

**GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND
AGRONOMIC TRAITS CONTRIBUTING TO SEED YIELD IN
SOYBEAN (*Glycine max* (L.) Merrill)**

ARUNAKUMAR, N. P.

**DEPARTMENT OF GENETICS AND PLANT BREEDING
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE
2008**

**GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND
AGRONOMIC TRAITS CONTRIBUTING TO SEED YIELD IN
SOYBEAN (*Glycine max* (L.) Merrill)**

ARUNAKUMAR, N. P.

*Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of*

Master of Science (Agriculture)

In

Genetics and Plant Breeding

Bangalore

April, 2008



**DEPARTMENT OF GENETICS AND PLANT BREEDING
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

CERTIFICATE

This is to certify that the thesis entitled “**GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND AGRONOMIC TRAITS CONTRIBUTING TO SEED YIELD IN SOYBEAN (*Glycine max* (L.) Merrill).**” Submitted by **Mr. ARUNAKUMAR, N. P.**, in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) IN GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by him during the period of his study in this university under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Bangalore
April 2008

(M. Swamy)
Major Advisor

Approved by:

Chairperson:

M. Swamy

Members:

M. R. Gururaja Rao

I. S. Aftab Hussain

C. R. Ravishankar

Acknowledgement

I express from heart my esteem and profound sense of gratitude to Dr. M. Swamy Professor, Scheme Head, AICRP on soybean, Dept. of Genetics and Plant Breeding, GKVK, Bangalore and chairperson of my advisory committee for his invaluable guidance, pragmatic ideas, ardent involvement, constant supervision and constructive criticism during the course of research and preparation of manuscript. In fact, I was fortunate to have such a great personality as the chairperson of my advisory committee.

The moral zeal and constant assurance at every count bestowed by other members of advisory committee Dr. M. R. Gururaja Rao, Professor, Dept. of Genetics and Plant Breeding, GKVK, UAS, Bangalore and Dr. C. R. Ravishankar, Professor and Scheme Head, Millets scheme, ZARS, V.C. farm, Mandya, Dr. I. S. Aftab Hussain, Professor, Dept. of Plant Physiology, GKVK, Bangalore and M. Chandrappa, Soybean Agronomist, AICRP on Soybean, ZARS, Bangalore for their critical suggestion and constant encouragement throughout the period of this investigation and preparation of thesis.

I would like to thank the staff of the Department of Genetics and Plant Breeding, GKVK, UAS, Bangalore for their constant help during the course of study.

Student's life is incomplete without making friends; I would like to take this opportunity to thank my beloved friends for all their support and encouragement throughout my education.

Bangalore
April, 2008

(ARUNAKUMAR, N. P.)

Genetic variability for drought tolerance and agronomic traits contributing to seed yield in soybean (*Glycine max* (L.) Merrill)

Abstract

An investigation was carried out using 344 genotypes and four checks during *Kharif-2006* and *Summer-2007* seasons in AICRP on soybean UAS, GKVK, Bangalore. These genotypes were screened for genetic variability for seed yield and its attributing characters. The inter character correlation and path analysis were carried out to reveal the relationship of different characters with seed yield and discriminant function analysis was done to arrive at good combination of characters to select for high yielding genotypes. The selected genotypes were screened for thermo-tolerance and then, thermo-tolerant genotypes were screened for drought tolerance and their root morphology was also studied. High values of PCV and GCV were recorded for plant height, number of branches per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, 100 seed weight and seed yield per plant. The estimate of heritability was high for plant height with high genetic advance. Path coefficient analysis indicated that selection for high number of seeds per plant and high 100 seed weight will be effective to achieve the selection of high yielding lines because these characters had recorded high direct effect on seed yield per plant. Under discriminant function analysis highest relative efficiency was observed when selection was based on seeds per plant and number of branches per plant under two character combinations. Where as, among three characters combinations the highest relative efficiency was observed for the combination of days to 50 per cent flowering, seeds per plant and branches per plant. Based on these combinations, 50 high yielding genotypes were selected. The selected genotypes were screened for thermo-tolerance. Where, eight thermotolerant genotypes were selected based on top total rank scores. They were screened for drought tolerance and for their root morphology. Finally, the genotypes PK-34 and KB-79 were selected as thermo-tolerant as well as drought-tolerant lines among all the genotypes.

CONTENTS

CHAPTER	TITLE	PAGE No.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-19
III	MATERIAL AND METHODS	20-43
IV	EXPERIMENTAL RESULTS	44-82
V	DISCUSSION	83-100
VI	SUMMARY	101-102
VII	REFERENCES	103-118
VIII	APPENDIX	119-130

LIST OF TABLES

Sl.No.	TITLE	Page No.
1	Analysis of variance for different quantitative traits in soybean	47
2	Estimates of phenotypic and genotypic coefficients of variability, heritability and expected genetic advance in respect of nine characters in soybean genotypes	48
3	Phenotypic correlation coefficients among nine quantitative traits in soybean	52
4	Path coefficient analysis showing the direct and indirect effects of different characters on seed yield in soybean at phenotypic level	54
5	Selection indices for single and different combinations of yield component characters in Soybean	58
6	Soybean genotypes with their survival (%) under temperature induced response after three days recovery	61
7	Survival of Soybean seedlings at different temperature and duration combinations	63
8	Survival of Soybean seedlings at different series of induction temperature	64
9	Effect of induction treatment followed by lethal temperature on survival percent and recovery growth in soybean	66
10	Analysis of variance for different recovery growth parameters in soybean	67
11(a)	Analysis of variance for different traits in soybean under 25% F.C. moisture stress	70
11(b)	Analysis of variance for different traits in soybean under 50% F.C. moisture stress	70
11(c)	Analysis of variance for different traits in soybean under 100% F.C.	70
12	Shoot length (cm) of soybean genotypes as influenced by different levels of moisture under pot culture	72
13	Root length (cm) of soybean genotypes as influenced by different levels of moisture under pot culture	72
14	Leaf area (cm ²) of soybean genotypes as influenced by different levels of moisture under pot culture	73
15	Root dry weight (mg) of soybean genotypes as influenced by different levels of moisture under pot culture	73
16	Shoot dry weight (mg) of soybean genotypes as influenced by different levels of moisture under pot culture	75

17	Total dry weight (mg) of soybean genotypes as influenced by different levels of moisture under pot culture	75
18	Percent membrane leakage in soybean genotypes as influenced by different levels of moisture under pot culture	77
19	Rate of water loss (mg/cm ² /hr) in soybean genotypes as influenced by different levels of moisture under pot culture	77
20	Mean values for different growth and root morphological traits of soybean genotypes	79
21	Analysis of variance for different growth and root morphological traits in soybean	80

LIST OF PLATES

Sl .No	TITLE	Between pages
1	Recovery growth of thermo-tolerant and susceptible soybean genotypes after induction and lethal temperature treatment	67-68
2	General view of pot culture experiment to screen for drought tolerance	70-71
3	Drought tolerant (KB-79) and susceptible (VLS-40) soybean genotypes under moisture stress condition	70-71
4	Root morphology of different soybean genotypes under pipe study	81-82

INTRODUCTION

I INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is considered as miracle crop containing 40% protein and 20 % oil. It plays major role in the world food system. It produces three times more protein than rice, wheat, maize, and it is excellent source of polyunsaturated fatty acids (PUFA). In China, soybean is known as “meat of the field”. Under the present situation of shortage of edible oil as well as protein and problems like malnutrition in India, it has a greater role to play. Soybean cultivation, production, processing and utilization have been gaining rapid momentum in the country. Presently in India, it has covered an area of 8.87 m. ha. with 9.46 m. tons of production with productivity of 1067 kg per hectare (Annon-2008). Karnataka is one of the soybean cultivating states with an area of 1,78,000 hectares accounting for the production of 1,14,000 tons with a productivity of 640 kg per hectare (Annon-2006).

Since majority of the cultivated area comes under rainfed condition during *Kharif* season, the productivity level is low in soybean. The genetic variability for the characters of economic importance is the basic prerequisite for improvement of any crop species. Yield being a complex character is influenced by number of other yield contributing characters and greatly influenced by variation in environmental factors. The observed variability in these characters is the sum total effect of concerned genes plus the influence of environment. Thus, it is necessary to partition the variability into heritable and non-heritable components with suitable genetic parameters, such as genotypic and phenotypic coefficient of variation, heritability and genetic advance. Since, seed yield is a complex character resulting from the interplay of various related traits and the environmental influence, its heritability is low. As a result, direct selection for yield is less efficient in improving productivity of a crop. The correlation analysis studies are of great help in formulating efficient scheme of multiple trait selection, as they provide means for direct and indirect selection of component characters for improvement of yield (Bhandarkar, 1999).

Even though the selection for high yield is made by breeders, the productivity will be low because of several other reasons. In soybean, the primary one is moisture stress along with high or low temperature. These stresses are often encountered by soybean crop sown late in *kharif* due to late onset of monsoon. Normally, the crop is grown under rainfed situation during *kharif* with poor management. Further, soybean is sensitive to moisture and high temperature stress. Higher temperatures above 30⁰ C are known to induce flower drop, senescence, reduced pod set and affect pollen viability, seed quality and protein content in the seed, thereby reduce the productivity in many crop plants (Hall, 1992). Based on heat-tolerance in food legumes, the legumes were ranked from heat-tolerant to sensitive in the order of groundnut, soybean, pigeon pea and chickpea. It has been well established that, the plants, which are subjected to sublethal stress before being exposed to the lethal stress, perform better compared to the ones, which are directly exposed to the lethal stress. Such a phenomenon is often referred to as acquired tolerance. So based on the principle of acquired tolerance, a novel technique has been developed in the laboratory and designated as Temperature Induction Response (TIR). Using this TIR technique, thermo tolerant lines/genotypes in many crop plants have been identified by earlier workers (Ganesh Kumar, 1999; Sreekanth Attaluri, 1998).

Since, water is also one of the most important limiting factor for crop productivity, the demand for drought tolerant genotypes will be high as water resources and the funds to access them become more limited. The difficulties in selection of drought tolerant lines in the past have included the identification of physiological characteristics that are correlated with drought stress that could be used as indicators of drought tolerance. So, physiologists are able to identify various plant characteristics that correlate with drought tolerance such as root characteristics (Basal *et al.*, 2003). Crops are commonly subjected to periodic water deficits during any particular growing season. Measuring drought tolerance of individual plants or established genotypes under field conditions is

difficult due to variation in weather condition. This has led to efforts of drought simulation studies in green house and pot culture studies at seedling stage (Landsberger *et al.*, 2006). Hence, the present study is envisaged to measure variability for yield, high temperature tolerance and drought tolerance. By keeping this in view, the objectives putforth for present investigation are as follows.

1. Standardization of protocol for temperature induced response and moisture stress.
2. Evaluation of germplasm for moisture stress using temperature induced response.
3. Estimation of genetic variability, association between yield and yield attributing characters.
4. Identification of genotypes for drought tolerance with high yield potential.

REVIEW OF
LITERATURE

II REVIEW OF LITERATURE

A review of literature on soybean relevant to the present study is presented below under the following captions.

2.1 Variability, Heritability and Genetic advance

2.2 Correlations and Path co-efficient analysis

2.3 Selection indices

2.4 Temperature stress

2.5 Moisture stress

2.6 Root morphological studies

2.1 Variability, Heritability and Genetic advance

Dai (1981) observed lower genotypic co-efficient of variation than phenotypic co-efficient of variation for growth period, number of seeds per pod and plant height in 31 local varieties. Average heritability values were high for 11 characters, while, genetic advance was relatively high for yield components except seeds per pod. Miku and Damaskin (1982) found high heritability for plant height, pods per plant, seeds per plant, height of initiation of lowest pod, number of fruiting nodes on the main stem in three F₂ hybrid population. High heritability and high values of genetic advance for branches per plant, plant height, pods per plant and seed yield per plant and low genetic advance for days to maturity, seeds per pod and 100 seed weight although they had high heritability was observed by Rashid and Islam (1982).

Gai *et al.* (1984) observed that at a similar stage of maturity both determinate and indeterminate types had fewer main racemes, more sub racemes, more primary and secondary branches and more flowers per main raceme but varied with respect to peak flowering period from 4 – 14 days after

floral initiation. Konwar and Taludkar (1984) reported high genotypic and phenotypic variance for days to flowering, plant height, days to 50 per cent flowering, days to maturity, but high genetic advance and high heritability for traits like days to maturity and plant height at 50 per cent maturity.

Hanson (1985) estimated heritability in 140 genotypes for length of total reproductive period, period for pod initiation and establishment and period for pod filling and maturation which ranged from 65-85 per cent, indicating that these traits would respond for selection. On the other hand, Chan *et al.* (1986) found greater heritability values for earliness than seed number, seed weight and total pods in two F₂ population. Ecochard (1986) reported high heritability for leaf area per plant, plant height, seed yield per plant and number of pods per plant.

Rasaily *et al.* (1986) observed considerable genetic variability for height, seed yield and number of branches, nodes and pods per plant and high heritability for height, number of nodes, days to flowering and days to maturity. Sharma *et al.* (1986) found high genetic variability, heritability and genetic advance, for seed yield per plant and fourteen agronomic and quality characters except for oil.

Janicka and Szyrmer (1987) reviewed that anthesis lost for 2-6 weeks according to variety and growing conditions. With early varieties, flowering occurs at roughly the same time at all nodes, while in indeterminate types, it occurs in successive stages at different insertion heights, starting from the base of the plant. They observed similar pattern with respect to pod set and seed filling. They further reported that tall varieties tend to produce more flowers than early short varieties and varietal difference was shown in flower and fruit drop, which varies from 27-87 percent. High mean heritability for seed weight followed by seed number per pod, oil, protein content and pod number per plant was noticed by Malik and Singh (1987).

Nelson (1987) observed significant difference in yield between short seed filling period and long seed filling period categories in each of the two maturity groups while Plazinic (1987) reported that soybean growth period duration differed significantly between varieties. Varietal differences were also observed for number of pods, seeds per plant, germination vigour and germination percentage.

Pushpendra and Ram (1987) reported high heritability for plant height, seed weight and days to 50 per cent flowering and suggested that selection for these traits would be effective. In another study of heritability and genetic variance in 12 varieties and their hybrids, Surain Momirovic (1987) observed highest broad sense heritability for 100-seed weight and number of nodes per plant. Higher values of heritability were also found for seed number, seed yield and pod number in decreasing order.

Teren'eva (1987) noted highest number of flowers before the onset of flowering in mid varieties, while mid late varieties had the highest number after the beginning of flowering. Intervarietal differences were noted in the percentage of pod set and surviving to harvest, but no clear difference between maturity groups were detected in these traits.

Yao *et al.* (1987) observed high estimates of heritability for growth period, number of clusters per plot, 100-seed weight, plant height, number of single seeded pods and number of seeds per pod. High heritability for beginning of flowering, maturity and for plant height was estimated Lin and Nelson (1988). Similarly Yao (1988) reported high estimates of heritability for seed weight per plant, clusters per plant, pods per plant, 100 seed weight and growth period.

Bhardwaj and Bhagsari (1989 and 1990) observed significant differences among the genotypes in respect of seed yield, HI & LAI. They also observed significant variation for all traits (biomass and plant height). On the other hand Ghatge and Kadu (1993) found highest variability for days to

maturity, plant height and seed yield. Estimates of genotypic and phenotypic coefficients of variation were highest for seed yield, plant height and plant spread. Heritability was high for days to 50 per cent flowering followed by days to maturity, plant height, leaf length and leaf breadth. Genetic advance was greatest for seeds per plant and plant height, indicating additive genetic control for these traits.

Rajarithnam *et al.* (1996) observed high estimates of heritability and genetic advance for pod number, plant height, seed yield, number of primary branches and 100-seed weight.

Bhandarkar (1999) noticed high heritability for days to initial flowering, days to 50 per cent flowering, plant height, 100-seed weight, days to maturity and number of primary branches. Moderate heritability was observed for mature pods per plant and seed yield. High heritability and genetic advance as percent of mean for plant height, 100-seed weight, days to initial flowering, days to 50 per cent flowering, number of primary branches and days to maturity showed the possibilities of improvement of these traits contributing to yield.

Jain and Ramgiry (2000) found high phenotypic and genotypic coefficient of variability for seed yield per plant, followed by plant weight, plant height and moderate coefficient of variability for 100-seed weight, seed per pod, pod bearing nodes and days to flowering. High heritability estimates accompanied by high genetic advance as a percentage of mean were noticed for seed yield, plant height and pods per plant. Rajanna *et al.* (2000) reported considerable variability for all characters at all sowing dates. The estimates of GCV and PCV were high and PCV was a good indicator of its GCV as inferred from the narrow difference between them for all the characters.

Agarwal *et al.* (2001) noticed high GCV for degree of indeterminate growth habit, plant height and branches per plant, while estimates of GCV were moderate for days to flower initiation and days to flower termination, but low

for days to maturity. Dixit *et al.* (2002) reported high estimates of genetic variation and heritability for harvest index, seed yield per plant and biological yield per plant.

Dhillon *et al.* (2005) noticed sufficient genetic variability for most of the characters and high heritability coupled with high genetic advance for seed yield per plant. Eizanloo *et al.* (2005) reported significant differences between cultivars of different maturity groups and cultivars within the maturity groups for all the traits except plant height, number of pods per plant, 100 seed weight and number of seeds per plant but in respect of seed yield, significant variation was observed only between maturity groups and not among cultivars within maturity groups.

2.2 Correlations and Path co-efficient analysis studies

Various characters that contribute to the yield are better identified through the techniques of correlation and path analysis. Simple correlation helps us to know the relationship between two characters, where as path co-efficient analysis identifies the real merit of characters contributing towards a particular dependent variable. This also helps to separate the direct and indirect effects of a character. Previous works in relation to correlation and path co-efficient analysis is reviewed here.

Kueneman and Wallace (1979) observed that duration of flowering was correlated with days to first flowering and days to maturity were positively correlated with yield. Sharma (1979) reported that though the direct effect of plant height on yield was negligible, its indirect effects through number of pods per plant were fairly marked. Number of pods per plant and number of pod clusters per plant made important direct and indirect contributions to seed yield.

Akhanda *et al.* (1981) in a correlation study conducted for two planting dates reported positive correlation of seed yields for July and August plantings with flowering period and plant height.

Barbind *et al.* (1981) indicated that among 16 varieties of soybean, only number of days to maturity was significantly and positively correlated with yield. Few determinate lines of soybean had the best combination of high seed yield in a study by Wilcox and Sediya (1981).

Alam *et al.* (1983) found phenotypic and genotypic correlations between characters like earliness, height, the number of branches per plant, number of seeds per plant, number of seeds per pod and seed oil content. While, Kamendra Singh and Ram (1983) noticed positive genotypic and phenotypic correlations between dry matter and yield with branching ability and broader leaflets.

Ma (1983) studied the yield and eleven of its components and reported that direct and indirect effects of these components on yield where, number of seeds per plant and 100 seed weight were found to have high direct effect. Sharma *et al.* (1983) through path coefficient analysis recorded maximum contribution of pod number per plant and days to maturity to seed yield. Zhou (1983) observed close association of seed weight per plant with plant height, number of internodes on the main stem, pod and seed number per plant. Through path analysis he noticed major effect of 100 seed weight and seeds per plant on seed yield.

Gai *et al.* (1984) observed negative correlation of pod set with days to maturity and flower numbers in determinate and indeterminate varieties of soybean. Diazcarrasco and Leon Gonzalez (1985) noticed high correlation of height and lateness with pods per plant. They indicated that yield could be increased by selecting for lateness, tallness and more pods per plant.

Fundora Mayor and Soto (1985) reported positive correlations of days to flowering and fruiting date with yield. Hanson (1985) observed high genotypic correlation between period for pod initiation and establishment and total reproductive period. Path coefficient analysis revealed positive direct effect of number of seeds per plant and 100 seed weight on seed weight per plant (Liu *et al.*, 1985).

In a study by Salado Navarro (1985), correlations between yield and seed protein percentage were non-significant, while a positive correlation was observed between reproductive period duration and effective filling period. Yield was positively associated with reproductive period duration, growth stages and seed growth rate and negatively associated with dry matter allocation to seed. Seed filling duration showed a weak association with yield. Seed filling duration and dry matter allocation to seed were negatively correlated with each other. Amarnatha (1986) observed significant positive correlation between seed yield and days to 50 percent flowering, days to maturity, plant height, number of branches per plant, number of pods per plant, number of seeds per plant and 100 seed weight. He recorded negative correlation of 100 seed weight with plant height, branches per plant, pods per plant, seeds per plant and seeds per pod.

Hwang and Kim (1986) observed highest direct effect through path coefficient analysis of number of seeds on seed yield. Nelson (1986) observed positive relationship between the duration of seed fill and seed yield, positive and significant association of grain yield with pods and branches per plant. Pods per plant had maximum direct effect on yield and also contributed indirectly through branches per plant, while 100 grain weight also exerted a high direct positive effect (Rajput *et al.*, 1986).

Salado Navarro *et al.* (1986) concluded that, higher yielding lines usually had longer seed filling periods, selection for other traits would not necessarily result in increased yield. The yield was mainly correlated with

weight of above ground parts and with number of pods and seeds per plant as reported by Sickhar and Lugovoi (1986).

Tong (1986) detected positive correlations of seed yield per plant with number of productive branches per plant, pods per plant, seeds per plant, 100 seed weight, but negative correlation with height and internodes per main stem. Where as, Choulwar and Borikar (1987) noticed the direct effect of 100 seed weight, pod length and number of seeds per pod on seed yield per plant.

Gyusova and Ilcheva (1987) found close association between seed number per plant and plant height. Seed weight per plant was associated with seed number per plant and seed yield per unit area. While, Nakamura *et al.* (1987) reported that the seed weight to pod weight ratio was positively related with 100 seed weight. Analysis of data on seed filling period and seed yield by Nelson (1987) revealed that the long seed filling period gave higher yields and also early flowering was associated with long seed filling periods.

Plazinic (1987) showed that number of flowers, young pods set and mature pods per plant were all correlated with growth period duration and also with seed yield per plant. Song *et al.* (1987) observed significant and positive correlation of yield with number of seeds per pod but not with days to flowering, days to maturity, 100 seed weight, protein and oil content.

Surian Momirovic (1987) reported that seed yield was mainly influenced by node number per plant, followed by seed number per plant, height of the lowest pod and 100 seed weight. While, Auyeung (1988) in his studies, showed that in some population, seed filling period was highly correlated with yield but in another population of indeterminate lines, seed filling period was not related to yield indicating that seed filling period was not an effective trait for indirect selection in indeterminate lines.

Chen (1988) noticed negative correlation between seed weight and leaf area index, leaf length and positive correlation between seed weight and leaf

width and leaf area. He also observed high degree of association between yield and number of pods per plant and number of clusters per plant. While, Guffy (1988) revealed that yield was significantly and positively correlated with seed filling period and seed number. He also showed that long seed filling periods were significantly and positively correlated with large seeds and late maturity.

Lin and Nelson (1988) found positive genotypic and phenotypic correlation of days to beginning of flowering and days to full maturity with plant height, indicating that obtaining tall, determinate plants with early flowering would be difficult. Yield was significantly affected by time of flowering in all the maturity groups. They also indicated that time of flowering is relatively more important than height in determining seed yield of determinate soybean genotypes.

Smith *et al.* (1988) reported that early flowering was related to seed filling period but not to yield and also suggested that seed yield is influenced by both rate and duration of seed filling period. Bhardwaj and Bhagsari (1990) observed positive correlation of yield with harvest index in large and small seeded genotypes. Positive correlation between seed weight, number of days to maturity and length of fruiting period was found by Song *et al.* (1990) but there was negative correlation between seed weight and most other agronomic traits.

Egli and Yu (1991) observed a linear relationship between crop growth rate and number of seeds per M_2 . But the number of seeds per M_2 , at a constant CGR was inversely related to genotypic differences in seed growth rate. Whereas Lu *et al.* (1991) showed that seed yields generally increased with increased biological yield, plant height, LAI and number of nodes.

Positive correlation of pods per plant, clusters per plant and 100-seed weight with seed yield was noticed. While, days to maturity, plant height and branches per plant exhibited significant and positive correlation with clusters per plant and pods per plant. Path analysis revealed higher direct effects of pods per plant and 100-seed weight on seed yield per plant. All the characters

exhibited higher indirect effects via pods per plant on seed yield was revealed by Rajanna *et al.* (2000). Jain *et al.* (2000) noticed higher genotypic correlation coefficients than the phenotypic correlation coefficients. Seed yield did not exhibit any association with any other traits except harvest index. Branches per plant exhibited positive correlation with pods per plant and plant weight. Archana *et al.* (2001) reported positive correlation of seed yield with pods per plant and days to 50 per cent flowering where as 100- seed weight was negatively correlated with seed yield.

Rezaizad *et al.* (2001) observed highest significant correlation coefficient between seeds per plant and seed yield per plant. Other significant correlation coefficients were found between biomass per plant and yield, and between number of pods per plant and yield. Path analysis revealed that the correlation of plant height and number of days to 90 per cent maturity on yield was due to the indirect effects exerted through other traits.

Namrata *et al.* (2002) noticed positive correlation of crop growth and yield components with seed yield. Number of branches per plant, number of pods per plant, number of seeds per pod and 100-seed weight were also positively and significantly correlated with seed yield, while plant height was negatively correlated. Backes *et al.* (2003) found the number of pods per plant is highly correlated with grain yield.

Bhairav *et al.* (2006) noticed positive and significant correlation of pods per plant, biological yield per plant, branches per plant, harvest index, 100-seed weight and plant height with seed yield both at genotypic and phenotypic levels. Path analysis showed positive and high direct effect of biological yield per plant and harvest index towards seed yield per plant. Where as, the indirect effect of other component characters through the above traits towards seed yield per plant was positive. Positive correlation was also observed by Kumar *et al.* (2006) between

seed yield and yield components viz. number of pods per plant and 100 seed weight.

2.3 Selection indices

Smith (1936) proposed a plant selection model for making selection on several characters simultaneously using discriminant function developed by Fisher (1936). In selecting characters such as yield, differences due to genotypes were largely influenced by non-heritable variation such as soil and location. If proper weightages are not assigned to the different yield contributing characters depending on the extent to which they indicate a contribution of gene for yield, maximum contribution of the desired gene for yield in the plants or lines selected might not be achieved. Because of these reasons, Smith (1936) recommended the use of discriminant function to indicate the genotypic values of a plant or lines by giving proper weightages to the characters.

Mannur *et al.* (1991) noticed two indices which combined seed yield, pods per plant and seed weight, with or without oil content as an additional trait, gave the highest relative efficiency. Inclusion of pods per plant in any selection index combination increased its relative efficiency. In general, the relative efficiency of selection indices improved with increase in the number of characters upto a total of four, and thereafter decreased and Dao *et al.* (1992) found highest relative efficiency when all 10 characters were involved (115 per cent), but for simplicity and economy a combination of 5 characters Viz., yield per plot, maturity, plant height, pods per plant and 100-seed weight, which gave a selection efficiency of 114 per cent was recommended.

