental combination recorded highest positive heterobeltiosis. In the present investigation, several hybrids expressed negative heterosis for this trait. This revealed that majority of the hybrids expressed dwarf to intermediate plant height. Swamy *et. al.* (1983) reported that cultivars with dwarf to medium type is favourable for drought tolerance. Heterosis for plant height was also reported by Nijaguna and Mahadevappa (1983), Dwivedi (1985) and Souframanien *et. al.* (1998). In rice breeding programme, days to 50 percent flowering is an important trait for developing early duration varieties. In the present investigation, eighteen and nineteen hybrids expressed significant negative heterosis and heterobeltiosis respectively. The cross combination NLR 30491/CR 811-1 had highest negative heterosis as well as heterobeltiosis for this trait. Heterosis for earliness in rice was reported by Mallick *et al.* (1978).

In the present study for number of ear bearing tillers per plant eleven hybrids showed positive heterosis while 13 hybrid exhibited heterobeltiosis which in confirmity with the results reported by Saini and Kumar (1973), Kalaimani and Sundaram (1987). Highly significant positive heterobeltiosis was recorded by N22/CN 875-135-1-3 (61.54%). Among the eight parents included in the study, WGL 14280-1 and KMJ 10-2-2 gave highest number of ear bearing tillers per plant. However, the cross between WGL 14280-1 and KMJ 10-2-2 (high x high) resulted neither in higher number of effective tillers nor in high percent heterosis. On the other hand, two hybrids KMJ 10-2-2/CR 811-1 and WGL 14280-1/N22 with high x low parental combination exhibited high percent heterobeltiosis. On the other hand, other hybrids viz. NLR 33899/N22 and NLR 33899/CN875-135-1-3 with low x low parental combinations showed high percent heterosis.

Panicle length is another important component of grain yield since it bears the sink. More the length of panicle, it is likely to bear more number of grains per plant. In the present study most of the cross combinations expressed significant and positive heterosis and heterobeltiosis. Maximum heterobeltiosis of 21.72 per cent for panicle length was recorded by the hybrid WGL 14280-1/N22. High x high parental combination NLR 33899/CN 875-135-1-3 showed positive significant heterosis. Cross combinations which involved the parents

WGL 14280-1 (high) and N22 (high) exhibited positive heterosis and heterobeltiosis.

Number of spikelets per panicle recorded significant positive heterosis in five hybrids and heterobeltiosis in ten hybrids. The hybrid combination NLR 30491/N22 recorded the highest positive heterobeltiosis of 51.23 per cent (high x low). This trait registered 47.03 per cent heterobeltiosis in cross combination N22/KMJ 10-2-2 (low x low). Similar results were reported by Murayama (1973). High heterosis for grain yield in rice was due to number of spikelets per panicle (Saini and Ishkumar, 1973). Spikelet fertility percent is one of the most vital characters that determines the yield potential of rice genotype under water limited environments. NLR 30491/CR 811-1 (high x low), Tulasi/CR 811-1 (high x low) and NLR 33899/CR 811-1 (low x low) displayed significant positive heterobeltiosis for spikelet fertility percent. The two hybrids which expressed significant, positive mid parental heterosis were NLR 30491/CR 811-1 (high x low) and NLR 33899/CR 811-1 (low x low) and Tulasi/CR 811-1 (high x low) were the top three among hybrids that displayed significant positive heterobeltiosis for spikelet fertility percent. The two hybrids which expressed significant positive better parental heterosis were NLR 30491/CR 811-1 (high x low) and NLR 33899/CR 811-1 (low x low).

Harvest index, the ratio between the economic yield (rice grain) and total dry matter produced is an important physiological parameter ²⁴¹ which indicates the yield potential of a genotype. Highest heterobeltiosis was recorded in WGL 14280-1/CR 811-1 (high x low) among the 22 hybrids that displayed better parental heterosis. Where as twenty hybrids exhibited mid parental heterosis, of which WGL 14280-1/CR 811-1 recorded highest heterobeltiosis of 45.95 per cent. Heterosis for harvest index was also observed by Kim (1985) and Souframanien *et. al.* (1998). WGL 14280-1/NLR 30491 (high x low), WGL 14280-1/KMJ 10-2-2 (high x low) and WGL 14280-1/N22 (high x low) were the top three among 13 hybrids that displayed positive and significant heterobeltiosis for 1000-grain weight whereas, seventeen hybrids exhibited positive and significant heterosis. Positive heterosis for test weight was reported by Saini and Ishkumar (1973), Nijaguna and Mahadevappa (1983) and Kim (1985). Dwivedi (1985) observed heterosis over mid parent, better parent and standard check.

In the present study, maximum positive heterobeltiosis of 221.43 percent was recorded by the cross Tulasi /CR 811-1 (high x low) for grain yield per plant. This cross also recorded significant positive heterobeltiosis for root dry weight, shoot dry weight, relative water content, number of ear bearing tillers per plant, panicle length, spikelet fertility percent, harvest index and test weight and significant negative

heterosis for number of days to 50% flowering. Richharia and Singh (1983), Shanmugasundaram and Sivasubrahmanian (1983) reported that heterosis for yield was mostly due to simultaneous heterosis in other yield components viz. days to flowering, plant height, number of panicles per plant, panicle length and grains per panicle. According to Whitehouse *et. al.* (1958), there could be no separate gene system for yield *per se* as yield is an end product of the multiple interactions between its various components. They also opined that hybrid vigour of small magnitude for individual yield components may be additive or synergistic effect on yield. The results of the present investigation were in agreement with this view, the other noteworthy cross combination which exhibited heterobeltiosis for grain yield per plant was NLR 30491/N22 (high x low). Heterosis for grain yield was also reported by Sardana and Borthakur (1985), Wilfred manuel and Palanisamy (1989), Wilfred manuel and Prasad (1992). The present study indicated that seventeen hybrids out of twenty eight cross combinations exhibited significant positive heterosis. Thirteen combinations recorded more than 20 per cent increased grain yield per plant over the mid parental value. These crosses involved WGL 14280-1; N22, CR 811-1 and CN 875-135-1-3 as one of the parents and recorded different levels of positive heterosis for grain yield per plant. The high heterosis might be the result of dominant genes contributed by these parents. The study revealed that three crosses viz. Tulasi/CR 811-1; NLR 33899/

CN 875-135-1-3; WGL 14280-1/N22 had high heterotic values for grain yield per plant. These crosses can be utilized for exploitation of heterosis successfully. Swaminathan *et. al.* (1972) and Virmani *et. al.* (1981) also suggested that 20-30 per cent yield advantage for hybrid varieties over standard parent could offset the high cost of hybrid seed.

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Heterosis under favourable environment

Based on the study involving hybrid combinations under favourable condition, significant positive heterobeltiosis was recorded in root dry weight (52.60%), shoot dry weight (155.42%), relative water content (13.81%), plant height (24.90%), number of ear bearing tillers per plant (106.90%), panicle length (23.23%), number of filled grains per panicle (43.02%), harvest index (57.86%), test weight (15.34%), specific leaf weight (24.74%), leaf area per plant (278.12%) and grain yield per plant (82.72%), negative but non significant heterobeltiosis was observed in crop duration (-9.47%). High magnitude of heterosis over the mid parent was noted in root dry weight (65.90%), shoot dry weight (156.26%), root to shoot ratio (56.36%), relative water content (14.63%), number of days to 50% flowering (0.56%), plant height (30.77%), number of ear bearing tillers per plant (122.22%), panicle length (24.11%), number of spikelets per panicle (32.54%), number of filled grains per panicle (44.93%), spikelet fertility per cent (22.43%), harvest index (61.31%), test weight (17.22%), specific leaf weight (36.69%), leaf area

per plant (316.51%) and grain yield per plant (103.60%) (Table 17). The heterosis over mid parent was significant for all the traits (Table 17). Leaf area per plant is a major physiological component of yield, since, it is the product of leaf number and leaf size, presence of sufficient leaf area is required for maximizing photosynthesis. The present investigation with respect to leaf area revealed that KMJ 10-2-2/Tulasi (low x low) was the only cross combination that displayed heterobeltiosis as well as heterosis. Heterosis for leaf area was reported by Yamaguchi and Yoshida (1985).

No cross combination displayed significant positive heterobeltiosis for characters like root to shoot ratio, number of days to 50% flowering and spikelet fertility per cent. However all combinations exhibited heterobeltiosis in negative direction for number of days to 50% flowering which is desirable. High root dry weight enhances drought tolerance and it is a desirable character for water limited environments. Hence, positive heterosis is preferable. NLR 30491/CN 875-135-1-3; KMJ 10-2-2/CR 811-1; NLR 33899/Tulasi (low x high) and NLR 33899/WGL 14280-1 (low x low) were some of the cross combinations exhibited significant positive heterosis over mid parent.

For shoot dry weight, the hybrid NLR 30491/CN 875-135-1-3 (high x high) showed the highest percent of heterobeltiosis and the same cross

expressed the highest percent of positive significant heterosis over mid-parent. The other cross combinations which displayed significant positive heterobeltiosis were KMJ 10-2-2/CN 875-135-1-3 (high x high), KMJ 10-2-2/CR 811-1 (high x high). Relative water content is the water retention capacity of plant leaves under moisture stress situation and this is one of the important physiological traits to withstand drought condition. Relative water content had registered positive significant heterosis in three crosses and heterobeltiosis only one hybrid. The only cross combination that exhibited heterobeltiosis was N22/CR 811-1 (high x high). On the other hand, the hybrids WGL 14280-1/NLR 30491 (high x high), N22/CR 811-1 (high x high) and Tulasi/CR 811-1 (high x high) showed heterosis over mid-parent.

