Adaptation analysis for yield and its attributes in niger *(Guizotia abyssinica* Cass*)*

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE
In
AGRICULTURE

(PLANT BREEDING AND GENETICS)

By

PRATHAP KUMAR M R

Department of Plant Breeding and Genetics,
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur
College of Agriculture
Indore (MP)

CERTIFICATE I

*This is to certify that the thesis entitled **"Adaptation analysis for yield and its attributes in niger (Guizotia abyssinica Cass)"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in Plant Breeding and Genetics** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Prathap Kumar M R** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

(Dr. Mridula Billore)
Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	(Dr. Mridula Billore)	______
Member	(Dr. A.S. Holkar)	______
Member	(Dr. V.S. Gautam)	______
Member	(Dr. H.C. Tiwari)	______

CERTIFICATE II

This is to certify that the thesis entitled ***"Adaptation analysis for yield and its attributes in niger (Guizotia abyssinica Cass)"*** *submitted by* ***Mr. Prathap Kumar M R*** *to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, in partial fulfillment of the requirements for the degree of* ***Master of Science in Agriculture*** *in the Department of* ***Plant Breeding and Genetics,*** *has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination of the same.*

Place : Indore
Date : 17.05.05

(Dr. Mridula Billore)
Chairman
Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

Chairman	(Dr. Mridula Billore)	
Head of Section	(Dr. A.S. Holkar)	
Director of Instruction	(Dr. R.A. Khan)	DEAN Agriculture College, INDORE

HEAD OF THE SECTION
PLANT BREEDING & GENETICS
COLLEGE OF AGRICULTURE INDORE

Director Instruction
J.N. Krishi Vishwa Vidyalaya
JABALPUR.

ACKNOWLEDGEMENT

I avail this opportunity to express my deep sense of gratitude to my Advisor and Chairman of Advisory Committee Dr. Mridula Billore, Associate Professor (Plant Breeding and Genetics), College of Agriculture, Indore for her illuminating guidance, kind encouragement and generous help throughout the course of investigation.

I owe a-wholehearted gratitude with reverence to Prof., A.S. Holkar, (Plant Breeding and Genetics), Dr. V;S; Gautam, Associate Professor (Agronomy), Dr. H.C. Tiwari, Associate Professor (Statistics), the members of the advisory committee for their able guidance, supervision and enthusiastic interest showered on me throughout this study.

I am extremely grateful to Dr. H.S. Patil (Breeder) NARP, MPKV, Western Ghat Zone, Igatpuri for his inspiring suggestions and valuable guidance during the study and preparation of this manuscript.

I am extremely thankful to Dr. P.N. Gadewadikar, Professor, Head of the Section, Plant Breeding and Genetics, College of Agriculture, Indore for proper co-operation and constant encouragement.

I wish to extend my cordial thanks to Dr. J.S. Raghu, Dean, College of Agriculture, Indore for providing me necessary facilities to complete this investigation.

It is my special pleasure to express deep appreciation to my friends and juniors who helped me during my thesis work in one way or the other.

I find no rhetorical gems from the ocean of words to express my profound feelings to my most venerable parents and all the other members of my family whose affection, sacrifice, enthusiastic inspiration, devotion and care made it possible for me to achieve this goal and whose blessing have been a perennial source of inspiration throughout my study.

Place: Indore

Date: 18.08.04

(Prathap Kumar M R)

List of Contents

List of Tables

List of Figures

CHAPTER – 1

INTRODUCTION

A plant must be capable of exploiting both its physical and biological environments and be able to remain productive even under various biotic and abiotic stresses. Evaluation of such a property is now gaining importance. It is now an established fact that for a less favoured farmer, stability of yield is of more value as compared to the high production obtained through high investment. This necessitates to evaluate the varietal performance and varietal adaptation under various micro and macro environments for which the interaction between the genotypes and environments needs to be worked out. Such a study will help in identifying a genotype with a high production potential possessing stability performance over a wide range of environments, which is location in the referred case.

Niger (*Guizotia abyssinica* Cass) is extensively grown as a rainfed crop in marginal and sub marginal sloppy lands by tribal farmers. In Madhya Pradesh niger is grown in an area of 126 thousand ha with the production and productivity of 28.7 thousand tonnes and 228 kg/ha respectively (Hegde *et al.*, 2000). The fluctuating yields in different parts of India require the development of stable genotypes of niger across the environment. Some genotypes perform well over a wide range environment while others require specific environmental conditions to express their full genetic potential.

Keeping the above facts in view, this investigation has been planned to gather the information or consistency in performance of genotypes over locations with the following objectives:

1 To determine the genotype x environment interaction over locations viz., Indore, Dhar, Jhabua.

2 To know the adaptability of genotypes for yield and its attributes over all three locations.

3 To find out the stability of traits over varying environmental conditions.

CHAPTER – 2

REVIEW OF LITERATURE

Genotypes x environment interactions are of major importance to the plant breeders in the process of evolution of improved varieties. When varieties are grown at several locations for testing their performance, their relative rankings usually differ. Genotype x environment interaction is always realized, whether the varieties are pure lines, single crosses, double crosses, top crosses, single lines or any other material with which breeder is working (Eberhart and Russell, 1966).

Johanson (1909) explained the meaning of phenotype, which he described as the appearance or form arising as a result of interaction of genotype and environment. He was well ahead of others in realizing the importance of environment in developing processes. However, the existence of genotypes x environment interaction was first reported by Fisher and Mackenzie (1923) from the results of a varietal trial on potatoes. The break through came when Fisher (1926) presented the analysis of variance for factorial designs in field experimentation. This was used by Immer *et al.* (1934) to analyse the yield data obtained from a barley trial.

Sprague and Federer (1951) explained how variance components could be compartmented into effects of genotypes, environments and their interaction in equating the observed mean squares in ANOVA to their expectations on random model.

Allard (1961) pointed out that there is a relationship between genetic diversity and consistency in performance in different environments. According to him mixed populations were more stable than pure lines, owing to higher buffering.

Comstock and Moll (1963) demonstrated the significant effect of genotype x environment interactions in slowing the progress from selection.

Finlay and Wilkinson (1963) used regression as a quantitative measure of phenotypic stability to describe the varietal adaptability over a range of environments. According to them, absolute phenotypic stability could be expressed by b = 0 and the ideal variety in respect of adaptation would be the one having maximum yield potential in most favourable environment and maximum phenotypic stability.

Allard and Bradshaw (1964) suggested selection of stable genotype that interacts less with the environments in which they are to be grown with a view to reduce the genotype x environmental interaction to a considerable extent.

According to Eberhart and Russell (1966) in addition to mean and regression, deviation from regression should be given importance. Perkins and Jinks (1968) proposed that a regression of genotype x environmental interaction on environmental index had to be obtained rather than regression of mean, performance as done in the Eberhart and Russell's model.

Paroda *et al.* (1973) were of the opinion that minimum of three contrasting environments would be quite sufficient in order to select most stable genotypes as well as to predict their mean performance.

Luthra and Singh (1974) concluded after comparing some stability models and parameters that the relative rankings of the genotypes in Eberhart and Russell's and Perkin and Jink's model would be same.

The limited literature available on stability analysis in niger has been presented below:

Joshi and Patil (1982) studied four promising introductions of niger at three locations in Maharashtra for seed yield. They observed significant G x E interaction for seed yield. The genotype IGP-76 had the highest seed yield, though its regression value was little more but its deviations were the least, indicating its adaptability to different environments and as ideal genotype in the present study.

Verulkar and Upadhyay (1989) evaluated nine varieties of niger for stability parameters with respect to seed yield, days to flower, days to maturity, plant height, branches per plant, capsules per plant and 1000 seed weight in nine environments. The linear component of G x E interaction was larger in magnitude than non linear component for all the traits. CHH-1 was the only genotype found to be stable for seed yield per plant, plant height and 1000 seed weight. However, Gaudaguda-1 and N-71 have yielded significantly higher than other cultivars.

Misra *et al.* (1991) studied eighteen improved niger varieties during rainy season for two years. The varieties showed differential adaptation to different seasons. The varieties suitable for rainy season were: ONS-7, ONS-5, ONS-2, GA-10 and CHH-1 and for winter season were: ONS-4, GA-1, ONS-2, ONS-8 and GA-5.

Upadhyay (1993) evaluated ten genotypes of niger over four years for stability parameters with respect to seed yield, days to flower, days to maturity, plant height, branches per plant, capsules per plant and 1000 seed weight. CHH-1 was found to be stable genotype for all traits studied. Varieties like CHH-1, CHH-2 and Ootacamund with high seed yield were also stable for most of the characters including seed yield.

Kumar *et al.* (1993 and 1994) studied twenty niger selections for their stability of yield, days to flower, days to maturity, plant height, capsules per plant, 1000 seed weight, seed yield per plant. They identified few stable selections viz., Phule-1 and GA-10 for seed yield per plant, N-5 and ONS-8 for 1000 seed weight and Gaudaguda for days to maturity.

Kumar *et al.* (1998) studied twenty niger genotypes under four micro-environments for yield per plant, days to flower, days to maturity, plant height, 1000 seed weight and harvest index. The genotypes Phule-1 and GA-10 were found stable for yield per plant and NBC-2 and KEC-7 were reported to be stable for oil content.

Borole *et al.* (1998) evaluated eight genotypes of niger at seven locations in Maharashtra for selection of stable variety of niger. They observed significant G x E interaction. The genotype IGP-76 was found with average stability for yield and yield components.

Kumar *et al.* (1998) studied twenty genotypes for stability. G x E interactions were found to be significant for several characters. They concluded that the cultivars Phule-1, Gaudaguda, GA-1, GA-10, N-5, NBC-2 and RCR-140 were stable.

Patil *et al.* (1999) studied adaptability analysis for seed yield, 1000 seed weight, capitula per plant, days to maturity and plant height for twelve genotypes of niger over six environments. G x E interaction was observed significant for all traits studied. The genotypes viz., IGP-76 and IGPN-9628 were found responsive and adaptable to all environments for all the traits, while IGPN-9610 was responsive and stable for seed yield (q/ha), days to flower, days to maturity and branches per plant.

Hegde *et al.* (1999) studied thirteen genotypes of niger over seven locations for seed yield, days to maturity, days to flower, capsules per pant and branches per plant. The genotypes viz., JNS-1, JNC-3, GA-10 and IGP-76 were responsive and stable across the environments for all traits studied. They further evaluated six niger composites along with three check varieties at seven locations. They reported presence of G x E interaction for days to maturity, branches per plant, capsules per plant and seed yield. It is concluded that the composite JNC-11 and variety IGP-76 possess average stability for all the characters. In an other experiment they evaluated eight genotypes of niger over seven locations with respect to seed yield. A significant G x E interaction was observed. The genotypes viz., JNS-7, GA-10, BNS-9, SNS-8 and No.71 were observed to be well adapted over environments. A positive and significant correlation was also observed, indicating that the stability parameters were governed by independent genetic system in niger.

Goswami *et al.* (2000) studied the performance of eight strains of niger under All India Co-ordinated Programme at six locations during kharif 1998 for grain yield, days to maturity and branches per plant. The G x E linear was significant for grain yield (q/ha), suggesting the differential responses under different locations. The strain JNC-11 was found to be stable for all characters studied.

Hegde et al. (2000) evaluated eight elite genotypes of niger over seven locations for seed yield, days to maturity, branches per plant and capsules per plant. Significant mean sum of square due to genotypes, environments and G x E interaction were observed. Genotypes viz. BNS-9, SDN-5 and IGP-76 possessed average stability for all the traits studied.

Patil and Purkar (2000) evaluated seven elite genotypes of niger along with three released varieties as check for stability parameters with respect to seed yield and oil content at five locations in Maharashtra under rainfed condition. Significant differences for genotypes and environments were observed indicating presence of sufficient genetic variability among genotypes and environments studied. The G x E interaction was found significant.

Patil et al. (2000) evaluated eight genotypes of niger over seven locations in Maharashtra for seed yield, 1000 seed weight, seed per capsule, capsules per plant, days to maturity and plant height. The variance due to genotypes, environments, G x E interactions, environment + (G x E) and environment linear were found significant. On partitioning of G x E interaction, both components were significant. On perusal of individual parameter of stability, the genotype IGP-76 was found most responsive and stable for all characters studied. The genotype Phule-4 was found stable for seed yield and capitula/plant, whereas JN-4 have shown below average stability for 1000 seed weight and seeds per capitulum.

Patil (2001) studied ten genotypes of niger at five locations in Maharashtra during kharif 1997-98 under rainfed conditions. Genotype x Environment interaction was present for seed yield (q/ha), seeds per capsule, capsule per plant, branches per plant, days to maturity, days to flower and plant height. The genotypes IGP-76 for all traits and IGPN-9606 for all traits except days to maturity were found responsive and stable.

Patil et al. (2002) studied adaptability analysis for seed yield and its components for 12 genotypes of niger over six locations. Significant differences were observed for genotypes and environments suggesting presence of substantial genetic variability among the genotypes and environment studied. G x E interaction was observed for all characters studied. The genotypes viz. IGP-76 and IGPN-9606 were found responsive and stable for seed yield, days to flower, days to maturity and branches per plant.

CHAPTER – 3

MATERIALS AND METHODS

This chapter consists of the methods employed and materials used during the conduct of the experiment, which have been briefly explained below:

3.1 EXPERIMENTAL SITES

The experiment was conducted at three different locations viz. Experimental Farm, College of Agriculture, Indore, Krishi Vigyan Kendra, Dhar and Krishi Vigyan Kendra, Jhabua. These three locations are situated between 74°47'E to 74°9' E longitude and 22°54'N to 22°57'N latitude.

Indore and Dhar belongs to Malwa plateau region which is characterized by having rainfall of 800-1000 mm and low relative humidity with medium black soil and Jhabua being a hill region records average rainfall of 600-700 mm with very low relative humidity and the soil is mostly sandy red. The meteorological conditions prevailed during the crop growth period in these locations have been given in Table 2.

3.2 EXPERIMENTAL MATERIALS

The present investigation comprised ten genotypes of niger (*Guizotia abyssinica* Cass.) obtained from JNKVV-GTZ Collaborative Research Project on Niger, College of Agriculture, Indore. These genotypes have been listed in Table 1.

Table 1 List of genotypes studied

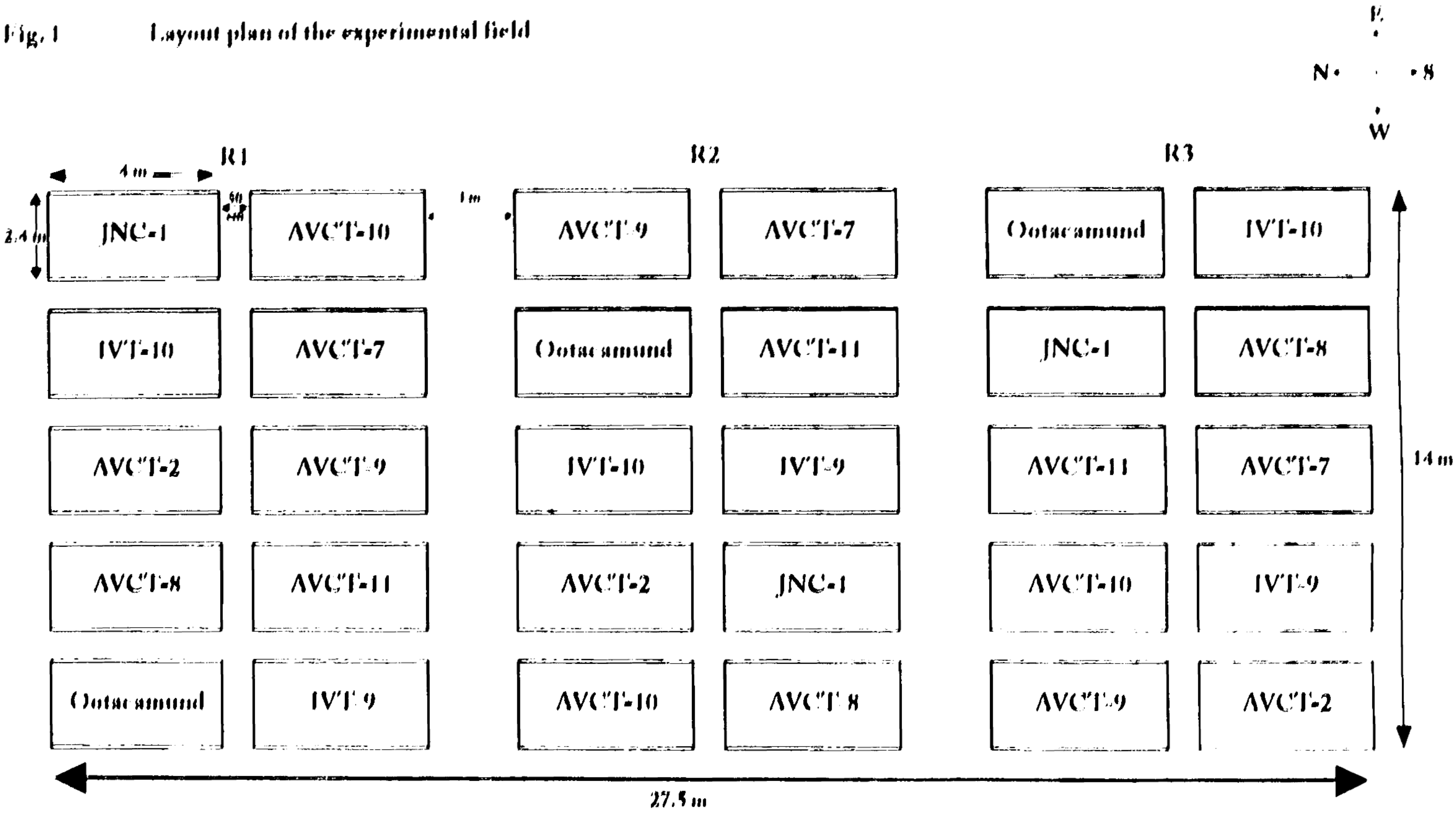
SN	Genotype
1	BNS-6
2	BNS-7
3	IGP-76 (NC)
4	NRS 96-3
5	BNS-1
6	BNS-8
7	BN-6
8	BNS-20
9	JNC-1
10	Ootacamund