Liang *et al.* (1997) noticed among selection methods for yield, index selection was more beneficial than correlation or direct selection. Genetic gain and selection index improved with increased number of selection factors. However, in some simple selections with only 2 or 3 factors, selection index and selective effect were as large as in multiple factor selection. Selection

index based on yield, number of branches per plant, days to maturity and oil percentage is recommended by Dhumale *et al.*, (1992).

Phan Thi Dao (1997) reported that all indices were better efficient than direct selection for yield. Relative efficiency increased with the number of traits incorporated into the indices. Genotypic correlation of trait with seed yield was the most effective criterion for choosing characters for the construction of indices. Jannink *et al.* (2000) found index selection combining information on early height and lodging or yield eliminated undesirable correlated responses of lodging and yield while maintaining genetic gain for early height.

Archana *et al.* (2005) reported that the highest index score was not necessarily always associated with the highest grain yield. Fifteen progenies were identified as having high index scores, and were selected for forwarding to the F₄ generation.

2.4 Temperature stress studies

High temperature is one of the important abiotic stresses that in combination with water stress have great impact on agriculture productivity (Levitt, 1980). Temperature stress occurs when it prevails more than the required level for enough time and causes irreversible damage to various plant cellular functions and also development. Plants can be damaged in different ways by high day or high night temperatures and either by high soil or high air temperatures.

Dry matter is the culmination of several plant growth and developmental processes. The amount of dry matter accumulated in soybean per unit input (light, water and nutrients) determines the efficiency of the production system. Temperature above or below an optimum value reduces dry weight or biomass accumulation. With air temperatures above 30 °C, dry matter accumulations in whole plants begin to decline in soybean (Raper *et al.*, 1977). Increasing

temperature affects dry matter accumulation due to direct effect on leaf initiation (Thomas and Raper, 1976). Temperatures above 38 °C during the day reduced dry matter production (Craufurd and Wheeler 1999; Prasad et al., 1999) and decreased biomass by 25 per cent at 35 °C (Wood, 1968) to 50 per cent at 45 °C (Wheeler *et al.*, 1997) in groundnut.

Development is defined as a sequence of phenological events which are influenced by the environment (Landsberg, 1977). Temperature is the most critical factor affecting development. High temperature has major effects on plant development, especially during the reproductive stage.

The impact of high temperature on photosynthesis and several other vegetative growth parameters have been reviewed by Long (1991). Shibles *et al.* (1975) and Thomas and Raper (1976) found that duration of the vegetative period in soybean was significantly affected by high temperatures.

Lin *et al.* (1984) have shown that maximum protection was achieved only in the induced seedlings of soybean and these induced seedlings had higher levels of heat shock proteins.

Upon induction heat shock, there is differential expression of heat shock genes and is the major cause for genetic variability under high temperature stress. It is well established that genetic variability can be seen only upon induction and is fairly well characterized in different crops species (Uma *et al.*, 1995, Jayaprakash *et al.*, 1998, Srikanth Babu, 1999).

Therefore, to screen a genotype for thermotolerance, it is necessary to expose it to induction stress before its exposure to the lethal stress. Based on these studies, an efficient screening technique to identify the thermotolerant lines has been developed, which is referred as Temperature Induction Response (TIR) technique. According to this technique, the seedlings are exposed to induction temperature before exposure to severe temperature. The tolerant genotypes showed higher survival rate and more recovery growth as compared

to the susceptible genotypes or lines (Srikanth Babu *et al.*, 2001, Senthil Kumar, 2001).

2.5 Moisture stress studies

Sammons *et al.* (1978) have classified the soybean cultivars as drought resistant and susceptible based on individual performance relative to average seedling response to soil moisture stress. Bunce *et al.* (1984) showed that extent of dry matter accumulation is dependent on degree of soil moisture stress and duration.

Studies conducted by Muchow *et al.* (1986) revealed water deficits decreased in leaf expansion rate more than the leaf production in soybean. The significant relationship between fresh weight and height stress indices was noticed by Kpoghomou *et al.* (1990) and they also observed cultivars that grew taller under drought had greater dry matter (DM) accumulation and higher germination stress indices, indicating the reliability of height for predicting cultivar performance under such conditions.

Hoogenboom *et al.* (1986) noticed shoot and root growth with characteristic exponential growth curves during early vegetative development when no moisture stress was evident. When water stress was imposed during the later stages of vegetative growth or early reproductive development, an increase in root growth rate and a decrease in shoot growth rate was observed in the non irrigated treatment.

Hirasawa *et al.* (1994) noticed higher seed yield in the water stressed plots. This was related to the cultivars with better well developed root system in deep soil layers enabling absorption of water from the deeper soil layer which resulted in maintenance of high leaf water potential and delaying the decrease in photosynthetic rate due to resistance.

Sarkar (1994) noticed correlation between plant injury, leaf area and increased total dry matter with drought tolerance. Further he reported that the cultivars with higher drought tolerance showed higher crop growth rate (CGR) during drought stress period compared to other cultivars.

Itoh and Kumura (1986) reported short-term water deficit reduced stem growth but recovered when there was continuous and long water due to acclimatization. While, Kim *et al.* (2000) revealed that the sustained longer Leaf growth in well-watered than water-deficit conditions, and there was a sizable proportion of leaves which ceased growth earlier when water stressed.

Kim *et al.* (2001) found most of seedlings of the drought-tolerant cultivars with high vigour and root penetration than those of the drought-sensitive cultivars under the new screening conditions. And indicate that the new method can be used as a simple and effective screening procedure for drought tolerance in soybean breeding programs.

Tetsuji *et al.* (2003) noticed in cultivars with higher drought tolerance, crop growth rate (CGR) during the drought stress period was higher than in other cultivars. They also maintained a larger leaf area during the stress period. Although reproductive development was retarded by the drought stress, it tended to be retarded less in drought-tolerant cultivars.

Yanyun *et al.* (2006) found that the root system of PI 407155 maintained higher moisture content and biomass accumulation than that of Essex under severe moisture stress. The percentage electrolyte leakage in Essex was almost twice that in PI 407155 under medium moisture stress. Both molecular and physiological studies indicated that PI 407155 had higher level of tolerance to dehydration stress than Essex, therefore providing a new potential soybean genome for developing dehydration stress cultivars.

2.6 Root morphological studies

Gerrit Hoogenboom *et al.* (1987) stated that roots play an important role in plant survival during periods of drought. They have also reported large increase in root growth when drought stress occurred during later stages of vegetative growth.

Pantalone *et al.* (1996) reported that phenotypic root scores could be utilized in selection programme to rapidly evaluate large number of progeny in order to identify those with extensive fibrous root system.

The correlation of mean membership index of drought tolerance with relative values of total root length, root volume and root dry weight per plant under stress condition was reported by Gai junyi *et al.* (2005).

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation was carried out during *kharif* and *summer* seasons of 2006-07 in the experimental plot of AICRP on soybean scheme, Gandhi Krishi Vignana Kendra campus, University of Agricultural Sciences, Bangalore, which is situated at an altitude of 930m, latitude of 13⁰.15'.00 N and longitude of 77⁰.32'.00 E which represents the Eastern Dry Agro-climatic Zone of Karnataka. The location receives an average annual rainfall of about 930 mm with two peaks in its distribution one being in May-June and other in September-October. The material and methods used in the present study on genetic variation for yield, thermo-tolerance and drought tolerance associated characters are presented in this chapter.

The investigation was conducted under four experiments.

1. Genetic variability studies
2. Temperature Induced Response (TIR)
3. Drought tolerance studies
4. Root morphological studies

Experiment –I

3.1 Material and Methods

The material used for genetic variability for yield and yield attributing characters consisted of 344 genotypes and four checks viz., Bragg, MACS-450, KHSb-2 and JS-335. The seeds were collected from the AICRP on soybean, UAS, GKVK, Bangalore.

3.2 Experimental layout

The layout of the experiment followed Augmented RCBD. The genotypes were allotted randomly in 8 blocks, where each block included 50 genotypes including four checks.

3.3 Crop management

The crop was raised during *kharif* 2006 and protective irrigation was given when there was prolonged drought condition. Each entry was sown in two rows with spacing of 30 cm X 10 cm and uniform crop stand was maintained by thinning. Recommended cultural practices and plant protection measures were followed as per the package of practices.

3.4 Observations recorded

The following observations were recorded on five randomly selected plants in each of genotype.

1. Days to 50 % flowering

The number of days required from sowing to flowering in 50 per cent plants in each genotype was recorded by taking whole population into consideration for each genotype.

2. Days to maturity

Total number of days taken from sowing to physiological maturity was recorded.

3. Plant height (cm)

The height of the five plants was recorded from base to tip of the plant for each genotype at harvest and averaged to obtain Plant height per plant.

4. Branches per plant

It was recorded by counting the total number of branches on each of the selected plant.

5. Pods per plant

The total number of pods harvested in each of the selected plant were recorded and the mean was obtained.

6. 100 seed weight (g)

It was recorded by taking the weight of 100 seeds from selected five plants and averaging them.

7. Seeds per plant

The number of seeds per plant was recorded by counting the total number of seeds of selected plants and averaging them.

8. Seeds per pod

The number of seeds in each pod of selected five pods in each plant was recorded and averaged to obtain number of seeds per pod.

9. Seed yield per plant (g)

Total weight of seeds per plant was recorded in each selected plant and the mean was calculated.

3.5 Analysis of Variance (ANOVA):

ANOVA for different characters was carried out as per the method suggested by Federer (1956).

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-ratio
Entries	(e-1)	eSS	eMS	eMS/EMS
Checks	(c-1)	cSS	cMS	cMS/EMS
Lines	(v-1)	vSS	vMS	vMS/EMS
Lines vs Checks	1	c vs SS	c vs MS	c vs MS/EMS
Error	c (b-1)	ESS	EMS	

Where,

e = Number of entries (Test entries and Checks)

c = Number of checks

v = Number of test entries

b = Number of blocks

3.6 Phenotypic variance

The variance among the treatments (all genotypes including check) for each character was computed and such variance was considered as phenotypic variance (V_p).

3.7 Environmental variance

The variance within each genotype for each character among the repeated checks was considered as the environmental variance for that character. So, four environmental variances were obtained for four checks. The average of these was considered as the environmental variance (V_E).

3.8 Genotypic variance

Thus, the genotypic variance for each character was estimated by deducting the V_E from V_P for the corresponding character. This method of computing V_G is a kin to the one suggested by Allard (1960) for estimating V_E as average of non-segregating generations (i.e. Average of variance of parents and F_1) when replicated data is not available.

3.9 Estimation of genetic parameters

To know the genetic variability among the genotypes were estimated as mentioned below.

1. Co-efficient of variability

Both phenotypic and genotypic coefficient of variation were computed as per Burton and De Vane (1953)

$$GCV (\%) = \frac{\sqrt{V_G}}{\bar{X}} \times 100$$

$$\text{PCV (\%)} = \frac{\sqrt{V_p}}{\bar{X}} \times 100$$

Where, σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

$\bar{X}$ = Grand mean of the characters

GCV = Genotypic coefficient of variation

PCV = Phenotypic coefficient of variation

PCV and GCV were classified (Robinson *et al.*, 1949) as below.

0-10% = Low

10-20% = Moderate

20% and above = High

2. Heritability (broad sense) (%)

Heritability was estimated by using the formula (Lush, 1949).

$$h^2 (\%) = \frac{V_g}{V_p} \times 100$$

Where, h^2 = Heritability percentage

V_g = Genotypic variance

V_p = Phenotypic variance.

Heritability percentage was categorized as per Robinson *et al.* (1949).

While 0-30% = low

30-60% = moderate

60% and above = high.

3. Genetic Advance (GA)

Genetic advance was calculated by the formula suggested by Johnson *et al.*, (1955).

$$GA = h^2 \times \sigma_p \times K$$

Where, h^2 = Heritability (broad sense)

σ_p = Phenotypic standard deviation

K=Selection differential which is 2.06 at 5% intensity of selection (Lush, 1949).

4. Genetic Advance as per cent of mean

$$GA \text{ as per cent mean} = \frac{GA}{\bar{X}} \times 100$$

Where, GA = Genetic advance

$\bar{X}$ = Treatment mean for the character.

The genetic advance as per cent mean was classified (Johnson *et al.*, 1955) as given below:

0-10% = Low;

10-20% = Moderate

20% and above = high

3.10 Correlation and path analysis

Correlation coefficients were computed to find the association amongst characters using the formula (Johnson *et al.*, 1955a).

$$r_{xy} = \frac{COV(x, y)}{\sqrt{v(x) \cdot v(y)}}$$

Where, r_{xy} = Correlation coefficient between x and y

COV (x, y) = covariance between x and y

V(x) = Variance of x and

V(y) = Variance of y

3.10.1 Path coefficient analysis

The phenotypic correlation coefficients were further partitioned into direct and indirect effects with the help of path coefficient analysis as suggested by Wright (1921) and Dewey and Lu (1959).

Grain yield per plant was assumed to be the dependent variable (effect) which is influenced by other characters, the independent variables (causes) directly as well as indirectly. The variation in grain yield per plant unexplained by the 'n' causes was presumed to have been contributed by a residual factor 'R' which is uncorrelated with other factors.

Path coefficients were obtained by solving the simultaneous equations, which express the basic relationship between correlations and path coefficients. The equations are as follows:

$$\begin{aligned}
 r_{1,y} &= P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} + \dots + r_{1,n} P_{n,y} \\
 r_{2,y} &= P_{2,y} + r_{2,1} P_{1,y} + r_{2,3} P_{3,y} + \dots + r_{2,n} P_{n,y} \\
 r_{3,y} &= P_{3,y} + r_{3,1} P_{1,y} + r_{3,2} P_{2,y} + \dots + r_{3,n} P_{n,y} \\
 &\vdots \\
 &\vdots \\
 &\vdots \\
 r_{n,y} &= P_{n,y} + r_{n,1} P_{1,y} + r_{n,2} P_{2,y} + \dots + r_{n,n} P_{n,y}
 \end{aligned}$$

Where, $r_{1,y}$ to $r_{8,y}$ denote the correlation coefficients between independent characters 1 to 'n' and dependent character 'Y'; $r_{1,2}$ to $r_{7,n}$ denote the correlation

coefficients between all possible combinations of independent characters and $P_{1,y}$ to $P_{n,y}$ denote the direct effects of characters 1 to 'n' on character 'Y'.

Residual factor which measures the contribution of rest of the characters of usual scheme was obtained as follows:

$$\text{Residual effect} = P_{r,y} = \sqrt{1 - \sum P_{iy} r_{iy}}$$

3.11 Selection indices

3.11.1 Formulation of selection indices

The discriminant function technique of Fisher (1936) used by Smith (1936) to propose a selection model for selecting several characters simultaneously was adopted. The function aims at discriminating the desirable genotypes from undesirable ones based on their phenotypic performance. The genetic worth of an individual as described by Smith (1936) is,

$$H = a_1 G_1 + a_2 G_2 + \dots + a_n G_n$$

Where;

$G_1, G_2, \dots, G_n$ are the genotypic values of individual characters.

$a_1, a_2, \dots, a_n$ on the weight assigned to each of the character which signify their relative importance

Phenotypic performance of various characters is used in defining another function (I) as

$$I = b_1 P_1 + b_2 P_2 + \dots + b_n P_n$$

Where;

$b_1, b_2, \dots, b_n$ are to be estimated such that the correlation between H and I i.e., $r(HI)$ becomes maximum. When one such function is obtained, discrimination

of desirable genotypes from the undesirable ones will be possible on the basis of phenotypic performance *i.e.*, $P_1, P_2, \dots, P_n$ directly.

The maximization of r (HI) leads to set of simultaneous equations which upon solving give the direct estimate of b_i -values. They are as follows,

$$\begin{aligned} b_1 P_{11} + b_2 P_{12} + \dots + b_n P_{1n} &= a_1 G_{11} + a_2 G_{12} + \dots + a_n G_{1n} \\ b_1 P_{21} + b_2 P_{22} + \dots + b_n P_{2n} &= a_2 G_{22} + a_2 G_{22} + \dots + a_n G_{2n} \\ &\vdots \\ b_1 P_{n1} + b_2 P_{n2} + \dots + b_n P_{nn} &= a_1 G_{n1} + a_2 G_{n2} + \dots + a_n G_{nn} \end{aligned}$$

This in the matrix form becomes,

$$\begin{pmatrix} P_{11} & P_{12} & \dots & P_{1n} \\ P_{21} & P_{22} & \dots & P_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \dots & P_{nn} \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix} = \begin{pmatrix} G_{11} & G_{12} & \dots & G_{1n} \\ G_{21} & G_{22} & \dots & G_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ G_{n1} & G_{n2} & \dots & G_{nn} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{pmatrix}$$

The solution of these equations gives the estimates of b_i values in the following manner $b = P^{-1} Ga$.

Where; b is column vector

P^{-1} is the inverse of phenotypic variance and covariance matrix.

G is the genotypic variance and co-variance matrix and a is the column vector for the economic weights.

The selection index is given by the mathematical description of the function (I) and the selection criterion or the index value for each individual may be determined and written as;

$$I = b_1P_1 + b_2P_2 + \dots + b_nP_n$$

3.11.2 Expected genetic gain and relative efficiency from the use of the selection index

a) Genetic advance based on single character

The expected gain through selection for a single character was calculated using the formula suggested by Johnson *et al.* (1955a).

$$GA = \frac{g_{1.2}}{\sigma_{P1}} \times K$$

Where;

$g_{1.2}$ = Genotypic covariance between selected and unselected characters

σ_{P1} = Phenotypic standard deviation of the selected character

K = Selection differential at 5 per cent (K= 2.06)

b) Genetic advance based on a combination of a character

The expected genetic advance through selection based on a combination of characters was predicted by the formula given by Robinson *et al.* (1949).

$$GA (SI) = Z/P \sqrt{P_i G_{iy}}$$

Where;

GA (SI) = Genetic advance based on selection index

$Z/P = K$ = Selection differential (2.06 at 5%)

P_i = Coefficients of a selection index

G_{iy} = $G_{1y}, G_{2y}, G_{3y} \dots \dots \dots G_{ny}$.

i.e., genotypic covariance between the selected (x) and unselected (y) characters.

c) Relative efficiency (RE)

Considering the efficiency of yield alone as 100 per cent, the relative efficiency of a particular selection index was computed as per the following formula of Brim *et al.* (1959),

$$RE = \frac{\text{GA based on selection index}}{\text{GA by straight selection}} \times 100$$

Experiment – II

Temperature Induced Response (TIR)

3.1 Experimental material

The soybean seeds of Hardee and other 49 high yielding genotypes were selected based on selection index scores and the following experiment was conducted with the germinated seedlings to meet the set objectives.

3.2 Germination and development of seedlings for assessing thermo tolerance.

The seeds of soybean were put for germination in moist germination paper in petriplates at 30⁰ C and 60 % RH. Two days old germinated seedlings of Hardee were used for all the standardization experiments and seedlings of different genotypes were used for screening under stress.

3.3 Temperature Induction Response (TIR) Technique: A method to assess thermo tolerance.

The principle in this technique is that, initially the seedlings are exposed to mild temperature (Induction Temperature) following which the seedlings were exposed to a severe temperature (Lethal Temperature). Survival per cent and recovery growth were determined as a measure of tolerance.

3.4 Standardization of protocol for lethal and optimum induction temperature

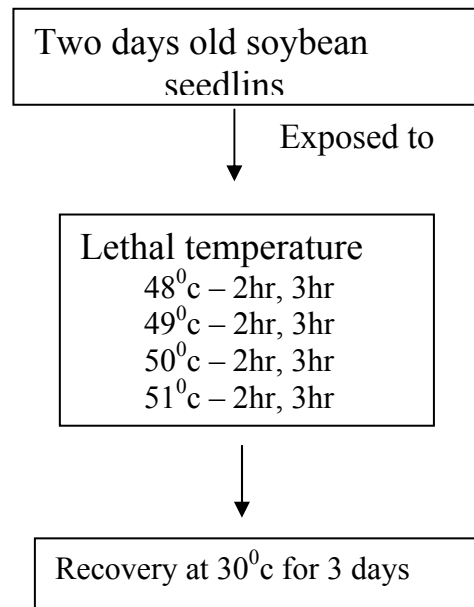
3.4.1 Standardization of Lethal Temperature:

Lethal Temperature is the temperature at which 95-100 % mortality of the seedlings occurs. It varies with the species and hence, it has to be standardized for each species. To identify or assess the threshold temperature, the soybean seedlings were exposed to different severe temperatures for varying duration without prior induction. Then, seedlings were allowed to recover at 30⁰c with 60 % relative humidity for 72 hours. At the end of recovery, per cent survival of seedlings was taken to arrive at the lethal temperature. Four replications of 20

seedlings each were maintained for each experiment. Per cent survival was arrived using the following formula.

$$\left. \begin{array}{l} \text{Per cent survival} \\ \text{of the seedlings} \end{array} \right\} = \frac{\text{Number of seedlings survived at the end of recovery}}{\text{Total seedlings taken for the experiment}} \times 100$$

Flow chart: Protocol for standardization of lethal temperature



3.4.2 Identification of optimum Induction Temperature

Optimum temperature was decided based on its effect on the recovery per cent of seedlings when subjected to lethal temperature upon induction. The germinated seedlings were subjected to different sublethal temperature called

induction temperature and at the end of induction, seedlings were exposed to lethal temperature. During the induction treatment, the seedlings were exposed to gradual increase in temperature for a specific period. The temperature regimes and duration were varied to arrive at optimum induction protocol. At the end of temperature treatment, seedlings were allowed to recover for 72 hours at 30⁰ C and 60 per cent relative humidity.

Optimum induction temperature was arrived based on the percent survival. The induction treatment, which showed 10 to 15 per cent seedlings survival was considered as optimum induction temperature.

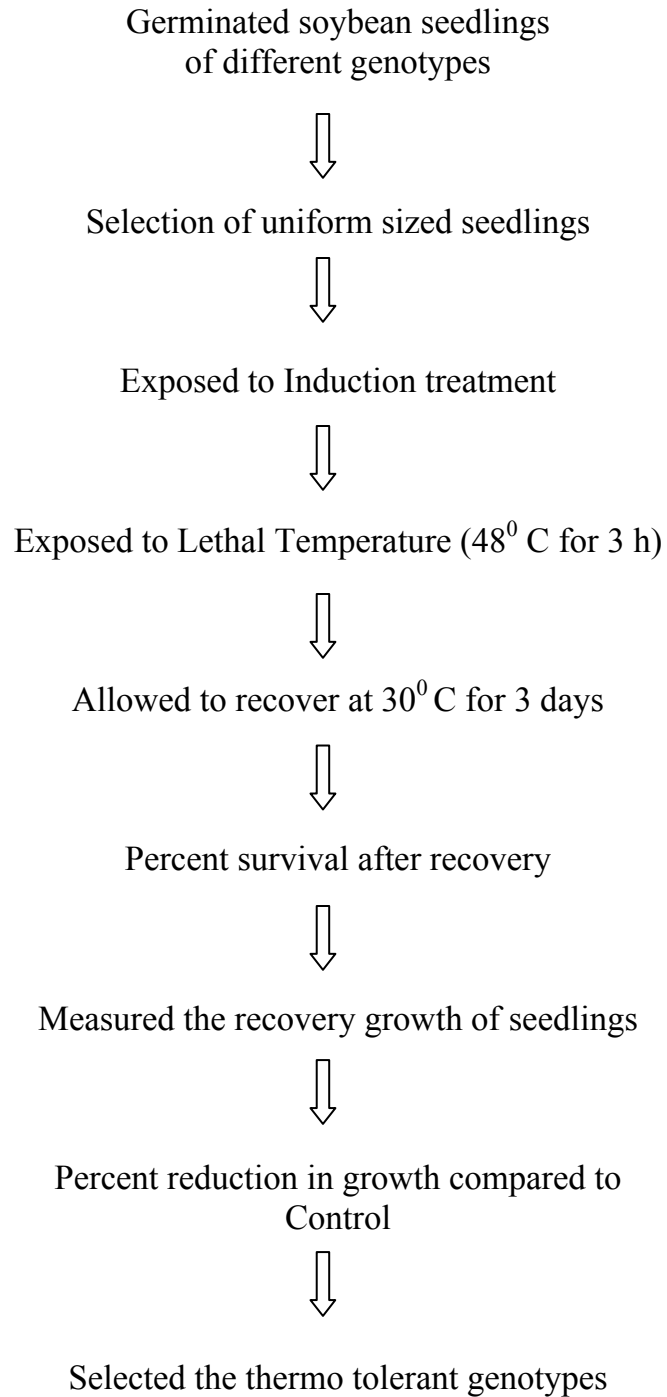
To compute recovery growth, the following formula was used.

$$\left. \begin{array}{l} \text{Percent reduction} \\ \text{in growth} \end{array} \right\} = \frac{\left[\begin{array}{c} \text{Recovery growth of} \\ \text{absolute control} \end{array} \right] - \left[\begin{array}{c} \text{Recovery growth} \\ \text{of treated} \end{array} \right]}{\text{Recovery growth of absolute control}} \times 100$$

3.4.3 Selection of thermo tolerant soybean genotypes:

The main aim of the investigation was to select thermo tolerant genotypes using the standardized induction and lethal temperature protocol. By utilizing the protocol about fifty high yielding genotypes were screened. The radical, hypocotyls growth and number of secondary roots were recorded at the end of recovery and percent reduction over control was calculated for each character. Ranks were assigned to each character, based on overall total rank, the top ranking genotypes were considered as thermo tolerant genotypes.

Flow chart: Screening of soybean genotypes for thermo tolerance



3.5 Statistical analysis

The analysis of variance as proposed by Panse and Sukhathme (1985) was carried out for different characters in order to assess the variability among genotypes. The treatment means were compared using Least Significant Difference method. Data from the experiment was subjected to completely randomized design (CRD) analysis using MSTAT-C and DESIGN statistical analysis packages.

Experiment – III

3.3 Drought tolerance studies

The soybean genotypes which showed higher total rank with good recovery growth under temperature stress in laboratory studies were considered as most thermo tolerant and genotype recorded complete death were considered as susceptible genotypes. Preinduced seedlings of nine tolerant and one susceptible genotypes were used for pot culture studies.

3.3.1 Experimental site

The pot culture experiment was conducted in summer season in plot number F-11, ZARS, UAS, GKVK, Bangalore.

3.3.2 Genotypes used

Nine thermo tolerant genotypes viz., MACS -212, PK-34, KB-249, CGP-387, GPC-357, NRC-17, KB-79, VLS-40, PK-1036 along with one susceptible genotype viz., MAUS-2 were used.

3.3.3 Experimental design

The experiment was laid out in completely randomized design with three replications.