Since, the number of filled grains per panicle influences harvest index and grain yield per plant, positive heterosis for this character is desirable. Significant desirable positive heterobeltiosis was recorded in Tulasi/CR 811-1 (low x low) and CN 875-135-1-3/CR 811-1 (high x high) parents respectively. For plant height, the hybrid NLR 30491/KMJ 10-2-2 (low x low) recorded highest significant positive heterobeltiosis. Heterosis for plant height was also reported by Paramasivan (1979), Nijaguna and Mahadevappa (1983) and Dwivedi (1985). The hybrids KMJ 10-2-2/CN 875-135-1-3 (low x high), Tulasi/CN 875-135-1-3 (low x high) and NLR 30491/CN 875-135-1-3 (low x high) which showed

significant negative heterosis over better parent exhibited good mean values in terms of plant height, thus indicating the possibilities of utilizing these cross combinations for desired plant height.

Highest significant positive heterobeltiosis for grain yield per plant was recorded by Tulasi/CR 811-1 (low x high) (82.72%). The other cross combinations which recorded high heterobeltiosis for grain yield per plant were N22/Tulasi (low x low), WGL 14280-1/KMJ 10-2-2 (high x low) and KMJ 10-2-2/Tulasi (low x low). These crosses also exhibited good mean performance for this trait. These cross combinations may be considered for exploitation of hybrid vigour by way of hybrid seed production. Out of the twenty eight cross combinations four crosses exhibited more than 50% increased yield over better parent (Table 17) and most of these hybrids involved Tulasi as one of the parents.

Heterosis under simulated drought condition

Heterosis was estimated for shoot and root growths of 6 day old seedlings under simulated drought conditions induced by different osmotic pressures of polyethylene glycol solutions. In the present study positive heterobeltiosis of 95.90 per cent was recorded of shoot length by the cross combination Tulasi/CR 811-1 at control conditions and hybrids showed positive significant heterobeltiosis. However, at higher order of osmotic pressures, heterobeltiosis for shoot length growth was highly

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significant at 3.00 bars. The hybrid Tulasi/CN 875-135-1-3 exhibited 250.0 per cent heterosis and seventeen hybrids displayed positive heterobeltiosis. At 6.00 bars, the hybrid NLR 30491/Tulasi recorded 317.65 per cent heterobeltiosis and at 10.00 bars the maximum heterobeltiosis of 962.50 per cent was recorded by WGL 14280-1/KMJ 10-2-2 and fifteen crosses expressed significant positive heterobeltiosis. From the present investigation it is evident that at higher order of osmotic pressures the heterobeltiosis was also at higher order. These crosses mostly involved Tulasi, the standard variety as one of the parents. The mean values of the above cross combinations were also high.

Heterosis studies on seedling root growth revealed that under control conditions the cross combination, NLR 33899/Tulasi displayed 206.49 percent heterobeltiosis and nineteen crosses showed positive and significant heterosis over mid-parent. Eighteen cross combinations expressed significant and positive heterobeltiosis, of which maximum of 143.54 percent was noticed in the hybrid NLR 33899/KMJ 10-2-2 at 3.00 bars of osmotic pressure. At -6.00 bars maximum heterosis over better parent was noticed in the cross combination WGL 14280-1/NLR 30491 (101.00%) and 13 hybrids showed significant and positive heterobeltiosis. On the other hand at higher order of -10.00 bars of osmotic pressure the highest percent of heterobeltiosis was recorded by the hybrid KMJ 10-2-2/Tulasi (1933.33%) and 14 cross combinations

exhibited significant positive heterosis over better parent. The crosses with any one of the parents viz., NLR 33899, KMJ 10-2-2 and Tulasi expressed maximum percent of heterobeltiosis for seedling root growth under simulated drought conditions. The studies on heterosis over two environments viz. moisture stress and normal situations revealed that the crosses involved with the parent CN 875-135-1-3 mostly exhibited high magnitude of positive heterosis for root to shoot ratio and on the other hand the same parent in normal environment showed negative heterosis over better parent.

From the discussion it is concluded that based on their mean performance under moisture stress environment, the genotypes viz., Tulasi and Bharani (NLR 30491) were good parents for root to shoot ratio, relative water content, plant height, number of filled grains per panicle, spikelet fertility percent, harvest index, test weight, leaf area per plant, leaf rolling and grain yield per plant. However, under favourable environment; the genotype CN 875-135-1-3 was the best for root to shoot ratio, panicle length, number of spikelets for panicle, number of filled grains for panicle, spikelet fertility percent, test weight, leaf area for plant and grain yield per plant. The genotype Tulasi was the best parent for relative water content, number of days to 50% flowering and harvest index.

Under moisture stress environment, the crosses NLR 33899/CN 875-135-1-3; NLR 33899/KMJ 10-2-2, and NLR 33899/KMJ 10-2-2 for number of days to 50% flowering, N22/Tulasi for plant height, N22/CN 875-135-1-3 for number of ear bearing tillers per plant, WGL 14280-1/N22 for number of spikelets per panicle, NLR 30491/CR 811-1 for number of filled grains per panicle and spikelet fertility percent, WGL 14280-1/CR 811-1 for harvest index, WGL 14280-1/NLR 30491 for test weight, Tulasi/CR 811-1 for leaf area per plant, NLR 33899/NLR 30491 for leaf rolling and Tulasi/CR 811-1 for grain yield for plant exhibited higher magnitude of desirable heterobeltiosis and these crosses could be further advanced for selection and improvement of the characters concerned in moisture stress environment.

Under favourable environment, the cross combination NLR 33899/Tulasi for root to shoot ratio, N22/CR 811-1 for relative water content, NLR 30491/KMJ 10-2-2 for plant height, Tulasi /CR 811-1 for number of ear bearing tillers per plant, WGL 14280-1/Tulasi for panicle length, NLR 33899/N22 for number of spikelets per panicle, Tulasi/CR 811-1 for number of filled grains per panicle, Tulasi/CR 811-1 for spikelet fertility percent, WGL 14280-1/CN 875-135-1-3 for harvest index, NLR 30491/N22 for test weight, KMJ 10-2-2/N22 for leaf area per plant and Tulasi/CR 811-1 for grain yield per plant displayed high percent of heterosis over better parent. The other cross combinations

viz. WGL 14280-1/KMJ 10-2-2; N22/Tulasi and KMJ 10-2-2/Tulasi which registered highest significant heterobeltiosis along with good mean performance, might be utilized in evolving improved varieties. These cross combinations were also identified as best hybrids and offer scope in commercial utilization by way of producing hybrid seed under normal environmental conditions.

5.4 COMBINING ABILITY ANALYSIS

To initiate a sound breeding programme for any specific environment, information on the gene action of the characters that require improvement is essential. In self pollinated crops like rice, the combining ability analysis is frequently used for testing the performance of parents in hybrid combinations and also for characterizing the nature and magnitude of gene action involved in the expression of quantitative traits. The ultimate objective of this analysis is to spot out the best parents for general combining ability effects and best hybrids for specific combining ability effects. General combining ability refers to the average performance of a line in a series of hybrid combinations and is attributable to additive (fixable) gene action. While, the specific combining ability refers to the deviation in the performance of a cross than that would be expected on the basis of the average performance of the lines involved and is attributable primarily to dominant, over dominant and epistatic effects of genes (non-additive). The non-additive gene action is mostly non-fixable.

The sum of the additive gene effects produced by the genes lacking dominance and by the additive contribution of genes along with dominance or epistatic effects in the additive component of genetic variance. Additive gene action tends to produce a normal phenotypic distribution. As shown by Griffings (1956) the total genetic variance among single cross progenies is equal to twice the general combining ability variance ($2 \sigma^2_{gca}$) plus the specific combining ability variance (σ^2_{sca}). Based on this relationship Baker (1978) postulated that the relative importance of general and specific combining ability should be assessed by estimating the components of variance and expressed them in the ratio

$$2 \sigma^2_{gca} / 2 \sigma^2_{gca} + \sigma^2_{sca}$$

The ratio of genetic components of variance and the estimates of combining ability components for moisture stress, yield and its components are discussed below.

Moisture stress environment

In the present study, significant gca and sca variances have been observed for the characters tested, suggesting there by the importance of both additive and non-additive components of gene action in determining the characters under study. However, the relative magnitude of gca has been found greater than sca variance. Predominance of

additive gene action for all the characters except for number of ear bearing tillers per plant and leaf rolling trait was observed (Table 19). 287

With regard to root dry weight, the ratio between the gca and total components of variance was nearer to unity indicating the importance of additive gene action governing this trait. Among the parents, NLR 33899, Tulasi and CN 875-135-1-3 expressed positive but non-significant gca effects. The cross N22 / Tulasi, a combination of low and low general combiners showed highest positive significant sca effect. Other cross combinations NLR 33899 / CN 875-135-1-3 (low x low), WGL 14280-1 / CN 875-135-1-3 (low x low) and Tulasi / CR 811-1 (low x low) general combiners also exhibited significant positive sca effects indicating the presence of non-additive gene effect. The sca effects would be important in self pollinated crop like rice to isolate good transgressive segregants. If additive genetic system is present good segregants may appear from the crosses with high x low and low x high general combiner combinations, which can be isolated and maintained through pedigree method of breeding.