3.3 EXPERIMENTAL DETAILS

The experiment was laid out in Randomized Block Design with three replications at all the three locations and the field layout has been depicted through Fig. 1. A brief details on the experiment have been presented below:

(a)	Number of environments (Locations)		Three viz., Indore, Dhar and Jhabua
(b)	Design		Randomized Block Design
(c)	Replication		3
(d)	Number of genotypes		10
(e)	Row spacing		30 cm
(f)	Plant spacing		10-15 cm
(g)	Plot size		
	(i) Gross		4 m x 2.4 m = 9.6 m^2 (8 rows)
	(ii) Net		3.5 m x 1.8 m = 6.3 m^2 (6 rows)
(h)	Total area		365 m^2

Fig. 1 Layout plan of the experimental field



* Same layout plant was followed in all the three locations

Table 2 Meteorological data during crop season under Indore condition

Location	Month	Av. Temp (°C)		Av. Relative humidity (%)	Total rainfall (mm)	No. of rainy days
		Min.	Max.			
Indore	Sept., 03	21.6	29.5	86.3	338.4	10
	Oct., 03	16.6	31.4	88.5	NIL	NIL
	Nov., 03	13.7	30.3	90.6	NIL	NIL
	Dec., 03	10.7	27.6	81.8	NIL	NIL
	Jan., 04	8.3	25.5	82.5	NIL	NIL
Dhar	Sept., 03	22.7	31.6	85.3	218.7	9
	Oct., 03	18.3	29.7	75.2	76.0	4
	Nov., 03	14.6	28.4	73.8	NIL	NIL
	Dec., 03	11.7	27.4	85.9	NIL	NIL
	Jan., 04	9.3	26.2	83.5	NIL	NIL
Jhabua	Sept., 03	23.7	30.5	83.6	301.6	12
	Oct., 03	17.5	31.5	73.5	97	5
	Nov., 03	13.5	30.7	76.0	NIL	NIL
	Dec., 03	11.5	28.5	82.1	NIL	NIL
	Jan., 04	10.4	26.5	87.5	NIL	NIL

Fig. 2 Meteorological data during crop season under Indore condition

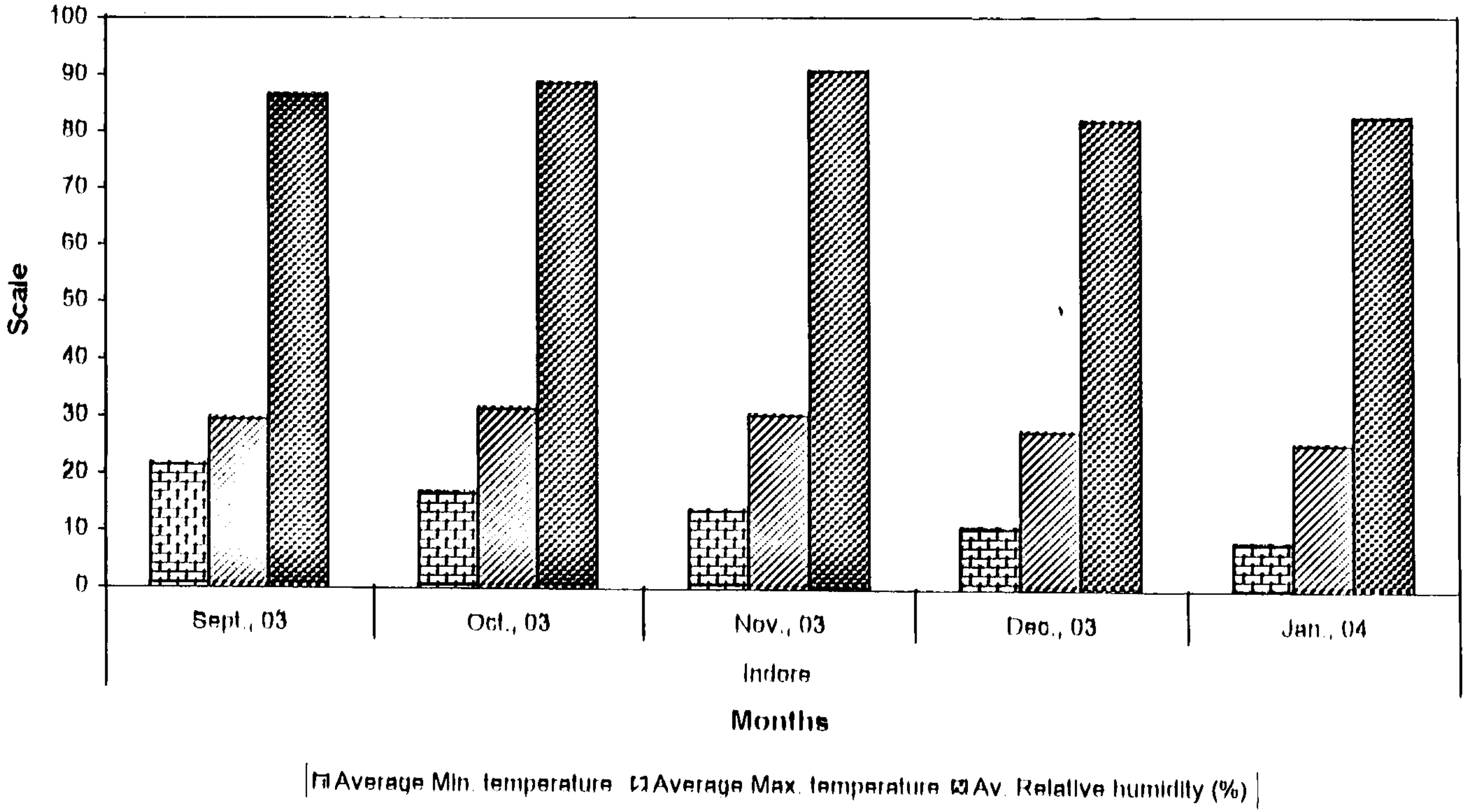


Fig. 3 Meteorological data during crop season under Dhar condition

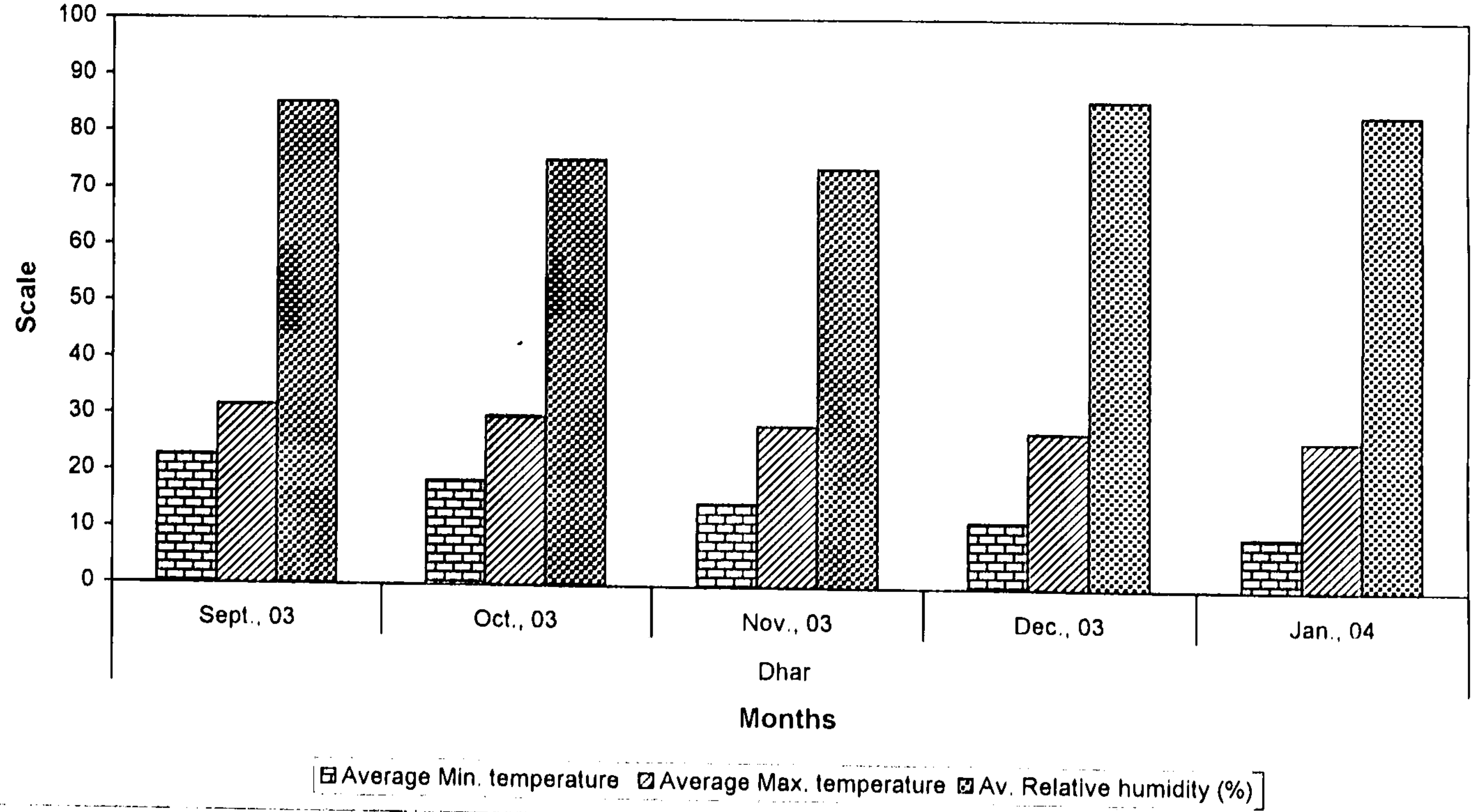
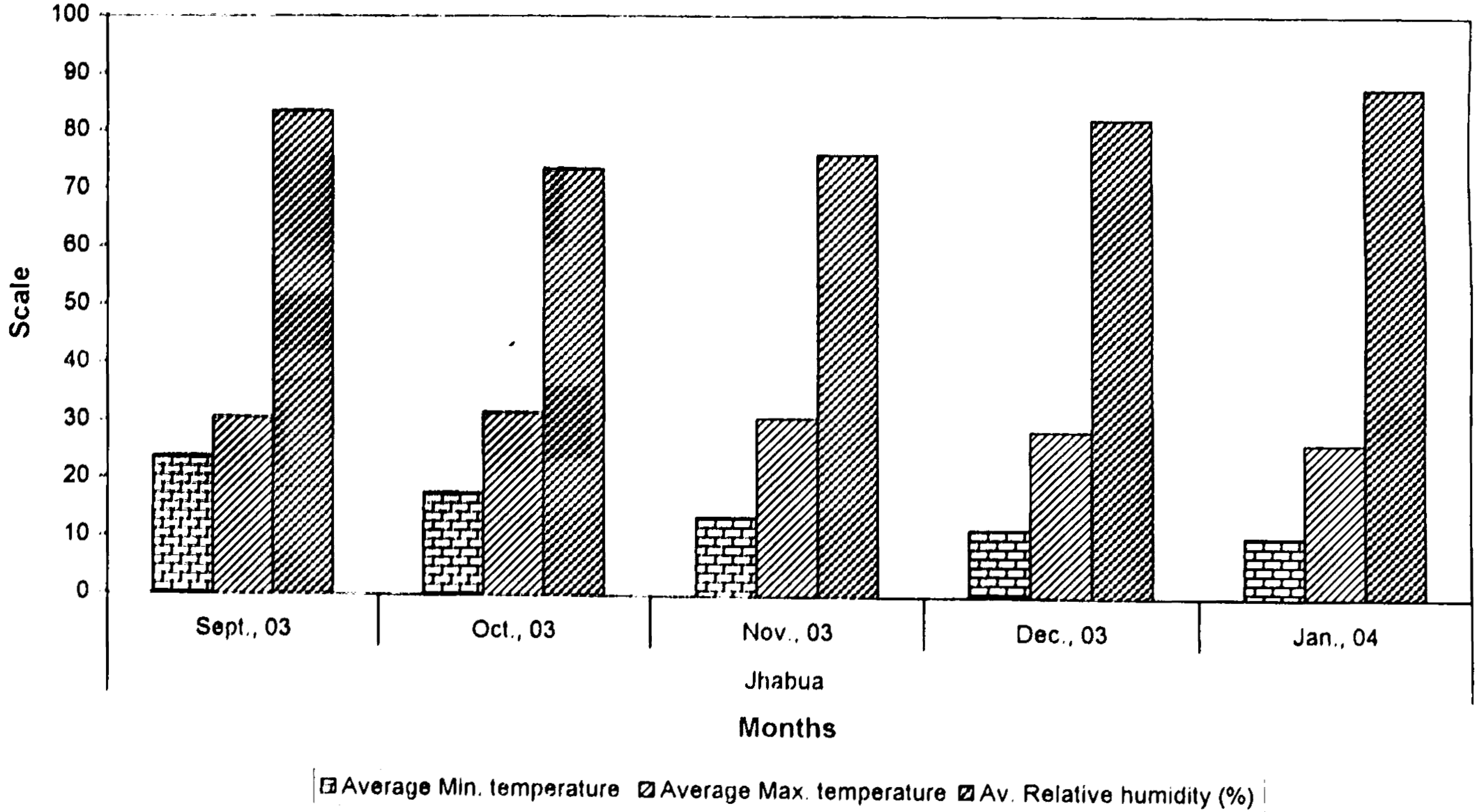


Fig. 4 Meteorological data during crop season under Jhabua condition



3.4 CULTURAL PRACTICES FOLLOWED

(a) Field preparation

The fields are ploughed thoroughly twice followed by 2 harrowings and planking to obtain optimum soil tilth for even depth of seed placement and subsequent emergence.

(b) Seed rate

Five kg per ha is the recommended seed rate for the line sowing based on this 50 g of seed per plot per variety (9.6 m^2) was used.

(c) Time of sowing

The sowing time has great impact on growth and development of the crop, which directly influences the yield. The correct sowing date for the Madhya Pradesh is between 2^{nd} week of July to the second week of August hence the crop was sown in the second week of July.

(d) Plant geometry

To obtain an optimum plant population of 3.3 lakh per ha the crop was sown with a spacing of 30 x 10 cm.

(e) Manures and fertilizers

To improve the physical condition of the soil and for obtaining good yields well-decomposed farmyard manure (FYM) @ 5 t/ha was incorporated at the time of preparatory tillage. The recommended dose of chemical fertilizer for Madhya Pradesh is 10 kg N + 20 kg P_2O_5/ha at the time of sowing and 10 kg N/ha at 35 days after sowing. Based on these recommendations each plot was applied with 24 g urea + 120 g single superphosphate at sowing and second dose of 24 g urea was top dressed 35 days after sowing.

(f) Irrigation

Since the crop is totally raised as rainfed during the kharif season the irrigation was not given to the crop.

(g) Weeding and interculture

First weeding followed by thinning was done after 20 days and second weeding was done 35 days after sowing.

(h) Harvesting

The crop was harvested when the leaves dried-up and head turned blackish in colour. After drying in sun for about a week by stacking at the threshing floor the crop was threshed by beating with stick.

Observations recorded

In order to record the observations, five competitive plants were selected from each plot in each replication in each location. The following observations were recorded on each selected plant, except for days to 50% flowering and days to maturity, which were recorded on. plot basis.

(i) Days to 50 per cent flowering

The period from the date of planting to the date when 50 per cent of the plants in a plot were in bloom was recorded and expressed in number of days.

(ii) Days to maturity

The period from the date of sowing to the date of ripening was recorded and expressed in number of days.

(iii) Plant height (cm)

The height of the plant was recorded in cm from the ground level to the tip of the main stem at the time of maturity.

(iv) Number of primary branches per plant

The number of primary branches borne on the main stem was recorded at maturity.