3.3.4 Treatments

The pot experiment consisted of three treatments, viz., control (no stress) or field capacity (100% F.C.), moderate stress (50% of F.C.) and severe stress (25% of F.C.). 350 ml cups were filled with 300 gm of red soil. To achieve different stress levels, different quantity of water was added to pots, the details of which are given below.

Treatment	Stress level	Relative water content	Water added
1	Control	100% F.C.	71 ml
2	Moderate stress	50% F.C.	35.5 ml
3	Severe stress	25% F.C.	18 ml

3.3.5 Methodology

The amount of water required to maintain field capacity was measured gravimetrically as mentioned in table above. The cups containing soil were weighed every day during the experimentation, and based on the loss of the weight of the cups, water was added regularly to required moisture level in different treatments. Two days old temperature induced seedlings were transplanted individually to each cup. Hundred percent field capacity was maintained for all the

treatments up to 15 days, then after 15 days, stress was induced upto wilting. When wilting symptom was noticed the plants were recovered by adding water to reach 100% F.C. The following observations were recorded after recovery.

3.3.6 Observations recorded

3.3.6.1 Root length(cm)

Seedlings were taken out without damaging the seedling roots in each replication and root length was measured from collar region to tip of the longest root after recovery and was expressed in cm.

3.3.6.2 Shoot length(cm)

The shoot length of selected seedlings was measured from collar region to the tip of the shoot after recovery and expressed in cm.

3.3.6.3 Leaf area(cm²)

The total leaf area of each of selected seedlings was measured and the average of three seedlings was taken.

3.3.6.4 Root dry weight (mg)

The seedlings were dried in a hot air oven at 65 °C for 4 days and the root weight was recorded in mg per seedling.

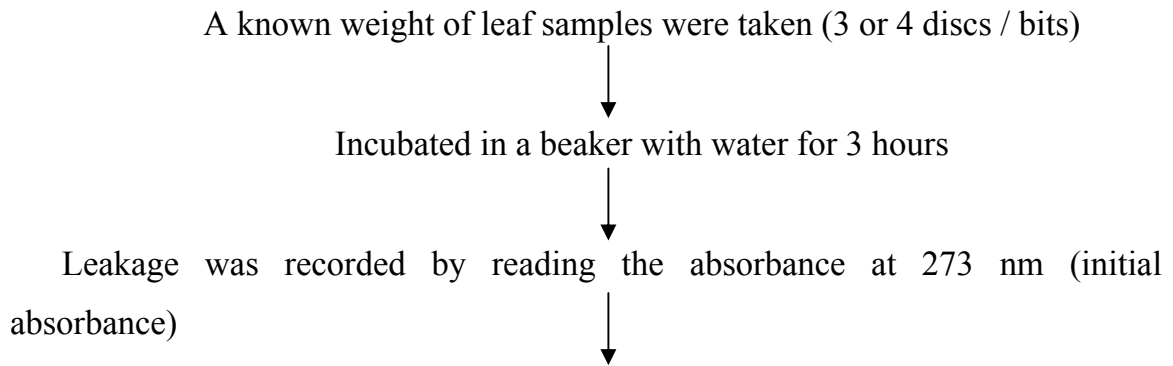
3.3.6.5 Shoot dry weight (mg)

Above seedling selected above were dried in a hot air oven at 65 °C for 4 days and the shoot weight was recorded in mg per seedling.

3.3.6.6 Total dry weight of seedling (mg)

The seedlings selected above were dried in a hot air oven at 65 °C for 4 days and the total dry weight was recorded in mg per seedling.

3.3.6.7 Membrane permeability based on leakage of solutes from leaf sample



That was kept in hot water bath (100°C) for 15 minutes and absorbance was recorded at 273nm (final absorbance) using UV- 2450 visible Spectrophotometer.

$$\text{Leakage \%} = \frac{\text{Initial absorbance}}{\text{Final absorbance}} \times 100$$

3.3.6.8 Rate of water loss

Third fully expanded leaf from the cotyledonary branches was collected by cutting at the joint of leaf petiole with the stem. The trifoliate leaf was spread over a filter paper on the laboratory table at a temperature of 25±2 °C and light intensity of 250 $\mu\text{Einstein m}^{-2} \text{s}^{-1}$. The fresh weight of the leaf was weighed at hourly interval up to 3 hours and the loss in weight in relation to original weight of the leaf was computed.

3.3.7 Statistical analysis

The analysis of variance as proposed by Panse and Sukhathme (1985) was carried out for different characters in order to assess the variability among genotypes. The treatment means were compared using Least Significant Difference method. Data from the experiment was subjected to completely randomized design (CRD) analysis using MSTAT-C and DESIGN statistical analysis packages.

Experiment IV

3.4 Root morphological study

The details of material used and the methods adopted in the experiment are described here under:

3.4.1 Genotypes used

Eight thermo tolerant genotypes viz., MACS-212, PK-34, KB-249, CGP-387, GPC-357, KB-79, VLS-40, PK-1036 along with one moderate (NRC-17) and one susceptible genotype (MAUS-2) were used.

3.4.2 Experimental site and layout

The experiment was carried out at 'K' Block of University of Agricultural Sciences, Bangalore during *summer-2007*, adopting Completely Randomized Design (CRD). Each genotype was replicated thrice. The crop was raised in poly vinyl chloride (PVC) pipes (100cm long and 18 cm diameter). Four to five seeds of each entry were hand dibbled in the PVC pipes filled with a mixture of sandy clay loam soil and FYM in 4:1 proportion. After germination one healthy seedling was allowed to grow in each pipe. The soil in each pipe was fertilized according to recommended package of practices and watering was done at four days interval.

3.4.3 Experimental design

The experiment was laid out in completely randomized design with three replications.

3.4.4 Method of sampling and recording of observations

Plant sampling was done at 30 days old crop. After the harvest of above ground portion of the plants, the PVC pipes were soaked overnight in water to loosen the soil. The next day, roots were washed thoroughly and the following observations were recorded on plant sample of each genotype.

3.4.4.1 Root length (cm)

Root length was measured from collar region to the tip of the longest root and expressed in cm.

3.4.4.2 Root volume (cm³)

Root volume was determined in cm³ by water displacement method.

3.4.4.3 Root Dry weight (g)

After separation of root and shoot, the root portion of each plant was oven dried at 70°C for 48 hours and the dry weight of samples recorded and expressed in grams.

3. 4.4.4 Shoot length (cm)

Height of plant from ground level to the tip of the longest leaf was measured and expressed in cm.

3. 4.4.5 Number of leaves

Number of leaves per plant was counted and recorded.

3. 4.4.6 Plant length (cm)

The sum of maximum root length and shoot length was computed and expressed in cm.

3. 4.4.7 Shoot Dry Weight (g)

The shoot portion of each plant was oven dried at 50° C for 48 hours and the dry weight of samples was recorded and expressed in grams.

3. 4.4.8 Total Dry Weight (g)

The sum of root dry weight and shoot dry weight was computed and expressed in grams.

3.4.4.9 Root: Shoot weight

The ratio of root weight to shoot weight was computed for this purpose.

3. 4.4.10 Root: Shoot length

The ratio of maximum root length to shoot height was computed for this purpose.

3.4.5 Statistical analysis

The analysis of variance as proposed by Panse and Sukhathme (1985) was carried out for different characters in order to assess the variability among

genotypes. The treatment means were compared using Least Significant Difference method. Data from the experiment was subjected to completely randomized design (CRD) analysis using MSTAT-C and DESIGN statistical analysis packages.

EXPERIMENTAL

RESULTS

IV EXPERIMENTAL RESULTS

The present investigation was carried out in four different experiments and the results of experiments presented under following headings.

- 1. Genetic variability studies**
- 2. Temperature Induced Response (TIR)**
- 3. Drought tolerance studies**
- 4. Root morphological studies**

Experiment – I

4.1 Genetic Variability Studies

The experimental results pertaining to variability for agronomic traits contributing to seed yield, association of characters with yield and relative contribution of characters towards seed yield are presented under the following subheadings.

1. Variability and other genetic parameters
2. Correlation and path analysis.
3. Selection indices

4.1.1 Variability and other genetic parameters

The results pertaining to the variability among genotypes used in present investigation are given below.

4.1.1.1 Analysis of variance

The data obtained for all the quantitative characters were analyzed to find out the differences among the three hundred forty eight genotypes. The mean of 348 genotypes for all the characters are presented in Appendix-I. The analysis of variance for each character with standard error are presented in Table.1. The range, mean with standard error, heritability in broad sense, GCV, PCV and genetic advance over mean (GAM) have been presented in Table.2 and briefly explained the characters below.

4.1.1.1.1 Days to 50 % flowering

The analysis of variance (Table.1) revealed significant differences among the genotypes for this character. The over all mean days taken for 50 % flowering in the germplasm collection was 35.1 days, with a wide range of variation from 25 days to 39 days, (Table.2). SH-444 (25 days) was earliest to flower and the genotype AGS-117 was late in flowering (39 days).

The co-efficient of variation values in terms of phenotype and genotype were 4.4 and 4.0 respectively, indicating less environmental influence on this character. This was further reflected in high heritability of 82.41 per cent. However, this trait exhibited low expected genetic advance as per cent of mean which was only 10.36.

4.1.1.1.2 Days to maturity

This character exhibited wide variation among the genotypes as evidenced from the significance of mean data of the genotypes. The range for this character was from 80 days to 107 days with a mean of 97.2 days. PK-1036 was the earliest

to mature (80 days) followed by JS-92-12 (81 days). The genotype NRC-23 was late to mature (107 days).

The values of phenotypic and genotypic coefficients of variation were 7.3 and 7.2 per cent respectively. The narrow difference between the two values showed very less environmental effect in the manifestation of this character. This was reflected in very high heritability of 97.69 per cent. However, genetic advance for this character was low with only 20.28 per cent of mean.

4.1.1.1.3 Plant height (cm)

Wide variation was observed for this character in the collection, which is evident by the highly significant difference obtained in the analysis of variance.

The plant height in the collection ranged from 13.6 cm to 63.8 cm with an over all mean of 30.97 cm. PK-1046 (63.8 cm) was the tallest among all the genotypes, while, EC-28754 (13.6 cm) was shortest among all the collections.

The phenotypic and genotypic coefficients of variation were more or less of same magnitude with values of 31.2 and 30.9 per cent respectively, indicating very negligible influence of environment on this character. This was evident with high heritability of 98.28 per cent and genetic advance of 87.35 per cent over mean.

4.1.1.1.4 Branches per plant

The test of significance showed that the genotypes do not differed significantly for this trait. The range was 1.0 to 4.8 with an over all mean of 2.0. The genotype DS-84 (5) had the highest number of branches per plant. Where as, the genotypes with least number of branches per plant were CGP-555, GS-54 and JS- 7516 (1).

Table 1. Analysis of variance for different quantitative traits in Soybean

Source of Variation	df	Mean sum squares								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Branches/plant	Pods/plant	Seeds/pod	100 seed weight (g)	Seeds/plant	Seed yield/plant (g)
Entries	347	2.701**	44.242*	94.826**	0.539	38.080**	0.286	8.724**	267.391**	4.155**
Checks	3	9.708**	858.708**	281.824**	0.115	134.375**	1.583	21.615**	694.042**	14.981**
Lines	343	2.364**	32.181**	92.051**	0.532	33.279**	0.251	8.418**	203.634**	3.467**
Lines vs Checks	1	97.106**	1738.038**	485.827**	4.393*	1396.091**	8.376**	74.907**	20855.998**	207.437**
Error	28	0.420	1.170	1.578	0.317	4.634	0.098	0.192	35.991	0.541
CD at 5 %		1.878	3.135	3.642	1.632	6.241	0.909	1.270	17.393	2.133
CV %		1.800	1.100	4.100	28.300	10.100	16.600	3.200	15.300	14.200

* - Significant at 5 % level

Entries = lines + checks

** - Significant at 1 % level

Table 2. Estimates of Phenotypic and genotypic coefficients of variability, heritability and expected genetic advance in respect of nine characters in Soybean genotypes

Characters	Range	Mean $\pm$ SE	$h^2\%$ (BS)	PCV %	GCV %	GAM
Days to 50% flowering	25-39	35.1 $\pm$ 0.65	82.41	4.4	4.0	10.36
Days to maturity	80-107	97.2 $\pm$ 1.08	97.69	7.3	7.2	20.28
Plant height (cm)	13.6-63.8	31.0 $\pm$ 1.26	98.28	31.2	30.9	87.35
Branches/plant	1-4.8	2.0 $\pm$ 0.56	39.89	37.0	23.4	42.10
Pods/plant	9-39	21.4 $\pm$ 2.15	86.20	27.8	25.8	68.25
Seeds/pod	1-3	1.9 $\pm$ 0.31	36.66	27.3	16.5	28.49
100 seed weight (g)	6-20	13.6 $\pm$ 0.44	97.33	21.1	20.8	58.43
Seeds/plant	20-110	39.1 $\pm$ 5.99	82.87	39.0	35.5	92.09
Seed yield/plant (g)	1.4- 14.4	5.2 $\pm$ 0.74	84.64	37.7	34.7	90.85

The phenotypic and genotypic coefficients of variability were 37.0 and 23.4 per cent respectively, indicating moderate level of environmental influence on this trait. This was reflected in the moderate heritability value of 39.89 per cent. The genetic advance (42.1 per cent) for this character was also moderate.

4.1.1.1.5 Pods per plant

Wide significant variation was observed among the genotypes for this trait. The average number of pods per plant was 21.37 with a range of 9 to 39.

The genotypes JS-95-60 (9) followed by JS-SH-96-31(10) had the lowest number of pods per plant. Where as, highest number of pods per plant were recorded in the genotype AGS-157 (39). The coefficient of variation values in terms of phenotypic and genotypic levels were 27.8 and 25.8 per cent respectively, indicating negligible environmental effect on this trait. This was further evident by high heritability value of 86.2 per cent along with high genetic advance of 68.25 per cent of mean.

4.1.1.1.6 Seeds per pod

The genotypes did not exhibit significant difference for this characters as indicated by analysis of variance. The range was 1 to 3 with a mean of 1.9. Highest number of seeds per pod was recorded in JS-176-156 (3). However, seeds per pod were lowest in DS-371 (1).

The coefficient of phenotypic (27.3 per cent) and genotypic (16.5 per cent) variability values indicated moderate environmental effect on this trait. This was evident with moderate heritability value of 36.66 per cent and moderate genetic advance of 28.49 per cent of mean.

4.1.1.1.7 100 seed weight (g)

Analysis of variance has shown highly significant difference among the genotypes for this trait. This trait ranged from 6 to 20 g in different genotypes with a mean of 13.62 g. The genotype DS-97-11(20g) had the highest 100 seed weight. Where the genotype JS-SH-9301 and SH-444 (6g) recorded the lowest 100 seed weight. The coefficient of variation was moderate at phenotypic (21.1%) and genotypic (20.8%) level indicating moderate influence of environmental factors on this character. High heritability of 97.33 per cent along with high genetic advance of 58.43 per cent of mean was recorded for this trait.

4.1.1.1.8 Seeds per plant

Highly significant differences were observed for this character. The range of variation was 20 to 110 with a mean value of 39.14. The genotypes AGS-107(20) and GS-54 (20) had the lowest number of seeds per plant. Where as, highest number of seeds per plant was recorded in PK-1059 (110).

Moderate variability was noticed for number of seeds per plant as reflected by the coefficient of phenotypic and genotypic variation values of 39.0 and 35.5 per cent respectively, indicating low influence of environmental factors on this character. This was supported by high heritability estimate of 82.87 per cent. However, it exhibited high estimates of genetic advance 92.09 per cent of mean.

4.1.1.1.9 Seed yield per plant (g)

Significant differences between the genotypes was noticed as indicated by the results of analysis of variance for this character. The seed yield varied from 1.4 g to 14.4 g with a mean value of 5.2 g per plant. The genotypes MACS-515 and

MACS-532 have recorded highest yield of 14.4 g per plant. The lowest yield of 1.4 g was recorded in case of NRC-23.

The phenotypic and genotypic coefficients of variability were 37.7 and 34.7 per cent respectively, inferring low level of influence of environmental factors on this trait. High heritability estimate of 84.64 per cent with high genetic advance of 90.85 per cent over mean was observed for this trait.

4.1.2 Correlation analysis

The phenotypic correlation coefficients were determined to know the nature of relationship existing between seed yield and its component characters as well as association among component characters themselves.

The results of correlation have been tabulated in Table.3. They are presented below.

Seed yield was significantly positively correlated with pods per plant, seeds per pod, 100 seed weight, seeds per plant and branches per plant.

Days to 50 per cent flowering was positively and significantly associated with plant height, number of pods per plant, number of seeds per plant. It was positively but non significantly associated with days to maturity, number of seeds per pods and number of branches per plant. Where as, it was negatively but non significantly associated with 100 seed weight.

Days to maturity was positively and significantly associated with plant height. But this character was positively but non significantly associated with, number of pods per plant, 100 seed weight, and number of branches per plant, and

Table 3. Phenotypic correlation coefficients among nine quantitative traits in Soybean

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	1.000	0.070	0.183**	0.205**	0.021	-0.103	0.162**	0.013	0.117*
X2		1.000	0.212**	0.077	-0.083	0.021	-0.030	0.043	-0.011
X3			1.000	0.401**	0.019	-0.293**	0.281**	0.290**	0.081
X4				1.000	0.089	-0.173**	0.796**	0.432**	0.676**
X5					1.000	-0.193**	0.546**	0.109*	0.419**
X6						1.000	-0.269**	-0.071	0.297**
X7							1.000	0.352**	0.811**
X8								1.000	0.292**
X9									1.000

* - Significant at 5 % level **X1** = Days to 50% flowering

** - Significant at 1% level **X2** = Days to maturity

X3 = Plant height (cm)

X4 = Pods/ plant

X5 = Seeds/ pod

X6 = 100 Seed weight (g)

X7 = Seeds/ plant

X8 = Branches/plant

X9 = Seed yield/ plant (g)

negatively but non significantly associated with number of seeds per pod and number of seeds per plant.

Association of plant height with number of pods per plant, number of seeds per plant and number of branches per plant was positive and significant. Where as, it was negatively and significantly correlated with 100 seed weight. It showed strong positive association with number of pods per plant and moderate association with number of seeds per plant and number of branches per plant.

Number of pods per plant was positively and significantly associated with number of seeds per plant and number of branches per plant. But negatively and significantly associated with 100 seed weight. It was positively non significantly associated with number of seeds per pod.

Seeds per pod had significant negative association with 100 seed weight and was significantly and positively associated with number of seeds per plant and number of branches per plant.

Hundred seed weight was negatively and significantly associated with number of seeds per plant, which intern was positively associated with number of branches per plant.

4.1.3 Path coefficient analysis

The path coefficient analysis at phenotypic level was worked out to find the direct and indirect contribution of different quantitative traits to the seed yield in soybean. The phenotypic correlations were partitioned into direct and indirect effects of component characters on the seed yield and the results of the same is presented in the table.4.

Table 4. Path coefficient analysis showing the direct and indirect effects of different characters on seed yield in Soybean at phenotypic level

	X1	X2	X3	X4	X5	X6	X7	X8	r with seed yield
X1	0.0206	0.0007	-0.0078	0.0133	0.0006	-0.0563	0.1462	-0.0001	0.117*
X2	0.0014	0.0101	-0.0091	0.0050	-0.0023	0.0112	-0.0272	-0.0003	-0.011
X3	0.0038	0.0021	-0.0428	0.0261	0.0005	-0.1599	0.2535	-0.0019	0.081
X4	0.0042	0.0008	-0.0172	0.0650	0.0024	-0.0945	0.7183	-0.0029	0.676**
X5	0.0004	-0.0008	-0.0008	0.0058	0.0273	-0.1050	0.4929	-0.0007	0.419**
X6	-0.0021	0.0002	0.0126	-0.0113	-0.0053	0.5454	-0.2426	0.0005	0.297**
X7	0.0033	-0.0003	-0.0120	0.0517	0.0149	-0.1466	0.9026	-0.0024	0.811**
X8	0.0003	0.0004	-0.0124	0.0281	0.0030	-0.0386	0.3175	-0.0067	0.292**

Residual effect = 0.0533

* - Significant at 5 % level

** - Significant at 1 % level

X1 = Days to 50% flowering

X2 = Days to maturity

X3 = Plant height (cm)

X4 = Pods/ plant

X5 = Seeds/ pod

X6 = 100 Seed weight (g)

X7 = Seeds/ plant

X8 = Branches/plant

X9 = Seed yield/ plant (g)

Among all the characters studied, number of seeds per plant had highest direct effect (0.902) on seed yield followed by 100 seed weight (0.545). On the other hand days to 50 per cent flowering (0.0206), days to maturity (0.010) exhibited very low positive direct effect on seed yield. Indirect effect of plant height (-0.042) and number of branches per plant (-0.0067) were very low and negative.

Days to 50 per cent flowering showed very low positive direct effect (0.0206) on seed yield. Its indirect contribution through number of seeds per plant was moderate and positive (0.1462) which was responsible for its significant positive association with grain yield (0.117).

Direct effect of days to maturity was positive and very low (0.0101) and it has shown very negligible positive indirect effect through number of pods per plant (0.005) and 100 seed weight (0.0112). Where as, this character has exhibited very low negative indirect effect through plant height (-0.0091), number of seeds per pod (-0.0023), number of seeds per plant (-0.0272) and number of branches per plant (-0.0003).

The direct contribution of plant height on seed yield was low and negative (-0.0428) but has moderate indirect positive contribution through number of seeds per plant (0.2535). Where as, its indirect contribution through 100 seed weight was moderate and negative (-0.159). Thus, it has shown non significant negligible positive association with yield (0.081).

Number of pods per plant exhibited very low direct contribution towards yield (0.065). However, indirect contribution through number of seeds per plant was high (0.718) which resulted in high positive association with seed yield (0.676).

The direct effect of number of seeds per pod on seed yield is very low and positive (0.027). Where as, it has shown high indirect contribution through number of seeds per plant (0.4929). This was responsible for high and positive association of this trait with seed yield.

Hundred seed weight exerted high positive direct effect on yield (0.545). Its indirect effect through number of seeds per plant was moderate and negative (-0.242) resulting in moderate positive association of this characters with seed yield (0.297).

Number of seeds per plant exerted highest positive direct effect on seed yield (0.902). Its indirect effect through other traits was negligible and negative through 100 seed weight per plant (-0.146). Even then, it has showed high positive association with seed yield (0.811), which may be attributed for the high direct effect on seed yield.

The direct effect of number of branches per plant was very low and negative (-0.006).Where as, its indirect contribution through number of seeds per plant was moderate and positive (0.317) towards seed yield. This has resulted in moderate positive association of this trait with seed yield (0.292).

It was observed that number of seeds per plant and 100 seed weight had very high positive direct effect on seed yield per plant, which is the main cause for high correlation with seed yield. Although other traits except days to maturity , 100 seed weight which exhibited high indirect effect on seed yield via seeds per plant.

4.1.4 Selection indices

Selection indices for seed per plant were formulated by involving the characters which are having high direct effect and significant positive correlation with seed yield per plant. Seed yield was considered as dependent character in the analysis. Expected genetic advance for each of the selection indices was computed at five per cent selection intensity. Relative efficiency for each selection index was calculated by taking relative efficiency of straight selection for seed yield as 100 per cent (Table. 5).

Among the individual characters, highest efficiency was observed when selection was based on number of seeds per plant (258.5 %). Lowest efficiency was observed when selection was based on number of branches per plant (61.8%). Among the two independent character combinations, highest efficiency was observed when selection was based on seeds per plant and number of branches per plant (975 %) followed by combination of days to 50 per cent flowering and number of branches per plant (614.9 %). Where as, the lowest relative efficiency was obtained for the combination of number of seeds per pod and number of seeds per plant (24.20 %).

The highest relative efficiency (1319.70 %) was observed with three characters combination Viz., $X_1 + X_7 + X_8$ followed by $X_5 + X_7 + X_8$ (1058.50 %). Where as, among four characters combination highest selective efficiency (1624.5 %) was obtained for combination of $X_1 + X_6 + X_7 + X_8$ characters. While among five character combination $X_1 + X_5 + X_6 + X_7 + X_8$ (432.4 %) and among six characters combination was $X_1 + X_4 + X_5 + X_6 + X_7 + X_8$ (299.6 %) exhibited higher relative efficiency, but both were same compared to four character combinations.

Table 5. Selection indices for single and different combinations of yield component characters in Soybean

Sl. No.	Combination of characters	GA from strait selection	GA from Discriminant function selection	Relative efficiency
1	2	3	4	5
1	X1	4.73	11.67	246.30
2	X4	4.73	6.93	146.40
3	X5	4.73	3.68	77.70
4	X6	4.73	10.19	215.10
5	X7	4.73	12.25	258.60
6	X8	4.73	2.93	61.80
7	X9	4.73	4.73	100.00
8	X7+X8	1.95	19.05	975.00
9	X6+X8	1.95	8.74	447.20
10	X5+X8	1.95	3.37	172.80
11	X4+X8	1.95	11.43	585.20
12	X1+X8	1.95	12.01	614.90
13	X6+X7	11.42	10.19	89.20
14	X5+X7	11.42	2.76	24.20
15	X4+X7	11.42	8.46	74.10
16	X1+X7	11.42	3.25	28.50
17	X5+X6	7.28	3.53	48.50
18	X4+X6	7.28	9.75	134.00
19	X1+X6	7.28	11.67	160.30
20	X4+X5	2.45	8.38	341.40
21	X1+X5	2.45	12.04	489.10
22	X6+X7+X8	1.95	17.88	915.40
23	X5+X7+X8	1.95	20.68	1058.50
24	X4+X7+X8	1.95	12.79	654.80
25	X1+X7+X8	1.95	25.70	1319.70
26	X5+X6+X8	1.95	6.30	322.70
27	X4+X6+X8	1.95	11.22	574.10
28	X1+X6+X8	1.95	16.37	837.70
29	X4+X5+X8	1.95	12.66	647.80
30	X1+X4+X8	1.95	10.11	517.80
31	X5+X6+X7	11.42	4.12	36.20
32	X4+X6+X7	11.42	10.58	92.60
33	X1+X6+X7	11.42	18.85	165.00
34	X4+X5+X7	11.42	8.05	70.50
35	X1+X4+X6	7.28	12.11	166.63
36	X4+X5+X6	7.28	7.26	99.80
37	X5+X6+X7+X8	1.95	10.65	545.40
38	X4+X6+X7+X8	1.95	12.60	645.00
39	X1+X6+X7+X8	1.95	31.74	1624.50
40	X4+X5+X6+X8	1.95	9.38	480.30

Table 5. Continued...