For shoot dry weight, estimates of variance due to gca were higher than the variance due to sca. The ratio of general combining ability component of variance to total genetic variance was almost close to unity indicating the preponderance of additive gene action governing this

character. Similar results were recorded by Shahid *et al.* (1994). Among the parents, only one parent NLR 30491 showed positive significant gca effect. Fifteen crosses showed non-significant positive sca effects. Since, additive gene action was found predominant, desirable segregants may appear in subsequent generations and superior lines can be isolated through simple selection by pedigree method.

When root to shoot ratio was considered, both gca and sca variances were found to be significant. The combining ability component ratio between gca variance to total genetic variance was close to unity indicating the preponderance of additive gene action governing the character under study (Shahid *et al.* 1994). Among the parental lines NLR 33899, Tulasi and CR 811-1 were good general combiners. The cross combinations NLR 33899 / Tulasi (high x high), NLR 33899 / CN 875-135-1-3 (high x low), NLR 33899 / CR 811 (high x high) and Tulasi/ CR 811-1 (high x high) recorded significant sca effects indicating both additive and non-additive gene actions. The crosses showing high sca effects with at least one good general combiner could produce desirable transgressive segregants in subsequent generations. Progenies with good root to shoot ratio could be isolated from the above cross combinations.

For relative water content, both gca and sca variances were found to be significant. The ratio of general combining ability component of

variance to total genetic variance was intermediate indicating the presence of both additive and non-additive gene actions operating the control of this trait. Among the parental lines Tulasi and CN 875-135-1-3 were found to be good general combiners with significant positive gca effects. Three crosses WGL 14280-1 / CN 875-135-1-3 (low x high), NLR 30491 / CN 875-135-1-3 (low x high) and Tulasi / CR 811-1 (high x low) recorded positive significant sca effects for relative water content. These crosses involving one parent with desirable and significant gca effect could give desirable segregants in future generations. Since, both additive and non-additive gene actions were responsible for relative water content, hybridization followed by selection, intermating the selections and reselection may help to improve this character.

Combining ability for number of days to 50% flowering indicated that the variance due to gca were higher than sca. The ratio of general combining ability component of variance to total genetic variance was nearer to unity, this revealed the importance of additive gene action governing this trait. Similar results were reported by Sardana and Borthakur (1987). Both additive and non-additive gene action was also recorded by Singh and Richharia (1978). However, non-additive gene action for this trait was also observed by Ranganatham *et. al.* (1973) and Haque *et. al.* (1981). Less number of days to 50% flowering is related to early maturity. Since, earliness is a desirable trait to

escape moisture stress under water limited environments, the parents showing negative and significant gca effects should be selected for improving this character. Among the parental lines WGL 14280-1 ; N22 and KMJ 10-2-2 were the best general combiners. The cross combinations WGL 14280-1 / N22 and N22 / KMJ 10-2-2 exhibited significant negative sca effect indicating additive gene action. Hence, improvement towards earliness can be made in the above two hybrids by employing pedigree method of breeding.

In the present study, both gca and sca variances were significant for plant height. The ratio between gca variance to total genetic variance was close to unity indicating the predominance of additive gene action governing this trait. Contrary to these observations, non-additive gene action for this character was reported by Ananda Kumar and Sreerangasamy (1984) and Paramasivan (1990). However, both additive and non-additive gene action were found for this character by Singh and Richharia (1978). The parents WGL 14280-1 ; KMJ 10-2-2 and CR 811-1 were the good general combiners for optimum plant height. The cross WGL 14280-1 / CN 875-135-1-3 a combination of high x low general combiners showed highest significant negative sca effect indicating the operation of non-additive gene action. The cross WGL 14280-1 / KMJ 10-2-2, a combination of two high general combiners showed negative sca effect showing the operation of additive gene action. This

particular cross combination could be exploited for desired plant height by simple selection through pedigree method of breeding.

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Estimates of variance due to sca were higher than the gca variance for the character number of ear bearing tillers per plant. The ratio of general combining ability component of variance to total genetic variance was found to be intermediate indicating the presence of both additive and non-additive gene action controlling this character. This is in agreement with the results reported by Rao *et. al.* (1980), Amirthdevarathinam (1984), Sardana and Borthakur (1987). WGL 14280-1 and KMJ 10-2-2 recorded positive gca effects. Two hybrids N22 / CN 875-135-1-3 and CN 875-135-1-3 / CR 811-1 with low x low general combiners expressed significant positive sca effects indicating the operation of non-additive gene action for this trait. Exploitation for this trait might be possible in low x low cross combinations through the use of biparental matings in F_2 and the use of selection procedures such as diallel selection matings.

Variance due to gca was greater than sca variance for panicle length. In the present study the ratio of general combining ability component of variance to total genetic variance was almost close to unity indicating the predominance of additive gene action for this character. These findings were in conformity with the results of Rahman *et, al.*

(1981) and Sardana and Borthakur (1987). Among the parental lines WGL 14280-1 and CN 875-135-1-3 recorded significant and positive gca ²⁴⁷ effects. The hybrid WGL 14280-1 / CN 875-135-1-3 involving both the parents with high gca effects recorded high and significant positive sca effect indicating the role of additive gene action for this character. Therefore, improvement of this trait would be possible through simple selection.

The estimates of variance due to gca were higher than the sca variance for the trait number of spikelets per panicle. The components of variance due to gca ratio to total genetic variance was found to be close to unity indicating the presence of additive gene action. These findings are in agreement with the earlier reports of Mohanty and Mahapatra (1973) and Murai and Kinoshite (1986). Only two parents viz., NLR 30491 and CN 875-135-1-3 exhibited positive gca effects. Three cross combinations viz. N22 / KMJ 10-2-2 (low x low) WGL 14280-1 / CN 875-135-1-3 (low x high) and Tulasi / CR 811-1 (low x low) recorded significant positive sca effects indicating the operation of non-additive gene action. Number of spikelets per panicle can be improved by choosing breeding method such as diallel selective mating or biparental mating and advancing the selected material through pedigree method later.

The gca variance was greater than the sca variance for number of filled grains per panicle. The ratio between the gca and the total genetic variance is close to unity indicating the importance of gene action governing this trait. The parents NLR 30491 and CN 875-135-1-3 were found to be good general combiners. The cross combination WGL 14280-1 / CN 875-135-1-3 (low x high) ; WGL 14280-1 / CR 811-1 (low x low) ; NLR 30491 / CR 811-1 (high x low) and KMJ 10-2-2 / Tulasi (low x low) showed the highest positive sca effects indicating the presence of non-additive gene action also.

Combining ability studies for spikelet fertility per cent revealed significant variance for both gca and sca. The ratio of general combining ability component of variance to total genetic variance was almost close to unity, indicating the preponderance of additive gene action governing this trait. However, none of the parents showed significant gca effects. NLR 33899, NLR 30491, Tulasi and CN 875-135-1-3 exhibited non-significant positive gca effects. Whereas WGL 14280-1 ; N22 ; KMJ 10-2-2 and CR 811-1 expressed non-significant negative gca effects. The only hybrid KMJ 10-2-2 / Tulasi (low x high) recorded the highest positive significant sca effect indicating the importance of non-additive gene controlling this trait.

Estimation of variance due to gca was higher than the sca variance and both were significant for harvest index. The ratio of gca component of variance to total variance was nearer to unity indicating the role of additive gene in controlling this important physiological trait. However, predominance of non-additive gene action in the expression of harvest index was reported by Sharma *et. al.* (1988). Among the parental lines WGL 14280-1 ; NLR 34091 and Tulasi recorded significant positive gca effects. Five hybrids exhibited significant positive sca effects. WGL 14280-1 / NLR 30491 (high x high) ; WCL 14280-1 / CN 875-135-1-3 (high x low) WGL 14280-1 / CR 811-1 (high x low), N22 / KMJ 10-2-2 (low x low) and CN 875-135-1-3 / CR 811-1 (low x low). Since, both the additive and non-additive gene actions were involved, hybridization followed by *inter se* crossing among the superior selects in the segregating generations would be profitable in capitalizing both the types of gene action.

Considering test weight, additive gene action played a greater role in the expression of this trait confirming the observations of Sardana and Borthakur (1989), Supriochakraborty *et. al.* (1994), Sankar Rao (1994) and Ganesan *et. al.* (1997). On the contrary both gene actions were observed by Ravikumar (1987) and Lavanya *et. al.* (1997). Only non-additive gene action for this trait was observed by Ram *et. al.* (1991) and Singh *et. al.* (1996). WGL 14280-1 was the only parent recorded

significant positive gca effect. Nine cross combinations exhibited significant positive sca effects of which WGL 14280-1 / NLR 34091 (high x low) showed the highest significant sca effect. 260

For leaf area per plant, the variance due to gca was high when compared to sca variance. The ratio of gca variance to the total component of variance was nearer to unity indicating the importance of additive gene controlling this character which are in agreement with the results of Choi (1985) and Mazumdar *et. al.* (1990). NLR 30491 and CN 875-135-1-3 showed significant positive gca effects, while N22 and KMJ 10-2-2 exhibited significant negative gca effects. Only three hybrids NLR 33899 / CN 875-135-1-3 (low x high) NLR 30491 / KMJ 10-2-2 (high x low) and Tulasi / CR 811-1 (low x high) recorded significant positive sca effects indicating that the non-additive gene action is also important.