(v) Number of capitulums per plant

The effective number of capitulums (head) per plant was counted at the time of harvest.

(vi) Seed yield per plant

Total seeds per plant were weighed in gram.

(vii) Seed yield per plot (g)

The seed yield per plot was weighed in gram.

(viii) 1000 seed weight (g)

One hundred seeds drawn randomly were weighed in gram and the seed w eight was recorded.

(ix) Biological yield per plant

The total dry weight (seed yield + weight of straw) per plant was recorded in g.

(x) Harvest index

The harvest index was calculated by using the following formula:

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The data obtained from five plants were averaged to get mean per plant. These means were subjected to location wise analysis of variance followed by pooled analysis. The data were analysed for the design of experiment following the standard procedure given by Panse and Sukhatme (1967).

Analysis of variance

The mean values for each character of individual variety were based on competitively selected five plants from each replication for computation of environment analysis. The format of ANOVA is presented below:

SN	Source of variation	df	Mean squares	Expectation of mean squares
1.	Replications	2		
2.	Genotypes	9	M_1	$\sigma_e^2 + r\sigma_g^2$
3.	Error	18	M_2	σ_e^2

Pooled analysis of data

One of the requirements before we pool the data to perform pooled analysis over locations was testing homogeneity of error variances. For testing homogeneity Barlett's test was used as follows:

Let there be n mean squares. S_1^2. S_2^2 .... S_n^2 based on K_1, K_2 .... Kr degree of freedom. From these values a pooled estimate of variance (S^2) was calculated.

$$\bar{S} = \frac{1}{\sum_{n}^{n} Kr} \left(\sum_{1}^{n} Kr\, Sn^2 \right)$$

Next the quantity χ^2 was calculated

$$\chi^2 = \left(\sum_{1}^{n} Kr \right) \log_e \bar{S}^2 - \sum_{1}^{n} Kr \log_e S_n^2$$

For convenience, the logarithm was taken to the base 10 and the result was multiplied by $\log_e 10$ that is 2.3026 to get the quantity χ^2. The χ^2 is distributed approximately as χ^2 with (n-1) degree of freedom, but is slightly biased upwards. This was corrected by dividing the χ^2 by correction factor. The correction factor is computed as:

$$C = 1 + \frac{N + 1}{3nk}$$

The quantity χ^2/C was then referred to the χ^2 table with (n-1) degree of freedom. Significance of χ^2 suggested that the error mean squares were heterogeneous and vice versa.

The data from the three locations were then pooled to estimate the genotype x environment interaction. The ANOVA for combined analysis of variance is given below:

SN	Source of variation	df	MSS	Expected MSS
1	Environment (e)	(e-1) = 2		
2	Genotypes (g)	(g-1) = 9	M_{11}	$\sigma_e^2 + r\sigma_{ge}^2 + re\sigma_g^2$
3	G x E	(g-1)(e-1) =18	M_{12}	$\sigma_e^2 + r\sigma_{ge}^2$
4	Pooled error	M = 60	M_{13}	σ_e^2

The mean sum of squares due to genotypes and environments were tested against mean sum of squares due to genotypes x environments. The mean sum of squares due to genotypes x environments was tested against pooled error.

Estimation of pooled error

The mean sum of squares due to error obtained in each individual environment were utilized and pooled error was calculated as follows:

$$\text{Pooled error} = \frac{(n_1\text{-}1)\,(\text{error MS } E_1) + \text{----} \,(n_e\text{-}1)\,(\text{error MS } E_e)}{(n_1\text{-}1) + (n_2\text{-}1) + \text{--------------------} \,(n_e\text{-}1)}$$

Where,

n_1 -1	=	error degree of freedom in first environment.
N_e - 1	=	error degree of freedom in e^{th} environment,
error MS E_1	=	MSS due to error for 1^{st} environment, and
error MS E_e	=	MSS due to error for e^{th} environment

Further, the error mean square is calculated using pooled error as below:

$$\text{Error mean square} = \frac{\text{Pooled error}}{\text{No. of replications}}$$

Now, the error mean square was used to test the significance of variance due to genotypes x environments. In case the mean sum of squares due to genotypes x environment was found significant; the analysis was further proceeded for the estimation of stability parameters.

Analysis for stability parameters

Stability analysis was done for those characters, which manifested significant genotype x location interaction. For this purpose following model proposed by Eberhat and Russell (1966) was used:

$$Y_{ij} = \mu_i + b_i . I_j + \delta_{ij}$$

Where,

Y_{ij}	=	The mean of i^{th} variety in j^{th} location
		(I = 1, 2.......v and j =1, 2.........n)
μ_i	=	The mean of i^{th} variety overall the locations.

b_i = Regression coefficient that measures the response of the i^{th} variety in varying environments.

I_j = Environmental index for j^{th} location, which is defined as the deviation of the mean of all the varieties for given environment from the overall mean i.e.

$$I_j = \left(\sum_i \frac{Y_{ij}}{g}\right) - \left(\frac{\sum_i \sum_j Y_{ij}}{ge}\right) \qquad \sum_j I_j = 0$$

and,

δ_{ij} = The deviation from regression of the i^{th} variety in j^{th} environment.

Stability parameters

The parameters of stability were calculated as below:

(a) The regression coefficient which is the regression of the performance of each variety under different environments on the environmental means overall the genotypes. This was estimated as follows:

$$b_i = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

where,

$\sum_j Y_{ij} I_j$ = The sum of product between variety and environmental index,

and

$\sum_j I_j^2$ = The sum of squares of all the entire environmental index.

To obtain bi values for all varieties following matrix as suggested by Singh and Chaudhary (1977) was used.

$[\bar{X}]\,[I_j] = [Y_{ij}\, I_j] = [S]$

where,

$[\bar{X}]$ = Matrix of means

$[I_j]$ = Vector for environmental index

[S] = Vector for sum of products i.e. $\sum_j Y_{ij} I_j$

(b) The other parameter to estimate stability of the varieties was a function of squared deviations form regression ($S_d{}^2$) which was estimated as follows:

$$S_{di}{}^2 = \left[\frac{\sum_j \delta_{ij}{}^2}{n-2} \right] - \left[\frac{S_e{}^2}{r} \right]$$

Where,

$$\sum_j \delta^2{}_{ij} = \left[\frac{\sum_j Y_{ij}{}^2 - Y_i{}^2}{n} \right] - \frac{\left(\sum_j Y_{ij} I_j \right)^2}{\sum_j I_j{}^2}$$

and $S_e{}^2$ = The estimate of pooled error (or the variance of the variety mean of j^{th} location)

Skeleton for appropriate analysis of variance proposed by Eberhart and Russell (1966) presented in Table 3.

Significance for the environment (linear) indicates significant differences among the locations. Significance of genotype x environment (linear) suggests that the b_i values of different genotypes are significantly different from each other. Significance of pooled deviations indicates that the varieties deviated from their b_i values at different environments.

Table 3 Skeleton of analysis of variance for stability analysis as per the Eberhart and Russell's stability model (1966)

SN	Source	df	SS	MS
1	Genotypes	(g-1) = 9	$\frac{1}{e}\sum_{i} Y_{i}^{2} - CF$	MS₁
2	Environment + (varieties x environment)	(e-1) + (g-1) (e-1) = 18	$\frac{\sum_{i}\sum_{j} Y_{ij}^{2} - \sum_{i} Y_{i}^{2}}{e}$	
3	Env. (linear)	1	$\frac{1}{g}\frac{\left(\sum_{j} Y_{ij} I_{j}\right)^{2}}{\sum_{j} I_{j}^{2}}$	
4	Variety x Env. (linear)	(g-1) = 9	$\sum_{i}\frac{\left[\sum_{j} Y_{ij} I_{j}\right]^{2}}{\sum_{j} I_{j}^{2}} - Environ.(linear)SS$	MS_2
5	Pooled deviations	g(e-2) = 10	$\sum_{i}\sum_{j} \delta_{ij}^{2}$	MS_3
	Genotype 1	(e-2) = 1	$\sum_{j} \delta_{ij}^{2}$	
	Genotype 2	(e-2) = 1	......	
	Genotype g	(e-2)	......	
	.....	......	......	
6	Pooled error	e (r-1) (g-1) = 60		MS_4
7	Total	Ge-1 = 89	$\sum_{i}\sum_{j} Y_{ij}^{2} - CF$	

According to Eberhart and Russell (1966) a variety can be considered as stable if it meets following requirements

(i) High mean yield (x)
(ii) B = 1 and
(iii) S_d^2 approaching zero

CHAPTER – 4

RESULTS

The experimental findings of stability performance of ten niger genotypes under three locations of Madhya Pradesh, viz., Indore, Dhar and Jhabua and over locations have been summarized under the following heads:

4.1 Analysis of variance

4.2 Pooled analysis of variance

4.3 Analysis of variance for stability parameters as per the Eberhart and Russell's phenotypic stability model (1966).

4.4 Estimation of stability parameters

4.5 Stability of traits

4.1 Analysis of variance

The analysis of variance was carried out for 10 traits viz., days to 50 per cent flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, 1000 seed weight (g), yield per plant (g), yield per plot (g), biological yield (g) and harvest index (%) for each location separately. The data (Table 4.1) showed that the variance due to varieties were highly significant for all the characters except for number of capsules in Dhar and for days to maturity, 1000 seed weight, seed yield per plant, biological yield per plant and harvest index in Jhabua.

4.2 Pooled analysis of variance

Prior to carry out the pooled analysis of variance, the test of homogeneity of error variances of three locations was applied for each character by utilizing the Bartlett's method (1937) appeared in Dabholkar (1992). The estimated χ^2 values (chi square values) were less than the table value at 5 per cent level of significance.

Table 4 Analysis of variance (location-wise) for various characters in niger

Location	Source of variation	d.f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
			Mean sum of squares									
Jhabua	Replication	2	0.0	0.7	326.065	25.501**	135.249	1.742*	2.266*	3338.909	4.8	227.99*
	Varieties	9	11.792**	40.829**	308.602	2.248	79.515	2.512**	1.538**	3160.085	10.162**	180.89**
	Error	18	0.59	0.329	184.068	1.423	43.256	0.325	0.399	1884.859	2.096	51.56
Dhar	Replication	2	0.1	0.233	77.714	0.825	21.468	0.198	0.206	746.834	14.533*	27.77
	Varieties	9	7.292**	18.42**	515.202**	7.617**	111.016	2.667**	2.685**	4951.097	16.018**	105.78**
	Error	18	0.359	0.862	52.819	0.663	47.862	0.087	0.182	507.599	3.829	24.71
Indore	Replication	2	1.23	0.133	335.964	2.161	19.987	0.172	0.544	3440.275	3.633	278.48*
	Varieties	9	7.866**	28.477**	521.712**	6.205**	197.150**	3.046**	1.985**	5342.335**	35.959**	399.00**
	Error	18	0.677	0.577	102.659	1.133	12.514	0.089	0.250	1051.237	9.114	76.34

* Significance at 5 per cent
** Significance at 1 per cent

The pooled analysis of variance was carried out to get the information about the genotypes x environment interactions for each character. The differences among varieties were highly significant for all the characters studied (Table 5). The locations under study showed highly significant difference for days to 50 per cent flowering (7.314), days to maturity (11.24), number of capsules per plant (63.20), biological yield per plant (9.67) and harvest index (82.8), while number of branches per plant (1.40), 1000 seed weight (0.23) and yield per plot (1204.39) were significant at 5 per cent probability level. however. the remaining two traits viz., plant height (103.09) and seed yield per plant (0.26) were non significant. The mean sum of square due to genotype x environment interaction was highly significant for all he traits under study.

4.3 Analysis of variance for stability parameters as per the Eberhart and Russell's phenotypic stability model (1966)

The variation due to environment (linear) was highly significant for all the traits except for plant height (128.49) and seed yield per plant (2408.78), which showed significant difference at 5 per cent probability level. The mean sum of squares due to genotypes x environments (linear) were highly significant for all the characters except for harvest index (34.11). The pooled deviations were highly significant for all the traits except for days to 50 per cent flowering (0.463) and seed yield per plot (965.973). It was non significant for seed yield per plant (0.178) (Table 6).

4.4 Estimation of stability parameters

To determine the regression coefficients and to find out the favourable environment for the expression of any trait the environmental index is needed to be estimated. The data in Table 7 indicated that the values of environmental index under Jhabua were negative for days to 50 per cent flowering (-0.722) days to maturity (-0.544), plant height (-3.685), number of branches per plant (-0.112), number of capsules per plant (-1.798). 1000 seed weight (-0.108), seed yield per plant (-0.013) seed

Table 5 Pooled analysis of variance for various characters in niger

Source of variation	d.f.	Mean sum of squares									
		Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
Environments	2	7.314**	11.248**	103.019	1.402*	63.209	0.230*	0.260	1204.394*	9.677**	82.86**
Varieties	9	7.909**	26.691**	151.886**	3.351**	42.590**	1.955**	1.409**	1513.747**	5.209**	86.37**
Var. x Env.	18	0.537**	1.276**	148.309**	1.002**	43.318**	0.393**	0.330**	1485.349**	7.751**	71.09**
Pooled error	60	0.181	0.196	37.727	0.357	11.517	0.055	0.092	382.632	1.671	16.95

* Significance at 5 per cent
** Significance at 1 per cent

Table 6 Analysis of variance for stability parameters as per the Eberhart and Russell's stability model (1966)

Source of variation	d.f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
Varieties	9	7.909**	26.691**	151.886**	3.151**	42.590**	1.955**	1.409**	1513.747**	5.209**	86.37**
Environments	2	7.314**	11.248**	103.019	1.402*	63.209**	0.230*	0.260	1204.394*	9.677**	82.80**
Var. x Env.	18	0.537**	1.276**	148.309**	1.002**	43.318**	0.393**	0.330**	1485.379**	7.751**	71.09**
Env. (linear)	1	14.629**	22.496**	206.039*	2.804**	126.418**	0.461**	0.520**	2408.788*	19.355**	165.60**
Var. x Env. (linear)	9	0.548**	0.838**	128.495**	0.739	42.131**	0.347**	0.461**	1897.455**	8.778**	34.11
Pooled deviation	10	0.463*	1.543**	151.311**	1.118**	40.054**	0.395**	0.178	965.973*	6.052**	97.26**
Pooled error	60	0.181	0.196	37.727	0.357	11.517	0.055	0.092	182.632	1.671	16.95

yield per plot (-6.103) and biological yield per plant (-1.133) but it was positive for harvest index (2.454). At Dhar most of the yield attributing characters viz., days to 50 per cent flowering (-0.222), days to maturity (-0.677), number of branches per plant (-0.305), number of capsules per plant (-1.074), seed yield per plant (-0.154), seed yield per plot (-6.565) and harvest index (-3.186) showed negative values. However, plant height (1.504), 1000 seed weight (0.173) and biological yield per plant (0.500) possessed positive values for environmental index.

At Indore, days to 50 per cent flowering (-0.944) and 1000 seed weight per plant (-0.065) exhibited negative environmental index, but rest of the characters viz., days to maturity (1.222), plant height (2.181), number of branches per plant (0.417), number of capsules per plant (2.872), seed yield per plant (0.167), seed yield per plot (12.669), biological yield per plant (0.633) and harvest index (0.712) possessed positive value for environmental index (Table 7).

The Eberhart and Russell's phenotypic stability model (1966) was applied to determine the stability parameters for characters possessing significant genotype x environment interaction.

The stability parameters for all characters have been given in Table 8. The stability parameters viz., **(i)** mean **(ii)** regression coefficient and **(iii)** deviation from regression (S^2d) for all the ten characters for each genotype were estimated and findings are presented in the following pages.

It was observed that the deviations from linearity were of different magnitude for most of the characters. The distribution of the genotypes in the quadrants has been depicted through Fig. 5 to 14.

4.4.1 Days to 50 per cent flowering

The grand mean value for this trait was 54.52.

The varieties BN-9 and Ootacamund had regression coefficient less than unity i.e. 0.81 and 0.79, with lower mean 53.88 and 52.66.