1	2	3	4	5
41	X1+X4+X5+X8	1.95	12.18	623.60
42	X4+X5+X6+X7	11.42	3.45	30.22
43	X1+X5+X6+X7	11.42	4.89	42.50
44	X1+X4+X5+X7	11.42	7.89	70.00
45	X1+X4+X5+X6	7.28	8.04	110.50
46	X4+X5+X6+X7+X8	1.95	4.45	228.10
47	X1+X5+X6+X7+X8	1.95	8.44	432.40
48	X1+X4+X5+X6+X7	11.42	2.32	20.40
49	X1+X4+X5+X6+X7+X8	1.9	5.88	299.60

X1 = Days to 50 % flowering

X4 = Pods/ plant

X5 = Seeds/ pod

X6 = 100 Seed weight (g)

X7 = Seeds/ plant

X8 = Branches/plant

X9 = Seed yield/ plant (g)

Based on the above combination of characters with high relative efficiency, 50 high yielding genotypes were selected and used for screening for thermo-tolerance.

Experiment – II

4.2 Temperature Induction Response Technique (TIR)

The primary objective of this study was to identify soybean genotypes for thermo-tolerance. The temperature induction response technique (TIR) was adopted to examine the variability among the genotypes for thermo-tolerance. Fifty soybean genotypes selected based on combination of characters for high yield in the previous experiment were screened through TIR technique during *summer 2007*. Initially, both induction and lethal temperatures were standardized. Then the variability in the genotypes for high temperature tolerance was analyzed.

4.2.1 Standardization of lethal and optimum induction temperature

For standardization of both lethal and induction temperatures, genotype Hardee was used.

1. Standardization of lethal temperature

For fixing the lethal temperature pre-germinated seedlings of soybean were directly exposed to different combinations of temperature and duration *Viz.*, 48⁰C for 2h and 3h, 49⁰C for 2h and 3h and 50⁰C, 51⁰C for 2h and 3h and the per cent survival was recorded at the end of recovery period of 72 h at 28⁰C.

Table 6. Soybean genotypes with their survival (%) under temperature induced response after three days recovery

Sl. No.	Genotypes	% Survival	Sl. No.	Genotypes	% Survival
1	VLS-40	44.0	27	PK-10	0.00
2	GPC-357	36.0	28	CGP-43	0.00
3	GPC-943	16.0	29	KHSb-2	0.00
4	SL-83	5.0	30	MACS-450	0.00
5	CGP-387	28.0	31	PK-1174	0.00
6	NRC-23	7.0	32	GPC-8174	0.00
7	DS-84	6.0	33	SL-112	0.00
8	Bragg	6.0	34	DS-9814	0.00
9	NRC-17	6.0	35	GPC-1544	0.00
10	PK-34	46.4	36	PK-1046	0.00
11	Hardee	7.0	37	RR-16	0.00
12	TS-2000	5.0	38	MAUS-2	0.00
13	KB-79	52.2	39	SH-37	0.00
14	NRC-33	17.0	40	SL-599	0.00
15	PK-1036	58.4	41	PK-891	0.00
16	JS-335	7.0	42	PK-1023	0.00
17	MACS-212	29.0	43	PK-1000	0.00
18	MACS-754	12.0	44	MK-34	0.00
19	MACS-55	11.0	45	MACS-491	0.00
20	JS-95-58	6.0	46	NRC-3	0.00
21	KB-249A	12.0	47	KB-165	0.00
22	KB-230	18.0	48	NRC-17	0.00
23	MK-1	7.0	49	PK-1241	0.00
24	MACS-17	12.0	50	RR-3	0.00
25	KB-249	23.0			
26	MACS-5203	15.0			

Seedling survival percentage decreased with increase in lethal temperature. The mortality of seedlings was 95-100% at 48⁰C for 3h (Table 6). Hence this temperature was considered as lethal temperature for soybean seedlings.

2. Induction temperature:

Germinated seedlings of soybean (variety-Hardee) were subjected to different induction temperature treatments, following which they were exposed to lethal temperature of 48⁰C for 3h and per cent survival was recorded after 72h recovery and the same is presented in Table.7.

The optimum induction protocol was arrived based on 10 to 15 per cent survival per cent after recovery period of 72 hr. This was observed at induction temperature of 30⁰ C (1 h) – 35⁰ C(1h) – 40⁰ C (1 h) – 45⁰ C(2h) (Table.7). Hence, this induction temperature was used to screen the soybean genotypes for thermo-tolerance.

4.2.2. Screening of soybean genotypes for thermo-tolerance

Adopting the standardized induction and lethal temperatures, the seedlings of 50 genotypes of soybean were screened for thermo-tolerance. The seedlings were exposed to induction temperature and then to lethal temperature.

Analysis of variance indicated presence of significance difference among the genotypes for all the traits. Among 50 genotypes screened for thermo-tolerance, 24 genotypes have shown 100 per cent mortality (Table. 8) and hence, they are considered as highly susceptible genotypes for high temperature. Another 26 genotypes have recorded different survival per cent, later the growth of seedlings of induced and absolute control was recorded and per cent reduction

Table 7. Survival of Soybean seedlings at different temperature and duration combinations

Sl.No.	Temperature	Survival (%)	Range of survival (%)
1	48(2hr)	95.50	95-100
2	48(3hr)	5.75	1-5
3	49(2hr)	0.00	0-0
4	49(3hr)	0.00	0-0
5	50(2hr)	0.00	0-0
6	51(2hr)	0.00	0-0
SEm ±		1.64	
CD at 5%		5.62	
CV %		6.10	

Table 8. Survival of Soybean seedlings at different series of induction Temperature (IT)

Sl. No.	I T	Survival (%)	Range of survival (%)
1	A	99.5	95-100
2	B	45.0	45-50
3	C	13.0	10-15
SEm ±		0.60	
CD at 5%		4.83	
CV %		5.10	

IT	LT
A = 33 ⁰ C (1 h)---- 38 ⁰ C (1 h) ---- 43 ⁰ C (2 h) -----	48 ⁰ C (3h)
B = 35 ⁰ C (1 h) ---- 40 ⁰ C (1 h) ---- 45 ⁰ C (2 h) -----	48 ⁰ C (3h)
C = 30 ⁰ C (1 h) ---- 35 ⁰ C (1 h) ---- 40 ⁰ C (1 h) ----- 45 ⁰ C (2 h)---- 48 ⁰ C (3h)	

IT = Induction Temperature

LT = Lethal Temperature

over absolute control was computed (Table. 9). The phenotypes of thermo-tolerant and susceptible genotypes (KB-79 and SL-112) can be seen in the Figure.1.

4.2.2.1 Survival percent

There was significant difference among the genotypes for survival per cent. Maximum survival of 58.4 per cent was recorded by PK-1036 followed by KB -79 (52.2 %). Where as, the minimum survival was 5 per cent (TS-2000) followed by 6 per cent (JS -95-58).

Among 26 genotypes, eight had shown high per cent of survival Viz., PK-1036 (58.4 %), KB-79 (52.2 %), NRC-17 (46.4 %), VLS-40 (44 %), GPC-357 (36 %), MACS-212 (29 %), CGP-387 (28 %) and KB-249 (23 %). Where as remaining 18 genotypes had shown moderate level of survival percent. Another 24 genotypes showed 100 per cent death. So, they are considered as highly susceptible genotypes for high temperature.

4.2.2.2 Radicle length

Analysis of variance for radicle length indicated significant difference among the genotypes. The trait varied from 0.2 cm to 1.9 cm with the mean of 0.7 cm.

Maximum recovery of radicle growth was seen in PK-34 (1.9 cm) followed by CGP-387 (1.8 cm), KB-79 (1.5 cm), MACS-212 (1.4 cm), GPC-537 (1.4 cm), KB -249 (1.3 cm) and GPC-943 (1.2 cm).

The per cent reduction in radicle length was maximum (98 %) in the genotype JS-95-58 and TS -2000, followed by MK-1, JS-335, NRC-33 & Bragg

Table 9. Effect of induction treatment followed by lethal temperature on survival percent and recovery growth in Soybean

Sl. No.	Varieties	% Survival	Rank	Radical length(cm)				Hypocotyl length (cm)				No. of secondary roots				Total rank
				Mean	Control	% Reduction	Rank	Mean	Control	% Reduction	Rank	Mean	Control	% Reduction	Rank	
1	VLS-40	44.00	4.0	0.8	4.6	83	1.0	2.2	7.0	68	6.50	6.20	25.0	75.0	13.0	24.5
2	GPC-357	36.00	5.0	1.4	10.0	86	3.0	1.8	5.0	63	4.50	7.60	30.0	75.0	13.0	25.5
3	GPC-943	16.00	11.0	1.2	13.6	91	10.0	1.4	4.6	69	9.00	5.60	30.0	81.0	17.5	47.5
4	SL-83	5.00	23.5	0.5	14.8	96	18.5	1.1	4.0	73	14.50	4.60	25.0	82.0	19.0	75.5
5	CGP-387	28.00	7.0	1.8	13.6	87	5.0	2.2	4.8	54	2.00	11.40	40.0	72.0	9.0	23.0
6	NRC-23	7.00	17.5	0.4	6.5	94	14.0	1.6	5.0	69	9.00	7.40	27.0	73.0	10.5	51.0
7	DS-84	6.00	21.5	0.7	10.5	93	11.5	1.2	4.0	71	12.00	4.00	18.0	78.0	15.0	60.0
8	Bragg	6.00	21.5	0.4	12.3	97	22.5	1.2	6.0	79	18.00	5.60	18.0	69.0	7.0	69.0
9	NRC-17	6.00	21.5	1.0	7.6	87	5.0	1.8	5.5	60	3.00	4.80	11.0	56.0	2.0	35.0
10	PK-34	46.40	3.0	1.9	12.4	85	2.0	0.9	3.0	69	9.00	7.60	12.0	37.0	4.0	16.0
11	Hardee	7.00	17.5	0.6	12.0	95	16.0	1.0	6.3	84	23.50	6.20	25.0	75.0	13.0	70.0
12	TS-2000	5.00	23.5	0.2	11.0	98	25.5	1.0	4.3	76	16.00	2.20	20.0	89.0	22.0	87.0
13	KB-79	52.20	2.0	1.5	12.4	88	7.5	1.6	5.3	70	11.00	5.00	10.0	50.0	3.0	23.5
14	NRC-33	17.00	10.0	0.4	14.5	97	22.5	1.5	6.6	77	17.00	1.80	20.0	91.0	23.0	72.5
15	PK-1036	58.40	1.0	0.5	13.5	96	18.5	1.3	6.3	53	1.00	9.20	25.0	63.0	6.0	27.0
16	JS-335	7.00	17.5	0.4	13.7	97	22.5	0.5	6.5	92	26.00	4.00	25.0	84.0	20.0	86.0
17	MACS-212	29.00	6.0	1.4	11.0	87	5.0	1.3	3.5	63	4.50	6.80	25.0	73.0	10.5	26.0
18	MACS-754	12.00	14.0	0.9	7.0	88	7.5	0.7	5.0	86	25.00	4.20	20.0	79.0	16.0	62.5
19	MACS-55	11.00	16.0	0.7	14.5	96	18.5	0.8	3.0	73	14.50	4.60	24.0	81.0	17.5	66.5
20	JS-95-58	6.00	21.5	0.3	12.8	98	25.5	1.1	5.5	80	19.50	1.80	30.0	94.0	25.0	91.5
21	KB-249A	12.00	14.0	0.7	11.5	94	14.0	1.2	2.5	80	19.50	5.60	14.0	60.0	5.0	52.5
22	KB-230	18.00	9.0	0.4	9.6	96	18.5	0.9	3.3	72	13.00	4.00	28.0	86.0	21.0	61.5
23	MK-1	7.00	17.5	0.4	12.1	97	22.5	0.5	2.9	82	21.00	1.80	22.0	92.0	24.0	85.0
24	MACS-17	12.00	14.0	0.6	8.2	93	11.5	0.6	3.8	83	22.00	6.40	10.0	36.0	1.0	48.5
25	KB-249	23.00	8.0	1.3	12.0	89	9.0	1.5	4.6	68	6.50	7.20	24.0	70.0	7.5	31.0
26	MACS-5203	15.00	12.0	0.7	12.0	94	14.0	0.6	4.0	84	23.50	7.60	25.0	70.0	7.5	57.0
Mean		18.92		0.7	11.6	94		1.2	4.7	73		5.60	22.8	72.7		44.5
SEm ±		0.21		0.1				1.0				0.09				
CD at 5%		4.92		0.2				0.3				1.76				
CV %		10.57		3.9				10.1				16.24				

Table 10. Analysis of variance for different recovery growth parameters in Soybean

Source of variation	df	Mean sum of squares			
		% Survival	Radicle length	Hypocotyl length	No. of secondary roots
Genotypes	25	602.09**	0.437**	1.33**	31.69**
Error	104	6.233	0.017	0.022	0.95

* - Significant at 5 % level

** - Significant at 1 % level



Thermo tolerant



Temperature susceptible

Figure 1. Recovery growth of thermo-tolerant and susceptible soybean genotypes after induction and lethal temperature treatment

(97 %) over control. Where as, the minimum reduction of 83 per cent was recorded by LS-40, followed by PK-34 (85 %), GPC-537 (86 %) and KB-79 (88 %).

4.2.2.3 Hypocotyl length

Significant differences were observed among the genotypes for hypocotyls length as revealed by the analysis of variance (Table.10). Maximum recovery growth of hypocotyl 2.2 cm and the minimum was 0.5 cm with the mean of 1.2 cm.

Maximum growth was seen in VLS-40 and CGP-387 (2.2 cm) followed by GPC-357 (1.8 cm), NRC -23 & KB-79 (1.6 cm). Where as, the minimum growth was observed in MK-1 and JS -335 (0.5 cm) followed by MACS-17 and MACS-5203 (0.6 cm).

The genotypes CGP-387 (54 %), GPC-357 (63 %), VLS-40 (68 %), KB-249 (68 %), NRC-23 (69 %), PK-34 (69 %) have shown lower per cent reduction compared to genotypes JS-335 (92 %), MACS-754 (86 %), MACS-5203 (84 %) and MACS-17 (83 %).

4.2.2.4 Number of secondary roots

Significant differences were noticed among the genotypes for number of secondary roots as evident by ANOVA (Table .10). Trait varied from 1.8 to 11.4 with the mean of 5.6.

Maximum number of secondary roots was observed in CGP-387 (11.4) followed by PK-1036 (9.2), GPC-357 (7.6), PK-34 (7.6), MACS-5203 (7.6) and

NRC-23 (7.4). Where as, minimum number of secondary roots was observed in MK-1 (1.8) and NRC-33 (1.8) followed by TS-2000 (2.2).

Ranks were assigned to each character and total rank was calculated. By looking to over all total rank the top ranking eight genotypes Viz., VLS-40, GPC-357, CGP-387, PK-34, KB-79, PK-1036, MACS-212 and KB-249 were selected as tolerant to temperature and these were used as source material along with one moderate (NRC-17) and one highly susceptible (MAUS-2) genotype in the next experiment.

Experiment – III

4.3 Drought tolerance studies

The results of pot culture experiment (Figure.2) conducted to assess the drought tolerance at seedling stage of eight thermo-tolerant genotypes, one moderately tolerant and one susceptible genotype selected based on their performance under Temperature Induction Response (TIR) study are presented here under.

The observations were recorded under the stress levels of 50 per cent and 25 per cent of field capacity (F.C.) at 7th and 3rd day of stress imposition respectively and they were compared to no stress (100 % F.C.) condition. Phenotypes of tolerant and susceptible genotypes (KB-79 and VLS-40) under the moisture stress imposed can be seen in Figure.3.

The analysis of variance (Table 11a, 11b and 11c) indicated significant variation among the genotypes for all the characters studied in this experiment.

Table 11(a). Analysis of variance for different traits in Soybean under 25% F.C. moisture stress

Source of variation	df	Mean sum of squares							
		Root length (cm)	Shoot length (cm)	Leaf area (cm ²)	Root dry wt (mg)	Shoot dry wt (mg)	Total dry wt (mg)	Percent leakage	Rate of water loss
Genotypes	9	4.48**	1.82*	141.12*	61.08**	40.75*	202.17**	7.53**	0.62*
Error	20	0.86	0.51	26.68	10.92	13.62	31.9	1.40	0.19

Table 11(b). Analysis of variance for different traits in Soybean under 50% F.C. moisture stress

Source of variation	df	Mean sum of squares							
		Root length (cm)	Shoot length (cm)	Leaf area (cm ²)	Root dry wt (mg)	Shoot dry wt (mg)	Total dry wt (mg)	Percent leakage	Rate of water loss
Genotypes	9	5.63**	1.71**	304.62**	43.20**	75.05**	210.85**	6.46*	0.62**
Error	20	0.75	0.22	59.73	14.28	11.24	20.50	1.70	0.09

Table 11(c). Analysis of variance for different traits in Soybean under 100% F.C.

Source of variation	df	Mean sum of squares							
		Root length (cm)	Shoot length (cm)	Leaf area (cm ²)	Root dry wt (mg)	Shoot dry wt (mg)	Total dry wt (mg)	Percent leakage	Rate of water loss
Genotypes	9	4.89**	3.97**	1918.16**	128.34**	270.47**	642.4**	9.73**	0.08**
Error	20	0.35	0.45	112.10	10.69	29.84	53.45	0.80	0.002

* - Significant at 5 % level & ** - Significant at 1 % level



Figure 2. General view of pot culture experiment to screen for drought tolerance

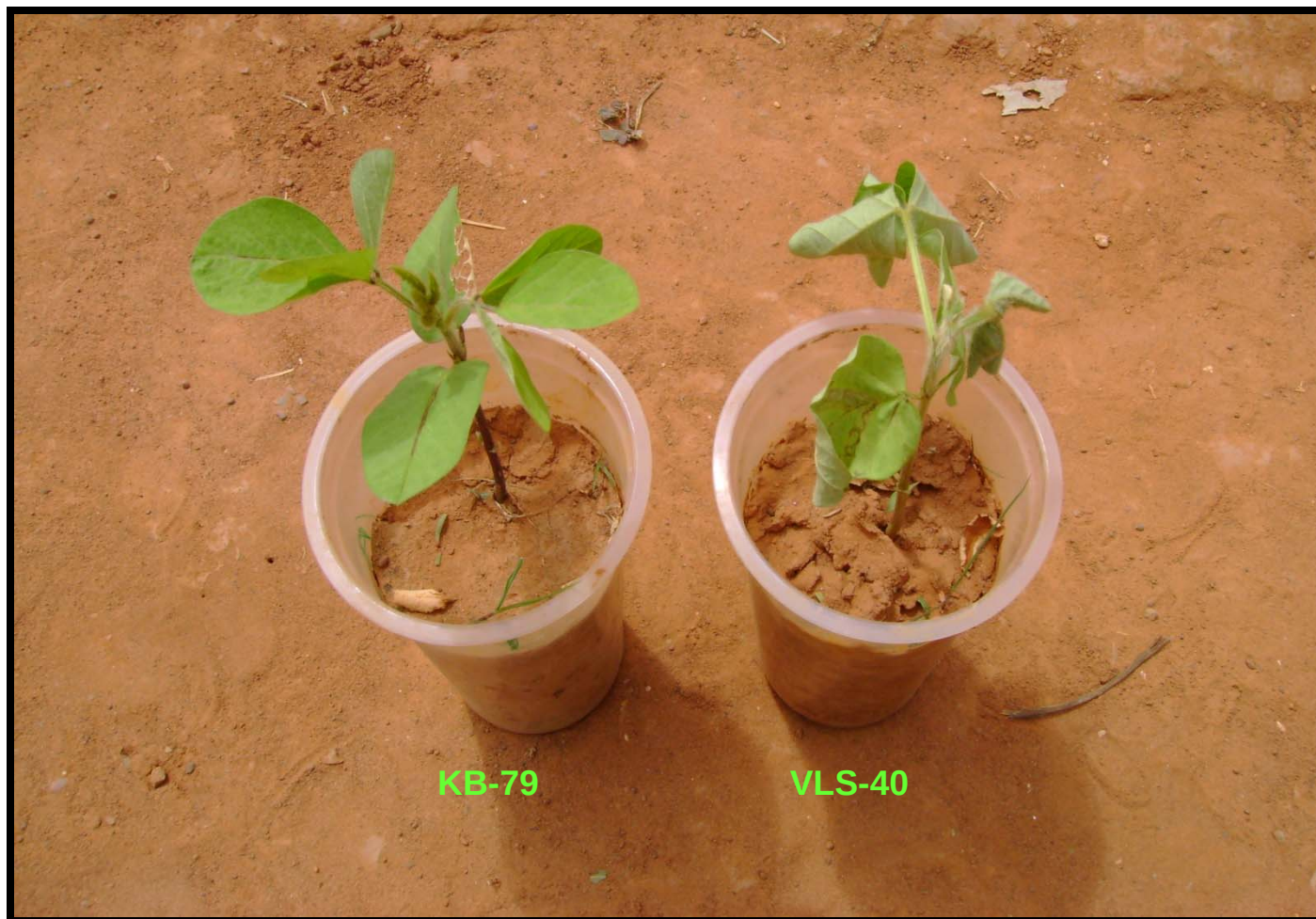


Figure 3. Drought tolerant (KB-79) and susceptible (VLS-40) soybean genotypes under moisture stress condition

4.3.1 Shoot length (cm)

The mean shoot length was 11 cm which ranged from 8.9 cm to 12.6 cm. Minimum per cent reduction (4.81 %) in shoot length was recorded by PK-34 followed by KB-79 (13.21%). While, maximum per cent reduction (26.19 %) was noticed in NRC-17 at 50% F.C. stress. Under 25% F.C. stress, the genotype GPC-387 (1.28%) recorded minimum per cent reduction followed by KB-249 (2.27%) and PK-34 (2.33%) where as, genotype VLS-40 recorded maximum (11.59%) per cent reduction in shoot length (Table.12).

4.3.2 Root length (cm)

In control, the root length was ranged from 10.3 cm to 14.8 cm with the mean of 12.2 cm. The mean root length was 13.2 cm in 50% F.C. stress, which ranged from 11.8 cm to 15.2 cm. In case of 25% F.C. stress, the mean root length was 14.2 cm which varied from 12.1 cm to 16.2 cm. (Table.13).

The lowest per cent increase was observed in MAUS-2 (0.68%) and highest in KB-79 (21.14%) followed by PK-34 (15.89%) under 50% F.C. stress (Table.13). Where as, under 25% F.C. stress, it ranged from 0.76 per cent (MAUS-2) to 47.27 per cent (KB-79) followed by 46.32 per cent (PK-34).

4.3.3 Leaf area (cm²)

Under control, leaf area ranged from 65 cm² to 148.7 cm² with mean of 87.5 cm². In 50 % F.C. stress, the mean leaf area was 57.2 cm² which ranged from 43 cm² to 75.7 cm² where as, in 25 % F.C. stress leaf area ranged from 27.7 to 51.7 cm² with mean of 36.3 cm² (Table.14).

Table 12. Shoot length (cm) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Reduction	Control	25% F.C.	% Reduction
MACS-212	10.20	8.80	13.73	8.40	8.20	2.38
PK-34	10.40	9.90	4.81	8.60	8.40	2.33
KB-249	11.40	9.30	18.42	8.80	8.60	2.27
CGP-387	11.30	9.50	15.93	8.70	8.30	4.60
GPC-357	10.10	8.60	14.85	7.80	7.70	1.28
NRC-17	12.60	9.30	26.19	9.70	8.90	8.25
KB-79	10.60	9.20	13.21	8.20	8.00	2.44
VLS-40	8.90	7.40	16.85	6.90	6.10	11.59
PK-1036	11.60	9.20	20.69	9.00	8.40	6.67
MAUS-2	12.60	10.40	17.46	9.70	8.80	9.28
Mean	11.00	9.20	16.21	8.60	8.10	5.11
SEm±	0.12	0.09		0.14	0.13	
CD at 5%	1.14	0.81		0.24	1.22	
CV%	5.33	5.19		5.50	8.62	

Table 13. Root length (cm) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Increase	Control	25% F.C.	% Increase
MACS-212	10.30	11.80	14.56	9.2	13.10	42.39
PK-34	10.70	12.40	15.89	9.5	13.90	46.32
KB-249	12.10	13.90	14.88	10.8	15.70	45.37
CGP-387	12.40	12.10	-2.42	11.1	14.50	30.63
GPC-357	12.50	12.90	3.20	11.2	14.20	26.79
NRC-17	12.60	12.00	-4.76	11.3	15.40	36.28
KB-79	12.30	14.90	21.14	11.0	16.20	47.27
VLS-40	11.20	12.20	8.93	10.0	12.10	21.00
PK-1036	13.10	15.20	16.03	11.7	13.10	11.97
MAUS-2	14.80	14.80	0.68	13.2	13.30	0.76
Mean	12.20	13.20	8.81	10.9	14.20	30.88
SEm±	0.10	0.15		0.1	0.16	
CD at 5%	1.01	1.40		1.1	1.58	
CV%	4.84	6.53		5.0	6.58	

Table 14. Leaf area (cm²) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Reduction	Control	25% F.C.	% Reduction
MACS-212	75.70	47.00	37.91	58.50	31.40	46.32
PK-34	66.70	56.30	15.59	51.50	38.30	25.63
KB-249	90.30	75.70	16.17	69.80	42.60	38.97
CGP-387	78.30	60.30	22.99	60.50	34.20	43.47
GPC-357	65.00	54.30	16.46	50.20	32.00	36.25
NRC-17	102.00	59.70	41.47	78.80	41.00	47.97
KB-79	66.30	63.30	4.52	48.70	34.30	29.57
VLS-40	93.00	43.00	53.76	71.90	27.70	61.47
PK-1036	148.70	56.00	62.34	114.90	51.70	55.00
MAUS-2	88.70	56.30	36.53	68.50	30.30	55.77
Mean	87.50	57.20	30.78	67.30	36.30	44.04
SEm±	1.93	1.41		1.78	0.94	
CD at 5%	18.00	13.16		17.20	8.80	
CV%	12.15	13.72		11.30	14.73	

Table 15. Root dry weight (mg) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Reduction	Control	25% F.C.	% Reduction
MACS-212	31.70	22.70	28.39	24.50	14.80	39.59
PK-34	24.30	20.00	17.70	18.80	14.80	21.28
KB-249	34.00	26.80	21.18	26.30	22.90	12.93
CGP-387	39.30	24.70	37.15	30.40	23.30	23.36
GPC-357	39.80	25.70	35.43	30.80	23.10	25.00
NRC-17	38.50	29.20	24.16	29.80	22.40	24.83
KB-79	23.30	21.30	8.58	18.00	14.70	18.33
VLS-40	36.50	27.40	24.93	30.10	28.60	4.98
PK-1036	39.00	26.60	31.79	28.20	26.00	7.80
MAUS-2	26.00	18.70	28.08	20.10	19.00	5.47
Mean	33.30	24.30	25.74	25.70	21.00	18.36
SEm±	0.59	0.69		0.49	0.06	
CD at 5%	5.57	6.44		4.78	5.62	
CV%	9.83	15.68		8.32	15.47	

In 50% FC stress the minimum reduction in leaf area was recorded by KB-79 (4.52 %) followed by PK-34 (15.59 %) while, maximum reduction of 62.34 per cent was recorded by PK-1036. Under 25% F.C. stress, while genotype PK-34 showed minimum reduction (25.63%), while the maximum reduction was observed in VLS-40 (61.47%).