For grain yield per plant, the gca variance was found to be greater than sca variance. The ratio of general combining ability component of variance to total genetic variance was found to be close to unity indicating the preponderance of additive gene controlling this trait. Predominant role of additive gene effects in the inheritance of grain yield per plant was reported by Anandakumar and Sree Rangaswamy (1984), Haque *et. al.* (1981) and Ganesan *et. al.* (1998). However, contrary to these findings the predominance of non-additive gene effects

in the expression of grain yield was observed by Sardana and Borthakur (1987), Ram *et. al.* (1989), Ram *et. al.* (1991) and Singh *et. al.* (1996). 261
NLR 33899, WGL 14280-1 and Tulasi were the best general combiners for this character. NLR 30491, N22 and KMJ 10-2-2 had significant negative sca effects. Three hybrids exhibited significant positive sca effects. NLR 33899 / CN 875-135-1-3 (high x low) displayed highest significant positive sca effect indicating non-additive gene action. Similarly the cross Tulasi / CR 811-1 (high x low) also resulted in significant sca effects which implied non-additive gene action. On the other hand crosses involving good general combiners (NLR 33899 ; WGL 14280-1 and Tulasi) displayed negative sca effect. This may be due to epistatic interactions resulting in the inter cancellation of the components of heterosis.

When leaf rolling during moisture stress was considered, gca variance was higher than sca variance. The ratio of general combining ability component of variance to total genetic variance was found to be intermediate indicating the presence of both additive and non-additive components of gene action in governing this trait. Since, leaf rolling under moisture stress conditions is not a desirable character, the parents showing negative and significant gca effects should be selected for improving this trait. Among the parents, NLR 30491 and Tulasi were the best general combiners. Fourteen hybrids displayed significant

negative sca effects. The hybrids NLR 30491/N22 ; NLR 30491 / KMJ 10-2-2 and NLR 30491 / CR 811-1 involving high and low general combiners exhibited significant negative sca effect. The hybrid NLR 30491 / Tulasi showed significant positive sca effect, though both the parents showed high significant negative sca effects. This may be due to epistatic interactions resulting in intercancellation of the components of heterosis.

Favourable environment

In the present investigation the significant gca and sca effects revealed that both additive and non-additive components of gene action was operating in the determination of most of the traits under study (Table 20). However, the additive component was more predominant for all the characters except for leaf area per plant.

Based on the effects of general combining ability, CN 875-135-1-3 and CR 811-1 were found to be the best combiners for root dry weight and root to shoot ratio. KMJ 10-2-2, Tulasi and CN 875-135-1-3 for shoot dry weight, Tulasi and CR 811-1 were considered good general combiners for relative water content, N 22 and KMJ 10-2-2 for number of days to 50% flowering. NLR 33899, WGL 14280-1, KMJ 10-2-2 and Tulasi for plant height, Tulasi and CR 811-1 for number of ear bearing tillers per plant. WGL 14280-1, Tulasi and CN 875-135-1-3 for panicle length, CN

875-135-1-3 for number of spikelets per panicle, WGL 14280-1 and CN 875-135-1-3 for number of filled grains per panicle, CN 875-135-1-3 for spikelet fertility, NLR 33899 and WGL 14280-1 for harvest index and test weight, NLR 33899 and CN 875-135-1-3 for grain yield per plant. The results further indicated that there was close relationship between mean performance of parents and their gca effects.

When sca effects were considered, the top three specific combiners for grain yield per plant were WGL 14280-1 / KMJ 10-2-2 ; CN 875-135-1-3 / CR 811-1 and N22 / Tulasi. For root to shoot ratio the best specific combiners were NLR 33899 / CR 811-1, N22 / CN 875-135-1-3 and NLR 33899 / Tulasi, while Tulasi / CR 811-1, Tulasi / CN 875-135-1-3 and KMJ 10-2-2 / Tulasi for spikelet fertility per cent.

Seedling growth on PEG simulated drought conditions

Besides field studies on drought tolerance in rice, laboratory studies were also conducted in control conditions. Drought conditions were simulated in the laboratory by using aqueous solutions of PEG having different osmotic pressures (0.00 ; 3.00 ; 6.00 and 10.00 bars). Genetic studies so far on this subject are very limited. Hence, the objective of the present investigation was to study the seedling growth of eight parents and 28F₁ hybrids under simulated drought induced by PEG.

In the present investigation, it was revealed that the gca and sca variances were found to be significant for seedling shoot and root lengths at different osmotic pressures of PEG, except for shoot length at 6.00 bars of osmotic pressure. The components of variance due to gca ratio to total genetic variance was found to be intermediate indicating the role of additive as well as non-additive gene actions controlling the inheritance of these traits. Under controlled conditions, the parents viz., KMJ 10-2-2, Tulasi, CN 875-135-1-3 and CR 811-1 were found to be good general combiners for shoot and root lengths, while NLR 33899, WGL 14280-1 and Tulasi expressed positive gca effects for root length. At 10.00 bars of osmotic pressure NLR 33899 and WGL 14280-1 and CR 811-1 displayed positive gca effects for root length.

When sca effects were considered, the top three cross combinations for seedling shoot length at control conditions were Tulasi / CR 811-1; WGL 14280-1/CN 875-135-1-3 and NLR 33899/N22, while for root length Tulasi / CR 811-1 ; NLR 33899 / Tulasi and N22 / CN 875-135-1-3. At 10.00 bars of osmotic pressure the best cross combinations for shoot length were NLR 33899 / CR 811-1, WGL 14280-1 / KMJ 10-2-2 and CN 875-135-1-3 / CR 811-1, where as for root length NLR 33899 / Tulasi, WGL 14280-1 / NLR 30491 and WGL 14280-1 / KMJ 10-2-2 expressed significant positive sca effects.

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From the present investigation over the two environments viz., moisture stress and normal situations, the following conclusions were drawn based on the results of gca and sca effects of parents and crosses respectively.

The gca effects showed that none of the parents exhibited good general combining ability for all the characters simultaneously. However individual characters may be utilized for further breeding programme for improving these traits.

When the performance of parents at both the environments was considered, the parents viz. CN 875-135-1-3 and NLR 33899 were observed to be best combiners. Tulasi for root dry weight, root to shoot ratio and relative water content, NLR 30491 for number of spikelets per panicle, number of filled grains per panicle, spikelet fertility percent, harvest index, leaf area per plant and specific leaf weight, WGL 14280-1 for number of days to 50% flowering, number of ear bearing tillers per plant and test weight were considered best combiners in moisture stress environment. However, in favourable environment, the parent CN 875-135-1-3 was found to be best combiner for root dry weight, shoot dry weight, root to shoot ratio, panicle length, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility per cent and grain yield per plant, CR 811-1 for relative water content, number

of ear bearing tillers per plant, test weight and specific leaf weight. The parents KMJ 10-2-2 and WGL 14280-1 were considered to be best 266
combiners in both the environments for number of days to 50% flowering and plant height. Analysis of mean performance of the parents and their gca effects revealed that *per se* performance of the parents is a direct reflection of their respective gca effects in most of the cases.

When the hybrids in both the environments were considered, the hybrid NLR 33899 / CN 875-135-1-3 displayed significant positive sca effect for root dry weight, shoot dry weight, root to shoot ratio, spikelet fertility percent, and grain yield per plant and WGL 14280-1 / CN 875-135-1-3 for root to shoot ratio, relative water content, plant height, panicle length, number of spikelets per panicle, spikelet fertility per cent, specific leaf weight and leaf area per plant under moisture stress situation. However, in favourable environment, the hybrid Tulasi / CR 811-1 exhibited positive significant sca effect for relative water content, number of ear bearing tillers per plant, number of spikelets per panicle number of filled grains per panicle, spikelet fertility per cent, harvest index, specific leaf weight and grain yield per plant. The hybrid Tulasi / CR 811-1 was found to be best specific combiner in both the environments.

Most of the characters were governed predominantly by additive gene action. The presence of both additive and non-additive gene actions were also recorded for characters like number of ear bearing tillers per plant and leaf rolling with moisture stress situation and for leaf area per plant with favourable environment. So both additive as well as non-additive gene actions could be profitably exploited for improvement of different traits. The breeding methods which will utilize both additive and non-additive gene action might be useful very much for enhancement of yield potential in rice. The biparental mating followed by recurrent selection and pedigree breeding are likely to hasten the rate of genetic improvement for different characters. However, there is also scope for commercial exploitation of hybrid vigour for grain yield as indicated by high heterobeltiosis coupled with significant sca effects in the top ranking cross combinations for grain yield.

5.5 CORRELATION STUDIES BETWEEN CHARACTER PAIRS

Generally, direct selection for moisture stress tolerance is not aimed at in view of the complex nature of this character besides environmental influence. As such high genotypic and environmental interactions are likely to restrict improvement for this character. Further, moisture stress tolerance and its related physiological traits show different associations among themselves. Similarly grain yield is the end product of the interaction of a number of others, often interrelated

attributes. A thorough understanding of the interaction of characters among themselves has been of immense value in breeding programme. The efficiency of selection for yield mainly depends on the direction and magnitude of the association between yield and its components and among the components themselves.

It has been generally accepted that correlations between different characters represent a co-ordination of different physiological processes which is often achieved through linkage. While formulating a breeding programme, knowledge on the strength and type of such association, between characters is an important pre-requisite. From this it would be possible to bring about genetic upgradation in one character through selection of the another related trait.

The results of the present study on character association both under moisture stress and favourable environments are discussed hereunder.