Fig. 5 Stability performance of genotypes for days to 50% flowering

OVER ALL MEAN = 54.52

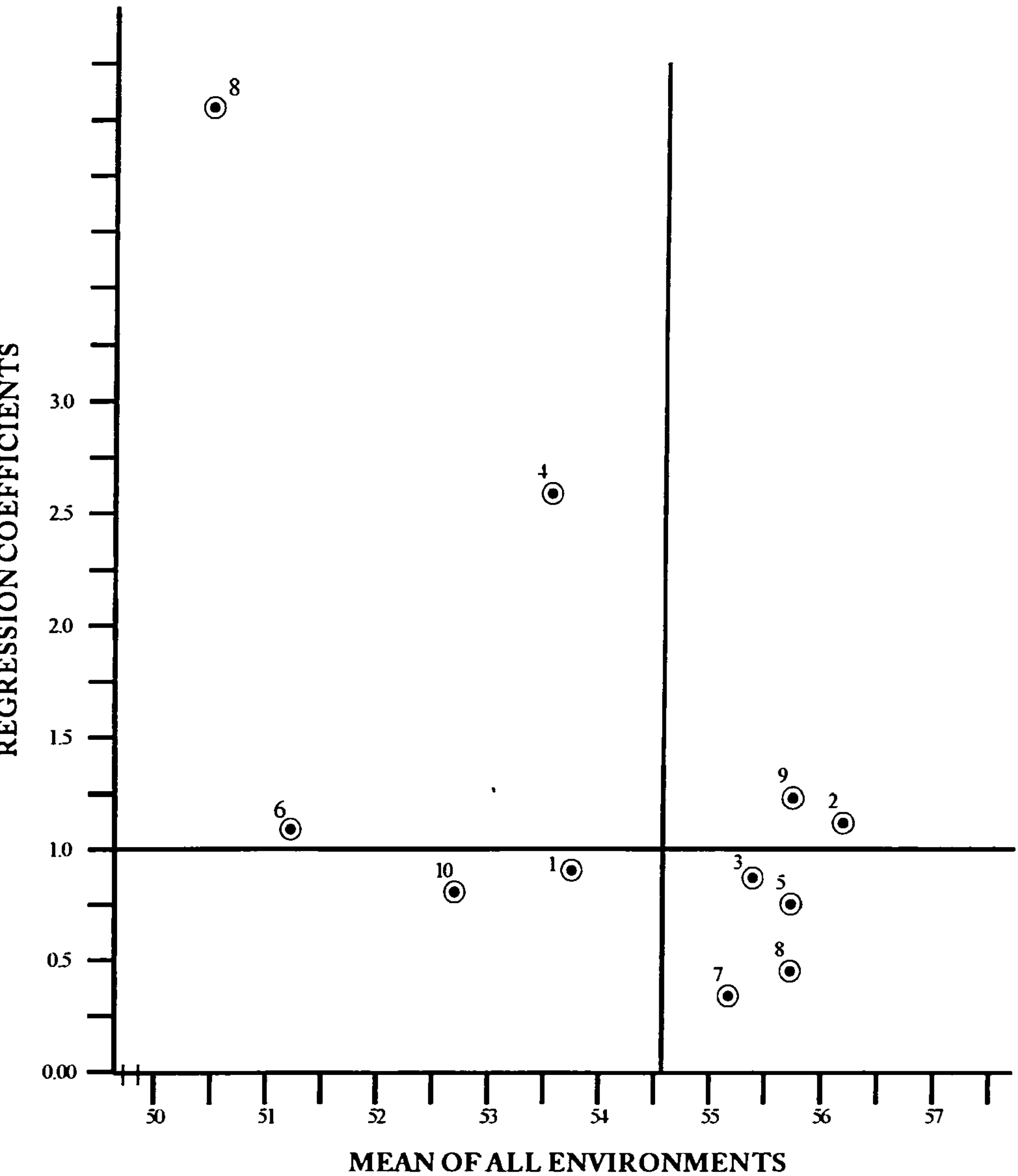


Table 7 **Environmental indices for various characters in niger**

SN	Characters	Jhabua	Dhar	Indore
1.	Days to 50% flowering	-0.722	-0.222	-0.944
2.	Days to maturity	-0.544	-0.677	1.222
3.	Plant height (cm)	-3.685	1.504	2.181
4.	No of branches / plant	-0.112	-0.305	0.417
5.	No. of capsules per plant	-1.798	-1.074	2.872
6.	1000 seed weight (g)	-0.108	0.173	-0.065
7.	Seed yield per plant (g)	-0.013	-0.154	0.167
8.	Seed yield /plot (g)	-6.103	-6.565	12.669
9.	Biological yield /plant (g)	-1.133	0.500	0.633
10.	Harvest index (%)	2.454	-3.186	0.712

respectively. than the grand mean and exhibited low value of deviation from regression (-0.17 and 0.35 respectively).

The genotypes BNS-7 and NRS 96-3 had regression coefficient above unity and were found associated with early flowering i.e. 53.55 and 51.22 respectively (Table 8).

Four varieties viz. BNS-1 (0.31). BNS-20 (0.49). IGP-76 (0.75) and BNS-6 (55.44) exhibited above average stability and were found to be associated with late flowering.

Varieties BNS-8 (1.12) and JNC-1 (1.24) showed below average stability but had delayed flowering.

4.4.2 Days to maturity

The grand mean value for this trait was 97.74.

Varieties JNC-1 (0.30). BNS-6 (0.38) and BNS-1 (0.38) possessed above average stability with early maturity i.e. 95. 96.88 and 96.88 respectively. and were also associated with low magnitude of deviation from regression.

Varieties BNS-7 (1.08) and NRS 96-3 (2.03) showed low mean with regression more than unity. but the variety NRS 96-3 possessed high value of deviation from regression i.e. 5.92.

The stability parameters presented in Table 8 and Fig. 6 revealed that varieties BNS-20 (0.74) and Ootacamund (0.74) possessed low regression coefficient. They also associated with late maturity.

A set of three varieties viz. IGP-76 (1.06). BN-9 (1.4) and BNS-8) (1.85) exhibited regression coefficient more than unity and associated with low deviation from regression along with late maturity.

4.4.3 Plant height (cm)

The grand mean value form this trait was 169.19.

Variety BNS-8 (0.82) was found to possess above average stability along with mean value (179.01) higher than the general mean and associated with low value of deviation from regression (-34.43).

Fig. 6 Stability performance of genotypes for days to maturity

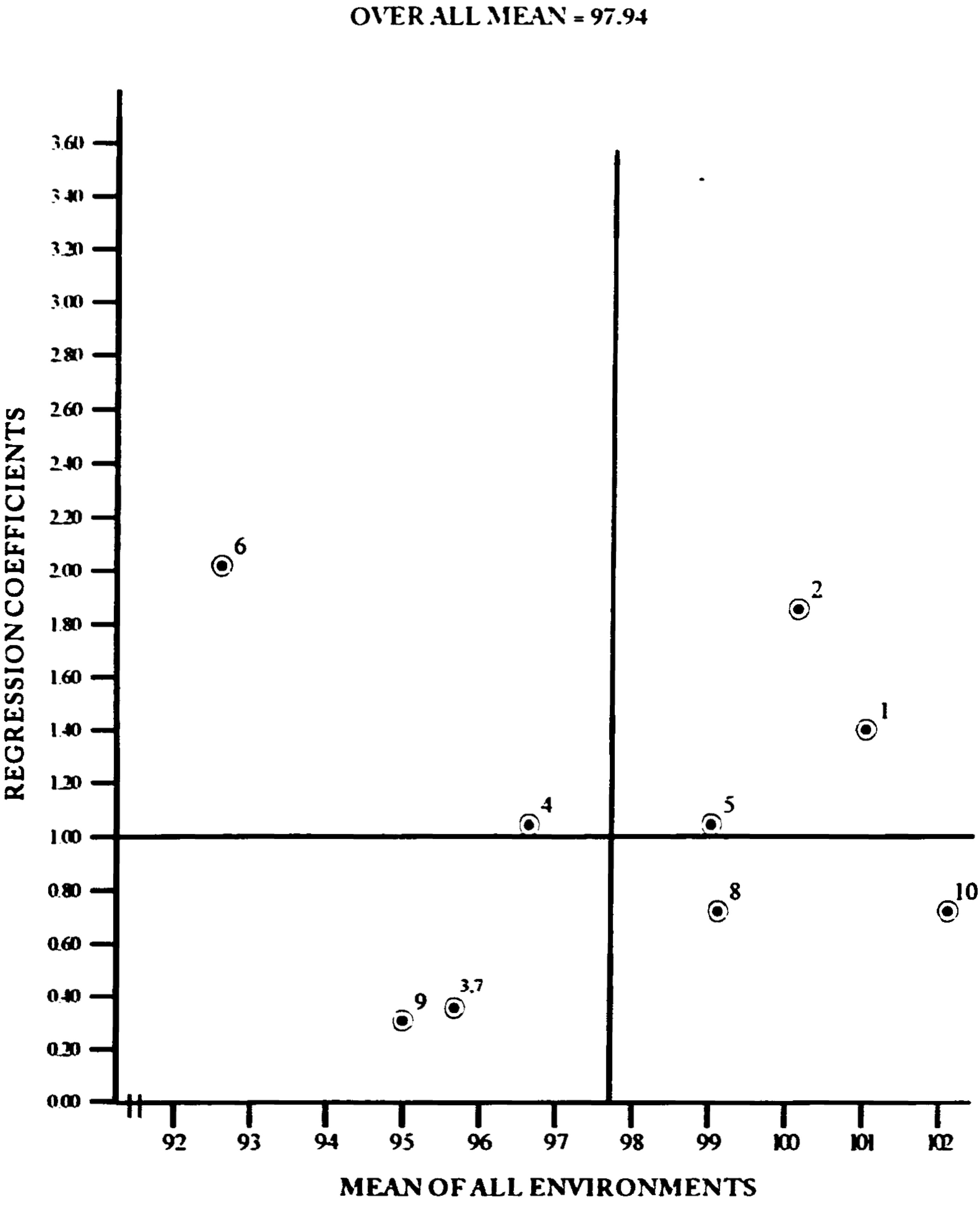


Fig. 7 Stability performance of genotypes for plant height

OVER ALL MEAN = 169.19

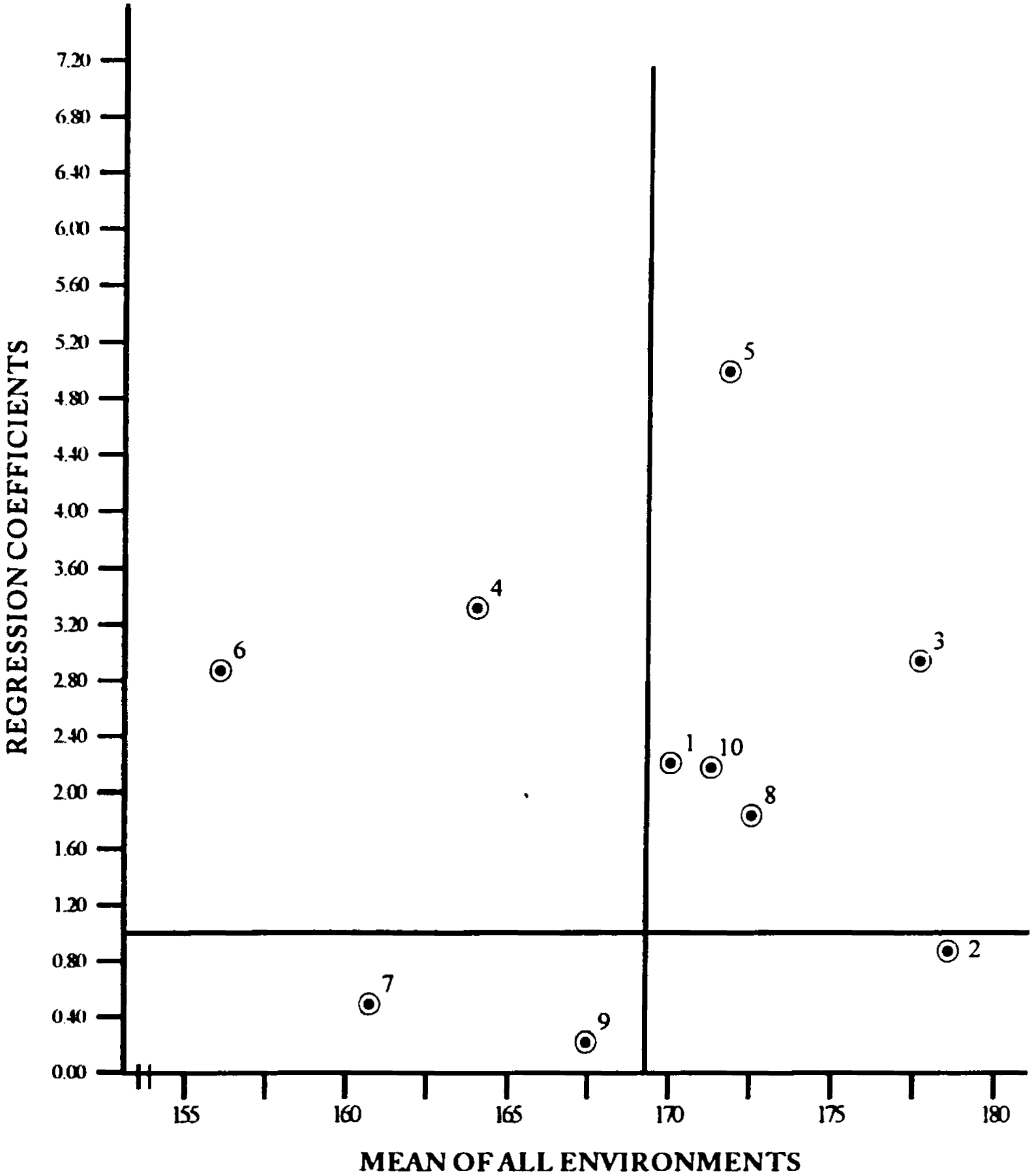


Table 8 Stability parameters for various characters in niger

SN	Varieties	Days to 50% flowering			Days to maturity			Plant height (cm)			No. of branches/plant		
		$\bar{X}$	b	S_d^2	$\bar{X}$	b	S_d^2	$\bar{X}$	b	S_d^2	$\bar{X}$	b	S_d^2
1.	BN-9	53.88	0.81	-0.17	101.00	1.40	0.35	170.04	2.24	62.61	9.66	3.92	0.02
2.	BNS-8	56.11	1.12	0.03	100.11	1.85	0.09	179.01	0.82	-34.43	11.64	2.94	0.05
3.	BNS-6	55.44	0.86	-0.17	95.88	0.38	-0.101	177.67	2.83	-24.92	11.18	0.44	-0.17
4.	BNS-7	53.55	2.55	0.62	96.66	1.08	-0.19	164.27	-3.26	-20.07	10.17	-0.49	2.15
5.	IGP-76	55.66	0.75	-0.15	99.00	1.06	-0.03	172.00	4.98	-31.96	11.00	0.45	-0.29
6.	NRS 96-3	51.22	1.03	0.17	92.66	2.03	5.92	156.94	2.90	-34.68	11.25	-0.24	1.25
7.	BNS-1	55.22	0.31	0.004	95.88	0.38	-0.101	160.11	-0.42	150.48	9.42	-0.69	-0.15
8.	BNS-20	55.66	0.49	-0.02	99.11	0.74	-0.11	172.65	1.83	140.18	8.24	0.30	-0.23
9.	JNC-1	55.77	1.24	-0.15	95.00	0.30	0.03	167.40	0.26	-33.86	10.17	2.85	-0.34
10.	Ootacamund	52.66	0.79	0.35	102.11	0.74	-0.11	171.80	-2.19	205.94	11.14	0.49	-0.10
	Mean	54.52			97.74			16.91			10.39		

contd….

X = Mean , b = Regression coefficient, S^2d = Deviation from regression

Table 8 Stability parameters for various characters in niger (contd....)

SN	Varieties	No. of capsules/plant			1000 Seed weight (g)			Seed yield per plant (g)		
		X	b	S_d^2	X	b	S_d^2	X	b	S_d^2
1.	BN-9	44.11	3.42	-7.06	3.61	-2.68	0.17	4.30	-3.86	0.22
2.	BNS-8	51.60	2.27	-11.47	3.85	1.94	0.004	4.24	-0.85	-0.08
3.	BNS-6	45.36	-0.68	78.41	4.72	5.59	1.132	5.35	-0.43	-0.03
4.	BNS-7	52.66	4.29	-9.15	3.74	-3.35	0.13	3.65	0.37	0.001
5.	IGP-76	44.84	0.37	-11.50	4.16	2.22	0.18	4.05	3.08	-0.06
6.	NRS 96-3	47.01	0.105	-11.00	5.40	1.80	-0.04	2.71	-0.35	-0.08
7.	BNS-1	44.74	0.88	-11.20	3.07	2.83	-0.023	3.84	5.99	-0.06
8.	BNS-20	42.91	-1.51	68.44	5.55	-0.59	-0.048	3.55	0.26	-0.07
9.	JNC-1	53.16	0.95	-11.09	4.65	-0.48	-0.025	3.81	0.50	-0.04
10.	Ootacamund	46.82	-0.106	10.77	5.75	2.71	-0.054	4.46	5.28	0.207
	Mean	47.32			4.25			4.00		

contd....

X = Mean , b = Regression coefficient, S^2d = Deviation from regression

Table 8 Stability parameters for various characters in niger (contd....)