4.3.4 Root dry weight (mg)

The root dry weight varied from 23.3 mg to 39.8 mg with mean of 33.3mg in control. Under 50% F.C. stress, the mean root dry weight was 24.3 mg which ranged from 18.7 to 29.2 mg. Where as, in 25% F.C. stress, the root dry weight ranged from 14.7 mg to 28.6mg with mean of 21.0mg (Table.15).

The per cent reduction for this trait ranged from 8.58 (KB-79) per cent to 37.15 (CGP-387) per cent under 50% F.C. stress, where as, variation for the same trait observed under 25% F.C. stress ranged from 4.98 per cent (KB-79) to 39.59 per cent (MACS-212).

4.3.5 Shoot dry weight (mg)

In control, the shoot dry weight ranged from 39.5 (mg) to 66.8 mg with mean of 51.8 mg. Under 50% F.C. stress, average shoot dry weight was 31.5 mg which ranged from 24.2 mg to 38.6 mg. Where as, the same trait under 25% F.C. stress, ranged from 19.6 mg to 31.8 mg with mean of 25.2 mg (Table.16).

The reduction percentage for this trait was minimum in genotype KB-79 (25.64%) followed by PK-34 (27.59%). Where as, PK-1036 (47.6%) has recorded maximum reduction under 50% F.C. stress, in 25% F.C. stress minimum reduction was 28.96 per cent (KB-79) and maximum reduction was 46.01 per cent (MAUS-2).

Table 16. Shoot dry weight (mg) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Reduction	Control	25% F.C.	% Reduction
MACS-212	43.10	24.20	43.85	33.30	22.60	32.13
PK-34	39.50	28.60	27.59	30.50	20.90	31.48
KB-249	61.70	38.60	37.44	47.70	27.90	41.51
CGP-387	55.40	31.60	42.96	42.80	27.60	35.51
GPC-357	44.00	29.90	32.05	34.00	24.00	29.41
NRC-17	59.20	35.00	40.88	45.70	26.90	41.14
KB-79	43.30	32.20	25.64	33.50	23.80	28.96
VLS-40	58.20	32.30	44.50	44.90	26.80	40.31
PK-1036	66.80	35.00	47.60	51.60	31.80	38.37
MAUS-2	47.00	28.00	40.43	36.30	19.60	46.01
Mean	51.80	31.50	38.29	40.00	25.20	36.48
SEm±	0.99	0.61		0.78	0.67	
CD at 5%	9.30	5.71		8.90	6.28	
CV%	10.54	10.98		8.82	14.66	

Table 17. Total dry weight (mg) of temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Reduction	Control	25% F.C.	% Reduction
MACS-212	74.80	46.80	37.43	57.80	45.00	22.15
PK-34	63.80	48.60	23.82	49.30	41.60	15.62
KB-249	95.70	65.40	31.66	73.90	55.90	24.36
CGP-387	94.70	56.30	40.55	73.20	54.20	25.96
GPC-357	83.80	55.60	33.65	64.80	47.90	26.08
NRC-17	97.70	64.20	34.29	75.50	50.00	33.77
KB-79	66.70	49.50	25.79	51.50	44.70	13.20
VLS-40	94.70	59.80	36.85	73.20	57.70	21.17
PK-1036	105.80	61.60	41.78	81.70	65.30	20.07
MAUS-2	73.00	46.70	36.03	56.40	38.60	31.56
Mean	85.10	55.40	34.19	65.70	50.10	23.39
SEm±	1.33	0.83		1.20	1.03	
CD at 5%	12.45	7.71		7.93	9.62	
CV%	8.59	8.29		9.01	11.27	

4.3.6 Total dry weight (mg)

Under control, total dry weight ranged from 63.8 mg to 105.8mg with mean of 85.1 mg. In 50% F.C. stress, mean total dry weight of seedling was 55.4 mg which ranged from 46.7 to 65.4 mg. Where as, in 25% F.C. stress, total dry weight ranged from 38.6 mg to 65.3 mg with mean of 50.1 mg (Table.17).

Under 50% F.C. stress, the minimum per cent reduction was observed in genotype PK-34 (23.82%) followed by KB-79 (25.79%) while maximum reduction was noticed is PK-1036 (41.78%). Where as, under 25% F.C. stress, the minimum reduction of was recorded by KB-79 (13.2%) followed by PK-34 (15.62%) while maximum reduction was noticed in NRC-17 (33.77%).

4.3.7 Per cent membrane leakage

Under control, this trait ranged from 5.34 per cent to 8.75 per cent with mean of 8.09 per cent. In 50% F.C. stress, average membrane leakage per cent was 11.62, which ranged from 9.05 per cent to 14.15 per cent. Where as, in 25% F.C. stress, this trait varied from 7.32 per cent to 14.25 per cent with mean of 10.43 per cent (Table.18).

Under 50% F.C. stress, minimum increase in per cent leakage was 3.43 per cent in genotype PK-34 followed by 28.32 per cent in KB-79 while, maximum per cent leakage of 111.99 was noticed in PK-1036. In 25% F.C. stress, the genotype KB-79 recorded minimum per cent increase (12.44%) and PK-1036 recorded maximum per cent membrane leakage (92.35%) .

Table 18. Percent membrane leakage in temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50% F.C.	% Increase	Control	25% F.C.	% Increase
MACS-212	8.72	11.83	35.67	8.32	11.25	35.22
PK-34	8.75	9.05	3.43	8.36	10.39	24.28
KB-249	8.51	11.83	39.01	8.12	10.60	30.54
CGP-387	7.92	12.05	52.15	7.56	9.96	31.75
GPC-357	8.59	10.96	27.59	8.19	14.25	73.99
NRC-17	8.09	13.54	67.37	7.72	8.97	16.19
KB-79	7.84	10.06	28.32	6.51	7.32	12.44
VLS-40	8.63	11.37	31.75	8.24	11.29	37.01
PK-1036	5.34	11.32	111.99	5.10	9.81	92.35
MAUS-2	8.53	14.15	65.89	8.14	-	-
Mean	8.09	11.62	46.31	7.63	10.43	39.31
SEm±	0.16	0.23		0.13	0.21	
CD at 5%	1.50	2.19		1.30	1.99	
CV%	11.60	11.11		10.20	10.91	

Table 19. Rate of water loss (mg/cm²/hr) in temperature induced Soybean genotypes as influenced by different levels of moisture under pot culture

Genotypes	Control	50 % F.C.	% Increase	Control	25% F.C.	% Increase
MACS-212	1.02	2.10	105.88	0.97	3.00	209.28
PK-34	1.15	1.99	73.04	1.10	3.26	196.36
KB-249	0.94	1.82	93.62	0.90	2.81	212.22
CGP-387	1.00	1.93	93.00	0.96	3.30	243.75
GPC-357	0.82	1.64	100.00	0.78	3.98	410.26
NRC-17	0.82	2.23	171.95	0.78	3.71	375.64
KB-79	0.82	1.56	90.24	0.78	2.20	182.05
VLS-40	0.88	2.86	225.00	0.84	2.64	214.29
PK-1036	0.58	2.51	332.76	0.56	3.23	476.79
MAUS-2	0.72	1.58	119.44	0.69	-	-
Mean	0.88	2.02	140.49	0.84	3.13	280.07
SEm±	0.02	0.03		0.03	0.08	
CD at 5%	0.22	0.29		0.18	0.74	
CV%	14.70	8.41		10.30	13.61	

4.3.8 Rate of water loss (mg/ cm² /hr)

Mean rate of water loss was 0.88 which ranged from 0.58 to 1.15 in control. Under 50% F.C. stress, this trait ranged from 1.56 to 2.86 with mean of 2.02. While in 25% F.C. stress, this character ranged from 2.2 to 3.98 with mean of 3.13 (Table-19).

Minimum per cent of increase in rate of water loss was observed in the genotype PK-34 (73.04 %) followed by KB-79 (90.24 %). Maximum increase in water loss compared to control was observed in PK-1036 (332.76 %) under 50% F.C. stress. Where as, in 25% F.C. stress, the minimum per cent increase was recorded by the genotype KB-79 (181.05%) followed by PK-34 (196.36%) while, maximum per cent increase was observed in genotype PK-1036 (476.79%).

Experiment – IV

4.4 Root morphological studies

In this experiment, observations were recorded from 30 days old plants. The analysis of variance (Table.20) revealed the presence of significant differences among the genotypes for all the characters except root: shoot weight ratio. The mean values for all the traits have been presented in Table.21.

4.4.1. Number of leaves

The mean number of leaves was 9. The genotypes MACS-212 and CGP - 387 recorded Maximum (12) Leaves. Where as, the genotypes PK -34 and GPC – 357 have recorded 10 leaves while genotype PK-1036 has recorded lowest number (6) of leaves.

Table 20. Mean values for different growth and root morphological traits of soybean genotypes.

Genotypes	Number of leaves	Root length (cm)	Shoot Length (cm)	Root :Shoot ratio	Total Length (cm)	Shoot dry wt (g)	Root dry wt (g)	Root: Shoot weight ratio	Total dry wt (g)	Root volume (cm³)
MACS-212	12.00	47.67	19.33	2.47	67.00	2.97	0.047	0.0160	3.02	3.07
PK-34	10.00	65.17	25.67	2.54	90.84	4.17	0.062	0.0148	4.23	3.63
KB-249	8.00	55.67	23.33	2.39	79.00	3.03	0.042	0.0138	3.07	2.73
CGP-387	12.00	55.83	25.00	2.23	80.83	3.20	0.055	0.0172	3.26	3.33
GPC-357	10.00	45.33	18.33	2.47	63.67	3.13	0.048	0.0156	3.18	3.17
NRC-17	8.67	51.00	23.33	2.19	74.33	3.30	0.046	0.0140	3.35	2.87
KB-79	8.67	68.00	22.00	3.09	90.00	3.60	0.058	0.0160	3.66	3.47
PK-1036	6.00	51.00	22.00	2.32	73.00	2.93	0.050	0.0172	2.98	2.73
VLS-40	7.00	54.33	21.67	2.51	76.00	2.77	0.052	0.0194	2.82	3.87
MAUS-2	7.67	42.00	20.00	2.00	62.00	2.23	0.024	0.0109	2.25	1.60
Mean	9.00	53.60	22.07	2.43	75.67	3.13	0.048	0.0155	3.18	3.05
SEm±	0.21	0.54	0.33	0.05	0.64	0.07	0.006	0.0005	0.07	0.06
CD at 5%	1.94	5.07	3.05	0.42	5.96	0.67	0.005	0.0047	0.70	0.52
CV%	12.67	5.55	8.11	10.22	4.62	12.62	6.410	17.8366	11.36	9.96

Table 21. Analysis of variance for different growth and root morphological traits in Soybean

Source of variation	df	Mean sum of squares								
		Number of leaves	Root length(cm)	Shoot length(cm)	Root:Shoot ratio	Shoot dry weight (mg)	Root dry weight (mg)	Root: Shoot weight ratio	Total dry weight (mg)	Root volume (cm ³)
Genotypes	9	12**	200.8**	16.8**	0.22*	0.78**	324.0**	0.000003	1.07**	1.2**
Error	20	1.3	8.8	3.2	0.06	0.15	9.6	0.000008	0.16	0.092

* - Significant at 5 % level

** - Significant at 1% level

4.4.2. Root length (cm)

This trait exhibited a mean of 53.6 cm. The Genotypes KB -79 had record maximum root length (68 cm) while, the genotypes KB-249 and CGP -387 had recorded medium root growth. Where as, MAUS -2 had recorded lowest root length (42 cm) compared to all the genotypes (Figure.4).

4.4.3. Root volume (cm³)

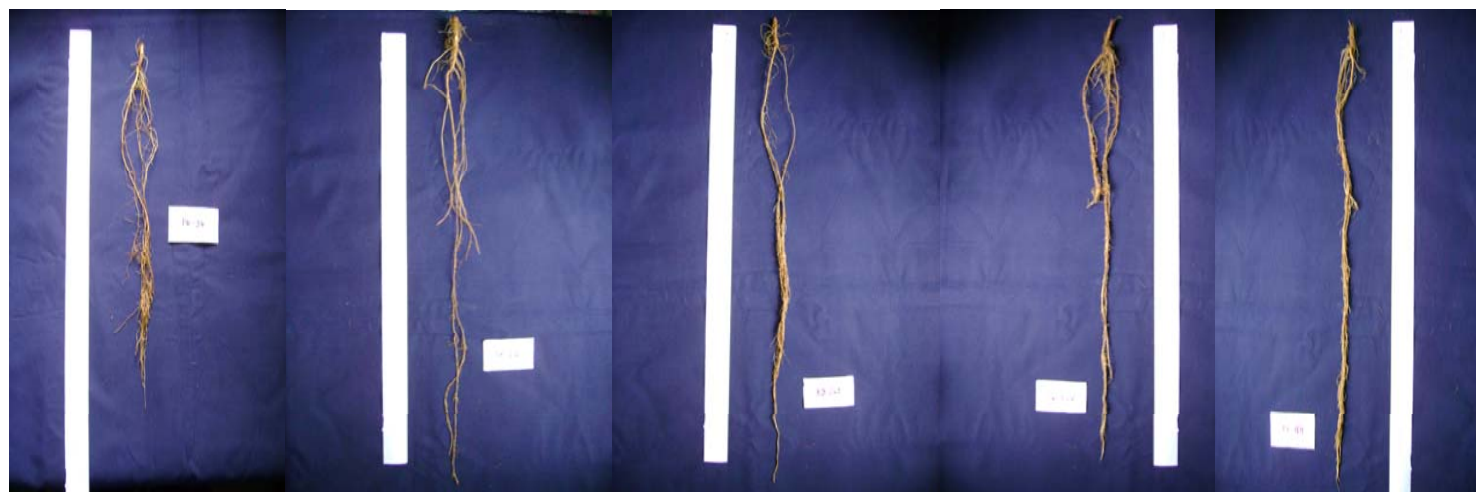
This trait recorded a mean of 3.05 cm³. Maximum root volume was recorded in genotype VLS 40 (3.87 cm³) followed by PK-34 (3.63 cm³) and KB -79 (3.47 cm³). Where as, least root volume was recoded in MAUS -2 (1.6 cm³).

4.4.4. Root dry weight (g):

This trait exhibited a mean of 0.048g. The genotype PK-34 had recorded maximum root dry weight (0.062g) followed by KB-79 (0.58g). The least root dry weight (0.024g) was recorded in genotype MAUS-2.

4.4.5 Shoot length(cm)

The mean shoot length was 22.07 cm. Where as genotype PK- 34 had recorded maximum shoot length (25. 67cm) followed by CGP- 387 (25 cm) and KB- 249 (23.3 cm) while the genotype GCP-357 had recorded lowest shoot length (18.33 cm).



GCP-537

PK -836

KB-249

VLS-40

KB - 79



MAUS-2

CGP-387

PK-34

MACS-450

NRC-17

Figure 4. Root morphology of different soybean genotypes under pipe study

4.4.6 Shoot dry weight (mg)

This trait recorded a mean of 3.13mg. Maximum shoot dry weight was recorded in genotype PK -34 (4.17mg) which was followed by KB -79 (3.6mg). Where as, the minimum shoot dry weight recorded in MAUS-2 (2.23mg).

4.4.7 Total dry weight(g)

The mean total dry weight was 3.18g and the highest total dry weight was noticed in genotype PK-34 (4.23g) followed by KB-79 (3.66g) where as, the lowest total dry weight was noticed in MAUS-2 (2.25g).

4.4.8 Total length (cm)

This trait exhibited mean of 75.67 cm. The genotype PK-34 (90.83 cm) had maximum total length followed by KB-79 (90 cm) and CGP-387(80.83 cm) while the genotype MAUS-2 (62 cm) had recorded lowest total length.

4.4.9 Root: Shoot weight ratio

The mean root to shoot weight ratio was 0.0155. The maximum ratio (0.0194) was recorded in VLS-40 fallowed by PK-1036 (0.0172). While, genotype MAUS-2 had recorded lowest (0.0109) ratio.

4.4.10 Root: Shoot length ratio

The mean root: shoot length ratio was 2.43. The highest ratio was observed in the genotype KB-79 (3.09) followed by PK-34 (2.54). Where as, lowest ratio was observed in genotype MAUS-2 (2.1).

DISCUSSION

V DISCUSSION

Most of the area under soybean comes under rainfed condition during *Kharif* season. Hence the productivity of soybean is low. In spite of the efforts made by breeders to develop high yielding genotypes, the productivity is low due to several other factors. In soybean, the primary reason is moisture stress accompanied by either low or high temperatures. These stresses are often encountered by soybean crop sown late during *kharif* due to late onset of monsoon. Further, the soybean is highly sensitive to moisture and high temperature stress. Therefore, some efforts have been made in this study to identify the genotypes tolerant to moisture and high temperature stresses with high yield potential. For achieving these objectives, the study was conducted in four different experiments.

- 1. Genetic Variability Studies**
- 2. Temperature Induced Response (TIR)**
- 3. Drought tolerance studies**
- 4. Root morphological studies**

5.1 Genetic variability Study

The knowledge about the nature and extent of genetic variability present in the genetic material is very important in successful planning of breeding programme in any crop plant. This necessitates the evaluation of existing genetic material for variability.

In this experiment 348 germplasm collections of soybean were evaluated for seed yield and yield attributing components.

These genotypes were grown in augmented design in plot no F-11, ZARS, UAS, GKVK, Bangalore during *kharif* 2006 under protective irrigation.

In the present investigation, an attempt was made to estimate the proportion of the genotypic variability and to determine the heritability in broad sense as well as predicted genetic advance with respect to nine quantitative characters and their direct and indirect effects on seed yield. The results obtained are discussed under the following headings:

1. Variability, heritability and genetic advance
2. Correlation between yield components
3. Path coefficient analysis
4. Selection indices

5.1.1 Variability, heritability and genetic advance

In the present study, analysis of variance revealed significant differences among 348 genotypes for all the characters except number of seeds per pod and number of branches per plant. These differences may be attributed to their genetic make up and the different geographical regions from which they have been originated.

The genotypes exhibited considerable amount of variability for seven quantitative characters studied. The range being 25 to 39 days for 50% flowering, 80 to 107 days for maturity, 13.6 cm to 63.8 cm for plant height, 9 to 39 for number of pods per plant, 1 to 3 for number of seeds per pod, 6 to 20 gm for 100 seeds weight, 20 to 110 for number of seeds per plant, 1 to 4.8 for number of branches per plant and 1.4 to 14.4 gm for seed yield per plant. The range values

given above indicated the scope for selection in the basic material for further improvement.

The range in the values reflects the extent of phenotypic variability in respect of these characters. Which includes genotypic, environmental and genotypic and environmental interaction components.

Therefore, the estimation of heritable (genetic) and non-heritable (environmental) variations is of great value in the choice of suitable breeding procedure. Johnson (1955) partitioned the total variance into genetic and environmental variance and their interaction factor. Now, it is an accepted fact in all biometrical studies as it helps in arriving at a precise conclusion about the true breeding value of a genotype. Thus, the components of variation such as phenotypic and genotypic coefficient of variability, heritability and predicted genetic advance as per cent of mean were computed in respect of both the yield and its component characters.

High values of PCV and GCV were observed for the characters plant height, number of pods per plant, number of seeds per pod, 100 seed weight, number of seeds per plant, number of branches per plant and seed yield per plant. High PCV and GCV for seed yield per plant and plant height was also observed by Ghatge and Kadu (1993) and Jain *et al.* (2000).

Dai (1981) observed lower genotypic coefficient of variation than coefficient of phenotypic variation for number of seeds per pod and plant height. Where as, in the present investigation lower genotypic coefficient of variation and high phenotypic coefficient of variation were noticed for number of seeds per pod and number of branches per plant and also Low GCV and PCV for days to 50 per cent flowering and days to maturity.

All these results and findings indicated presence of substantial variability in respect of these quantitative characters. Lower differences between PCV and GCV indicates the less influence of environment and reflect on reliability of selection based on phenotypic performance.

The coefficient of variation indicated only the extent of variability present in different characters and does not indicate the heritability portion. This could be ascertained from the heritability estimates, which in broad sense includes both additive and non additive gene effects (Hanson 1953) and in narrow sense includes only due to additive components (Lush, 1949 and Johnson *et al.*, 1955 in animals). Knowledge about heritability of a trait is helpful to enable the plant breeder to decide the method of selection procedure to be followed to improve the trait under a given situation. In the present study heritability in broad sense has been estimated. The results indicated that the estimates of heritability were high for days to 50 per cent flowering. Similar observations were made by Bhandarkar (1999) and Plazinic (1987). High heritability for plant height was also observed by Yao *et al.* (1987) and Jain *et al.* (2000)

The estimates of heritability were high for number of pods per plant. These results are in confirmation with the results of Jain *et al.* (2000) and Ecochard (1986). Where as, Bhandarkar (1999) observed moderate heritability for the same trait. Hundred seed weight recorded high estimate of heritability. These results on par with the results of Rajarathinam *et al.* (1996) and Bhandarkar (1999).

High heritability estimates for days to maturity, number of seeds per plant and seed yield per plant was observed. Bhandarkar (1999), Ghatge and Kadu (1993), Rasaily *et al.* (1996) also recorded high heritability for days to maturity. Surain Momirovic (1987) observed high heritability for number seeds per plant. Where as high heritability for seed yield per plant was noticed by Sharma *et al.* (1986), Ecochard (1986), Jain *et al.* (2000) and Rajathinam *et al.* (1996).

Moderate heritability was observed for number of seeds per pod and number of branches per plant. Contrary to this, Yao *et al.* (1987) and Malik and Singh (1987) observed high estimate of heritability for number of seeds per pod while, high heritability for number branches per plant was reported by Bhandarkar (1999) and Sharma *et al.* (1986). These results suggest that the above mentioned characters with high heritability can be considered for improvement.

It is understood that heritability estimates are useful while making selection based on the phenotypic characters. Nevertheless, as pointed out by Johnson *et al.* (1955a), its use would be limited as it is prone to change with fluctuation in environment and other factors. Hence, the estimates of heritability have a role to play in determining the effectiveness of selection for character provided they are considered in conjunction with the predicted genetic advances as suggested by Panse and Sukhatme (1957) and Johnson *et al.* (1955a).

In the present investigation, where diverse germplasm collections are involved, high heritability and high genetic advance were exhibited by plant height, number of pods per plant, 100-seed weight, number of seeds per plant and seed yield per plant. Naturally, selection based on phenotypic observations in these characters would be effective.

These are in accordance with the results of Sharma *et al.* (1986). Where as, Konwar and Talukdar (1984) noticed high heritability with high genetic advance for days to maturity and plant height. Ghatge and Kadu (1993) also observed high genetic advance for number of seeds per plant and plant height only. While, Bhandarkar (1999) observed high heritability and genetic advance for plant height, 100 seed weight, days to 50 % flowering, days to maturity and number of branches

per plant. Where as, Jain *et al.* (2000) found high genetic advance for seed yield, plant height and number of pods per plant.

Moderate heritability with high genetic advance was observed for branches per plant, which indicated that direct selection can be applied for improving this trait.

High heritability with low genetic advance noticed for days to 50% flowering and days to maturity suggested that these two characters are controlled by non additive gene components and may not be effective for phenotypic selection for their improvement.

5.1.2 Correlation between different yield contributing characters.

Seed yield is a complex quantitative character governed by a large number of genes and is greatly affected by environmental fluctuations. Selection of superior genotypes based on yield as such is not effective. For rational approach towards the improvement of yield, selection has to be made for the components of yield. Association of yield components and yield that assumes special importance as the basis for selecting characters of plant often arise because of either linkage or pleiotrophy (Harland, 1939).

Positive significant correlation of seed yield per plant with number of pods per plant, number of seeds per pod, 100 seed weight, days to 50 % flowering, number of seeds per plant and number of branches per plant was observed. While low positive correlation with plant height was recorded. The results were on accordance with the reports of Amarnatha (1986), Rajput *et al.* (1986), Namrata *et al.* (2002) and Archana *et al.* (2001) reported significant positive correlation between seed yield and days to 50 per cent flowering, where as Barbind *et al.*

(1981) noticed positive significant association of days to maturity with seed yield per plant.

In the present study, days to 50 per cent flowering had high positive correlation with plant height, number of pods per plant and number of seeds per plant. While, days to maturity, number of seeds per pod and number of branches per plant were non significantly correlated. Lin and Nelson (1988) noticed positive correlation between days to 50 % flowering and plant height.

Days to maturity showed positive significant correlation with plant height. Where as, with number of seeds per pod, number of seeds per plant and seed yield per plant its association was negative but not significant. Lin and Nelson (1988) was also observed positive association between days to maturity and plant height. While,

Significant positive association of plant height with number of pods per plant, number of seeds per plant and number of branches per plant was noticed. Where as, it was negatively significantly associated with 100 seed weight. This was on par with the results obtained by Amarnatha (1986). However Gyusova and Ilcheva (1987) found positive association only between plant height and number of seeds per plant.

Number of pods per plant recorded significant positive correlation with number of seeds per plant and number of branches per plant. The results were in line with the earlier reports of Zhou (1983), Amarnatha (1986). Negative correlation was observed between 100 seed weight and number of pods per plant. This was in agreement with the results of Amarnatha (1986).

Seeds per pod were positively and significantly associated with number of seeds per plant, number of branches per plant and seed yield per plant. These results are in conformity with those of Alam *et al.* (1983). However, it was negatively significantly associated with 100 seed weight. This was on par with the results of Amarnatha (1986).

Hundred seed weight had shown significant negative association with plant height, number of pods per plant, number of seeds per pod and number of seeds per plant. It had negative but non-significant association with days to 50 per cent flowering. These results are on par with the findings of Amarnatha (1986) and Bhairav *et al.* (2006).

Number of seeds per plant positively associated with days to 50 per cent flowering, plant height, number of pods per plant and number of seeds per pod. Where as, it had a negative and significant association with 100 seed weight. These observations are in conformity with the earlier studies of Alam *et al.* (1983) and Zhou (1983).

Number of branches per plant was recorded positive and significant association with, number of pods per plant, number of seeds per plant and plant height. These results are on par with the observations of Amarnatha (1986).

Based on the results of the present study, it can be concluded that more emphasis could be given while making selections for number of seeds per plant, number of pods per plant, number of seeds per pod, number of branches per plant and 100 seed weight in the order as they showed very high to fair degree of positive association with seed yield.

5.1.3 Path coefficient analysis

Phenotypic path coefficient analysis (Table.4) revealed highest direct effect of number of seeds per plant and 100 seed weight on seed yield. While, number of pods per plant showed highest indirect effect through number of seeds per plant indicating that selection for this trait will be highly effective. Even though 100 seed weight has high direct effect, it was recorded negative indirect effect on seed yield through number of seeds per plant. Since its direct positive effect was more than indirect negative effect, it showed high positive correlation with seed yield. Similar results were also reported by Rajput *et al.* (1986) and Liu *et al.* (1985).