In the present study on grain yield per plant was positively associated with root dry weight, root to shoot ratio, relative water content, plant height, panicle length, spikelet fertility percent, harvest index, test weight and leaf area per plant and negatively associated with number of days to 50% flowering, specific leaf weight and leaf rolling

under water limited conditions. Similar association of grain yield per plant with spikelet fertility percent, harvest index and test weight was reported by Xiang *et. al.* (1986) and Chen *et. al.* (1986), with plant height, ear bearing tillers per plant and test weight by Dhanraj *et. al.* (1987). Root dry weight under moisture stress situation is one of the important traits for drought tolerance. Shahid *et. al.* (1994) reported the association between root dry weight and drought tolerance. In the present investigation, root dry weight was positively correlated with shoot dry weight, root to shoot ratio, relative water content, plant height, panicle length, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility percent, grain yield per plant and leaf area per plant. However, this trait had negative correlation with number of days to 50% flowering, ear bearing tillers per plant, test weight, specific leaf weight and leaf rolling.

Positive association between shoot dry weight and grain yield per plant was observed in the present study. Shoot dry weight also expressed positive correlation with panicle length, number of spikelets per panicle, number of filled grains per panicle and spikelet fertility percent. In the present study root to shoot ratio was found to be positively correlated with grain yield per plant, leaf area per plant, spikelet fertility and relative water content under moisture stress situation, thereby revealing that root to shoot ratio had an important role on yield and its components under moisture stress conditions.

Relative water content is one of the vital physiological characters under moisture stress situations, which influences grain yield. Relative water content was positively associated with plant height, panicle length, number of days to 50% flowering, number of filled grains per panicle, spikelet fertility, harvest index, leaf area per plant and grain yield per plant. Several workers recorded positive association between number of days to 50% flowering and grain yield per plant (Gomathinayagam *et. al.* 1988 ; Yadav 1992 and Chauhan *et. al.* 1993). However, in the present study negative association was observed between grain yield per plant and number of days to 50% flowering. These results were confirmed by Dhanraj *et. al.* (1987).

Plant height is an important trait in rice which influences grain yield. Height is also influenced by environmental conditions. In the present study, plant height was found to be positively associated with grain yield per plant, panicle length, number of spikelets per panicle, number of filled grains per panicle, and spikelet fertility percent. Similar results were obtained by Supriochakraborty and Hazarika (1994) and Sarwagi *et. al.* (1997). Test weight was negatively correlated with plant height which is in confirmity with the results reported by Singh *et. al.* (1984) and Marimuthu *et. al.* (1990).

Positive association between number of ear bearing tillers per plant and grain yield per plant was observed in the present study. Similar results were obtained by Rao (1990), Singh *et. al.* (1994) and Varma *et. al.* (1997). However Mishra *et. al.* (1973) and Nakayama and Saito (1976) revealed negative association of number of panicles with grain number per panicle and test weight. Accordingly, in the present study also, ear bearing tillers per plant showed negative association with number of spikelets per panicle and 1000-grain weight.

The present investigation revealed that panicle length was positively correlated with grain yield per plant, 1000-grain weight, harvest index, number of spikelets per panicle and plant height, confirming the results reported by Dhanraj *et. al.* (1987), Prasad *et. al.* (1988) Remabai *et. al.* (1992) and Supriochakraborty and Hazarika (1994).

Grain yield per plant was positively associated with number of panicles per plant, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility percent, harvest index and test weight and was negatively associated with leaf rolling. Positive correlation was reported between grain yield and harvest index and number of spikelets per panicle by Gomosta (1988), Rao (1990), Chaubey and Richharia (1993) and Supriochakraborty and Hazarika (1994). With

increase in number of filled spikelets, the grain weight increases resulting in high harvest index which in turn results in higher grain yield.

Leaf area per plant recorded significant positive association with grain yield per plant. Similar observations were also reported by Yadav *et. al.* (1998). Maintaining optimum leaf area till maturity is a desirable plant type character. Early senescence is not desirable as it proportionately affects the translocation of photosynthates to grain. However, excess of leaf area proves detrimental to the plant due to mutual shading of leaves and affect light interception and there by photosynthetic efficiency. Under water limited conditions excess foliage will increase transpiration thus resulting in water loss and detrimental to the physiological functions of the plant.

Leaf rolling trait is an important physiological response of the plant under moisture stress conditions. Plant conserve water in unfavourable environments and continue to survive at the cost of grain production. In the present investigation, leaf rolling trait was negatively correlated with grain yield per plant and its components.

Favourable environment

Grain yield showed positive correlation with root dry weight, shoot dry weight, root to shoot ratio, relative water content, number of ear bearing tillers per plant, panicle length, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility per cent, harvest index, test weight, specific leaf weight and leaf area per plant. However, negative association was observed for plant height. Relative water content had positive correlation with root dry weight, number of ear bearing tillers per plant, number of filled grains per panicle and negatively associated with harvest index.

Plant height displayed positive association with root to shoot ratio, number of spikelets per panicle, number of filled grains per panicle, harvest index, test weight and leaf area per plant and negatively correlated with grain yield per plant, spikelet fertility per cent and relative water content. Leaf area per plant under favourable environment was significantly and positively correlated with shoot dry weight, number of ear bearing tillers per plant, spikelet fertility and specific leaf weight. But negatively associated with panicle length.

From the present investigation both under moisture stress and favourable environments it is inferred that root dry weight, relative water content, number of spikelets per panicle, spikelet fertility per cent,

harvest index and grain yield showed positive correlation with root to shoot ratio. Hence, these characters would be expected to play significant role in selection of better genotypes for improving moisture stress tolerance. Similarly, root dry weight, shoot dry weight, relative water content, number of ear bearing tillers per plant, panicle length, spikelet fertility per cent, harvest index, test weight, leaf area per plant exhibited highest positive association with grain yield per plant. The simultaneous selection for these traits might bring about an improvement in grain yield.

5.6 PATH COEFFICIENT ANALYSIS

The correlation coefficients measure the relationships between pairs of characters. But a dependent character is a product of interaction among many mutually associated component characters and variation in any one component trait disturbs the whole network of cause-effect system. The path coefficient analysis, a statistical device developed by Wright (1921) which takes into account the cause and effect relation between the variables is unique in partitioning the association into direct and indirect effects through other independent variables to any dependent variable. The present study was taken up to estimate the relative contribution of physiological and yield contributing characters towards grain yield under moisture stress as well as favourable environments.

Moisture stress situation

The results of path coefficient analysis under moisture stress situation, revealed that root dry weight, plant height, number of ear bearing tillers per plant, panicle length, number of filled grains per panicle, harvest index, test weight, leaf area per plant and leaf rolling exhibited moderate to high direct effects. These characters also exhibited positive and significant correlation with grain yield. Shoot dry weight ; root to shoot ratio, number of days to 50% flowering expressed negative effects on grain yield.

Root dry weight exerted a direct positive effect of a very high magnitude (1.546) on grain yield per plant under moisture stress situation (Shahid *et. al.* 1994). However, its effect was neutralized by the negative effects of shoot dry weight, root to shoot ratio and relative water content, finally leading to a total positive correlation coefficient of 0.819 between root dry weight and grain yield. It is interesting to note that root to shoot ratio shows positive correlation (0.837) with grain yield per plant which tends to display direct negative effect on grain yield. However, root to shoot ratio contributed positively through root dry weight, plant height, number of spikelets per panicle and leaf area per plant. Similar trend was observed in the case of relative water content and number of spikelets per panicle.

Though the characters viz., plant height (0.345), panicle length (0.469) ; harvest index (0.346), test weight (0.305) and leaf rolling (0.707) ²¹⁶ had high positive total correlation; their direct effects were moderate. This might be due to high indirect positive influence of root dry weight. Jangale *et. al.* (1987) stated that a positive correlation between a particular trait and yield did not necessarily lead to a direct positive effect on yield.

Favourable environment

Path coefficient analysis of physiological and yield determining traits on grain yield under favourable environment indicated that shoot dry weight, root to shoot ratio, number of ear bearing tillers per plant, number of filled grains and spikelet fertility percent exerted a direct influence on the grain yield, which also had positive significant association with it. Contrary to these observations the characters root dry weight, number of spikelets per panicle and specific leaf weight displayed negative direct effects, while the total correlation with grain yield was positive. This may be due to the high positive indirect effects through shoot dry weight and root to shoot ratio. From path analysis of grain yield with drought tolerant and other component traits studied in both the environments ; it was clearly understood that root dry weight, root to shoot ratio, relative water content ; panicle length, ear bearing tillers per plant, number of spikelets per panicle, number of filled grains

per panicle and spikelet fertility percent were the best characters which contributed to grain yield per plant, both directly and indirectly through various other component traits. Hence, it was suggested that selection should be practised for root dry weight, root to shoot ratio, relative water content, panicle length, number of ear bearing tillers per plant, number of spikelets per panicle, number of filled grains per panicle and spikelet fertility percent for isolating superior lines with genetic potentiality for high grain yield under moisture stress conditions.