SN	Varieties	Seed yield/plot (g)			Biological yield/plant (g)			Harvest Index (%)		
		$\bar{X}$	b	S_d^2	$\bar{X}$	b	S_d^2	$\bar{X}$	b	S_d^2
1.	BN-9	538.00	-0.69	412.21	14.77	5.35	-1.39	31.56	1.70	67.09
2.	BNS-8	566.89	1.36	-355.69	15.11	3.34	-1.65	29.08	1.74	28.96
3.	BNS-6	562.63	2.85	-309.47	13.4	1.80	-1.37	41.70	0.54	-4.37
4.	BNS-7	520.22	-2.30	397.35	14.22	-0.16	9.56	27.66	-0.87	14.88
5.	IGP-76	544.33	2.58	1017.92	13.11	-1.71	-1.15	32.39	-0.02	56.94
6.	NRS 96-3	496.90	2.40	-203.49	11.33	-0.13	2.31	25.47	0.42	0.10
7.	BNS-1	507.52	3.45	898.59	12.66	-0.65	-0.75	31.21	2.17	63.03
8.	BNS-20	547.12	4.61	-96.13	12.66	1.05	4.26	29.66	-0.25	12.01
9.	JNC-1	530.01	0.13	-375.89	14.55	1.69	-1.52	27.03	0.53	-14.35
10.	Ootacamund	543.59	-4.40	-381.85	11.55	-0.57	5.26	40.1	4.03	92.44
	Mean	535.72			13.33			31.59		

X = Mean , b = Regression coefficient, S^2d = Deviation from regression

Data depicted through Fig. 4 and Table 8 revealed that the set of five varieties viz., BNS-20 (1.83), Ootacamund (-2.19), BN-9 (2.24), BNS-6 (2.83) and IUP-76 (4.98) possessed higher mean values showing below average stability alongwith high values of deviations from regression except BNS-6 (-24.92) and IGP-76 (-31.96).

Varieties viz., JNC-1 (0.26) and BNS-1 (-0.42) showed above average stability alongwith low mean values for plant height than grand mean and in which BNS-1 was found associated with high magnitude of deviation from regression (150.48).

Two varieties viz., NRS 96-3 (2.9) and BNS-7 (-3.26) exhibited below average stability with low mean values.

4.4.4 Number of branches per plant

The grand mean value for this character was 10.39.

A very narrow range of regression coefficients was recorded for all the varieties, which have been presented in Fig. 8 and Table 8.

Varieties NRS 96-3 (-0.24), BNS-6 (0.44), IGP-76 (0.45) and Ootacamund (0.49) showed above average stability with high mean values for number of branches per plant (11.25, 11.18, 11 and 11.14, respectively).

It is obvious from Fig 8 and Table 8 that the variety BNS-8 (2.94) showed below average stability, which exhibited regression coefficient more than one with higher mean values than the general mean.

Varieties BNS-20 (0.30), BNS-7 (-0.49) and BNS-1 (-0.69) were observed to possess low mean values (8.24, 10.17 and 9.42, respectively) alongwith low magnitude of deviation from regression except BNS-7 (2.15).

Varieties exhibited below average stability with low mean values were JNC-1 (2.85) and BN-9 (3.92).

4.4.5 Number of capsules per plant

The grand mean value for this character was 47.32.

Fig. 8 Stability performance of genotypes for number of branches per plant

OVER ALL MEAN = 10.39

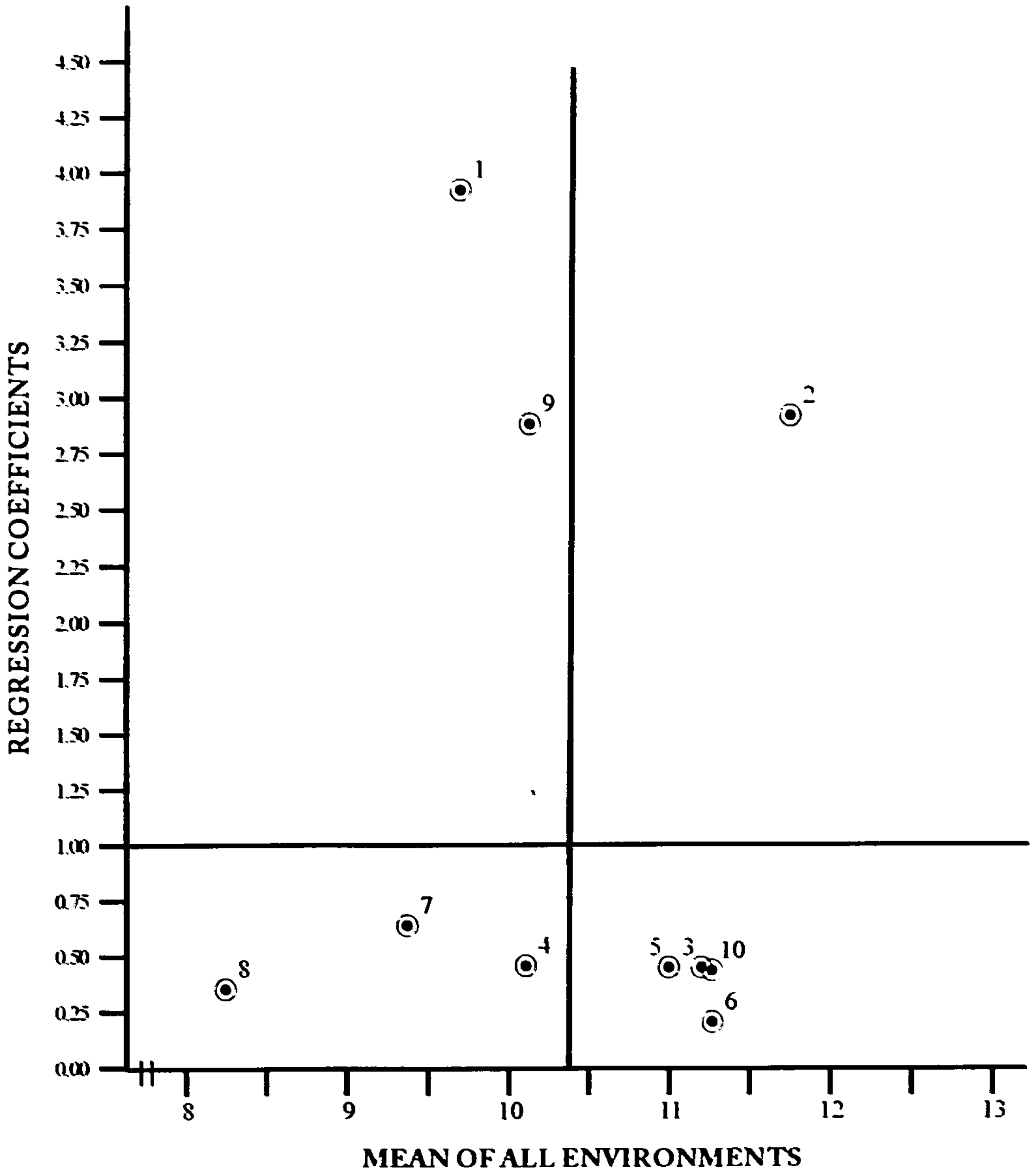
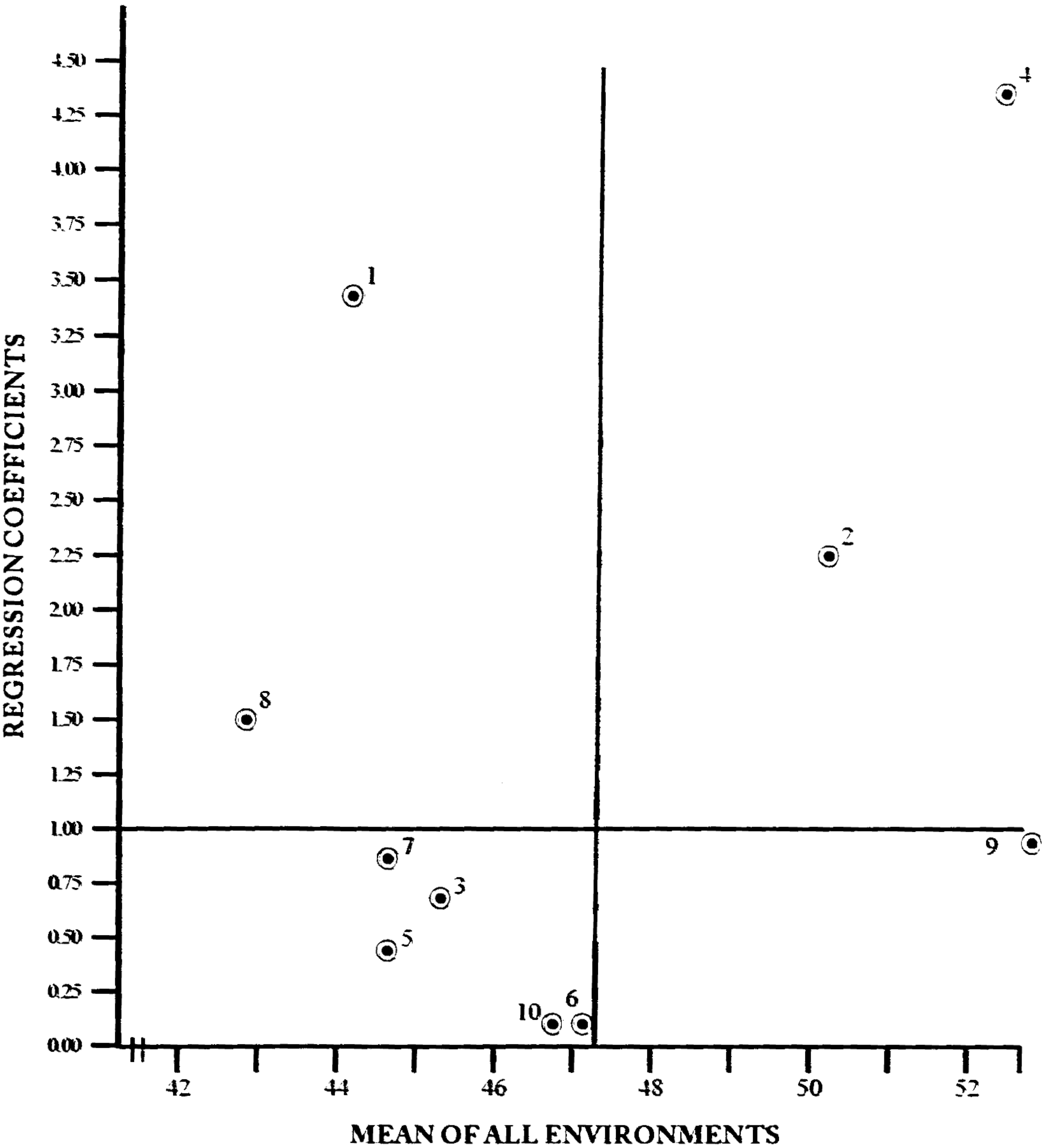


Fig. 9 Stability performance of genotypes for number of capsules per plant

OVER ALL MEAN = 47.32



The variety JNC-1 (0.95) was found to exhibit above average stability with high mean value (53.16) and high magnitude of deviation from regression (-11.09).

Varieties BNS-8 (2.27) and BNS-7 (4.29) had higher mean values (51.60 and 52.66, respectively) than the overall mean and below average stability. BNS-7 was found to have low value of deviation from regression (-9.15).

A set of five varieties viz., NRS 96-3 (0.105), Ootacamund (-0.106), IGP-76 (0.37), BNS-6 (-0.68) and BNS-1 (0.88) were found to possess lower mean values than the grand mean and exhibited above average stability. Among them, BNS-6 was associated with high value of deviation from regression (78.41).

Varieties BNS-20 (-1.51) and BN-9 (3.42) possessed lower mean values than the population mean and exhibited below average stability.

4.4.6 1000 seed weight (g)

The grand mean value for this character was 4.25.

Varieties JNC-1 (-0.48) and BNS-20 (0.59) exhibited above average stability for 1000 seed weight 4.65 and 5.55, respectively and were associated low value of deviation from regression (Fig. 10 and Table 8).

Two varieties viz., NRS 96-3 (1.8) and BNS-6 (5.59) had higher mean values than grand mean, regression coefficient greater than one and showed below average stability.

A group of six varieties viz., BNS-8 (1.94), IGP-76 (2.22), BN-9 (-2.68), Ootacamund (2.71), BNS-1 (2.83) and BNS-7 (-3.35) exhibited below average stability and possessed lower mean values than the grand mean.

4.4.7 Seed yield per plant (g)

The grand mean value for the character was 4.00.

Varieties BNS-6 (-0.43) and BNS-8 (-0.85) exhibited above average stability with higher mean values (5.35 and 4.24, respectively) than the

Fig. 10 Stability performance of genotypes for 1000 seed weight

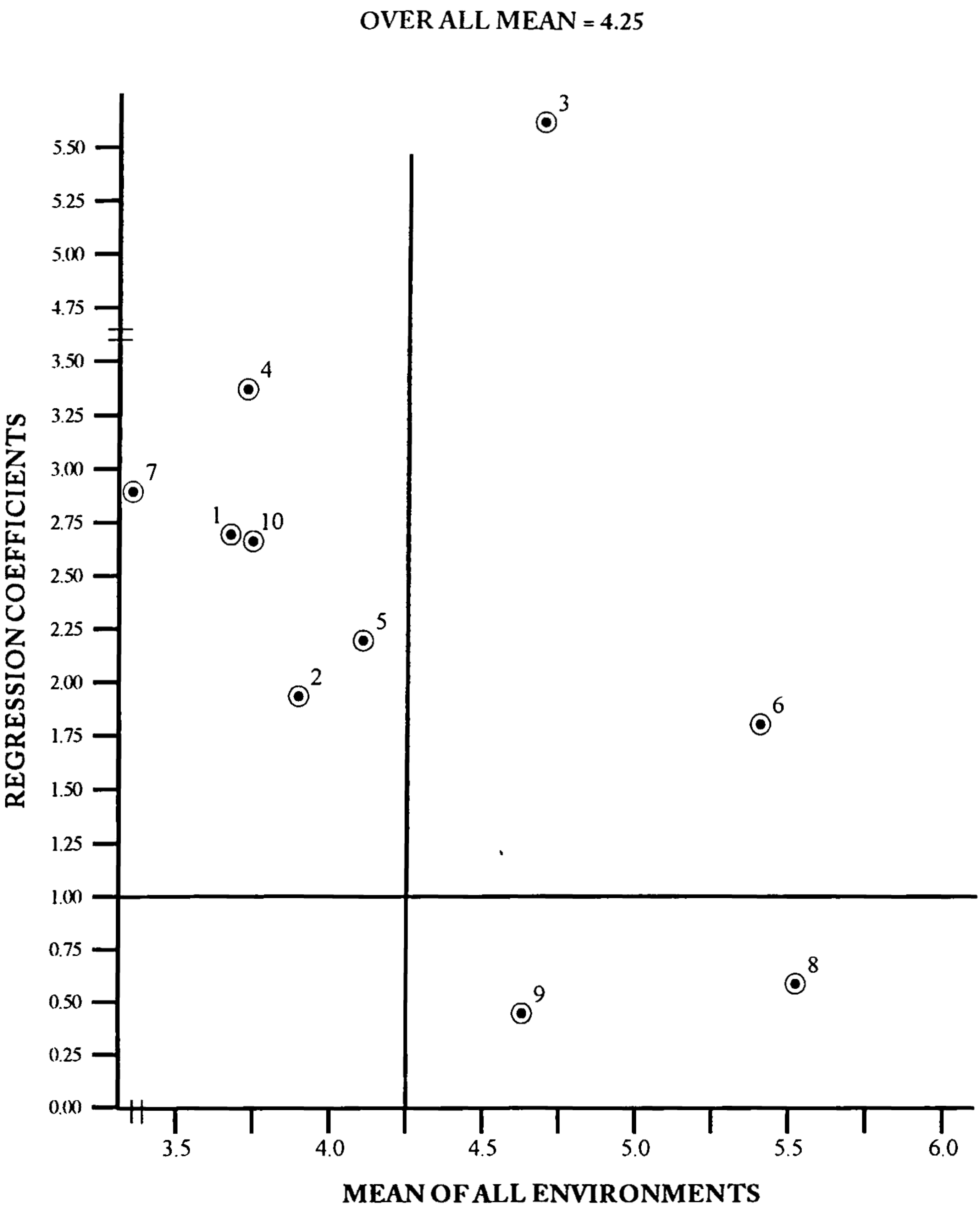
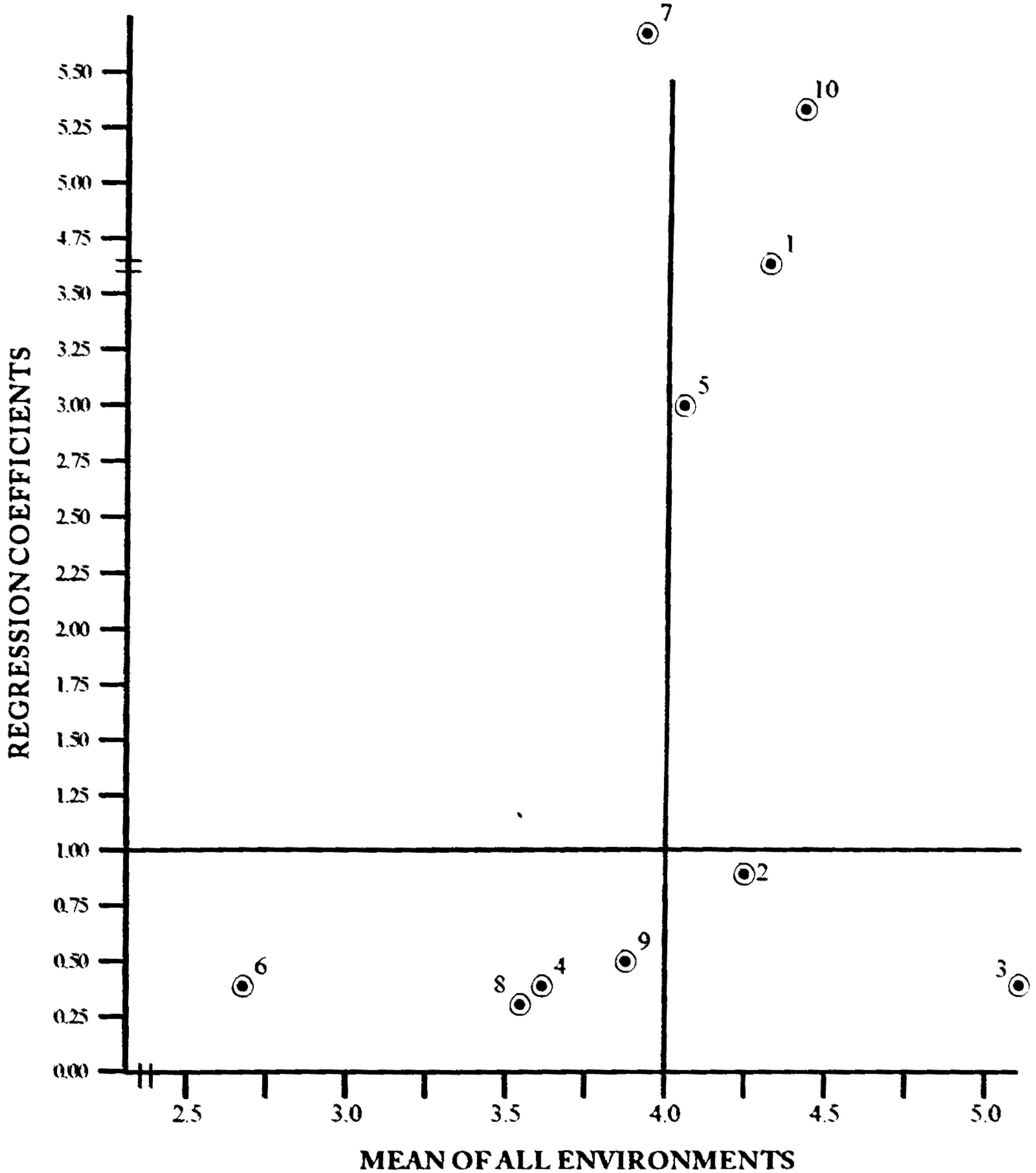