Plant height recorded high negative indirect effect through 100 seed weight indicating that increase in plant height reduces the seed yield. Hence, selection for this character will not be effective.

An overview of the results of path coefficient analysis indicated that selection for number of seeds per plant and 100 seed weight will be effective to achieve the selection of high yielding lines, because these characters had recorded high direct effect on seed yield per plant. Similarly indirect selection for number of pods per plant will be effective to achieve high seed yield per plant because it had high indirect positive effect on yield through number of seed per plant. The residual effects were 0.0533 at phenotypic level indicating that the characters study were to influence the seed yield in soybean.

5.1.4 Selection indices

It is evident that yield is a complex character which depends on number of independent traits. Therefore, selection of plants on yield alone would not be effective. Hence, selection of superior genotypes based on discriminant function

analysis renders selection easy and would provide a total score for each genotype from consideration of two or more characters contributing to seed yield simultaneously. Evidence to the above statement Liang *et al.* (1997) noticed among selection methods for yield, index selection was more beneficial than correlation or direct selection and Phan Thi Dao (1997) also reported that, all indices were better efficient than direct selection for yield. In the present study, selection indices were formulated with six characters exhibiting positive and significant correlations with yield, high heritability and high genetic advance. Totally fifty different selection indices were constructed based on six components contributing to seed yield.

Considering selection indices based on individual characters, number of seeds per plant showed higher relative efficiency. Higher relative efficiency of this character may be attributed to higher correlation, high genetic advance and high heritability. Among two character combinations, highest relative efficiency was noticed for combinations number of seeds per plant and number of branches per plant (974.9%) over straight selection. Highest relative efficiency was obtained for combinations of days to 50 per cent flowering + seeds per plant + branches per plant (1319.73%) followed by seeds per pod + seeds per plant + branches per plant (1058.52%) for three character combinations. while days to 50 per cent flowering + hundred seed weight + seeds per plant + branches per plant combination with relative efficiency of 1624.46% was better combination among all the selection indices. Dao *et al.* (1992) found highest relative efficiency when all 10 characters were involved

The main objective of construction of selection indices was to obtain information about the character or combination of characters, which would serve as the best indicator of yield in a selection programme. Relative efficiency

increased with the number of traits incorporated into the indices. In the present study also, it was observed that the efficiency obtained from the selection of the individual characters was lower compared to selection index comprising of combination of more characters.

Based on the above best combination of characters, 50 high yielding genotypes were selected and used to screen for thermo-tolerance.

5.2 Temperature induction response study

Plant survival and productivity is severely affected by environmental stresses. Since, higher plants are immobile, they may have a greater need for protection from transient stresses. Plants try to overcome the adverse effects of these stresses mainly by adopting avoidance and tolerance mechanisms. Plants and plant processes can be damaged in different ways by either high soil or high air temperatures (Kolderup, 1979; Ketring, 1984). Existence of genetic variability for any trait is very useful in identification and selection of genotypes for the trait in question. The trait could be either tolerant to temperature stress, moisture stress, salinity or pathogens. Significant variability among species and genotypes within a species is known to occur for various kinds of stresses. Avoidance mechanism for high temperature is transpirational cooling. If water is a limiting factor, the adverse effect of high temperature is still aggravated (Levitt, 1980; Frova, 1997). Under such situations, there is every need to improve the intrinsic tolerance to high temperature in any crop. This can be achieved by exploiting the genetic variability existing across species and amongst the genotypes within a species.

In nature, temperature stress often occurs gradually and during the initial stages of mild non-lethal stress, the stress responsive genes are expressed leading to synthesis of heat stress responsive proteins called heat shock proteins (HSPs)

and these stress responsive proteins provide adequate tolerance when the organism is subsequently exposed to lethal stress. This is evident during induction stress (Vierling, *et al.*, 1988).

The induction temperature is generally sub lethal temperature, which imparts tolerance to extreme temperatures. This is referred as acquired thermo-tolerance (Vierling, *et al.*, 1988; Keeler *et al.* 2000).

There are evidences to prove that genetic variability for stress tolerance is seen only on exposure to sub-lethal induction stress. For instance, genetic variability in wheat for high temperature tolerance at a lethal temperature of 50⁰C can be seen only when subjected to prior induction treatment of 30⁰C. Several similar studies have shown that genetic variability for stress tolerance is seen only upon induction stress (Uma *et al.* 1995; Jayaprakash *et al.* 1998 and Kumar *et al.* 1999).

A technique known as temperature induction response (TIR) was developed by Department of Crop Physiology UAS, GKVK, Bangalore to screen for genetic variability for temperature tolerance. This technique can be used to screen a large number of population at seedling level. Several recent studies provide convincing evidences that this technique has specific advantage for identifying the existing genetic variability for intrinsic tolerance and to identify the tolerant lines or genotypes (Srikant Babu, 1999; Sentil kumar, 2001).

Soybean is an important pulse cum oilseed crop, predominantly grown under rainfed conditions during *Kharif* season. It may experience moisture and temperature stress, particularly when sowing is delayed. Hence, with the idea of examining the genetic variability and to identify thermo-tolerance genotypes, the present study was conducted and the results obtained are briefly discussed.

5.2.1 Standardization of lethal and induction temperature for TIR technique:

The underlying principle of TIR technique is that, initially the seedlings that are exposed to optimum induction or sub lethal temperature following exposure to lethal temperature would withstand the lethal stress because of specific proteins synthesized during induction. This technique can be used to screen and identify thermo-tolerant lines / genotypes from among the large number of genotypes. This technique depends on the availability of variability within the species. With this background, an attempt was made to identify thermo-tolerant genotypes in soybean.

For utilization of this technique, lethal and induction temperature protocol have to be developed and standardized. It is evident that the lethal and induction temperatures vary depending on the species. Pea has a lower temperature threshold of 48⁰c (Srikanth Babu, 1999) while groundnut has high threshold temperatures of 55⁰c (Sreekanth Attaluri, 1998). Hence, there was a need to standardise these protocols for soybean also.

For achieving this, soybean seedlings were exposed to different induction and lethal temperatures to arrive at optimum induction and lethal temperatures. Based on 95-100 per cent seedling mortality, 48⁰C for 3 hr was selected as lethal temperature. Optimum induction temperature was found to be 30⁰C (1h) – 35⁰C (1h) – 40⁰C (1h) – 45⁰C (2h) at which there was 10-15 per cent mortality and good recovery growth.

5.2.2 Selection of thermo-tolerance genotypes

The TIR technique has specific advantage of exploiting the existing genetic variability for intrinsic tolerance and is has been used to identify the thermo-

tolerance lines. This is also evident from the recent studies conducted by Srikanth Babu (1999), and Senthil kumar (2001).

Fifty soybean genotypes were selected based on selection indices scores and screened by exposing the seedlings to standardized sub-lethal induction stress before exposing to severe stress. Significant variability for thermo-tolerance was noticed in soybean indicating the possibility of selecting suitable genotypes. There were certain distinct genotypes showing higher per cent of survival and lower per cent reduction in recovery growth with top total ranks like MACS-212, PK-34, KB-249, CGP-387, GPC-357, KB-79, VLS-40 and PK-1036. These were selected as thermo-tolerance genotypes and the same were used to screen for drought tolerance.

5.3 Drought tolerance studies

The genotypes selected in the above experiment were induced and the induced seedlings were used to screen for drought tolerance. The analysis of variance revealed presence of significant difference among the genotypes for all characters studied in this experiment.

In general, the shoot length decreased with increase in intensity of the stress. This was evident from the studies conducted by Hoogenboom *et al.* (1986). At the moderate stress level (50%F.C.), the genotype PK-34 followed by KB-79 and MAUS -212 had less reduction in shoot length compare to other genotypes. Where as, under 25% F.C. stress level the genotypes GPC- 357 followed by KB-79 and PK- 34 showed less reduction compare to other genotypes. This may be due to higher level of tolerance to increased stress levels.

During drought, soil begins to dry at the surface and drying extends to the lower soil horizon. Under such, condition the growth and yield of soybean

depends on deep and proliferated roots that can effectively make use of water stored in the sub soil.

In the present investigation, the root length increased with increase in stress level. These results were in accordance with the results of Hoogenboom *et al.*(1986). Under 50 % field capacity (F.C.) stress, the genotypes KB-79 followed by PK-34 and PK-1036 had recorded highest per cent increase in the root length in comparison with non stress condition. Under 25% F.C. stress also, the genotype KB-79 and PK-34 showed highest per cent increase in root length followed by the genotypes KB-249 and MACS-212. Kim *et al.* (2000) also observed higher root penetration in drought tolerant genotype was higher than the drought sensitive genotype.

Generally the drought tolerant genotype maintain higher root mass under moisture stress condition. In the present study, the genotypes KB- 249 and NRC-17 recorded less per cent reduction of root mass compared to control under 50% F.C. stress. Where as, under 25% F.C. stress, genotype KB-79 and PK-1036 and MAUS-2 had less per cent reduction in root mass. Hence KB-79 maintained higher root mass under both the stress conditions, this was tolerant to drought compared to other genotypes.

Normally shoot length decreases under water stress. Similar results were also observed by Hoogenboom *et al.* (1986). In the present investigation, the genotypes PK-34, KB-79 followed by MACS -212 recorded less percent reduction in shoot length under 50% F.C. stress compared to control and in case of 25% F.C. stress, condition GPC-357, KB-79, PK-34 followed by KB-249 had shown less per cent reduction in shoot length compared to control. The shoot length reduction was higher in case of 50% F.C. compared to 25% F.C. stress. However the

genotype KB -79 had shown less percent reduction under both the stress conditions indicating its capacity to withstand and grow better under water stress.

The plants having highest shoot dry weight will add to higher total dry weight under moisture stress condition. Higher total dry weight under stress show correlation with drought tolerance. This was earlier observed in the study of Sarkar (1994) and also by Sharma *et al.* (1986).

In the present study, the mean values under both the stress levels for this character differed significantly among the genotypes indicating genotypic variability under 50% F.C. stress. The genotype KB-79 followed by PK-34 had recorded less per cent reduction in shoot dry weight compared to control. The same genotypes had shown less per cent reduction under 25% F.C. stress also this indicated water stress tolerance of genotypes PK-34 and KB-79.

The drought tolerant genotype maintains larger leaf area under stress condition which was evident from the studies of Sarker (1994) and Tetsuji *et al.* (2003).

The genotypes PK-34 and KB-79 followed by KB-249 recorded less per cent reduction in leaf area under both the stress conditions compared with less stress condition, indicating that these genotypes are comparatively more tolerant to drought condition.

Generally, plants having high dry weight have in built genetic potential to perform better under different stress conditions (Sharma *et al.*, 1986). Hence, it is an important character to be considered in evaluation of soybean genotypes for moisture stress situation. In the present investigation under 50 % F.C. stress, the genotypes PK-34, KB-79 followed by KB-249 had recorded less per cent

reduction in total dry weight compared to control. Where as, in 25% F.C. stress KB -79, PK-34 followed by MACS -212 showed less per cent reduction in total dry weight compared to control. This indicates genotypes have the capacity to maintain higher dry weight under stress which in turn indicates the drought tolerance of the genotype. Sarkar (1994) noticed the positive correlation of increase in total dry weight with drought tolerance.

The rate of water loss increases with the increase in stress level due to damage to the cells. In the present study, the genotype PK- 34, KB- 79 followed by CGP -249 had recorded less per cent increase in rate of water loss compared to control under 50 % F.C. stress. Under 25 %F.C. stress, genotypes KB-79 and PK-34 followed by MACS-212 had shown less per cent increase in rate of water loss compared to control. This indicates the ability of temperature induced genotypes PK-34 and KB-79 to with stand and maintain cellular stability under water stress condition.

Membrane leakage will increase under water stress condition generally. In this study also, increase in per cent membrane leakage was noticed. While, the genotypes PK-34 and KB-79 had recorded less percent increase in membrane leakage over control compared to other genotypes under both 50% F.C. and 25 % F.C. water stress conditions.

Based on all traits recorded in this experiment the genotypes PK-34 and KB-79 were selected as drought tolerant lines among all the genotypes.

5.4 Root morphological studies

Drought is the major abiotic stress causing significant yield loss in soybean especially under rainfed conditions. Under water stress condition, deep root

system is considered as an important trait for drought resistance. Hence, in the present investigation, root morphology of the genotypes was studied to support the drought tolerance of genotypes.

In the present investigation, the genotypes PK-34 and KB-79 recorded maximum root length, root volume, root dry weight, shoot dry weight and total dry weight and also recorded high root to shoot length ratio.

In the previous experiment also, the above mentioned genotypes have shown good drought tolerant characters compared to other genotypes. By this root morphological study, it is confirmed that PK-34 and KB-79 were resistant to water stress conditions. Since, good root system provides drought tolerance to the plant. This was evident from the study conducted by Pantalone *et al.* (1996) and Gerrit Hoogenboom *et al.* (1987) with similar results, Kim *et al.* (2001) also noticed drought tolerant cultivars showing higher vigor and root penetration than those of the drought sensitive cultivars.

Practical utility of the present study

- The drought tolerant genotypes KB-79 and PK-34 can be used as donor parents in drought breeding programme.
- The selection criteria can be used to screen for drought tolerant lines in the related crops.

Future line of work

- The genotypes KB-79 and PK-34 need to evaluate under field stress condition for their performance.
- The identified genotypes can be utilized to develop molecular markers for further use to hasten the breeding programme.

SUMMARY

VI SUMMARY

An investigation was carried out using 344 genotypes and four checks during *Kharif*-2006 and *Summer*-2007 seasons at AICRP on soybean UAS, GKVK Bangalore. These genotypes were screened for genetic variability for seed yield and its attributing characters, thermo-tolerance through Temperature Induced Response (TIR) technique, drought tolerance using gravimetric method and for root morphology.

Genetic variability was assessed using genotypic and phenotypic variance, genotypic and phenotypic coefficient of variation, heritability and genetic advance. The inter character correlation and path analysis were carried out to reveal the relationship of different characters with seed yield and discriminant function analysis was done to arrive at good combination of characters to select for high yielding genotypes. The selected genotypes were screened for thermo-tolerance and then, thermo-tolerant genotypes were screened for drought tolerance and their root morphology was also studied.

The salient features of the experimental findings are as follows:

- The analysis of variation for all the characters studied indicated presence of significant difference among the genotypes or lines except for number of seeds per pod and number of branches per plant. High values of PCV and GCV were recorded for plant height, number of branches per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, 100 seed weight and seed yield per plant. The estimate of heritability was high for plant height with high genetic advance.

- Positive significant correlation of seed yield per plant with number of pods per plant, number of seeds per pod, 100 seed weight, days to 50 per cent flowering, number of seeds per plant and number of branches per plant was observed. While low positive correlation with plant height was recorded.
- Path coefficient analysis indicated that selection for number of seeds per plant and 100 seed weight will be effective to achieve the selection of high yielding lines because these characters have recorded high direct effect on seed yield per plant.
- Under discriminant function analysis highest relative efficiency was observed when selection was based on seeds per plant and number of branches per plant followed by combination of days to 50 per cent flowering and number of seeds per plant under two character combinations. Where as, among three characters combinations the highest relative efficiency was observed for the combination of $X_1 + X_7 + X_8$ (1319.73%) followed by $X_5 + X_7 + X_8$ (1058.52%), based on these combinations, 50 high yielding genotypes were selected.
- The selected high yielding genotypes were screened for thermo-tolerance. Eight thermotolerant genotypes were selected based on high total rank scores. They were screened for drought tolerance and their root morphology. Finally the genotypes PK-34 and KB-79 were selected as thermo-tolerant as well as drought-tolerant lines among all the genotypes, because their performance was good both under Temperature Induced Response technique and drought tolerance study and also they have shown good root morphological characters.

REFERENCES

VII REFERENCES

- Agarwal, A. P., Patil, S. A. and Salimath, P. M., 2001, Variability, heritability and genetic advance of some quantitative characters over the seasons in soybean, *Madras Agric. J.*, **88**:36-39.
- Akhanda, A. M., Prince, G. M., Green, V. S. and Hinson, K., 1981, Phenology and correlation of growth phases in late planted soybean in Florida USA, *Indian J. Agric. Sci.*, **51**(4): 214-20.
- *Alam, S., Muresan, T. and Denceser, S., 1983, Correlations between yield and agronomic characters in soybean (*Glycine Max* (L.) Merrill) and the heritability of these characters. *Agron. J.*, **26**: 37-48.
- Allard, R.W., 1960, Principles of plant breeding. John Wiley and sons Inc.320-322.
- Amarnatha, K.C.N., 1986, Genetic variability, correlations and path analysis of some quantitative characters in soybean (*Glycine Max* (L.) Merrill). M.Sc. (Agri) Thesis submitted to University of Agricultural Sciences, Bangalore, Karnataka, India. 57-62.
- Anonymous 2006, QRT report of AICRP on soybean UAS, GKVK Bangalore, pp.10-12.
- Anonymous 2008, Annual report of NRC on soybean Indore, Madhya Pradesh, pp. IX.
- Archana, T., Narkhede, M. N. and Khorgade, P. W., 2001, Correlation studies in soybean (*Glycine max* (L.) Merrill). *Ann. Plant Physiol.*, **13**: 195-198.

- Archana, T., Shanti Patil, Vandana Khambalkar, Khedikar, Y. P. and Meena Wankhede, 2005, Selection indices for seed yield and yield contributing characters in soybean (*Glycine max* (L.) Merrill). *Adv. Plant Sci.*, **18**: 373-377.
- Auyeung, M.T., 1988, Evaluation of seed filling period as an indirect selection trait for higher yield and its relationship with nitrogen parameters in soybean., *Dissert. Abst. International. B (Science and Engineering)*, **48**: 1850 .
- Backes, R. L., Reis, M. S., Cruz, C. D., Sedyama, T. and Sedyama, C. S., 2003, Correlation estimates and assessment of selection strategies in five soybean populations. *Crop Breed. Appl. Biotech.*, **3**(2): 107-115.
- Barbind, R.P., Reddy, V. G. and Ashmatoddin, M., 1981, Correlation and regression studies in soybean. *J. Maharashtra Agric. Univ.*, **6**: 128-130.
- Basal, H., Bebeli, P., Smith, C. W. and Thaxton, P. M., 2003, Root growth parameters of converted race stocks of upland cotton and two BC₂F₂ populations. *Crop Sci.*, **43**: 1983-1988.
- Bhairav, B., Sharma, S. P. and Vimal Sharma., 2006, Correlation and path coefficient analysis of soybean [*Glycine max* (L.) Merrill]. *Crop Improvement.*, **33**: 190-193.
- Bhandarkar, S., 1999, Studies on genetic variability and correlation analysis in soybean (*Glycine max* (L.) Merrill). *Mysore J. Agri. Sci.*, **33**: 130-132.
- Bhardwaj, H.L. and Bhagsari, A.S., 1989, Harvest index yield and physiological characteristics of soybean as related to seed size. *Soybean Genet. News l.*, **16**: 133-136.

- Bhardwaj, H.L. and Bhagsari, A. S., 1990, Harvest index and related characteristics of small and large seeded soybean genotypes. *Soybean Genet. News l.*, **17**: 109-113.
- Brim, C.A., Johnson, H.W. and Cockerham, C.C., 1959, Multiple selection criteria in soybean. *Agron. J.*, **51**:42-46.
- Bunce, Donald, T., Krizek, Avner Carmi, Roman, M., Mirecki, Freeman,W., Snyder and James, A., 1984,Comparative effects of soil moisture stress and restricted root zone volume on morphogenetic and physiological responses of soybean [*Glycine max* (L.) Merr.]. *J. Exp. Bot.*, **36** :25-38.
- Burton, G. W. and De Vane, E. H., 1953, Estimating heritability in tall fescue (*Festuca arunidinaceae*) form replicated clonal material. *Agron. J.*, **45**: 478-481.
- *Chan, K. L., Lee, R.S. and Thseng, F.S., 1986, Genetic variation of soybean hybrid populations by natural selection in spring crop season at four locations and frequency distributions for certain agronomic characters in F₂ generations. *J. Agric. Res. China.*, **35**: 263-279.
- Chen, Y., 1988, Analysis of inheritance and correlation of leaf shape of hybrid progenies from cultivars of different leaf shape in soybean. *Soybean Sci.*, **7**: 13-18.
- Choulwar, S. B. and Borikar, S. T., 1987, Path analysis in M₇ generation of cowpea. *J. Maharastra Agric. Univ.*, **12**; 431.
- Craufurd, P. Q. and. Wheeler, T. R., 1999. Effect of drought and plant density on radiation interception, radiation-use efficiency and partitioning of dry matter to seeds in cowpea. *Exp. Agric.*, **35**: 309-325.

- *Dai. O.H., 1981, Preliminary studies on the variation and inheritance of the main quantitative characters in local varieties of summer sown soybean in Southern Anhui. *Zhonggho Youliao.*, **2**: 18-23.
- Dao, P. T. and Ram, H. H., 1992, Index selection for yield improvement in soybean in the tropics. *Soybean Sci.*, **11**: 198-203.
- Dewey, D.R. and Lu, K.H., 1959, A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, **51**: 515-518.
- *Diazcarrasco, H. and Leon Gonzalez, J. P., 1985, Phenotypic correlations in soybean and their importance in selection for yield. *Ciencias de la Agricultura.*, **24**: 99-103.
- Dhillon, S. K., Gurdeep Singh and Gill, B. S., 2005, Genotypic and phenotypic variability and heritability of some yield and quality characters in soybean [*Glycine max* (L.) Merrill]. *Legume Res.*, **28**: 276-279.
- Dhumale, D. B., Deshmukh, D. T. and Chikhale, N. G., 1992, Selection indices in soybean. *J. Maharashtra Agric. Univ.*, **17**: 142-143.
- Dixit, S. S., Pawar, K. S., Rawat, Y. S. and Jagdish Singh 2002, Genetic variability in soybean [*Glycine max* (L.) Merril]. *Res. Crops.*, **3**: 195-196.
- *Ecochard, R., 1986, Inheritance of measurable selection criteria in soybean. *Paris France CFTTOM.*, 129-135.
- Egli, D.B. and Yu, Z. W., 1991, Crop growth rate and seeds per unit area in soybean. *Crop Sci.*, **31**: 439-442.
- Eizanloo, A., Zeinali, H., Hoseinzadeh, A.H., Hoseini, N.M. and Sabokdast, M., 2005, Performance of commercial soybean varieties under water stress condition at the late reproductive stage. *Indian J. Agric. Res.*, **36**: 1011-1023.

- *Federer, W.T. Augmented (or hoonuiaku) designs, 1956, Hawaiian Planter's Records., **55**:191-208.
- *Fisher, R.A., 1936, The use of multiple measurements in taxonomic problems. *Ann. Eugen.*, **7**: 179-189.
- *Frova, C. 1997, Genetic dissection of thermotolerance in Maize. In Grillo, S., Leone, A., Eds. Physical stress in plants. *Newyork, Springer-Verlag*. 31-82.pp
- *Fundora Mayor, Z. and Soto, J. A., 1985, Effect of different factors on seed protein content in soybean [*Glycine Max* (L.) Merrill]. *Ciencias de la Agric.*, **25**: 51-57.
- Gai, J., Palmer, R.G. and Fehr, W.R., 1984, Bloom and pod set in determinate and indeterminate soybeans grown in China. *Agron. J.*, **76**: 979-984.
- Gai Junyi, Liu Ying and LuHuiNeng, 2005, Identification of rhizosphere abiotic stress tolerance and related root traits in soybean. *Acta Agronomica Sinica.*, **31**:1132-1137.
- Ganesh Kumar, 1999. Identification of Thermotolerant lines in Sunflower (*Helianthus annuus* L.) based on Temperature Induction Response (TIR): Role of HSPs and LEAs in temperature and osmotic stress. Ph.D thesis submitted to University of Agricultural Sciences, Bangalore – 65.
- Gerrit Hoogenboom, M. G. H. and Curt M. Peterson, 1987, Root growth rate of soybean as affected by drought stress. *Agron. J.*, **79**: 607-617.
- Ghatge, R. D. and Kadu, R. N. 1993, Genetic variability and heritability studies in soybean. *Adv. Plant Sci.*, **6**: 224-228.

- *Guffy, R.D., 1988, Genetic and physiological studies of the rate and duration of seed fill in soybean. *Dissert. Abst. International*, (Science and engineering), **48**: 1850 – 1851
- *Gyusova, M. and Ilcheva, E., 1987, Height in soybean plants as an index of agronomic and metro-logical conditions for seed yield development. *Vasil Kalarav.*, **27**: 11-125.
- Hall, A. E., 1992, Breeding for heat tolerance. *Plant Breed. Rev.*, **10**: 129-167.
- Hanson, W.D., 1953, Association of seed yield with partitioned lengths of the reproductive period in soybean genotypes. *Crop Sci.*, **25**: 525-529.
- *Harland, D.C., 1939, The Genetics of cotton. Jonathan Capse, London, pp. 15-28.
- *Hirasawa, T., Tanaka, K., Miyamoto, D., Takei, M. and Ishihara, K. 1994, Effects of pre-flowering soil moisture deficits on dry matter production and ecophysiological characteristics in soybean plants under drought conditions during grain filling. *Japanese J. Crop Sci.*, **63**: 721-730.
- Hoogenboom, G., Huck, M.G. and Peterson, C.M., 1986, Measured and simulated drought stress effects on daily shoot and root growth rates of soybean. *Netherlands J. Agric. Sci.*, **34**:497-500.
- *Hwang, Y.H. and Kim, D.V., 1986, Efficiency of selection environment in early generation selection of hybrid populations of soybean for full and late season cropping. *Adms. Crops, Korea Republic.*, **28**:154-171.
- Itoh, R. and Kumura, A., 1986, Acclimation of soybean plants to water deficit II. Recovery of photosynthesis and leaf water status. *Japan J. Crop Sci.*, **30**:300-305.