Table 32 : Table showing best parents, best hybrids, high heterotic crosses over better parent, best general and specific combiners for different characters under moisture stress situation

S. No.	Character	Best parents (mean basis)	Best hybrids (mean basis)	Heterotic crosses over better parent	Best general combiners	Best specific combiners
1.	Root dry weight	NLR 33899 Tulasi NLR 30491	N22 / Tulasi Tulasi CR811-1 NLR 33899/CN875-135-1-3	Tulasi / CR 811-1 NLR 33899 / CN 875-135-1-3 CN 875-135-1-3 / CR 811-1	Tulasi CN 875-135-1-3 NLR 33899	NLR 33899 / CN 875-135-1-3 N22 / Tulasi Tulasi / CR 811-1
2.	Shoot dry weight	CN 875-135-1-3 NLR 30491 NLR 33899	N22 / Tulasi NLR 33899 / CN 875-135-1-3 NLR 30491/CN 875-135-1-3	N22 / Tulasi WGL 14280-1 / CR 811-1 WGL 14280-1 / KMJ 10-2-2	NLR 30491 NLR 33899 CN 875-135-1-3	N22 / Tulasi NLR 33899 / CN 875-135-1-3 WGL 14280-1 / CR 811-1
3.	Root / Shoot ratio	Tulasi NLR 33899 CR 811-1	Tulasi / CR 811-1 WGL 14280-1 / Tulasi NLR 33899 / Tulasi	NLR 33899 / CN 875-135-1-3 WGL 14280-1 / CN 875-135-1-3 KMJ 10-2-2 / CN 875-135-1-3	Tulasi NLR 33899 CR 811-1	NLR 33899 / CN 857-135-1-3 WGL 14280-1 / CN 875-135-1-3 NLR 30491 / N22
4.	Relative water content	CN 875-135-1-3 CR 811-1 Tulasi	Tulasi / CR 811-1 NLR 33899 / KMJ 10-2-2 NLR 30491 / N22	NLR 33899 / KMJ 10-2-2 Tulasi / CR 811-1 NLR 30491 / KMJ 10-2-2	Tulasi CN 857-135-1-3 CR 811-1	NLR 33899 / KMJ 10-2-2 Tulasi / CR 811-1 WGL 14280-1 / CN 875-135-1-3
5.	Days to 50% flowering	KMJ 10-2-2 N22 Tulasi	NLR 30491 / CR 811-1 NLR 33899 / WGL 14280-1 WGL 14280-1 / N22	NLR 33899 / KMJ 10-2-2 NLR 30491 / KMJ 10-2-2 N22 / KMJ 10-2-2	WGL 14280-1 KMJ 10-2-2 N22	NLR 30491 / CR 811-1 NLR 33899 / WGL 14280-1 NLR 33899 / Tulasi
6.	Plant height	WGL 14280-1 NLR 30491 KMJ 10-2-2	WGL 14280-1 / Tulasi WGL 14280-1 / KMJ 10-2-2 N22 / KMJ 10-2-2	N22 / Tulasi Tulasi / CR 811-1 NLR 33899 / Tulasi	KMJ 10-2-2 WGL 14280-1 CR 811-1	WGL 14280-1 / CN 875-135-1-3 WGL 14280-1 / Tulasi CN 875-135-1-3 / CR 811-1
7.	Number of ear bearing tillers per plant	WGL 14280-1 KMJ 10-2-2 NLR 33899	CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CR 811-1 N22 / CN 875-135-1-3	N22 / CN 85-75-135-1-3 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CR 811-1	WGL 14280-1 KMJ 10-2-2 N22	CN 875-135-1-3 / CR 811-1 N22 / CN 875-135-1-3 KMJ 10-2-2 / CR 811-1
8.	Panicle length	CN 857-135-1-3 Tulasi NLR 33899	WGL 14280-1 / CN 875-135-1-3 WGL 14280-1 / NLR 30491 WGL 14280-1 / N22	WGL 14280-1 / N22 WGL 14280-1 / NLR 30491 WGL 14280-1 / CN 857-135-1-3	CN 857-135-1-3 WGL 14280-1 NLR 30491	WGL 14280-1 / CN 875-135-1-3 N22 / Tulasi WGL / 14280-1 / N22
9.	Number of spikelets per panicle	NLR 875-135-1-3 NLR 30491 NLR 33899	WGL 14280-1 / CN 875-135-1-3 NLR 33899 / NLR 30491 NLR 30491 / CN 875-135-1-3	NLR 30491 / N22 Tulasi / CR 811-1 NLR 30491 / CR 811-1	NLR 30491 CN 875-135-1-3 NLR 33899	N22 / KMJ 10-2-2 WGL 14280-1 / CN 875-135-1-3 Tulasi / CR 811-1

S. No.	Character	Best parents (mean basis)	Best hybrids (mean basis)	Heterotic crosses over better parent	Best general combiners	Best specific combiners
10.	Number of filled grains per panicle	CN 875-135-1-3 NLR 30491 NLR 33899	WGL 14280-1 / CN 875-135-1-3 NLR 30491 / CR 811-1 NLR 33899 / NLR 34091	NLR 30491 / CR 811-1 WGL 14280-1 / CR 811-1 Tulasi / CR 811-1	NLR 30491 CN 875-135-1-3 Tulasi	NLR 30491 / CR 811-1 WGL 14280-1 / CN 875-135-1-3 KMJ 10-2-2 / Tulasi
11.	Spikelet fertility (%)	Tulasi NLR 30491 NLR 33899	NLR 3049 / CR 811-1 KMJ 10-2-2 / Tulasi NLR 33899 / CN 875-135-1-3	NLR 30491 / CR 811-1 Tulasi / CR 811-1 NLR 33899 / CR 811-1	NLR 30491 Tulasi NLR 33899	KMJ 10-2-2 / Tulasi NLR 33899 / CN 875-135-1-3 WGL 14280-1 / CN 875-135-1-3
12.	Harvest index	Tulasi NLR 30491 NLR 33899	WGL 14280-1 / Tulasi WGL 14280-1 / CR 811-1 WGL 14280-1 / CN 875-135-1-3	NLR 34091 / CR 811-1 WGL 14280-1 / CR 811-1 KMJ 10-2-2 / CR 811-1	NLR 30491 WGL 14280-1 Tulasi	CN 875-135-1-3 / CR 811-1 WGL 14280-1 / CR 811-1 N22 / KMJ 10-2-2
13.	Test weight	Tulasi CN 875-135-1-3 CR 811-1	CN 875-135-1-3 / CR 811-1 WGL 14280-1 / Tulasi WGL 14280-1 / CR 811-1	WGL 14280-1 / NLR 34091 WGL 14280-1 / N22 WGL 14280-1 / KMJ 10-2-2	WGL 14280-1 CR 811-1 CN 875-135-1-3	WGL 14280-1 / NLR 30491 NLR 33899 / N22 N22 / KMJ 10-2-2
14.	Specific leaf weight	NLR 30491 NLR 33899 KMJ 10-2-2	WGL 14280-1 / CN 875-135-1-3 NLR 30491 / CN 875-135-1-3 NLR 30491 / CR 811-1	NLR 30491 / CN 875-135-1-3 WGL 14280-1 / CN 875-135-1-3 NLR 33899 / N22	NLR 30491 WGL 14280-1 KMJ 10-2-2	WGL 14280-1 / CN 875-135-1-3 NLR 33899 / N22 NLR 30491 / CN 875-135-1-3
15.	Leaf area per plant	NLR 30491 CN 875-135-1-3 Tulasi	Tulasi / CR 811-1 NLR 33899 / CN 875-135-1-3 NLR 33899 / NLR 30491	Tulasi / CR 811-1 NLR 30491 / KMJ 10-2-2 NLR 33899 / CR 811-1	NLR 30491 CN 875-135-1-3 Tulasi	Tulasi / CR 811-1 NLR 34091 / KMJ 10-2-2 WGL 14280-1 / CN 875-135-1-3
16.	Grain yield per plant	Tulasi NLR 33899 NLR 30491	NLR 33899 / CN 875-135-1-3 Tulasi / CR 811-1 NLR 33899 / Tulasi	Tulasi / CR 811-1 NLR 30491 / N22 WGL 14280-1 / N22	NLR 33899 Tulasi WGL 14280-1	NLR 33899 / CN 875-135-1-3 Tulasi / CR 811-1 NLR 30491 / N22
17.	Leaf area per plant	NLR 30491 Tulasi NLR 33899	N22 / Tulasi CN 875-135-1-3 / CR 811-1 NLR 33899 / CR 811-1	NLR 33899 / NLR 30491 WGL 14280-1 / Tulasi NLR 33899 / Tulasi	NLR 33899 CN 875-135-1-3 WGL 14280-1	KMJ 10-2-2 / CR 811-1 NLR 30491 / CN 875-135-1-3 N22 / CR 811-1

Table 33 : Table showing best parents, best hybrids, high heterotic crosses over better parent, best general and specific combiners for different characters under favourable situation