Fig. 11 Stability performance of genotypes for seed yield per plant

OVER ALL MEAN = 4.00



general mean. Both of them were found associated with low value of deviation form regression (-0.03 and –0.08, respectively), on the other hand IGP-76 (3.08), BN-9 (-3.86) and Ootacamund (5.28) showed below average stability associated with higher mean and larger deviation from regression (except IGP-76).

Varieties BNS-20 (0.26), NRS 96-3 (-0.35), BNS-7 (0.37) and JNC-1 (0.50) exhibited above average stability with low mean and low deviations from regression.

The variety BNS-1 (0.26) had below average stability coupled with low mean (Fig 11 and Table 8).

4.4.8 Seed yield per plot (g)

The grand mean value for this character was 535.72.

Variety BN-9 (-0.69) possessed regression coefficient less than one and exhibited above average stability with high mean value (538.00) and possessed high magnitude of deviation from regression (412.21).

A set of five varieties viz., BNS-8 (1.36), IGP-76 (2.58), BNS-6 (2.85), Ootacamund (-4.40) and BNS-20 (4.61) showed below average stability with high mean values than the grand mean. They all exhibited high value of deviation from regression (except BNS-20).

Variety JNC-1 (0.13) possessed above average stability and low mean value but high value of deviation from regression.

Three varieties viz., BNS-7 (-2.30), NRS 96-3 (2.40) and BNS-1 (3.45) showed below average stability and low mean values (Fig 12 and Table 8).

4.4.9 Biological yield per plant (g)

The grand mean value for this character was 13.33.

The variety BNS-7 (-0.16) was found to exhibit above average stability with higher mean value (14.22) and high magnitude of deviation from regression (9.59).

Fig. 12 Stability performance of genotypes for seed yield per plot

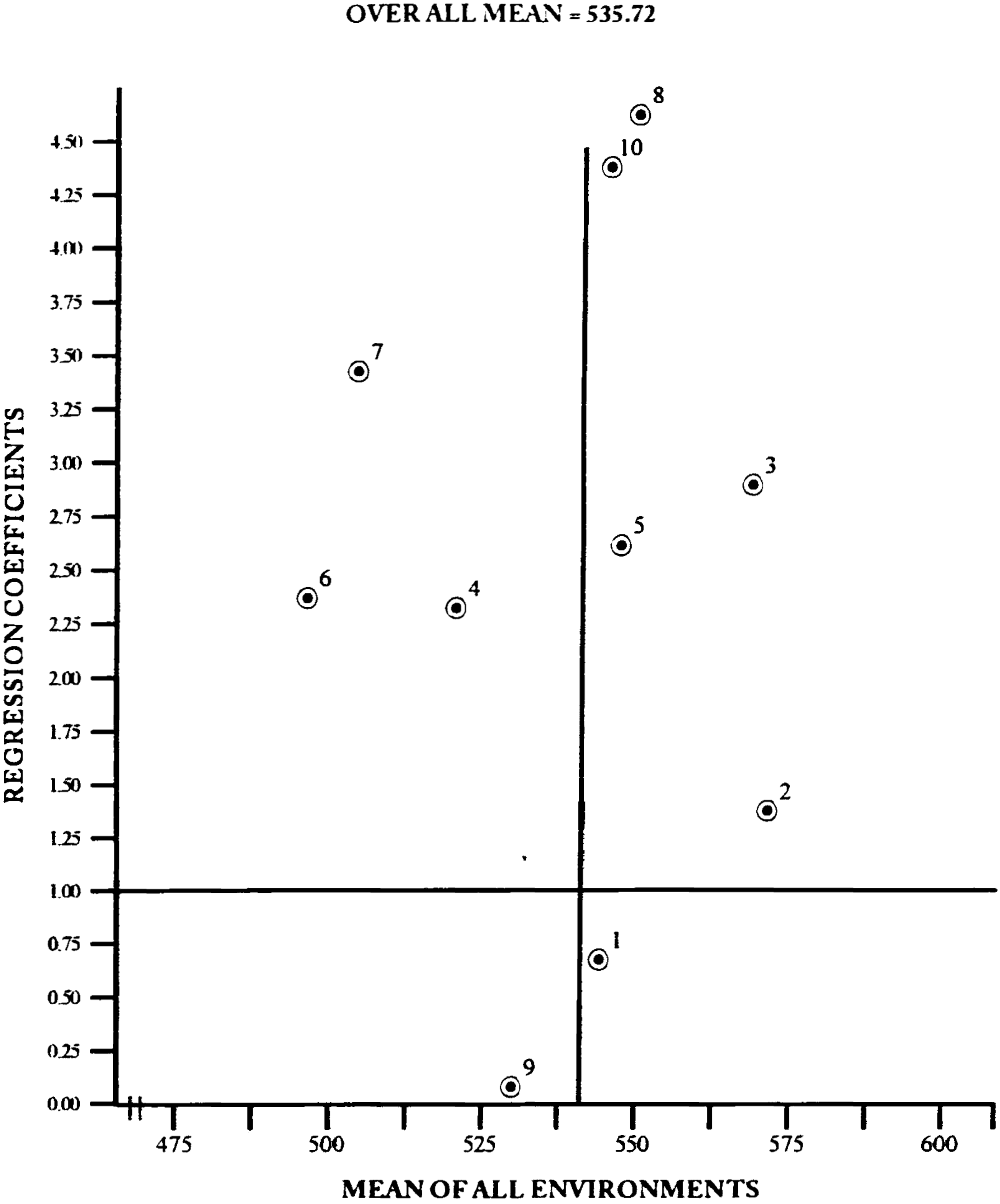
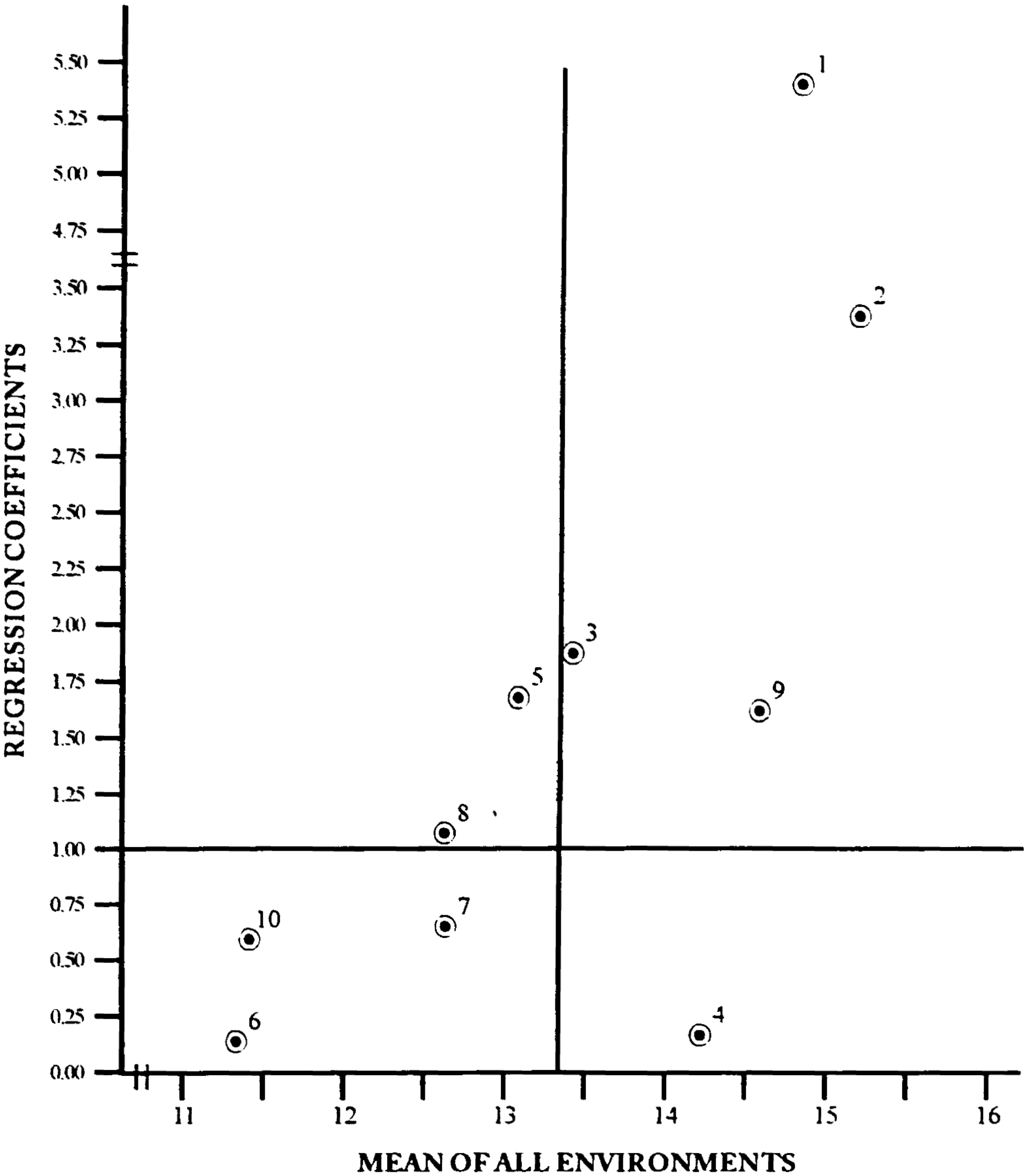


Fig. 13 Stability performance of genotypes for biological yield per plant

OVER ALL MEAN = 13.33



A set of four varieties JNC-1 (1.69), BNS-6 (1.8), BNS-8 (3.34) and BN-9 (5.35) had higher mean values than the overall mean and below average stability. All these varieties possessed low values of deviation from regression (Fig. 13 and Table 8).

Varieties NRS 96-3 (-0.13), Ootacamund (-0.57) and BNS-1 (-0.65) were found to possess lower mean values than general mean and exhibited above average stability and were found associated with high value of deviation from regression except BNS-2 (-0.75).

Varieties BNS-20 (1.05) and IGP 76 (-1.71) possessed lower mean values than the population mean and exhibited below average stability.

4.4.10 Harvest index

The grand mean value for this character was 31.59.

Varieties IGP-76 (-0.02) and BNS-6 (0.54) exhibited above average stability with higher mean values (32.39 and 41.70, respectively) than the general mean. The later one was found associated with high value of deviation from regression (-4.37). On the other hand, variety Ootacamund (4.03) showed below average stability associated with higher mean and large deviation from regression. Varieties BNS-20 (-0.25), NRS 96-3 (0.42), JNC-1 (0.53) and BNS-7 (-0.87) exhibited above average stability with low mean and high magnitude of deviation from regression.

A group of three varieties i.e. BN-9 (1.70), BNS-8 (1.74) and BNS-1 (2.17) had below average stability coupled with low mean (Fig 14 and Table 8).

4.5 Stability of traits

A perusal of data in Table 9 indicated that the traits namely days to maturity, number of branches per plant, 1000 seed weight and seed yield per plant showed least variation over locations (on the basis of mean performance). The mean values for days to maturity were 97.2, 97.06 and 98.96; for number of branches per plant, 10.28, 10.08 and 10.81; for 1000 seed weight, 4.14, 4.42 and 4.19. Seed yield per plant were 3.98, 3.84 and 4.16 respectively under Jhabua, Dhar and Indore conditions.

Fig. 14 Stability performance of genotypes for harvest index

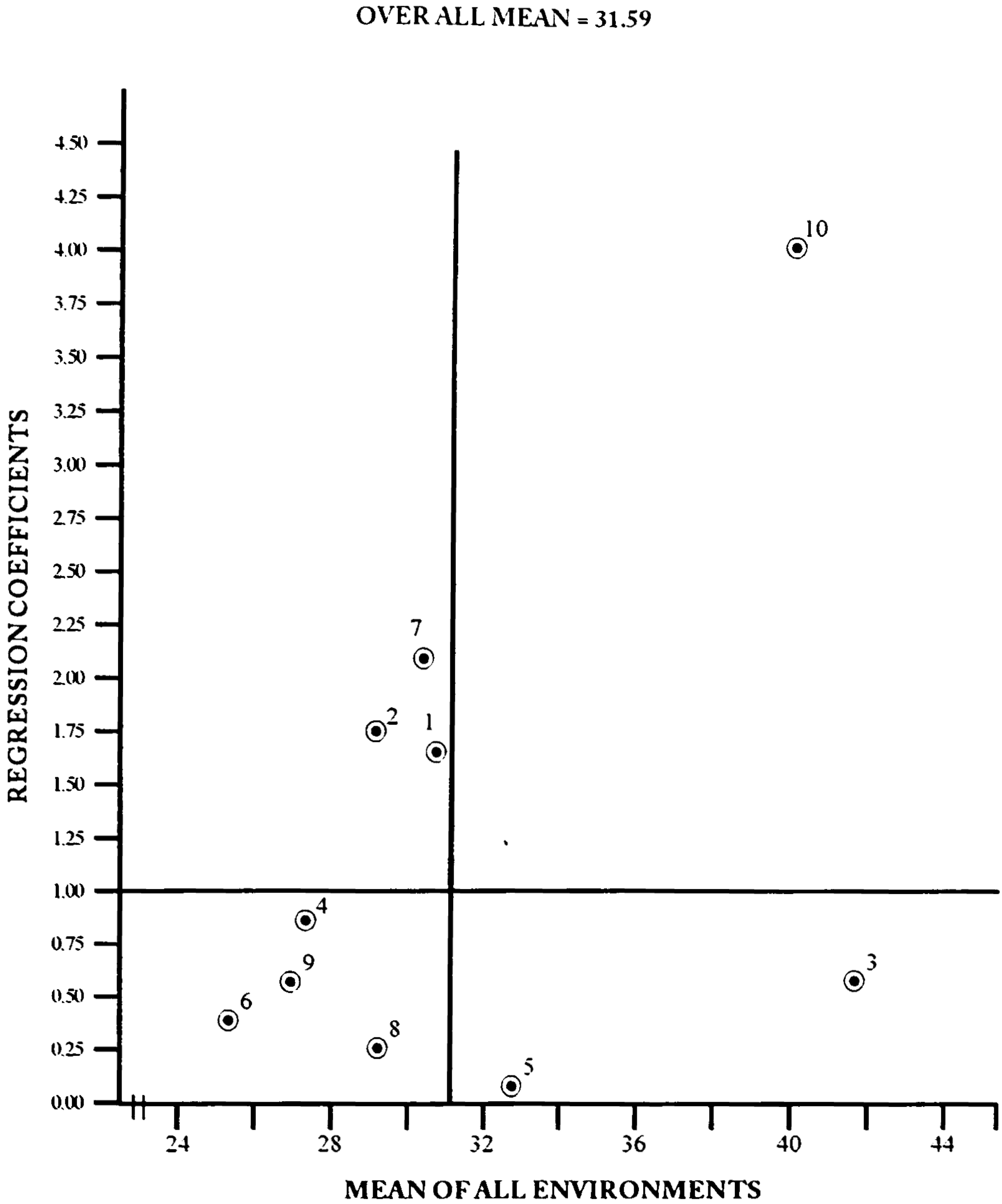


Table 9 **Mean value of traits in each location**

SN	Characters	Jhabua	Dhar	Indore
1.	Days to 50% flowering	53.8	54.3	55.46
2.	Days to maturity	97.2	97.06	98.96
3.	Plant height (cm)	165.50	170.69	171.37
4.	No of branches / plant	10.28	10.08	10.81
5.	No. of capsules per plant	45.52	46.25	50.19
6.	1000 seed weight (g)	4.14	4.42	4.19
7.	Seed yield per plant (g)	3.98	3.84	4.16
8.	Seed yield /plot (g)	529.62	529.16	543.39
9.	Biological yield /plant (g)	12.20	13.83	13.96
10.	Harvest index (%)	34.04	28.42	32.30

CHAPTER – 5

DISCUSSION

When genotypes are compared over environments, the relative ranking usually differs. Such change in order, ranking and relative values among genotypes over several environments are due to the phenomenon of genotype x environment (GxE) interaction. The GxE interaction is a limitation in most plant breeding programmes engaged in improvement of qualitative attributes like seed yield. The occurrence of GxE interaction has provided a challenge to better understanding of genetic control of variability and thus, to rationalization of procedures for breeding improved genotypes in crop plants (Breese, 1969). These interactions are usually present under all genetic status of a genotype including pure lines, single cross or double cross hybrids top crosses, or any other material used for breeding (Eberhart and Russell, 1966). In this context, it is necessary to pay attention in reducing and characterizing the G x E interaction and in controlling it, so as to develop genotypes with desired response at varying environmental conditions.