- Jain, P. K. and Ramgiry, S. R., 2000, Genetic variability of metric traits in Indian germplasm of soybean (*Glycine max* (L.) Merrill). *Adv. Plant Sci.*, **13**: 127-131
- Jain, P. K., Ramgiry, S. R. and Singh, C. B., 2000, Genetic association and path analysis for pod and seed attributes in soybean. *Adv.Plant Sci.*, **13**: 377-381.
- *Janicka, M. and Szyrmer, J., 1987, Problems of flowering and pod set in soybean plants. *Biuletyn Instytutu Hodowli I Aklimatyzacji Rozlin*, **164**: 51-59.
- Jannink, J. L., Orf, J. H., Jordan, N. R. and Shaw, R. G., 2000, Index selection for weed suppressive ability in soybean. *Crop Sci.*, **40**: 1087-1094.
- Jayaprakash, T. L., Ramamohan, G., Krishna Prasad, B. T., Gnanesh Kumar, Prasad, T. G. and Udayakumar, M., 1998. Genotypic variation in differential expression of LEA2 and LEA3 genes and proteins in Finger millet and Rice seedling systems. *Ann. Bot.*, **82**: 513-522.
- Johnson, H.W., Robinson, H.F. and Comstock, R.E., 1955, Estimates of genetic and environmental variability in soybean. *Agron. J.*, **47**: 314-318.
- Johnson, H.W., Robinson, H.F. and Comstock, R.E., 1955a, Genotypic and phenotypic correlations in soybean and their implications in selection. *Agron. J.*, **47**: 478-482.
- Kamendra Singh and Ram, H.H., 1983, Dry matter yield and branching ability as selection parameters in soybean. *Soybean Genet. News l.*, **10**: 13-15.
- Keeler, S.J., Boettger, C.M., Haynes, J.G., Kuches, K.A., Johnson, M.M., Thureen, D.L., Keeler, Jr. C.L. and Kitto, S.L. 2000. Acquired thermotolerance and expression of the HSP100/C1pB genes of Lima bean. *Plant Physiol.*, **123**: 1121-1132.

- Ketrings, D.L. 1984. Temperature effects on vegetative and reproductive development of peanuts. *Crop Sci.*, **24**: 877-882.
- *Kim, Y., Shanmugasundaram, S., Yun, S., Park, H. and Park-MoonSoo, 2001 A simple method of seedling screening for drought tolerance in soybean. *Korean J. Crop Sci.*, **46**: 284-288.
- *Kim-WookHan and Hong-ByungHee, 2000, Effects of water deficit on leaf growth during vegetative growth period in soybean. *Korean J. Crop Sci.*, **45**: 1-5.
- *Kolderup, F. 1979. Application of different temperatures in three growth phases of Wheat. I. Effects on grain and straw yield. *Acta Agron.*, **29**: 6-10.
- Konwar, B.K. and Taludkar, P., 1984, Environmental influence on the genetic parameters in soybean. *J. Res. Assam Agric. Univ.*, **5**: 135-142.
- Kpoghomou, B. K., Sapra, V. T. and Beyl, C., 1990, Screening for drought tolerance soybean germination and its relationship to Seedling responses. *Crop Sci.*, **164**: 104-109.
- Kueneman, T.A. and Wallace, D.H., 1979, Simplified growth analysis of non climbing dry bean at three spacing in the tropics. *Exp. Agric.*, **15**: 273-284.
- Kumar, G., Krishna Prasad, B. T., Savitha, M., Gopalakrishna, R., Mukopadhyay, K., Ram Mohan, G. and Udaya Kumar, M. 1999. Enhanced expression of heat shock proteins in thermo tolerant lines from the progenies selected on the basis of temperature induction response (TIR). *Theor. Appl. Genet.*, **99**: 359-367.
- Kumar, Y. K. D., Vishwanath, A. P., Ananda, M. R., Rehaman, H. M. A. and Vittal-Navi., 2006, Correlation and regression studies in soybean (*Glycine max* L. Merrill). *Environment and Ecology*. **24**: 1040-1042.

- *Landsberg, J. J. 1977. Effects of weather on plant development. In: Landsberg, J. J. and Cutting C. V. (Eds.). *Environmental Effects on Crop Physiol.*, Academic Press, London, pp 289-307.
- Landsberger, P.S., Smith, C.W., Thaxton, P. M. and Mcmichael, B. L., 2006, Development of a screening method for drought tolerance in cotton seedlings. *Crop Sci.*, **46**: 2108-2110.
- *Levitt, J. 1980. Responses of plants to environmental stress. Vol. 1. Chilling, freezing and high temperature stress. Academic Press, New York, USA.
- Liang-ZhenLing and Liang-Ying, 1997, Correlation between yield and main agronomic characters and relation to selection of soyabeans (G. max) under intercropping. *Soybean Sci.*, **16**: 54-59.
- Lin, C.Y., Roberts, J.K. and Key, J.L., 1984. Acquisition of thermo tolerance in Soybean seedlings. Synthesis and accumulation of heat shock proteins and their cellular localization. *Plant physiol.*, 74:152-160.
- Lin, M.S. and Nelson, R.L., 1988, Relationship between plant height and flowering date in determinate soybean. *Crop Sci.*, **28**: 27-30.
- *Liu, D.T., Zhou, Y.F. and Chan, H.F., 1985, Genotypic correlations and path analysis of quantitative characters of local spring soybeans varieties in China. *J. Fujian Agric. univ.*, **14**: 37-42.
- Long, S. P. 1991. Modification of the response of photosynthetic productivity to rising temperature by atmospheric CO₂ concentrations: Has its importance been underestimated. *Plant, Cell and Environment*, **14**: 729-739.
- Lu, Z.H., Sun, K. Y., Chang, C.Y., Li, Q. Z., Yang, M.P. and Dai, S.J., 1991, Morphological and physiological parameters and farming techniques for summer sown soybeans. *Soybean Sci.*, **10**: 115-120.

- *Lush, J.L., 1949, Heritability of quantitative characters in farm animals. Proc. 8th Congr. *Hereditas*, **35**: 356-375.
- Ma, Y.G., 1983, Correlation between yield and its components and path coefficient analysis in F₂ soybean. *Hereditas.*, **5**: 16-19.
- Malik, S.S. and Singh, B.B., 1987, Genetic variability and heritability in interspecific crosses of soybean. *Indian J. Agric. Sci.*, **57**: 122-124.
- Mannur, D. M., Salimath, P. M., Patil, S. S. and Parameshwarappa, R., 1991, Genetic studies in interspecific crosses of soybean Glycine max (L.) Merrill X Glycine formosana. III. Selection indices. *Indian J. Genet.*, **51**: 471-475.
- *Martin, S. K., 1989, Genetic gain by stages in regional soybeans. *Ana. Esco. Superi de Agric.*, **43**: 389-393.
- *Miku and Damaskin, D.P., 1982, Methods of determining coefficient of heritability in soybean. *Referativnyi Zhurnal*, 36-45.
- Muchow, R. C., Sinclair, T. R., Bennett, J. M. and Hammond, L. C., 1986, Response of leaf growth, leaf nitrogen, and stomatal conductance to water deficits during vegetative growth of field - growth soybean. *Crop Sci.*, **29**:1190-1195.
- *Nakamura, S., Nakazawa, Y. and Ohba, T., 1987, Variability and its factors in ratio of seed weight to pod-shell weight in soybean. *Japanese J. Crop Sci.*, **56**: 372-378.
- Namrata Jain, Vinamrata Jain and Kurchania, S. P., 2002, Correlation and regression study on weed parameters and yield attributes with seed yield of soybean. *JNKVV Res. J.*, **36**: 92-94.
- Nelson, R.L., 1987, The relationship between seed-filling period accessions. *Fld. Crop Res.*, **15**: 245-250.

- Nelson, R.L., 1986, Defining the seed filling period in soybeans to predict yield. *Crop Sci.*, **26**: 132-135.
- Panse, V.G. and Sukhathme, S.S., 1957, Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.*, **17**: 318-328.
- Panse, V.G. and Sukhathme, P.V., 1985, statistical methods for agricultural workers, ICAR publication New Delhi, pp.112-118.
- Pantalone, V. R., Rebetzke, G. J., Burton, J. W. and Carter, Jr., 1996, Phenotypic evaluation of root traits in soybean and applicability to plant breeding. *Crop Sci.*, **36**: 456-459.
- Phan-Thi-Dao, 1997, Criteria for choice characters for construction of selection index in soybean. *Soybean Sci.*, **16**: 264-268.
- *Plazinic, V., 1987, Contribution to the study of the effect of genotypic and phenotypic variation on the agronomic value of the seeds in soybean [*Glycine hispida* Max.]. *Arhiv Za Poljoprivredne Nauke*, **48**: 1-90.
- Prasad, P. V. V., Craufurd, P. Q. and Summerfield, R. J., 1999. Fruit number in relation to pollen production and viability in groundnut exposed to short episodes of heat stress. *Ann. Bot.*, **84**: 381-386.
- Pushpendra and Ram, H.M., 1987, Genetic components of variation for certain yield contributing traits in soybean. *Indian. J. Agric. Sci.*, **57**: 221-224.
- Rajanna, M. P. Viswanatha, S. R, Kulkarni, R. S. and Ramesh, S., 2000: Genetic variability in soybean (*Glycine max* (L.) Merrill. *Crop Res.* , **20**: 108-112
- Rajarathinam, S., Muppidathi, N. and Pandian, R. S., 1996, Variability and character association in soybean during *rabi* season. *Madras J Agric. Sci.*, **83**: 776-777.

- Rajput, M.A., Sarwar, G. and Tahir, K.H., 1986, Path co-efficient analysis of developmental and yield components in soybean. *Soybean Genet. News l.*, **13**:87-91.
- *Raper, L.R., Parson, D. T., Patterson and Kramer., P. J., 1977. Relationship between growth and nitrogen accumulation for vegetative cotton and soybean plants. *Botanical Gazette*, **138**: 129-137.
- Rasaily, S.K., Desai, N.D. and Kukadia., M.U., 1986, Genetic variability in soybean [*Glycine Max* (L.) Merrill]. *Gujarath Agric. Univ. Res. J.*, **15**: 273-283.
- Rashid, M.H. and Islam, M.A., 1982, Co-efficient of genetic variability, heritability and correlation of agronomic characters in soybean. *Madras Agric. J.*, **69**:479-481.
- *Rezaizad, A., Samadi, B. Y., Ahmadi, M. R. and Zeinali, H., 2001, Relationships between yield and yield components in soybean using path analysis. *J. Sci. Tech. Agric.*, **5**:107-115.
- Robinson, H. F., Comstock, R. E. and Harvey, P. H., 1949, Estimation of heritability and degree of dominance in corn. *Agron. J.*, **41**: 353-359.
- *Salado Navarro, L.R., 1985, Yield, seed protein percentage and physiological traits in simulated and field grown soybean. *Dissert. Abstr. International, (Sciences and Engineering)*, **46**: 710.
- *Salado Navarro, L.R., Sinclair, T.R. and Hinson, K., 1986, Yield and reproductive growth of simulated and field grown soybean. I. seed filling duration, *Crop Sci.*, **26**: 966-970.
- Sammons, D. J., Peters, D. B. and Hymowitz, T., 1978, Screening soybeans for drought resistance. I. growth chamber procedure. *Crop Sci.*, **18**:1050-1055.

- Sarkar, R. K., 1994, Studies on some morpho-physiological characters in relation to drought tolerance in soybean. *Indian J. Plant Physiol.*, **37**: 40-42.
- Senthil Kumar, M. 2001, Development and characterization of thermo tolerant Sunflower (*Helianthus annuus* L.) hybrid: An approach based on Temperature Induction Response (TIR) and molecular analysis. M.Sc.(Agri.) Thesis submitted to Dept. of Crop Physiology, Univ. Agric. Sci., Bangalore.
- Sharma, S.K., 1979, Note on path coefficient analysis in the populations of soybean grown at two locations. *Indian. J. Agric. Sci.*, **49**: 820-821.
- Sharma, S.M., Rao, S.K., and Goswami, U., 1983, Genetic variation, correlation and regression analysis and their implications in selection of exotic soybean. *Mysore J. Agric. Sci.*, **17**: 26-30.
- *Sharma. S.M., Rana, N.D. and Mehta, H., 1986, Genetic variability, interrelationships and path coefficient analysis in a collection of small seeded soybean. *Egyptian J. Genet. And Cyt.*, **15**: 273-283.
- *Shibles, R. M., Anderson, I. C. and Gibson, A. H., 1975. Soybean. In: Evans L.T., (Ed.). *Crop physiology*. Cambridge: Cambridge University Press, UK. pp 151-190.
- *Sichkar, V.I. and Lugovoi, A.P., 1986, The character of correlations between yield components in soybean. *Novosibirsk, USSR*, 92-100.
- Smith, H.F., 1936, A discriminant function for plant selection. *Ann. Eugenet.*, **7**: 240-250.

- Smith, J.R., Nelson, R.L. and Vasilar, B. L., 1988, Variability among soybean breeding lines in relation to yield and seed fill duration, *Agron. J.*, **80**:825-829.
- *Song, Q.J., Gai, J. Y. and Ma, Y.H., 1987, A study on the peculiarity and genetic variability of soybean 1 and race population from the middle Yangtze valley. *J. Nanjung. Agric. Univ.*, **3**: 29-36.
- Song, H.S., Lee, Y. I., Know, S.H., Sony I.M. and Kwon, K.H., 1990, Relationship between seed weight and agronomic traits in Korean native soybeans. *Korean J. Crop. Sci.*, **35**: 23-28.
- Sreekanth Attaluri, 1998, Thermotolerant Groundnut (*Arachis hypogea*. L.) genotypes identified based on TIR technique also exhibited enhanced expression of a few stress responsive proteins. M.Sc (Agri.) thesis submitted to Department of Crop Physiology, University of Agricultural Sciences, Bangalore -65.
- Srikanth Babu, V., 1999, Identification of high temperature stress tolerant genotypes in Garden pea (*Pisum sativum* L. Hortense) using Temperature Induction Response (TIR) technique. M.Sc. (Agri.) Thesis submitted to Department of Crop Physiology, University of Agricultural Sciences, Bangalore – 65.
- Srikanth Babu, V., Ganesh Kumar, Krishnaprasad, B. T., Gopalkrishna, R., Savitha, M. and Udaya Kumar, M., 2001, Identification of pea genotypes with enhanced thermo-tolerance using temperature induced response (TIR) technique. *J. Plant Physiol.*, **20**: 77-82.
- *Surian Momirovic, G., 1987, Heritability and genotypic and phenotypic correlations in respect to morphological traits of various soybean varieties. *Univerzitet u Beogradu*, **29**:87-93.

- *Teren'eva, I.N., 1987, Physiological basis of agronomic practices applied to varieties of soybean. *Novosibirsk.*, 133-139.
- Tetsuji, O., Alexandre, L. N., Norman, N., Jose, R. B. F., Satoshi, T. and Osamu, I., 2003, Drought Tolerance Characteristics of Brazilian Soybean cultivars Evaluation and characterization of drought tolerance of various Brazilian soybean cultivars in the field. *Plant Production Sci.*, **7**: 129-137.
- Thomas, J. F. and Raper. C. D., 1976, Photoperiodic control of seed filling for soybeans. *Crop Sci.*, **16**: 667-672
- *Tong, Y., 1986, Correlation and path analysis for the main quantitative character of soybean. *Ningxia Agric. Sci. Tech.*, **6**: 31-34.
- Uma, S., Prasad, T.G. and Udaya Kumar, M. 1995, Genetic variability in recovery growth and synthesis of stress proteins in response to polyethylene glycol and salt stress in finger millet. *Ann. Bot.*, **76**: 3-49.
- *Vierling, E., Nagao, R.T., DeRocher, A.E. and Harris, L.M., 1988, A heat shock protein localized to chloroplasts is a member of a eukaryotic super family of heat shock proteins. *EMBO J.*, **7**: 575-581.
- Wheeler, T. R., Chatzialioglou, A., Craufurd, P. Q., Ellis, R. H. and Summerfield. R. J., 1997, Dry matter partitioning in groundnuts exposed to high temperature stress. *Crop Sci.*, **37**: 1507-1513.
- Wilcox, J.R. and Sedyama, T., 1981, Inter relationship among height, lodging and yield in determinate and indeterminate soybean. *Euphytica.*, **30**: 323-326.
- Wood, I. M. W. 1968. The effect of temperature at early flowering on the growth and development of peanut (*Arachis hypogaea* L.). *Aus. J. Agric. Res.*, **19**: 241-251.

Yanyun Chen, Pengyin Chen and Benildo G. de los Reye, 2006, Differential Responses of the Cultivated and Wild Species of Soybean to Dehydration Stress. *Crop Sci.*, **46**:2041-2046.

*Yao, T.Z., 1988, Correlative heritability analysis of main agronomic characters of North-east spring soybean variety. *Acta Agricultura sinica*, **10**: 23-27.

*Yao, T.Z., Wang, Z. and Kang, B., 1987, Study on heritability and correlation of quantative characters of soybean variety. *Acta Agricultura sinica*, **9**: 31-37.

Zhou, F.S., 1983, Path analysis of the major agronomic characters in parental cultivars of soybean, *Hereditas.*, **5**: 79.

* Original not seen

APPENDICES

Appendix-I

Mean data of different quantitative traits in 348 Soybean genotypes

Sl.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height(cm)	Branches/ plant	Pods/ plant	Seed/ pod	100 seed weight (g)	Seeds /plant	Seed yield/ plant (g)
1	10 KR -1R	34.0	92.0	29.2	1.8	18.2	2.4	14.0	42.9	6.0
2	BR-13	35.0	95.0	33.6	1.2	30.0	2.2	12.0	66.7	8.0
3	30 KR -1	35.0	93.0	39.4	2.0	22.2	1.8	14.0	40.0	5.6
4	BP-86-75	34.0	90.0	35.8	2.6	25.6	2.3	10.0	60.0	6.0
5	AGS-28	35.0	90.0	31.6	1.8	22.0	1.6	10.0	36.0	3.6
6	AGS-12	36.0	95.0	33.6	1.8	20.0	1.9	16.0	37.5	6.0
7	AGS-21	35.0	95.0	35.6	1.8	22.0	1.8	14.0	40.0	5.6
8	AGS-50	34.0	90.0	33.4	2.0	20.2	2.1	16.0	42.5	6.8
9	CGP-32	36.0	104.0	32.4	1.6	20.8	1.9	14.0	40.0	5.6
10	AGS-34	35.0	99.0	50.6	2.0	26.8	1.9	10.0	52.0	5.2
11	CM-720	35.0	95.0	54.4	2.8	38.6	2.1	8.0	80.0	6.4
12	EC-16808	36.0	99.0	32.2	1.4	18.0	1.8	16.0	32.5	5.2
13	CGP-1943	36.0	104.0	38.8	1.6	29.2	2.3	12.0	66.7	8.0
14	EC-3915-115	36.0	104.0	42.6	2.0	27.6	1.7	10.0	48.0	4.8
15	DS-371	36.0	103.0	30.6	2.0	22.0	1.0	10.0	32.0	3.2
16	CGP-97	35.0	99.0	24.0	2.0	18.8	1.8	12.0	33.3	4.0
17	DS-335	33.0	90.0	22.8	2.6	24.8	1.7	16.0	42.5	6.8
18	DS-93101	36.0	104.0	29.6	2.4	20.0	1.8	12.0	36.7	4.4
19	DS-154	36.0	104.0	43.6	3.0	22.0	1.7	12.0	36.7	4.4
20	DS-7414	36.0	95.0	25.4	1.4	16.0	1.5	12.0	23.3	2.8
21	DS-9814	36.0	95.0	22.8	2.2	34.0	2.2	18.0	73.3	13.2
22	DS-393A	35.0	95.0	24.8	1.8	13.0	1.7	18.0	22.2	4.0
23	DS-17-5	35.0	95.0	29.8	1.8	28.0	2.3	10.0	64.0	6.4

24	DS-97-11	32.0	88.0	17.4	1.2	16.2	1.4	20.0	22.0	4.4
25	DS-79-19	32.0	90.0	24.4	2.2	23.2	1.7	16.0	40.0	6.4
26	EC-16808	36.0	104.0	43.2	2.6	20.0	1.9	16.0	37.5	6.0
27	CGP-555	35.0	92.0	27.0	1.0	12.6	2.0	14.0	25.7	3.6
28	CGP-1024	36.0	104.0	37.2	3.0	28.2	1.8	12.0	50.0	6.0
29	DS-56-57	35.0	95.0	40.0	1.8	24.0	1.7	12.0	40.0	4.8
30	DS-5657	35.0	95.0	33.2	1.8	23.8	1.9	14.0	45.7	6.4
31	DS-7573	31.0	92.0	24.0	1.6	17.4	1.5	14.0	25.7	3.6
32	DS-2	37.0	90.0	38.6	2.4	22.8	1.5	12.0	33.3	4.0
33	CGP-76	38.0	95.0	34.0	3.4	28.0	2.4	12.0	66.7	8.0
34	DS-72-244	37.0	95.0	27.6	3.0	35.2	1.8	10.0	64.0	6.4
35	DS-8916	35.0	95.0	23.0	1.8	24.4	1.2	16.0	30.0	4.8
36	EC-28754	32.0	83.0	13.6	3.0	16.0	1.8	18.0	28.9	5.2
37	CGP-65	35.0	95.0	42.2	1.8	25.4	1.9	10.0	48.0	4.8
38	DS-8320	35.0	104.0	37.8	2.4	22.0	1.8	18.0	40.0	7.2
39	DS-531	36.0	98.0	22.4	1.2	23.0	1.4	16.0	32.5	5.2
40	DS-9318	37.0	98.0	33.4	1.6	25.2	1.6	16.0	40.0	6.4
41	DBI-104	37.0	104.0	34.2	1.8	20.6	1.5	14.0	31.4	4.4
42	CGP-1991	35.0	90.0	45.6	1.6	25.6	1.4	10.0	36.0	3.6
43	DS-93-408	36.0	104.0	41.6	2.4	32.2	1.9	12.0	60.0	7.2
44	CGP-43	36.0	104.0	36.6	2.0	25.2	2.0	14.0	51.4	7.2
45	DS-84	37.0	104.0	48.2	4.8	35.0	2.1	12.0	73.3	8.8
46	CGP-387	36.0	104.0	4.2	2.0	26.8	1.9	14.0	51.4	7.2
47	DS-8916	36.0	104.0	31.0	2.6	26.4	1.6	14.0	42.9	6.0
48	DS-5654*	37.0	82.0	17.8	2.4	16.0	1.7	18.0	26.7	4.8
49	DS-7462	37.0	98.0	40.6	2.8	28.8	1.5	12.0	43.3	5.2
50	DS-17-5	34.0	98.0	24.4	2.8	22.8	2.0	16.0	45.0	7.2
51	EC-93606	37.0	98.0	44.2	1.8	20.0	1.8	12.0	36.7	4.4
52	EC-24069	36.0	104.0	51.2	2.4	18.0	1.7	14.0	31.4	4.4
53	AGS-112	38.0	104.0	37.2	2.4	20.0	1.6	14.0	31.4	4.4
54	GPC-1544	38.0	104.0	3.5	2.4	28.6	1.9	14.0	54.3	7.6

55	AGS-117	39.0	98.0	36.6	1.2	15.0	1.3	12.0	28.0	2.4
56	GPC-537	37.0	104.0	40.4	2.0	27.6	1.7	14.0	45.7	6.4
57	GPC-7340	38.0	98.0	43.6	2.2	26.8	2.1	8.0	55.0	4.4
58	GPC-154	36.0	98.0	30.6	1.8	21.0	1.9	14.0	40.0	5.6
59	AGS-107	35.0	98.0	22.8	1.4	12.4	1.6	14.0	20.0	2.8
60	EC-76759	37.0	104.0	27.8	2.4	17.6	1.7	16.0	30.0	4.8
61	GPC-717	33.0	98.0	48.0	1.6	24.1	1.7	10.0	40.0	4.0
62	IC-15981	34.0	98.0	25.4	1.2	13.2	1.5	14.0	20.0	2.8
63	EC-91015	35.0	98.0	34.8	1.6	18.4	1.8	12.0	33.3	4.0
64	GS-54	36.0	98.0	27.3	1.0	12.0	1.7	8.0	20.0	1.6
65	Himsoy-5175	33.0	98.0	36.2	2.4	23.8	1.3	14.0	31.4	4.4
66	AGS-125	38.0	104.0	50.2	2.2	22.0	1.6	10.0	36.0	3.6
67	AGS-115	37.0	98.0	45.2	1.4	16.0	1.8	10.0	28.0	2.8
68	EC-291400	36.0	98.0	18.4	2.2	15.0	2.2	18.0	33.3	6.0
69	EC-139-813	33.0	99.0	26.7	2.0	16.8	1.8	16.0	30.0	4.8
70	EC-24069	35.0	95.0	34.6	2.4	20.2	2.6	12.0	51.7	6.2
71	GPC-8174	37.0	104.0	50.4	2.2	23.0	2.0	14.0	45.7	6.4
72	EC-76754	35.0	95.0	37.0	1.6	23.2	1.9	10.0	44.0	4.4
73	EC-75195	35.0	98.0	19.2	1.2	9.8	2.0	12.0	20.0	2.4
74	EC-11396	35.0	82.0	21.4	1.8	15.4	2.2	12.0	33.3	4.0
75	Himsoy-1588	36.0	98.0	28.6	1.8	18.4	1.6	18.0	28.9	5.2
76	EC-14902	37.0	98.0	28.6	2.2	17.0	1.5	14.0	25.7	3.6
77	GPC-151	35.0	98.0	27.2	1.6	16.2	1.8	14.0	28.6	4.0
78	Himsoy-1514	35.0	98.0	29.6	1.0	14.2	1.4	12.0	20.0	2.4
79	GPC-1771	35.0	98.0	44.4	3.0	27.6	2.2	10.0	60.0	6.0
80	Himsoy-1596	34.0	99.0	30.2	2.0	14.0	1.4	18.0	20.0	3.6
81	EC-241920	36.0	104.0	41.6	3.0	30.6	1.7	10.0	52.0	5.2
82	EC-29412	36.0	104.0	36.8	1.4	18.0	1.5	16.0	27.5	4.4
83	EC-241949	37.0	104.0	5.4	3.4	32.8	1.2	6.0	40.0	2.4
84	JS-SH-1310	37.0	98.0	33.4	1.3	13.4	1.5	12.0	20.0	2.4
85	JS-SH-916	34.0	104.0	23.0	1.6	13.0	1.5	18.0	20.0	3.6