S. No.	Character	Best parents (mean basis)	Best hybrids (mean basis)	Heterotic crosses over better parent	Best general combiners	Best specific combiners
1.	Root dry weight	CN 875-135-1-3 NLR 30491 CR 811-1	CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CR 811-1 KMJ 10-2-2 / CN 875-135-1-3	KMJ 10-2-2 / CR 811-1 NLR 30491 / CN 875-135-1-3 NLR 33899 / Tulasi	CN 875-135-1-3 CR 811-1 Tulasi	NLR 30491 / CN 875-135-1-3 KMJ 10-2-2 / CR 811-1 CN 875-135-1-3 / CR 811-1
2.	Shoot dry weight	Tulasi NLR 30491 CN 875-135-1-3	KMJ 10-2-2 / CN 875-135-1-3 KMJ 10-2-2 / CR 811-1 NLR 30491 / CN 875-135-1-3	NLR 30491 / CN 875-135-1-3 KMJ 10-2-2 / CN 875-135-1-3 KMJ 10-2-2 / CR 811-1	CN 875-135-1-3 KMJ 10-2-2 Tulasi	NLR 30491 / CN 875-135-1-3 KMJ 10-2-2 / CR 811-1 KMJ 10-2-2 / CR 875-135-1-3
3.	Root / Shoot ratio	CN 875-135-1-3 CR 811-1 NLR 30491	N22 / CN 875-135-1-3 NLR 33899 / CR 811-1 Tulasi / CR 811-1	NLR 33899 / Tulasi NLR 33899 / CR 811-1	CN 875-135-1-3 CR 811-1 N22	NLR 33899 / CR 811-1 N22 / CN 875-135-1-3 NLR 33899 / Tulasi
4.	Relative water content	Tulasi KMJ 10-2-2 NLR 30491	Tulasi / CR 811-1 N22 / CR 811-1 WGL 14280-1 / NLR 30491	N22 / CR 811-1 WGL 14280-1 / NLR 30491 NLR 30491 / N22	CR 811-1 Tulasi KMJ 10-2-2	N22 / CR 811-1 NLR 33899 / CN 875-135-1-3 Tulasi / CR 811-1
5.	Days to 50% flowering	N22 KMJ 10-2-2 Tulasi	Tulasi / CN 875-135-1-3 Tulasi / CR 811-1 NLR 33899 / NLR 30491	NLR 33899 / KMJ 10-2-2 NLR 33899 / N22 NLR 33899 / CN 875-135-1-3	KMJ 10-2-2 N22 WGL 14280-1	N22 / KMJ 10-2-2 Tulasi / CN 875-135-1-3 Tulasi / CR 811-1
6.	Plant height	KMJ 10-2-2 WGL 14280-1 NLR 30491	WGL 14280-1 / KMJ 10-2-2 NLR 33899 / NLR 30491 NLR 33899 / WGL 14280-1	KMJ 10-2-2 / CN 875-135-1-3 NLR 30491 / CN 875-135-1-3 Tulasi / CN 875-135-1-3	KMJ 10-2-2 WGL 14280-1 NLR 33899	NLR 30491 / KMJ 10-2-2 WGL 14280-1 / CN 875-135-1-3 WGL 14280-1 / N22
7.	Number of ear bearing tillers per plant	WGL 14280-1 NLR 30491 NLR 33899	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CR 811-1	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CR 811-1	CR 811-1 Tulasi KMJ 10-2-2	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / CN 875-135-1-3
8.	Panicle length	CN 875-135-1-3 WGL 14280-1 Tulasi	WGL 14280-1 / Tulasi WGL 14280-1 / CN 875-135-1-3 Tulasi / CR 811-1	WGL 14280-1 / Tulasi Tulasi / CR 811-1 NLR 30491 / Tulasi	CN 875-135-1-3 WGL 14280-1 Tulasi	WGL 14280-1 / Tulasi N22 / CR 875-135-1-3 Tulasi / CR 811-1
9.	Number of spikelets per panicle	NLR 30491 CN 875-135-1-3 KMJ 10-2-2	WGL 14280-1 / CN 875-135-1-3 CN 875-135-1-3 / CR 811-1 CN 33899 / CN 875-135-1-3	NLR 33899 / N22 Tulasi / CR 811-1 WGL 14280-1 / N22	CN 875-135-1-3 WGL 14280-1 NLR 33899	Tulasi / CR 811-1 NLR 33899 / N22 N22 / CN 875-135-1-3

S. No.	Character	Best parents (mean basis)	Best hybrids (mean basis)	Heterotic crosses over better parent	Best general combiners	Best specific combiners
10.	Number of filled grains per panicle	CN 875-135-1-3 NLR 30491 NLR 33899	CN 875-135-1-3 / CR 811-1 Tulasi / CR 811-1 NLR 33899 / CN 875-135-1-3	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 NLR 33899 / CR 811-1	CN 875-135-1-3 WGL 14280-1 CR 811-1	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / Tulasi
11.	Spikelet fertility per cent	NLR 33899 CN 875-135-1-3 WGL 14280-1	CN 875-135-1-3 / CR 811-1 Tulasi / CR 811-1 KMJ 10-2-2 / Tulasi	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / Tulasi	CN 875-135-1-3 CR 811-1 Tulasi	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 KMJ 10-2-2 / Tulasi
12.	Harvest index	NLR 33899 Tulasi WGL 14280-1	WGL 14280-1 / CN 875-135-1-3 NLR 33899 / WGL 14280-1 WGL 14280-1 / KMJ 10-2-2	WGL 14280-1 / CN 875-135-1-3 NLR 30491 / CR 811-1 NLR 30491 / KMJ 10-2-2	NLR 33899 WGL 14280-1 CN 875-135-1-3	Tulasi / CR 811-1 WGL 14280-1 / CN 875-135-1-3 NLR 30491 / Tulasi
13.	Test weight	CR 811-1 CN 875-135-1-3 NLR 33899	CN 875-135-1-3 / CR 811-1 Tulasi / CR 811-1 KMJ 10-2-2 / CR 811-1	NLR 30491 / N22 N22 / KMJ 10-2-2 NLR 30491 / KMJ 10-2-2	CR 811-1 CN 875-135-1-3 WGL 14280-1	NLR 30491 / N22 KMJ 10-2-2 / CR 811-1 NLR 33899 / N22
14.	Specific leaf weight	WGL 14280-1 N22 Tulasi	Tulasi / CR 811-1 NLR 33899 / CR 811-1 CN 875-135-1-3 / CR 811-1	NLR 33899 / CR 811-1 CN 875-135-1-3 / CR 811-1 Tulasi / CR 811-1	CR 811-1 NLR 33899 Tulasi	Tulasi / CR 811-1 CN 875-135-1-3 / CR 811-1 NLR 33899 / CR 811-1
15.	Leaf area per plant	CN 875-135-1-3 NLR 33899 CR 811-1	NLR 33899 / N22 NLR 30491 / CN 875-135-1-3 WGL 14280-1 / N22	KMJ 10-2-2 / Tulasi WGL 14280-1 / KMJ 10-2-2 WGL 14280-1 / N22	Tulasi CR 811-1 KMJ 10-2-2	KMJ 10-2-2 / Tulasi NLR 30491 / CN 875-135-1-3 NLR 33899 / N22
16.	Grain yield per plant	CN 875-135-1-3 NLR 33899 WGL 14280-1	CN 875-135-1-3 / CR 811-1 Tulasi / CR 811-1 WGL 14280-1 / KMJ 10-2-2	Tulasi / CR 811-1 N22 / Tulasi WGL 14280-1 / KMJ 10-2-2	CN 875-135-1-3 NLR 33899 WGL 14280-1	WGL 14280-1 / KMJ 10-2-2 Tulasi / CR 811-1 N22 / Tulasi

Table 34 : Table showing best parents, best hybrids, high heterotic crosses over better parent, best general and specific combiners for seedling growth in simulated drought conditions under different osmotic pressures of polyethylene glycol

Character	Best parents (mean basis)	Best hybrids (mean basis)	Heterotic crosses over better parent	Best general combiners	Best specific combiners
Control (0.00 bars) Shoot length	N22 NLR 30491 CN 875-135-1-3	Tulasi / CR 811-1 KMJ 10-2-2 / CN 875-135-1-3 WGL 14280-1 / CN 875-135-1-3	Tulasi / CR 811-1 NLR 33899 / Tulasi WGL 14280-1 / CN 875-135-1-3	Tulasi KMJ 10-2-2 CR 811-1	Tulasi / CR 811-1 WGL 14280-1 / CN 875-135-1-3 NLR 33899 / N22
Root length	KMJ 10-2-2 N22 CR 811-1	Tulasi / CR 811-1 NLR 33899 / Tulasi NLR 33899 / NLR 30491	NLR 33899 / Tulasi NLR 30491 / CN 875-135-1-3 NLR 33899 / NLR 30491	Tulasi WGL 14280-1 NLR 33899	Tulasi / CR 811-1 N22 / CN 875-135-1-3 NLR 33899 / Tulasi
3.00 bars Shoot length	NLR 33899 CR 811-1 KMJ 10-2-2	NLR 33899 / N22 WGL 14280-1 / CR 811-1 NLR 30491 / CN 875-135-1-3	Tulasi / CN 875-135-1-3 NLR 30491 / CN 875-135-1-3 NLR 30491 / Tulasi	CR 811-1 NLR 33899 N22	NLR 30491 / CN 875-135-1-3 NLR 30491 / Tulasi NLR 33899 / N22
Root length	WGL 14280-1 N22 Tulasi	KMJ 10-2-2 / Tulasi NLR 33899 / KMJ 10-2-2 NLR 33899 / Tulasi	NLR 33899 / KMJ 10-2-2 NLR 30491 / KMJ 10-2-2 KMJ 10-2-2 / Tulasi	KMJ 10-2-2 CN 875-135-1-3 Tulasi	KMJ 10-2-2 / Tulasi NLR 33899 / Tulasi WGL 14280-1 / CR 811-1
6.00 bars Shoot length	NLR 33899 N22 WGL 14280-1	NLR 33899 / CN 875-135-1-3 WGL 14280-1 / KMJ 10-2-2 N22 / Tulasi	NLR 30491 / Tulasi NLR 30491 / CN 875-135-1-3 NLR 30491 / KMJ 10-2-2	N22 NLR 33899 CR 811-1	NLR 30491 / CN 875-135-1-3 NLR 33899 / CN 875-135-1-3 WGL 14280-1 / KMJ 10-2-2
Root length	KMJ 10-2-2 Tulasi N22	WGL 14280-1 / NLR 30491 NLR 30491 / CN 875-135-1-3 NLR 33899 / Tulasi	WGL 14280-1 / NLR 30491 NLR 30491 / CN 875-135-1-3 WGL 14280-1 / CR 811-1	WGL 14280-1 NLR 33899 CR 811-1	WGL 14280-1 / NLR 30491 NLR 30491 / CN 875-135-1-3 NLR 33899 / Tulasi
10.00 bars Shoot length	NLR 30491 CR 811-1 CN 875-135-1-3	NLR 33899 / CR 811-1 WGL 14280-1 / KMJ 10-2-2 CN 875-135-1-3 / CR 811-1	WGL 14280-1 / KMJ 10-2-2 NLR 33899 / Tulasi NLR 33899 / CR 811-1	CR 811-1 NLR 33899 NLR 30491	NLR 33899 / CR 811-1 WGL 14280-1 / KMJ 10-2-2 CN 875-135-1-3 / CR 811-1
Root length	CR 811-1 CN 875-135-1-3 NLR 33899	NLR 33899 / Tulasi WGL 14280-1 / NLR 30491 WGL 14280-1 / KMJ 10-2-2	KMJ 10-2-2 / Tulasi NLR 33899 / Tulasi WGL 14280-1 / NLR 30491	NLR 33899 CR 811-1 WGL 14280-1	NLR 33899 / Tulasi WGL 14280-1 / NLR 30491 WGL 14280-1 / KMJ 10-2-2