Varietal adaptability to environmental fluctuations is important for stabilization of crop production both over regions and years. Adaptability is the ability of a genotype to give relatively narrow range of phenotypes in different environments. However, stability reflects the suitability of a variety for general cultivation over wide range of environments. In the evolutionary terms, the breeders' objective is to develop variety/population that are better adapted in a given environment (Simmonds, 1962). In view of this, the present investigation entitled "Adaptation analysis for yield and its attributes in niger (*Guizotia abussinica* Cass)" was conducted over three locations viz., Indore, Dhar and Jhabua to evaluate the stability parameters using Eberhart and Russell's phenotypic stability model (1966), for ten characters viz., days to 50 per cent flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, 1000 seed weight (g), yield per plant (g), yield per plot (g), biological yield per plant (g) and harvest index (%).

The discussion regarding different aspects of the present experiment has been furnished under the following heads:

5.1 Analysis of variance

5.2 Pooled analysis of variance

5.3 Analysis of variance for stability parameters as per Eberhart and Russell's phenotypic stability model (1966).

5.4 Estimation of stability parameters

5.5 Stability of traits

5.1 Analysis of variance

At Indore none of the genotype showed non significant difference for any of the trait studied, however at Dhar the mean sum of squares due to genotypes were highly significant for all the traits except for number of capsules per plant and seed yield per plant. In Jhabua days to 50 per cent flowering, days to maturity, 1000 seed weight, seed yield per plant, biological yield per plant and harvest index registered marked genotypic differences indicating the presence of notable genetic variability among the experimental material under study.

5.2 Pooled analysis of variance

Prior to carry out the pooled analysis of variance, the test of homogeneity of error variance of three locations was applied for each character by utilizing the Bartlett's method (1937) appeared in Dabholkar (1992) and the error mean squares at different locations were found homogeneous from findings. The pooled analysis of variance revealed that the differences among varieties were highly significant, it indicated that the experiment was conducted under variable environments, which has been further confirmed by the highly significant differences for all the characters under different locations (barring plant height and seed yield per plant). The mean sum of squares due to genotype x environment interaction were highly significant for all the characters under study suggesting the occurrence of prominent genotype x environment interaction indicating differential performance of varieties under different environments.

5.3 Analysis of variance for stability parameters as per the Eberhart and Russell's stability model (1966)

Both linear and non linear components of G x E interaction were significant for all the traits except for harvest index. However, in most of the characters linear component was of higher magnitude, suggesting the differential yield potential of genotypes in different environments and feasibility of stabilized production of niger genotypes across the environments. The significant pooled deviation was observed for all the characters barring days to 50 per cent flowering and seed yield per plot suggesting that the genotypes differ considerably with respect to their stability for different characters.

5.4 Estimation of stability parameters

The environmental index is needed to be estimated for determining the regression coefficient. The environmental index under Jhabua were found to be negative for all the characters except harvest index. Hence Jhabua can be considered unfavourable for the expression of all the traits under study. Similarly, Dhar also exhibited negative values for most of the characters except for plant height, 1000 seed weight and biological yield per plant which possessed positive values for environmental index. In Indore only two characters viz., 50 per cent flowering and 1000 seed weight exhibited negative value for environmental index and rest of the traits possessed positive values for the environmental index.

The positive values of environmental index suggested that the environment is favourable for the expression of those traits however the negative indices indicated a negative role of the environment in the expression of that traits. An overall observation of the environmental index for each location suggested that Indore location could be regarded as the most favourable one as it is showing positive values of environmental index for most of the yield contributing characters.

The Eberhart and Russell's (1966) phenotypic stability model was applied to compute the stability parameters viz., mean, regression coefficient and deviation from regression for all the ten characters of each genotypes. The stable genotype is one having high mean, unit regression coefficient and smallest deviation from regression. The stability parameters for each character have been discussed character wise here below:

5.4.1 Days to 50 per cent flowering

The varieties BN-9 and Ootacamund exhibited above average stability and high mean value with low value of deviation from regression. Hence, they were considered the most desirable for general environment for this trait under favourable environment, BNS-7 and NRS 96-3 varieties were found suitable and stable.

A group of four genotypes viz., BNS-1, BNS-20, IGP-76 and BNS-6 were found to be more desirable for poor environment which showed late flowering. Varieties JNC-1 and BNS-8 observed to be highly unstable as they exhibited below average stability and possessed high mean values.

In case of days to 50 per cent flowering the GxE interaction was found significant. On partitioning of it, into linear and non linear components, both components were found equally responsible for expression of this traits. However, linear component was higher in magnitude than non linear component, suggesting prediction can be possible across the environment. Verulkar and Upadhyay (1989) have reported preponderance of linear component of G x E interaction. However, Upadhyay (1993), Kumar *et al.* (1993, 1997 and 1998) and Patil (2001) reported major role of non linear component of G x E interaction.

5.4.2 Days to maturity

For any set of environment, the genotypes JNC-1, BNS-6 and BNS-1 performed better and proved to be stable with low mean value for days to maturity. For favourable environment, NRS 96-3 and BNS-7 were considered as the most desirable genotypes because of poor environment. Genotypes viz., BNS-20 and ootacamund were considered as the most suitable because of their high mean value for days to maturity with below average stability. Varieties IGP-76, BN-9 and BNS-8 observed to be unsuitable to any specific environment as they exhibited below average stability with low mean value.

GxE interaction was non linear in nature, suggesting that prediction for days to maturity across the environment is not possible. Variance due to GxE non linear was higher than linear GxE interaction variance. Similar results were reported by Upadhyay (1993) and Goswami *et al.* (2000), however, Verulkar and Upadhyay (1989), Kumar *et al.* (1993, 1994 and 1998) Hegde *et al.* (1999, 2000), Patil *et al.* (2000) and Patil (2001) have reported maximum role of linear component of G x E interaction in the expression of days to maturity in niger.

5.4.3 Plant height (cm)

Genotype BNS-8 was considered to be the most stable variety as it had regression coefficient near to unity with low deviation from regression and was measured having tall statured plant.

Varieties BNS-20, Ootacamund, BN-9, BNS-6 and IGP-76 were found to be better under specific environment with taller plant. JNC-1 and BNS-1 were found to be stable in poor environment. Two varieties viz., NRS 96-3 and BNS-7 exhibited below average stability. Hence, these were not desirable and stable under any specific environment.

Further, it was found that the non linear component G x E interaction was having higher magnitude value than linear component showing the non predictability of the trait across the environments. The above findings were contradictory to the findings of earlier workers viz., Verulkar and Upadhyay (1989), Upadhyay (1993), Kumar *et al.* (1993, 1994 and 1998), Patil *et al.* (1999 and 2000) and Patil (2001) who reported the possibility of prediction with higher value of linear component.

5.4.4 Number of branches per plant

Varieties NRS 96-3, BNS-6, IGP-76 and ootacamund showed above average stability with high mean values for number of branches per plant. Hence, these were considered to be the most desirable under general environment. On the other hand, BNS-8 possessed regression coefficient near unity with low magnitude of deviation from regression. Hence, they were found suitable for favourable environments.

Varieties BNS-20, BNS-7 and BNS-1 performed better in poor environment because it possessed above average stability with high mean value and low deviation from regression. Two varieties viz., JNC-1 and BN-9 were found to be unstable and undesirable for any set of environments because the varieties exhibited below average stability and low mean values.

The information obtained from pooled analysis of variance suggested that the non-linear component was more than the linear component of GxE variance. This suggests the impossibility of prediction of branches per plant across the locations. Almost the same results were reported by Goswami *et al.* (2000). However, the findings of Verulkar and Upadhyay (1989), Upadhyay (1993), Hegde *et al.* (1999), Hegde *et al.* (2000) and Patil (2001) do not agree with the findings of the present investigation.

5.4.5 Number of capsules per plant

For number of capsules per plant, genotype JNC-1 was found stable under general environment. On the other hand, varieties BNS-8 and BNS-7 were observed to be stable and desirable for favourable environments.

A set of five varieties viz., NRS 96-3, Ootacamund, IGP-76, BNS-6 and BNS-1 were found to be suitable and desirable under poor environment with low mean value. Varieties BNS-20 and BN-9 possessed below average stability with low mean values and hence proved undesirable.

The variance due to non-linear GxE was more than the variance due to GxE linear and thus, suggesting that the prediction cannot be possible for this trait. The similar results were also reported earlier by Kumar *et al.* (1993) and Goswami *et al.* (2000). However, in contrast to the present findings Verulkar and Upadhyay (1989), Upadhyay (1993), Kumar *et al.* (1994), Hegde *et al.* (1999), Patil *et al.* (1999), Hegde *et al.* (2000), Patil *et al.* (2000) and Patil (2000) reported linear component to be of higher magnitude.

5.4.6 1000 seed weight (g)

Genotypes JNC-1 and BNS-20 were considered to be the most desirable as they exhibited above average stability alongwith low value of deviation from regression. Two varieties viz., NRS 96-3 and BNS-6 had regression coefficient nearer to unity alongwith larger value of deviation from regression and were suitable for poor environments.

Varieties BNS-8, IGP-76, BN-9, Ootacamund, BNS-1 and BNS-7 exhibited below average stability with lower test weight. Hence, these were not desirable and stable under any specific environment.

The information obtained from pooled analysis of variance suggests that the non-linear component was more than the linear component of G x E variance. This suggests that the prediction of the performance for this trait cannot be possible. The findings of Verulkar and Upadhyay (1989) and Upadhyay (1993) also confirm the above facts. However, the results of Kumar *et al.* (1993, 1994 and 1998) and Patil *et al.* (1999) are contradictory to the present results.

5.4.7 Seed yield per plant (g)

For this trait, varieties BNS-6 and BNS-8 exhibited above average stability with higher mean values. Hence, these can be considered as stable varieties for the general environment. Under specific environment genotypes IGP-76, BN-9 and Ootacamund were desirable and stable possessing high yield. Four genotypes viz., BNS-20, NRS 96-3, BNS-7 and JNC-1 performed better under unfavourable environment. Variety BNS-1 exhibited below average stability with regression coefficient more than unity and low mean values. Hence, this variety was not suitable for any specific environment.

The variance due to linear GxE interaction was higher than the non-linear variance. Hence, suggesting the prediction of seed yield is possible across the environment. Present findings pertaining to seed yield per plant was also found in conformity with the findings of Verulkar and Upadhyay (1989), Upadhyay (1993), Kumar *et al.* (1993 and 1994).

5.4.8 Seed yield per plot (g)

Variety BN-9 was the most desirable under a range of environments because it possessed high mean value showing above average stability. A set of five varieties viz., BNS-8, IGP-76, BNS-6, Ootacamund and BNS-20 were found suitable for favourable environments.

Variety JNC-1 performed better in poor environment because it possessed above average stability and was low yielding. A group of three varieties viz., BNS-7, NRS 96-3 and BNS-1 were found to be undesirable and unstable since they exhibited below average stability with low mean values.

In case of seed yield per plot the linear component of GxE interaction was higher in magnitude than non-linear component, which suggested prediction could be possible across the environment. Kumar *et al.* (1998), Hegde *et al.* (1999), Patil *et al.* (1999), Hegde *et al.* (2000), Patil *et al.* (2000), Patil and Purkar (2000), Goswami *et al.* (2000), Patil (2001) and Patil *et al.* (2002) have reported preponderance of linear component of GxE interaction. However Joshi and Patil (1982) reported major role of non-linear component of GxE interaction.

5.4.9 Biological yield per plant (g)

For any set of environment, the genotype BNS-7 performed and proved to be stable with high mean value.

For favourable environment, JNC-1, BNS-6, BNS-8 and BN-9 were considered as the most desirable genotype because of its higher mean value and below average stability.

For poor environment, NRS 96-3, BNS-1 and Ootacamund were considered as the most suitable and stable genotypes because of their lower mean values and low yield. Varieties BNS-20 and IGP-76 observed to be unsuitable to nay specific environment and they exhibited below average stability with low mean values.

In the present study, it can be concluded that the prediction of the performance is possible as the linear component of G x E was higher in magnitude as compared to that of non-linear component of G x E interaction.

5.4.10 Harvest index (%)

Genotypes IGP-76 and BNS-6 were considered to be the most stable variety as they had regression coefficient near to unity with high mean value.

Variety ootacamund was found to be better under specific environment with higher harvest index. Varieties BNS-20, NRS 96-3, JNC-1 and BNS-7 were found to be stable in poor environment.

Varieties BN-9, BNS-8 and BNS-1 exhibited below average stability with lower harvest index. Hence, these were not desirable and stable under any specific environment.

The above said results of stability parameters could be summarized as given in the following table.

SN	Character	Varieties for low yielding environment	Varieties for specific environment	Stable varieties
1	Days to 50% flowering	BNS-6 IGP-76 BNS-1 BNS-20	BNS-7 (Jhabua) NRS 96-3 (Jhabua)	Ootacamund BN-9
2	Days to maturity	BNS-20 Ootacamund	NRS 96-3 (Jhabua, Dhar) BNS-7 (Jhabua)	BNS-6 BNS-1 JNC-1
3	Plant height (cm)	BNS-1 JNC-1	BN-9 (Dhar) BNS-6 (Indore) IGP-76 (Dhar) BNS-20 (Indore) Ootacamund (Dhar)	BNS-8
4	Number of branches per plant	BNS-20 BNS-1 BNS-7	BNS-8 (Dhar)	BNS-6 NRS 96-3 IGP-76 Ootacamund

5	Number of capsules per plant	BNS-6 IGP-76 NRS 96-3 BNS-1 Ootacamund	BNS-7 (Indore) BNS-8 (Jhabua)	JNC-1
6	1000 seed weight per plant		BNS-6 (Indore) NRS 96-3 (Dhar)	JNC-1 BNS-20
7	Seed yield per plant	BNS-7 NRS 96-3 BNS-20 JNC-1	BN-9 (Dhar) IGP-76 (Indore) Ootacamund (Indore)	BNS-8 BNS-6
8	Seed yield per plot (g)	JNC-1	BNS-8 (Indore) BNS-6 (Indore) IGP-76 (Indore) BNS-20 (Indore) Ootacamund (Dhar)	BN-9
9	Biological yield per plant (g)	NRS 96-3 BNS-1 Ootacamund	BN-9 (Dhar) BNS-8 (Indore) BNS-6 (Indore) JNC-1 (Indore)	BNS-7
10	Harvest index	BNS-7 NRS 96-3 BNS-20 JNC-1	Ootacamund (Indore)	BNS-6 IGP-76

5.5 Stability of traits

Almost all the characters showed unstability over these three locations except days to maturity, number of branches per plant, 1000 seed weight and seed yield per plant, which possessed least variations in their performance along with low values of G x E interaction over three locations viz., Indore, Dhar and Jhabua.