86	I-4	32.0	90.0	23.4	1.6	17.2	2.1	10.0	36.0	3.6
87	JS-SH-8753	36.0	104.0	30.6	1.6	22.2	1.6	18.0	35.6	6.4
88	JS-SH-33	35.0	98.0	24.8	1.2	10.2	2.0	12.0	20.0	2.4
89	IC-15997	38.0	90.0	31.4	3.0	15.8	2.5	8.0	40.0	3.2
90	JS-SH-96-04	35.0	99.0	26.2	1.4	20.4	1.8	14.0	37.1	5.2
91	JS-SH-93-9	38.0	98.0	27.8	1.4	17.0	2.2	12.0	36.7	4.4
92	JS-81716	34.0	105.0	35.0	2.0	24.0	2.0	10.0	48.0	4.8
93	IC-488603	34.0	98.0	19.0	1.5	12.0	1.7	8.0	20.0	1.6
94	JS-SH-56	35.0	98.0	25.4	1.6	16.2	1.6	14.0	25.7	3.6
95	JS-SH-94-167	34.0	98.0	20.8	2.2	28.4	2.1	12.0	60.0	7.2
96	JS-7516	37.0	90.0	25.2	1.0	14.4	1.7	12.0	25.0	3.0
97	JS-SH-33	37.0	104.0	24.2	1.4	13.2	1.5	16.0	20.0	3.2
98	JS-SH-8931	37.0	90.0	26.4	1.6	14.8	1.4	14.0	20.0	2.8
99	JS-87-60	36.0	98.0	22.8	1.2	11.6	1.7	12.0	20.0	2.4
100	IC-14	34.0	98.0	21.0	1.2	10.4	1.9	10.0	20.0	2.0
101	JS-7516	35.0	98.0	27.8	2.0	16.8	1.4	12.0	23.3	2.8
102	JS-176-156	34.0	90.0	48.6	1.6	24.0	3.0	8.0	60.0	4.8
103	JS-53	30.0	98.0	21.0	1.6	13.8	1.4	18.0	20.0	3.6
104	I-28	34.0	90.0	21.0	2.0	23.0	1.1	16.0	25.0	4.0
105	JS-81-714	36.0	98.0	36.4	1.8	18.4	1.6	16.0	30.0	4.8
106	Himsoy-1	37.0	104.0	36.4	1.8	23.6	1.6	16.0	37.5	6.0
107	JS-SH-8921	35.0	104.0	37.2	1.6	17.0	1.8	12.0	30.0	3.6
108	AGS-176	34.0	98.0	25.4	2.2	20.0	1.7	12.0	33.3	4.0
109	JS-SH-96-04	35.0	90.0	14.2	2.0	14.0	1.7	12.0	23.3	2.8
110	JS-89-45	35.0	92.0	32.8	2.0	20.0	1.8	10.0	36.0	3.6
111	JS-SH-8727*	36.0	99.0	30.4	1.4	15.2	1.6	16.0	25.0	4.0
112	AGS-167	36.0	99.0	34.4	1.2	16.8	1.7	10.0	28.0	2.8
113	JS-SH-96-31	36.0	99.0	19.8	1.2	10.0	2.3	8.0	20.0	1.6
114	JS-95-60	32.0	82.0	17.6	1.6	9.0	2.2	12.0	20.0	2.4
115	JS-90	31.0	90.0	17.8	1.2	12.2	2.5	12.0	30.0	3.6
116	JS-79-789	35.0	99.0	34.0	1.2	18.0	1.4	14.0	25.7	3.6

117	AGS-174	34.0	99.0	21.5	1.5	14.0	1.4	16.0	20.0	3.2
118	JS-92-12	33.0	81.0	17.4	1.0	9.6	2.1	8.0	20.0	1.6
119	JS-SH-9301	37.0	104.0	49.0	2.8	31.6	1.9	6.0	60.0	3.6
120	JS-SH-8760	31.0	100.0	24.0	1.5	19.0	1.2	16.0	22.5	3.6
121	JS-81618	35.0	100.0	31.0	1.0	17.2	1.2	13.0	20.0	2.6
122	KB-249A	34.0	99.0	21.0	1.2	35.0	2.7	7.0	94.3	6.6
123	KB-249	34.0	104.0	25.0	1.4	21.4	1.8	18.0	37.8	6.8
124	JS-79-82	35.0	104.0	29.0	2.8	21.6	2.1	16.0	45.0	7.2
125	JS-875	36.0	99.0	33.6	2.4	21.0	1.5	16.0	32.5	5.2
126	JS-128-5	34.0	104.0	28.6	1.4	15.0	1.6	20.0	24.0	4.8
127	JS-89-76	37.0	99.0	27.4	1.4	17.6	1.3	14.0	22.9	3.2
128	KB-117	33.0	99.0	22.9	2.0	21.0	1.8	16.0	37.5	6.0
129	KB-111	36.0	92.0	36.2	2.0	26.2	2.4	10.0	64.0	6.4
130	JS-98-21	36.0	99.0	29.0	1.8	23.8	1.5	18.0	35.6	6.4
131	KB-152	36.0	92.0	21.8	1.6	22.4	1.9	16.0	42.5	6.8
132	JS-37	34.0	98.0	37.4	3.4	29.0	1.5	10.0	44.0	4.4
133	KB-127	36.0	90.0	22.2	1.0	12.2	2.0	8.0	25.0	2.0
134	MACS-532	35.0	98.0	20.0	2.6	36.0	2.5	16.0	90.0	14.4
135	JS-SH-27-55	35.0	98.0	27.2	2.8	23.6	2.0	10.0	48.0	4.8
136	JS-98-91	34.0	98.0	25.8	1.8	20.8	1.4	14.0	28.6	4.0
137	KB-150	37.0	98.0	24.4	1.2	17.2	1.4	18.0	24.4	4.4
138	JS-70-25	35.0	98.0	32.4	3.2	26.6	1.7	10.0	44.0	4.4
139	KB-154	36.0	98.0	21.8	1.6	19.0	1.7	14.0	31.4	4.4
140	KB-263	30.0	87.0	16.8	2.2	15.2	1.5	14.0	22.9	3.2
141	KB-222	35.0	98.0	19.0	1.4	14.0	1.4	16.0	20.0	3.2
142	KB-148	34.0	98.0	30.2	2.2	16.6	1.5	16.0	25.0	4.0
143	JS-76-186	34.0	98.0	29.6	1.4	14.4	1.4	14.0	20.0	2.8
144	KB-165	36.0	98.0	21.8	2.0	21.2	1.7	16.0	35.0	5.6
145	KB-154	35.0	98.0	32.2	1.4	22.6	1.4	14.0	31.4	4.4
146	KB-242	34.0	99.0	28.0	2.0	18.8	1.3	16.0	25.0	4.0
147	KB-262	34.0	90.0	22.0	1.4	22.0	1.8	10.0	40.0	4.0

148	JS-78-608	36.0	90.0	18.4	1.2	10.8	1.9	14.0	20.0	2.8
149	JS-95-26	32.0	90.0	17.8	1.2	15.4	1.5	16.0	22.5	3.6
150	KB-246	33.0	98.0	30.4	1.8	17.0	2.2	14.0	37.1	5.2
151	JS-87-59	33.0	98.0	24.0	1.8	15.8	2.1	16.0	32.5	5.2
152	JS-89-76	35.0	99.0	37.0	3.0	18.0	1.6	14.0	28.6	4.0
153	JS-95-58*	37.0	98.0	29.8	2.2	23.6	1.7	16.0	40.0	6.4
154	KB-137	33.0	90.0	24.2	1.4	20.4	1.6	18.0	33.3	6.0
155	KB-248	33.0	99.0	21.8	1.6	14.8	1.8	18.0	26.7	4.8
156	JS-94-65	36.0	99.0	21.8	2.0	13.8	1.4	18.0	20.0	3.6
157	KB-230	35.0	99.0	39.0	1.4	24.0	1.9	12.0	46.7	5.6
158	JS-7546	36.0	99.0	30.8	1.8	13.0	1.5	20.0	20.0	4.0
159	KB-223	32.0	88.0	21.2	1.8	20.4	1.5	18.0	31.1	5.6
160	KB-130	34.0	99.0	39.4	1.6	20.6	2.1	8.0	42.5	3.4
161	MACS-6	35.0	99.0	37.0	2.2	31.2	1.6	12.0	50.0	6.0
162	KB-126	33.0	99.0	24.6	1.4	14.6	1.4	14.0	20.0	2.8
163	L-488	32.0	90.0	31.8	3.0	15.8	1.9	12.0	30.0	3.6
164	KB-241	36.0	99.0	22.8	1.2	16.0	1.3	16.0	20.0	3.2
165	MACS-829*	35.0	99.0	29.6	1.4	26.8	1.4	14.0	37.1	5.2
166	MACS-157	34.0	99.0	24.4	1.6	18.6	1.5	14.0	28.6	4.0
167	L-4494	33.0	99.0	24.2	2.0	17.2	1.2	18.0	20.0	3.6
168	MACS-730	35.0	103.0	39.6	2.6	16.8	1.2	8.0	20.0	1.6
169	MACS-144	37.0	99.0	30.4	1.8	18.8	1.6	12.0	30.0	3.6
170	MACS-61	34.0	99.0	27.0	1.0	16.0	2.0	14.0	31.4	4.4
171	KB-157	33.0	99.0	22.8	1.6	18.4	1.6	18.0	28.9	5.2
172	MACS-17	33.0	99.0	23.0	2.2	19.4	1.6	18.0	31.1	5.6
173	KB-163	35.0	90.0	20.4	1.0	15.6	1.6	14.0	25.7	3.6
174	L-83A	32.0	88.0	15.8	1.5	14.2	1.6	18.0	22.2	4.0
175	KB-125	33.0	87.0	19.8	2.0	17.4	1.7	12.0	30.0	3.6
176	KR-211C	32.0	99.0	22.2	2.0	12.2	1.6	16.0	20.0	3.2
177	KH-96-2	33.0	99.0	32.2	1.6	14.8	1.5	14.0	22.9	3.2

178	MACS-491	33.0	99.0	27.4	1.6	20.8	1.6	16.0	32.5	5.2
179	KB-244	35.0	100.0	33.1	1.6	19.6	1.3	14.0	25.7	3.6
180	MACS-329	36.0	100.0	39.6	2.2	32.0	1.4	10.0	44.0	4.4
181	MACS-55	35.0	99.0	27.0	2.4	21.0	1.5	18.0	31.1	5.6
182	MACS-5203	36.0	99.0	33.6	2.4	21.4	1.9	14.0	40.0	5.6
183	MACS-730	35.0	90.0	23.4	2.2	16.0	1.9	8.0	30.0	2.4
184	KB-151	35.0	99.0	22.8	2.4	15.0	1.7	20.0	26.0	5.2
185	MACS-491	37.0	99.0	42.2	1.8	22.6	1.9	16.0	42.5	6.8
186	LSb-3	35.0	100.0	24.4	2.0	18.6	1.7	16.0	32.5	5.2
187	KB-159	35.0	104.0	32.6	1.8	17.8	1.8	16.0	32.5	5.2
188	MACS-107	36.0	99.0	39.8	1.8	28.6	0.9	16.0	25.0	4.0
189	KB-131	36.0	99.0	25.6	1.2	13.2	2.3	16.0	30.0	4.8
190	KB-111	35.0	99.0	27.0	2.2	29.6	1.8	12.0	53.3	6.4
191	KB-230	33.0	100.0	23.0	2.2	19.2	1.8	16.0	35.0	5.6
192	Local Batt	32.0	99.0	53.2	3.0	29.6	1.8	10.0	52.0	5.2
193	L-83	34.0	99.0	48.6	3.2	26.4	1.7	14.0	45.7	6.4
194	MACS-301	34.0	90.0	31.2	3.0	22.4	2.0	10.0	44.0	4.4
195	KB-143	35.0	88.0	20.0	2.4	19.4	1.5	16.0	30.0	4.8
196	MACS-329	35.0	99.0	37.0	2.2	30.4	2.6	12.0	80.0	9.6
197	AGS-157	36.0	99.0	47.6	3.0	39.0	1.9	8.0	75.0	6.0
198	MACS-64	35.0	92.0	26.6	2.6	17.6	3.2	10.0	56.0	5.6
199	MK-34	35.0	101.0	35.0	1.6	25.4	2.1	14.0	54.3	7.6
200	MK-7	35.0	90.0	16.0	2.0	22.8	0.9	16.0	20.0	3.2
201	KR-211C	35.0	90.0	15.4	2.4	25.2	1.6	16.0	40.0	6.4
202	MACS-38	36.0	99.0	30.6	2.2	26.0	1.4	14.0	37.1	5.2
203	AGS-284	36.0	99.0	24.6	1.6	16.6	1.4	12.0	23.3	2.8
204	CGP-268	36.0	99.0	25.8	1.6	16.8	1.3	16.0	22.5	3.6
205	MK-32	35.0	90.0	34.4	1.4	23.2	2.0	14.0	45.7	6.4
206	MK-9	35.0	99.0	18.8	1.0	27.0	1.7	18.0	46.7	8.4
207	MK-33	36.0	98.0	29.6	2.0	19.2	1.8	14.0	34.3	4.8
208	MACS-212	35.0	99.0	43.7	2.8	30.0	2.0	10.0	60.0	6.0

209	MACS-441	36.0	99.0	38.0	2.6	36.6	1.6	14.0	60.0	8.4
210	MACS-49-1	35.0	100.0	36.8	2.8	26.0	1.1	14.0	28.6	4.0
211	MK-22	35.0	99.0	36.8	1.6	26.8	1.6	12.0	43.3	5.2
212	MK-15	36.0	99.0	27.6	2.0	21.8	1.5	18.0	33.3	6.0
213	MACS-2	35.0	99.0	41.8	2.2	30.6	1.4	14.0	42.9	6.0
214	MK-7-1	35.0	99.0	51.8	1.6	26.6	1.9	12.0	50.0	6.0
215	MACS-68*	35.0	90.0	33.6	2.2	21.2	1.5	14.0	31.4	4.4
216	MK-17	36.0	102.0	34.6	3.0	28.8	1.7	14.0	48.6	6.8
217	MK-11	38.0	98.0	28.2	1.6	24.0	1.5	14.0	37.1	5.2
218	MACS-578	35.0	102.0	27.4	2.4	20.8	1.6	16.0	32.5	5.2
219	MACS-389	34.0	98.0	37.2	2.8	23.2	1.1	16.0	25.0	4.0
220	MK-8	35.0	100.0	36.6	1.6	17.8	1.5	12.0	26.7	3.2
221	MACS-338*	35.0	99.0	49.2	2.2	23.0	1.9	12.0	43.3	5.2
222	MACS-1712	34.0	103.0	27.0	1.2	17.4	1.8	18.0	31.1	5.6
223	MK-9	32.0	90.0	28.2	1.6	22.2	1.5	16.0	32.5	5.2
224	MACS-798	34.0	99.0	27.0	1.4	12.1	2.0	18.0	24.4	4.4
225	MACS-756	34.0	100.0	26.8	2.4	24.4	1.5	18.0	37.8	6.8
226	MACS-14	36.0	101.0	32.6	1.4	24.8	1.5	16.0	37.5	6.0
227	MACS-38	34.0	100.0	32.8	1.6	24.6	1.6	14.0	40.0	5.6
228	MK-29	36.0	102.0	3.6	1.2	21.4	1.7	12.0	36.7	4.4
229	MK-21	34.0	101.0	31.4	2.4	24.8	1.6	12.0	40.0	4.8
230	MK-16	35.0	101.0	53.2	2.4	25.0	1.9	12.0	46.7	5.6
231	MACS-227	35.0	101.0	35.6	2.2	26.4	1.1	20.0	30.0	6.0
232	MK-123	34.0	100.0	29.4	2.6	23.8	1.4	18.0	33.3	6.0
233	MK-7	34.0	103.0	32.8	2.2	27.0	1.5	16.0	40.0	6.4
234	MACS-30	34.0	99.0	41.2	3.0	30.6	1.4	10.0	44.0	4.4
235	N-28	35.0	99.0	34.6	1.6	21.6	1.5	12.0	33.3	4.0
236	NRC-41	35.0	90.0	48.8	8.0	23.2	1.7	10.0	40.0	4.0
237	MACS-20	35.0	100.0	47.6	2.6	25.6	1.5	14.0	37.1	5.2
238	NRC-13	35.0	99.0	28.0	3.0	24.0	1.9	16.0	45.0	7.2
239	MACS-125	35.0	102.0	51.0	2.8	16.0	1.8	14.0	28.6	4.0

240	NRC-42	34.0	90.0	28.2	2.6	19.0	2.0	14.0	37.1	5.2
241	MAUS-168	35.0	90.0	37.2	2.4	23.6	2.5	14.0	60.0	8.4
242	MACS-629	35.0	106.0	28.4	1.8	16.0	1.8	14.0	28.6	4.0
243	MAUS-5	35.0	92.0	18.4	1.4	14.6	2.6	16.0	37.5	6.0
244	MACS-681	34.0	104.0	29.2	1.2	14.0	1.4	12.0	20.0	2.4
245	MAUS-520	36.0	106.0	30.0	1.0	17.4	1.9	12.0	33.3	4.0
246	NRC-BCA	35.0	106.0	26.2	1.2	14.0	1.8	14.0	25.7	3.6
247	NRC-41	35.0	104.0	33.4	1.8	16.0	1.8	14.0	28.6	4.0
248	NRC-37	36.0	105.0	26.2	1.6	20.0	1.8	12.0	36.7	4.4
249	MAUS-920A	36.0	106.0	26.8	1.2	12.0	1.7	12.0	20.0	2.4
250	NRC-19	35.0	104.0	30.8	2.4	20.0	1.7	12.0	33.3	4.0
251	NRC-33	35.0	92.0	25.8	2.0	14.0	1.7	12.0	23.3	2.8
252	NRC-3	34.0	106.0	36.4	1.4	23.4	1.7	14.0	40.0	5.6
253	NRC-33	37.0	106.0	31.6	2.4	22.0	1.8	16.0	40.0	6.4
254	NRC-12	31.0	82.0	14.0	1.4	12.0	1.7	14.0	20.0	2.8
255	NRC-23	34.0	107.0	22.8	2.4	11.6	1.7	7.0	20.0	1.4
256	NRC-15	35.0	106.0	36.6	2.6	26.0	1.4	12.0	36.7	4.4
257	NRC-17	34.0	106.0	28.8	2.0	21.6	2.0	14.0	42.9	6.0
258	PK-1024	35.0	106.0	24.8	1.6	15.0	1.8	16.0	27.5	4.4
259	MAUS-2	35.0	82.0	19.6	2.0	20.0	1.9	16.0	37.5	6.0
260	PK-1228	35.0	92.0	24.2	1.8	20.6	1.8	14.0	37.1	5.2
261	NRC-38	35.0	92.0	30.2	1.4	21.2	1.9	16.0	40.0	6.4
262	NRC-56	35.0	92.0	28.4	2.2	26.0	2.2	12.0	56.7	6.8
263	JS-335	38.0	83.0	29.0	2.0	30.0	1.8	12.0	55.0	6.6
264	MAUS-5	36.0	99.0	33.6	1.8	28.2	1.5	12.0	43.3	5.2
265	NRC-20	36.0	99.0	22.4	1.6	16.0	1.6	16.0	25.0	4.0
266	NRC-51	35.0	98.0	22.8	2.2	14.2	1.4	14.0	20.0	2.8
267	NRC-57	36.0	98.0	49.8	2.0	27.6	1.6	8.0	45.0	3.6
268	MACS-515	35.0	99.0	22.4	2.0	37.0	2.8	14.0	102.9	14.4
269	MAUS-920	36.0	99.0	34.8	1.4	22.2	2.0	10.0	44.0	4.4
270	NRC-6	33.0	98.0	29.6	1.6	28.4	1.9	12.0	53.3	6.4

271	RR-16	35.0	99.0	32.8	2.8	31.0	2.1	16.0	65.0	10.4
272	PK-1072	33.0	99.0	56.0	3.4	27.6	1.0	18.0	28.9	5.2
273	PK-34	35.0	98.0	46.8	2.6	22.6	4.0	8.0	90.0	7.2
274	PK-1137	36.0	99.0	43.8	1.8	23.8	1.3	16.0	30.0	4.8
275	PUSA-69	36.0	97.0	42.6	2.4	21.4	1.7	10.0	36.0	3.6
276	PK-1243	34.0	98.0	29.8	1.8	14.6	1.5	16.0	22.5	3.6
277	PK-1274	36.0	92.0	21.0	3.0	21.0	2.3	16.0	47.5	7.6
278	RR-3	36.0	99.0	19.6	2.0	18.2	2.0	18.0	35.6	6.4
279	UGM-47	35.0	99.0	56.0	1.5	20.0	1.8	8.0	35.0	2.8
280	PK-1136	36.0	101.0	53.8	2.2	25.8	1.7	12.0	43.3	5.2
281	PK-1046	36.0	102.0	63.8	2.0	25.6	1.6	12.0	41.7	5.0
282	RR-2	35.0	103.0	51.6	3.2	25.0	1.9	14.0	48.6	6.8
283	PK-1303	38.0	99.0	27.2	1.6	23.0	1.7	18.0	40.0	7.2
284	PK-891*	33.0	100.0	38.8	1.4	13.2	2.1	16.0	27.5	4.4
285	PK-1197	36.0	99.0	32.4	2.0	19.0	2.4	14.0	45.7	6.4
286	PK-1225	36.0	90.0	24.2	1.2	19.6	2.2	12.0	43.3	5.2
287	RR-476	36.0	106.0	29.4	1.4	23.6	2.3	12.0	53.3	6.4
288	PK-1036	38.0	80.0	32.2	1.6	29.4	2.0	14.0	60.0	8.4
289	RR-19*	35.0	106.0	28.6	1.6	24.6	1.4	18.0	33.3	6.0
290	PK-1032	35.0	104.0	37.1	1.8	26.0	1.3	16.0	35.0	5.6
291	PC-3	35.0	90.0	22.8	2.2	21.2	1.8	16.0	37.5	6.0
292	PK-1059	36.0	92.0	21.4	2.0	24.0	2.3	12.0	110.0	13.2
293	PK-1174	35.0	106.0	39.2	1.4	31.6	1.6	14.0	51.4	7.2
294	RR-20	34.0	106.0	27.8	2.2	17.6	2.1	14.0	37.1	5.2
295	PK-1241	34.0	106.0	22.6	1.8	19.2	2.1	18.0	40.0	7.2
296	PK-722	35.0	107.0	29.0	2.4	25.0	2.0	16.0	50.0	8.0
297	PK-1000	36.0	106.0	28.2	3.2	25.0	1.7	16.0	42.5	6.8
298	PC-3	36.0	90.0	16.0	1.8	12.0	1.8	16.0	21.9	3.5
299	PK-1308	35.0	106.0	33.2	2.4	14.0	2.0	14.0	28.6	4.0
300	PK-574	36.0	106.0	40.6	1.2	16.0	1.4	14.0	22.9	3.2
301	PUSA-37*	35.0	106.0	31.2	1.8	18.0	1.8	16.0	32.5	5.2

302	PK-1023*	35.0	106.0	37.2	3.0	24.0	1.7	20.0	40.0	8.0
303	PK-28031	36.0	106.0	32.6	2.0	14.0	1.6	20.0	23.0	4.6
304	SH-444	25.0	106.0	28.2	1.2	12.2	2.7	6.0	33.3	2.0
305	RAUS-971	35.0	92.0	39.8	1.4	18.0	1.4	14.0	25.7	3.6
306	RAUS-3	36.0	92.0	19.2	2.0	21.5	2.0	14.0	42.9	6.0
307	SH-4840	36.0	92.0	25.2	2.2	20.2	2.4	16.0	47.5	7.6
308	SH-54-94	37.0	106.0	27.6	2.2	14.8	1.5	16.0	22.5	3.6
309	SL-7205	38.0	92.0	27.6	2.0	18.4	1.6	14.0	28.6	4.0
310	SH-295	36.0	106.0	19.6	2.8	19.0	1.3	16.0	25.0	4.0
311	RPSP-35A	36.0	105.0	34.8	1.2	21.2	1.7	12.0	36.7	4.4
312	CGP-2451	36.0	106.0	35.8	1.4	19.6	1.0	10.0	20.0	2.0
313	SL-83	35.0	106.0	30.2	1.4	15.6	1.3	10.0	20.0	2.0
314	TS-98-1	34.0	107.0	27.4	2.0	19.4	1.6	10.0	32.0	3.2
315	SH-37	34.0	106.0	35.6	2.0	26.4	1.5	14.0	40.0	5.6
316	SL-157	35.0	96.0	45.8	2.8	24.2	1.9	12.0	46.7	5.6
317	VLS-49	35.0	92.0	25.0	1.4	17.2	1.8	14.0	31.4	4.4
318	RPSP-735*	34.0	92.0	35.2	1.6	12.0	1.9	16.0	22.5	3.6
319	SL-1433	35.0	92.0	21.0	2.0	25.4	2.0	18.0	51.1	9.2
320	VLS-53	35.0	106.0	51.0	1.6	24.0	1.9	14.0	45.7	6.4
321	SL-599	35.0	106.0	31.6	2.8	22.6	2.1	14.0	48.6	6.8
322	RPSP-2	36.0	106.0	39.0	1.8	25.0	2.1	12.0	53.3	6.4
323	PAS-41	35.0	91.0	30.4	1.8	15.0	1.9	14.0	28.6	4.0
324	SL-112	33.0	106.0	27.6	2.4	16.0	1.8	14.0	28.6	4.0
325	SL-1	34.0	90.0	41.2	2.0	23.2	1.5	16.0	35.0	5.6
326	TS-2000	35.0	90.0	36.2	1.6	19.8	1.8	10.0	36.0	3.6
327	VLS-11	33.0	106.0	53.6	2.6	24.6	1.7	16.0	42.5	6.8
328	SL-427	35.0	106.0	23.2	2.6	18.8	1.4	14.0	25.7	3.6
329	SL-432	36.0	90.0	29.0	2.2	19.6	2.0	12.0	40.0	4.8
330	SL-70	36.0	90.0	17.0	1.0	16.6	1.9	14.0	31.4	4.4
331	SL-96	36.0	106.0	34.4	1.2	13.2	1.5	10.0	20.0	2.0
332	YLS-40	38.0	92.0	30.0	1.8	14.2	1.6	14.0	22.9	3.2

333	TAS-41	33.0	92.0	19.7	1.2	14.7	1.9	14.0	28.6	4.0
334	SH-84-94	35.0	90.0	27.2	1.2	19.4	1.5	14.0	28.6	4.0
335	SH-518	35.0	92.0	23.2	2.4	19.8	2.0	16.0	40.0	6.4
336	SH-423	34.0	106.0	25.0	2.2	13.0	1.7	16.0	22.5	3.6
337	YLS-55	34.0	92.0	27.4	1.4	22.2	1.9	14.0	42.9	6.0
338	TAS-9234	33.0	106.0	30.0	3.0	19.0	1.5	14.0	28.6	4.0
339	SH-9133	34.0	106.0	30.9	2.0	23.4	1.7	14.0	40.0	5.6
340	CGP-585	35.0	106.0	29.8	2.2	16.0	1.9	12.0	30.0	3.6
341	VLS-34	33.0	107.0	2.6	2.6	24.0	2.0	17.0	48.2	8.2
342	VLS-52	36.0	92.0	15.0	1.4	18.8	1.4	14.0	25.7	3.6
343	VLS-56	32.0	82.0	14.0	2.4	19.6	1.6	18.0	31.1	5.6
344	VLS-50	34.0	106.0	31.0	2.6	32.0	2.0	14.0	62.9	8.8
345	Bragg	35.6	91.0	30.8	21.2	3.0	11.4	60.3	2.2	6.8
346	MACS-450	36.3	82.8	36.5	28.8	2.6	10.8	75.3	2.5	7.9
347	JS-335	37.3	82.6	29.3	30.3	2.0	12.0	53.4	2.3	6.4
348	KHSb-2	38.1	104.6	42.3	30.1	2.0	14.5	65.9	2.4	9.4
	Mean	35.14	97.17	30.97	1.98	21.37	1.88	13.62	39.14	5.18