Summary

CHAPTER - VI

SUMMARY

Tolerance to moisture stress is highly desirable varietal characteristic for water limited areas. Very little effort has been made to understand the mode of inheritance of drought tolerance. Knowledge of the genetics of drought tolerance in rice increases efficiency in efforts for evolving drought tolerant varieties.

The present study was undertaken at Agricultural Research Station, Nellore during Rabi 1996, 1997 and 1998 to conceptualize genetic information on variation for drought tolerance, yield and its component traits, their mode of inheritance and their interrelationships in rice crop under moisture stress as well as favourable environments.

Analysis of variance indicated the existence of significant variation among the 60 genotypes for the characters studied. The genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability (broad sense) were obtained by following appropriate statistical procedures. In the present study, high genotypic coefficient of variation was registered by root dry weight, shoot dry weight, plant height, number of ear bearing tillers per plant, number of filled grains per panicle and grain yield per plant indicating the existence of greater diversity for these characters in the genotypes studied. For different yield and drought tolerance

attributes, promising genotypes viz., CR 811-1; Tulasi and CN 875-135-1-3 were identified and they may serve as potential donors in practical breeding programmes.

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High heritability coupled with high genetic advance as percentage of mean was observed for number of days to 50% flowering, plant height and test weight indicating the involvement of additive genes in their expression and possibility of improving these characters through selection.

As genetic diversity forms sound basis for selection of parents, genetic diversity as measured by Mahalanobis D^2 statistic, was studied for drought tolerance, yield and its component traits under moisture stress conditions among 60 rice genotypes in Rabi 1996. The multivariate analysis revealed that the 60 genotypes had considerable diversity and could be accommodated into nine distinct clusters and the mode of distribution of genotypes from different eco-geographical regions into various clusters was at random, indicating that geographical isolation may not be the only factor causing diversity. Similarly the genotypes from the same geographical area falling into different clusters may be due to selection and genetic drift under diverse environmental conditions with in same geographical area. Therefore, it is suggested that geographical diversity may not always be a useful index of genetic

diversity in rice. Of the thirteen characters studied, number of days to 50% flowering, plant height and test weight were the major contributing characters for genetic divergence among the genotypes as these characters accounted for 85 per cent of the total divergence. Hence, selection of parents differing in these traits viz. root dry weight, shoot dry weight, relative water content, number of days to 50% flowering, plant height, number of ear bearing tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility percent, harvest index, test weight and grain yield per plant may be useful for the utilization of divergent material for heterosis breeding programmes in rice. Firm relationship between genetic divergence and geographic distance has not been established through the present investigation.

Based on the results of D^2 analysis eight parents viz., NLR 33899; WGL 14280-1 ; NLR 30491 ; N22, KMJ 10-2-2 ; Tulasi; CN 875-135-1-3 and CR 811-1 were selected and crossed in a diallel fashion without reciprocals and 28 hybrids were obtained. The field experiment was conducted in a randomized block design in Rabi 1998. Method 2 Model I of Griffings (1956) diallel approach was used for the combining ability analysis. Heterosis percentages were estimated both over mid-parental value and better parent.

Analysis of variance indicated the existence of highly significant variation among 36 genotypes for all the characters studied except for number of ear bearing tillers per plant and test weight. 286

The perusal of mean performance of parents and crosses revealed that NLR 30491 had better performance for plant height, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility per cent, harvest index, specific leaf weight, leaf area per plant and leaf rolling characters. While, Tulasi was best for root to shoot ratio, relative water content, number of days to 50% flowering, spikelet fertility per cent, harvest index, test weight and grain yield per plant. However, the performance of CN 875-135-1-3 was best in favourable environment. These parents can be used in intensive hybridization programme for incorporating above traits.

With regard to hybrid vigour, the magnitude of heterosis was very high for number of filled grains per panicle (128.46%), test weight (118.50%) and grain yield per plant (221.43%) under moisture stress condition. However the highest heterobeltiosis was recorded for shoot dry weight (155.21%), number of ear bearing tillers per plant (106.90%) and leaf area per plant (278.12%) under favourable environment. For other characters viz. root dry weight, relative water content, root to shoot ratio, spikelet fertility per cent ; harvest index and leaf area per plant the percentage of heterosis was high.

Under moisture stress and favourable environments, consistently highest heterobeltiosis was observed in the cross combination Tulasi / CR811-1 for grain yield per plant, number of spikelets per panicle, number of filled grains per panicle and spikelet fertility per cent, NLR 33899 / KMJ 10-2-2 for number of days to 50% flowering ; CN 875-135-1-3 / CR 811-1 and KMJ 10-2-2 / CR 811-1 for number of ear bearing tillers per plant.

As the hybrid Tulasi / CR 811-1 had consistently displayed high heterosis coupled with good mean performance, this cross combination was identified as best hybrid and can be utilized in hybrid seed production on commercial basis.

The analysis of variance for combining ability revealed that both general combining ability (gca) and specific combining ability (sca) variances were significant for all the characters studied in both the environments, except root to shoot ratio and leaf area per plant in favourable environment, indicating the importance of both additive and non-additive genetic variances for these characters. The gca effects indicated that parents viz., CN 875-135-1-3 ; Tulasi and WGL 14280-1 were the best general combiners. Specific combining ability effects indicated that high sca effects of any cross combination need not always depend on the level of gca effects of its parent. Out of the 28 cross

combinations tested in the present study, the hybrid Tulasi / CR 811-1 was appeared to be most promising for grain yield per plant in both the environments.

Based on the study, it is suggested that biparental mating followed by recurrent selection and pedigree breeding are likely to accelerate the rate of genetic improvement for different characters. At the same time, there is also scope for commercial exploitation of hybrid vigour for grain yield as indicated by significantly high heterobeltiosis.

Simple correlation coefficients were computed based on the data collected from the set of 36 genotypes to learn the nature and magnitude of interrelationships among different character pairs. The results of the present study indicated that root dry weight, root to shoot ratio, relative water content, plant height, panicle length ; spikelet fertility percent, harvest index, test weight and leaf area per plant were strongly associated with grain yield per plant under moisture stress situation. The simultaneous selection for these traits might bring about an improvement in grain yield per plant under moisture stress environment. However, under favourable environment number of ear bearing tillers per plant, number of spikelets per panicle, number of filled grains per panicle, spikelet fertility per cent, specific leaf weight and leaf area per plant were strongly correlated with grain yield. Selection based on these traits would help in improving the grain yield.

Path analysis of drought tolerant as well as yield contributing traits indicated that root dry weight, root to shoot ratio, relative water content, panicle length, number of ear bearing tillers per plant, spikelet fertility percent and number of filled grains per panicle, largely contributed to grain yield both directly and indirectly through other characters. Selection with greater emphasis on these characters would be effective in isolating better genotypes for moisture stress tolerance.

Analysis of variance for seedling growth under simulated drought conditions with PEG revealed presence of significant variation among 36 genotypes.

When the mean performance of parents and crosses was considered, it was found that the parents CN 875-135-1-3 and CR 811-1 had the highest root length at 10.00 bars of osmotic pressure. The hybrids NLR 33899/Tulasi ; WGL 14280-1/NLR 30491 and WGL 14280-1/KMJ 10-2-2 were good for root length, however, the cross combinations NLR 33899 / CR 811-1, WGL 14280-1 / KMJ 10-2-2 and CN 875-135-1-3/ CR 811-1 exhibited highest shoot length.

The analysis of variance for combining ability was indicated that both general combining ability (gca) and specific combining ability (sca) variances were significant for seedling growth except for shoot length

at 6.00 bars of osmotic pressure, which revealed the importance of both additive and non-additive genetic variances. The parents NLR 33899, WGL 14280-1 and CR 811-1 displayed positive gca effects for seedling root and shoot growths at 10.00 bars of osmotic pressure. The ratio of general combining ability component of variance to total genetic variance was intermediate, indicating the presence of both additive and non-additive component of gene action in governing the seedling growth under simulated drought conditions. 290

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