CHAPTER – 6

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The present investigation was conducted at Experimental Farm, College of Agriculture, Indore (M.P.), Krishi Vigyan Kendra, Dhar (M.P.) and Krishi Vigyan Kendra, Jhabua (M.P.) to carryout "Adaptation analysis for yield and its attributes in niger (*Guizotia abyssinica* Cass)". This experiment comprised 10 genotypes of niger grown in three replications in a Randomized Block Design during kharif, 2003 at each location.

The data were collected for ten traits viz., days to 50 per cent flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, 1000 seed weight (g), seed yield per plant (g), seed yield per plot (g), biological yield per plant (g) and harvest index (%). The data were subjected to analysis of stability as per the method outlined by Eberhart and Russell (1966) to study the genotype x environment interaction over locations, to know the adaptability of genotypes for yield and its attributes over three locations and to find out the stability of traits over varying environmental conditions.

Analysis of variance for all ten characters in different locations revealed the significant differences for all the characters in Indore, for all the characters except for number of capsules in Dhar and for days to maturity, 1000 seed weight, seed yield per plant, biological yield per plant and harvest index in Jhabua.

The pooled analysis of variance indicated highly significant differences among different varieties for days to 50 per cent flowering, days to maturity, number of capsules per plant and biological yield per plant. Harvest index, number of branches per plant, 1000 seed weight, and yield per plot were significant at 5 per cent probability level, genotype x environment interaction was also found to be significant for all the characters under study.

The environment (linear) effect was significant for all the characters. The mean sum of squares due to genotype x environment (linear) were highly significant for all the traits except number of branches per plant and harvest index. The pooled deviations were highly significant for all the characters except for seed yield per plant.

At Jhabua, all the characters showed negative environmental index except harvest index. At Dhar, most of the yield contributing characters showed negative environmental index except plant height, 1000 seed weight and biological yield per plant, whereas under Indore conditions, almost all other traits viz., days to maturity, plant height, number of branches per plant, number of capsules per plant, seed yield per plant, seed yield per plot, biological yield per plant and harvest index possessed positive values of environmental index. An overall observation of the environmental index for each location indicated that Indore was the most favourable location for the expression of almost all the characters under study.

Under low yielding environment, variety BNS-1 found desirable for days to 50 per cent flowering, plant height, number of branches per plant, number of capsules per plant and biological yield per plant. Variety JNC-1 for plant height, seed yield per plant, seed yield per plot and harvest index; variety Ootacamund for days to maturity, number of capsules per plant, biological yield per plant; variety BNS-20 for days to 50 per cent flowering, days to maturity, number of branches per plant, seed yield per plant and harvest index; however, under specific environment, the varieties found to be desirable for various characters were: BNS-8 (number of branches per plant at Dhar, number of capsules per plant at Jhabua, seed yield per plot and biological yield per plant at Indore), BNS-6 (plant height, seed yield per plot, biological yield per plant at Indore and 1000 seed weight at Jhabua), NRS 96-3 (days to 50 per cent flowering, days to maturity at Jhabua and 1000 seed weight at Dhar), BN-9 (plant height, seed yield per plant and biological yield per plant at Dhar), BNS-7 (days to 50 per cent flowering, days to maturity at Jhabua and number of capsules per plant at Indore), IGP-76 (seed yield per plant and seed yield per plot at Indore and plant height at Dhar), BNS-20 (plant height and seed yield per plot at Indore).

Variety BNS-6 proved the most suitable and stable for days to maturity, number of branches per plant, seed yield per plant and harvest index; variety JNC-1 for days to maturity, number of capsules per plant and 1000 seed weight, variety BN-9 for days to 50 per cent flowering and seed yield per plot; variety BNS-8 for plant height and seed yield per plant; Ootacamund for days to 50 per cent flowering and number of branches per plant; IGP-76 for number of branches per plant and harvest index; NRS 96-3 for number of branches per plant; BNS-20 for 1000 seed weight; BNS-7 for biological yield per plot.

On the basis of *per se* performance traits namely days to maturity, number of branches per plant, 1000 seed weight and seed yield per plant were found to be most stable attributes over varying environmental conditions.

6.2 Conclusions

On the basis of the present investigation it can be concluded that there was sufficient and marked influence of environment on expression of characters as evident by the significance of genotype x environment interaction.

The varieties BNS-20, JNC-1 and BNS-1 were suitable for low yielding environment and BNS-8, Ootacamund and BNS-6 performed well under high yielding environments, but varieties BNS-6 and JNC-1 were found most suitable and desirable under a range of environment. On the basis of *per se* performance of the variety it could be concluded that BNS-20 was suitable at Indore and Ootacamund had superior performance at Jhabua and Dhar.

The traits viz., days to maturity, number of branches per plant, 1000 seed weight and seed yield per plant were most stable traits over varying environmental conditions.

6.3 Suggestions for further work

1. The genotypes with high stability for grain yield should be evaluated for stability of oil content.

2. A large number of genotypes should be included in this type of study in order to detect the genotypes suitable for different agro-climatic regions of the state.

3. The experiment should be conducted over years and under more number of locations to draw more valid conclusions.

REFERENCES

Allard, B.W. and Bradshaw, A.D. (1964). Implication of genotype x environmental interaction in applied plant breeding. *Crop Sci.*, 4:503-505.

Allard, R.W. (1961). Relationship between genetic diversity and consistency of performance in different environments. *Crop Sci.*, 1:127-133.

Borole, R.D., Patil, H.S. and Sharma, S.M. (1998). Selection of stable variety of niger for Maharashtra State. A paper presented in *"Fifth National Scientific Symposium in Hindi"* held at College of Agriculture, Gwalior 474 002 (M.P.), India, 10-12 January, 1998. Abstract No.12, pp.15.

Breese, E.L. (1969). The measurement and significance of genotype-environment interactions in grasses. *Heredity*, 24:27-44.

Comstock, R.I. and Moll, R.H. (1963). Genotype environmental interactions in statistical genetics and plant breeding. National Academy of Sciences, *National Research Council Publication*, 982:164-196.

Dabholkar, A.R. (1992). Elements of biometrical genetics. Concept Publishing Company, New Delhi: 345-350.

Eberhart, S.A. and Russell, W.L. (1966). Stability parameters for comparing varieties. *Crop Sci.*6: 34-40.

Finlay, K.W. and Wilkinson, G.N. (1963). The analysis of adaptation in a plant breeding programme. *Aust.J.Agric.Res.*,14:742-754.

Fisher, R.A. (1926). The arrangement of field experiments. *J. Ministry of Agricultrure*, 33:503-513.

Fisher, R.A. and Mackenzie, W.A. (1923). Studies in crop variation II. The manurial response of different potato varieties. *J.Agric.Sci. ,Cambridge*, 13: 311-320.

Goswami, U., Duhoon, S.S. and Singh, B.R. (2000). Stability performance of some yields attributes in niger (*G. abyssinica* Cass). A paper presented in national seminar on *"Oilseeds and oils Research and Development Needs in the millennium"*, held at DOR, Hyderabad during 2-4 February, 2000. Extended summaries Abstract No.69 p.107.

Hegde, D.M., Patil, H.S., Singh, B.R. and Goswami, U. (1999). Analysis of adaptation in niger (*Guizotia abyssinica* Cass). *Indian J. Agric. Sci.*, 69 (12): 813-816.

__________ (1999). Genotype x environment interaction in niger composites.
J. Maharashtra Agri. Univ., 24(3): 246-248.

__________ (1999). Phenotypic stability for seed yield in niger. *J. Oilseeds Res.* 16(2): 241-244.

__________ (2000). Phenotypic stability in niger (*Guizotia abyssinica* Cass). *Crop Res.*, 19 (1): 97-101.

Immer, F.R., Hayes, H.K. and Power Leroy (1934). Statistical determination of barley varietal adaptation. *J.Amer.Soc. Agron.*, 22:403-419.

Johanson, W. (1909). Elemental dor Exakten Erblickkoitalohru Int.Vol. 515, pp. *Jena, Gustav Fisher.*

Joshi, P.B. and Patil, R.C. (1982). Stability of grain yield in niger. *J. Maharashtra Agri. Univ.*, 7(2): 137-138.

Kumar, S., Mahto, J. and Prasad, K.D. (1998). Analysis of stability for yield and yield attributes in niger (*Guizotia abyssinica* Cass). *J. Oilseeds Res.*, 15(1): 18-24.

Kumar, S., Mahto, J., Prasad, K.D. and Kumar, Amrendra (1998). Genotype x environmental interaction stability analysis in niger.
J. Res. (Birsa Agric. Univ.), 10(1): 20-24.

Kumar, S., Singh, P.K. and Trivedi, H.B.P. (1993). Stability of yield and its components in niger. (*Guizotia abyssinica* Cass) in different growing conditions. *Oil Crop Newsletter*, 10: 71-73.

__________ (1994). Stability of yield and its components in niger (*Guizotia abyssinica* Cass). *J. Res.* (Birsa Agric. Univ.), 6(1): 1-5.

Luthra, O.P. and Singh, R.K. (1974). A comparison of different stability models in wheat. *Theor.appl.genet.*, 45: 143-147.

Misra, R.C., Pradhan, K., Paikaray, R.K., Sahu, P.K. and Panda, B.S. (1991). Seasonal adaptability of niger varieties. *Oil Crop Newsletter*, 8:26-27.

Panse, V.G. and Sukhatme, P.V. (1967). Statistical methods for agricultural workers. ICAR Publication, New Delhi.

Paroda, R.S., Karwasra, R.R. and Yadav, H.R. (1973). Production of phenotypic performance through genotype environment interaction studies in fqdder cowpea (*Vigna sinesis* Brak). Paper presented at the *Second Congress of SABRAO*.

Patil, H.S. (2001). Stability analysis in niger (*Guizotia abyssinica* Cass). *Crop Res.*, 21(2): 192-197.

Patil, H.S., Borole, R.D. and Purkar, J.K. (2000). Analysis of stability for seed yield and yield attributes in niger (*Guizotia abyssinica* Cass). *Indian J. Agric. Res.*, 34 (1): 63-66.

Patil, H.S. and Purkar, J.K. (2000). Analysis of stability for seed yield and oil content in niger. *J. Oilseeds Res.*, 17(1): 43-46.

Patil, H.S., Purkar, J.K. and Duhoon, S.S. (1999). Adaptability analysis in niger. National Seminar on *"Regulatory Measures and Crop Improvement Policy Implications"* MPKV, Rahuri 413 722 (M.S.), during 23-24 December, 1999, Souvenir, pp.125-126.

Patil, H.S., Purkar, J.K. and Duhoon, S.S. (2002). Adaptability analysis in niger (*Guizotia abyssinica* Cass). *J. Oilseeds Res.*, 19(1): 82-85.

Perkins, J.M. and Jinks, J.L. (1968). Environmental and genotype environmental components of variability III Multiple Line Crosses. *Heredity*, 23: 339-356.

Simmonds, N.W. (1962). Variability in crop plants, its use and conservation. *Biol. Rev.*, 34: 31-38.

Singh, R.K. and Chaudhary, B.D. (1979). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi:239-266.

Sprague, C.F. and Federer, W.T. (1951). A comparison of variance components in corn yield trials, II Error, year x variety, location x variety components. *Agron.J.*,43: 535-541.

Upadhyay, P.C. (1993). Stability analysis for seed yield and its components in niger under rainfed conditions. *J. Oilseeds Res.*, 10(2): 206-210.

Verulkar, S.B. and Upadhyay, P.C. (1989). Phenotypic stability for yield and yield contributing characters of niger under rainfed conditions. *J. Oilseeds Res.*, 6(2): 322-327.

Appendix - I **Mean values for yield and its components at Jhabua**

SN	Varieties	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
1	BN-9	53.33	101.00	160.53	9.87	39.87	3.47	3.71	513.71	8.67	42.92
2	BNS-8	55.67	99.67	176.20	10.60	47.33	3.87	4.37	563.84	11.33	38.83
3	BNS-6	55.00	96.00	167.67	10.67	55.20	3.13	5.07	536.53	11.33	45.80
4	BNS-7	51.00	96.00	175.80	12.00	46.33	4.50	4.01	562.56	14.67	29.91
5	IGP-76	55.00	98.00	153.33	10.67	44.27	4.37	3.83	490.67	15.00	25.85
6	NRS 96-3	50.00	89.00	146.47	9.87	47.47	5.13	2.62	468.69	11.33	23.29
7	BNS-1	55.33	96.00	163.33	10.00	43.67	2.93	3.95	522.67	13.33	29.59
8	BNS-20	55.00	99.00	167.53	8.60	37.53	5.70	3.70	536.11	11.67	33.22
9	JNC-1	55.00	95.33	166.20	10.00	50.87	4.87	3.57	531.84	12.67	29.80
10	Ootacamund	52.67	102.00	178.00	10.53	42.73	3.50	5.02	569.60	12.00	41.86
	Mean	53.80	97.20	165.50	10.28	45.52	4.14	3.98	529.62	12.20	34.04

Appendix - II Mean values for yield and its components at Dhar

SN	Varieties	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
1	BN-9	53.67	99.33	184.00	8.00	38.17	3.07	5.27	570.4	18.00	29.38
2	BNS-8	55.33	98.33	178.33	11.27	49.37	4.23	4.32	552.83	16.67	25.83
3	BNS-6	55.00	95.33	178.17	11.40	35.93	5.52	5.58	552.32	13.67	41.23
4	BNS-7	54.00	96.00	163.80	9.03	46.40	3.23	3.40	507.78	10.67	32.40
5	IGP-76	55.67	98.67	182.03	11.07	44.33	4.63	3.67	564.30	13.00	29.45
6	NRS 96-3	51.67	93.67	159.47	12.37	46.13	5.70	2.82	494.35	13.33	22.70
7	BNS-1	54.67	95.33	145.00	9.27	43.20	3.60	2.82	449.50	13.33	21.20
8	BNS-20	56.00	98.33	161.33	7.87	54.13	5.47	3.43	500.13	10.67	32.37
9	JNC-1	55.33	94.33	169.87	9.20	52.83	4.60	3.87	526.59	15.00	25.92
10	Ootacamund	51.67	101.33	184.97	11.40	52.00	4.23	3.29	573.40	14.00	23.67
	Mean	54.30	97.06	170.69	10.08	46.25	4.42	3.84	529.16	13.83	28.42

Appendix - III **Mean values for yield and its components at Indore**

SN	Varieties	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of Capsules/ plant	1000 Seed weight (g)	Seed yield per plant (g)	Seed yield/ plot (g)	Bio-logical yield/ plant (g)	Harvest index (%)
1	BN-9	54.67	102.67	165.50	11.13	54.30	4.3	3.94	529.92	17.67	22.47
2	BNS-8	57.33	102.33	182.5	13.07	58.11	3.47	4.06	584.00	17.33	22.88
3	BNS-6	56.33	96.33	187.2	11.50	44.97	5.53	5.40	599.04	15.00	38.09
4	BNS-7	55.67	98.00	153.23	9.50	65.27	3.50	3.57	490.35	17.33	20.68
5	IGP-76	56.33	100.33	180.63	11.27	45.93	3.50	4.64	578.03	11.33	42.07
6	NRS 96-3	52.00	95.33	164.9	11.53	47.43	5.37	2.69	527.68	9.33	30.43
7	BNS-1	55.67	96.33	172.00	9.00	47.37	2.70	4.77	550.40	11.33	42.85
8	BNS-20	56.00	100.00	189.10	8.27	37.07	5.5	3.53	605.12	15.67	23.41
9	JNC-1	57.00	95.33	166.13	11.33	55.80	4.5	4.01	531.63	16.00	25.80
10	Ootacamund	53.67	103.00	152.43	11.50	45.73	3.53	5.07	487.79	8.67	54.77
	Mean	55.46	98.96	171.37	10.81	50.19	4.19	4.16	160.71	40.00	32.30

VITA

The author of this thesis Mr. Prathap Kumar M.R. S/o. Rame Gowda M.K. was born on 1st June 1980 at Mandya Dist. in Karnataka. He completed his schooling from Jawahar Navodaya Vidyalaya, Mandya Dist Securing first division in High School and Higher Secondary certificate examinations.

He joined college of Agriculture, V.C. Farm, Mandya of U.A.S. Bangalore in the year 1998 and successfully completed his B.Sc. Ag. Degree in the year 2002 with an OGPA of 8.49 out of 10.00 scale. He represented the university in the South zone youth festival held at Manasagangothri, Mangalore in the year 2001-02 in-group songs. Subsequent to the graduation he joined the Plant Breeding and Genetics section at College of Agriculture, Indore of JNKVV Jabalpur through ICAR All India Entrance Examination for Master Degree in the year 2002-03. For partial fulfillment of Masters Degree he was allotted on a neglected important tribal life line crop with research problem, "Adaptation analysis for yield and attributes in niger (*Guizotia abussinica* Cass)" which was successfully completed by him and presented in the form of this thesis. He completed his M.Sc. (Ag.) course with OGPA 7.71 out of 10.00 scale.