STABILITY ANALYSIS OF SELECTED MUTANTS IN NEELAMARI (*Indigofera tinctoria* L.)

by

SARANYA, V. S.

(2014-11-127)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Plant Breeding & Genetics

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis, entitled **"STABILITY ANALYSIS OF SELECTED MUTANTS IN NEELAMARI (*Indigofera tinctoria* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
Date: 23-07-2016

Saranya, V. S.
(2014-11-127)

CERTIFICATE

Certified that this thesis, entitled **"STABILITY ANALYSIS OF SELECTED MUTANTS IN NEELAMARI (*Indigofera tinctoria* L.)"** is a record of bonafide research work done independently by **Ms. Saranya, V. S. (2014-11-127)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
Date: 23-07-2016

Dr. Mareen Abraham
(Major Advisor, Advisory Committee)
Professor
Department of Plant Breeding & Genetics
College of Agriculture, Vellayani,
Thiruvananthapuram- 695522

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Saranya, V. S. (2014-11-127)**, a candidate for the degree of **Master of Science in Agriculture** with major in Plant Breeding & Genetics agree that this thesis entitled **"STABILITY ANALYSIS OF SELECTED MUTANTS IN NEELAMARI (*Indigofera tinctoria* L.)"** may be submitted by **Ms. Saranya, V. S.** in partial fulfillment of the requirement for the degree.

Dr. Mareen Abraham
(Chairman, Advisory Committee)
Professor
Department of Plant Breeding & Genetics
College of Agriculture, Vellayani.

Dr. P. Manju
(Member, Advisory Committee)
Professor and Head
Department of Plant Breeding & Genetics
College of Agriculture, Vellayani.

Dr. Vijayaraghavakumar
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Statistics
College of Agriculture, Vellayani.

Dr. Jessykutty P. C.
(Member, Advisory Committee)
Professor and Head
Department of Plantation and Spices
College of Agriculture, Vellayani

Dr. M. Indira
(Member, Advisory Committee)
Professor
Soil Science and Agrl. Chemistry
ORARS, Kayamkulam

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

It is a great pleasure for me to express gratitude to several personalities who guided and extended all help required directly or indirectly during my study.

I bow my head before God the Almighty for the blessings, mercy and love showered on me for the completion of my work and for being the lamp and light in my path.

I am pleased to place my profound etiquette to Dr. Mareen Abraham, Professor, Department of Plant Breeding and Genetics, College of Agriculture, Vellayani and esteemed Chairman of my Advisory Committee for her meticulous guidance, transcendent suggestions, constructive criticism and constant encouragement right from the conceptualization of the research work to preparation of the thesis.

It gives me immense pleasure to express my deep sense of gratitude to the members of my advisory committee Dr. P. Manju, Professor and Head, (Plant Breeding and Genetics), Dr. Vijayaraghavakumar, Professor and Head, (Agricultural Statistics), Dr. Jessykutty P. C, Professor and Head, (Plantation and Spices), College of Agriculture, Vellayani , Dr. Indira M, Professor, Soil Science and Agrl. Chemistry, ORARS, Kayamkulam for their valuable and expert suggestions, critical evaluation, everlasting patience and constant encouragement for the present investigation.

I cordially offer my profound gratitude to my teachers in Department of Plant Breeding and Genetics Dr. D.S. Radha Devi (Rtd.), Dr. Maya Devi, P. (Rtd.), Dr. D. Wison (Rtd.), Dr. Sunny K. Oommen (Rtd.), Dr. Jayalekshmi, V. G., Dr. Lekha Rani, Dr. Arya K., Ms. Seeja and Dr. Beena Thomas for their excellent teaching and guidance which enabled me complete my course work.

I am extremely grateful to farmers Samkumar, Thomsan, Soman, Habeeb, Chandran and Thankarajan and their family members, Jinu (Research Assistants of FSRS, Kottarakara), Sumina

and Liji (Research Assistant, Dept. of Plant Breeding and Genetics, College of Agriculture, Vellayani) for their help and co-operation during my research.

I cherish with appreciation the joyful and cheerful company of my colleague Nikitha, Jeena, Asha, Reshma, Athul and Sathesh who always shared the burden of my work, cheered me in the moments of despair and made the things much smoother.

With boundless affection and love, I would hearty acknowledge the timely help and encouragement of my beloved seniors and juniors Sreenivas Gogineni, AnjuVijayan, Soumya, Ramling, RajibDas, Kranthi Kumar, Darshan, Siddesh, vinay, Hari Krishna, Brunda, Bibishan, Praveena, Asoontha, Thouseem, Namitha, Prathibha and Manu in whose cheerful company I have never felt my work as burden.

I am short of words to in expressing my deep sense of obligation to my friends and cousins Sarath, Prasanth, Sanal, Gladson, Jibin, Sibi, Sincy and Gisha for their moral support, untiring help and constant inspiration to tackle many a hurdles during the work.

I allocate my highest respect and heartful regards from my inner core of hearts to my ever loved parents and my relatives who have given me life and taught the concepts of life and their dedicated efforts to educate me to this level.

I owe immense gratitude to Kerala Agricultural University for providing KAU Junior Research Scholarship.

I express my immense and whole hearted thanks to all my near and dear for their cooperation, help and loving care and concern during the course of study and research.

Saranya V. S.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	-	per cent
μ	-	Mean
^{0}C	-	Degree Celsius
AMMI	-	Additive main effect multiplicative interaction
ANOVA	-	Analysis of Variance
b_i	-	Regression coefficient
CD	-	Critical difference
cm	-	Centimeter
cm^2	-	Centimeter square
CV	-	Coefficient of variation
d.f	-	Degrees of freedom
DAP	-	Days after planting
et al.	-	and co-workers/co-authors
Fig.	-	Figure
g	-	Gram
$gm^{-2}day^{-1}$	-	Gram per meter square per day
g $plant^{-1}$	-	Gram per plant
i.e.	-	that is
IPCA	-	Interactive principle component analysis
kg	-	Kilogram
Kg h^{-1}	-	Kilogram per hacter
Kg m^{-2}	-	Kilogram per meter square
m	-	Meter
mg	-	Milligram
min	-	Minutes
ml	-	Milliliter

mm	-	Millimeter
MS	-	Mean square
N	-	Nitrogen
nm	-	Nanometer
No.	-	Number
PCA	-	Principle component analysis
$Plant^{-1}$	-	Per plant
P_2O_5	-	Phosphate
Pod^{-1}	-	Per pod
POP	-	Package of practice
ppm	-	Parts per million
RBD	-	Randomized block design
S.E(m)	-	Standard error mean
S^2_{di}	-	Deviation from regression
SD	-	Standard deviation
SE	-	Standard error
spp.	-	Species
TSW	-	Thousand seed weight
t ha^{-1}	-	Tonnes per hacter
viz.	-	Namely
Wt.	-	Weight

Introduction

1. INTRODUCTION

Neelamari (*Indigofera tinctoria* L.), commonly known as Indian indigo, belongs to the family Leguminoceae. It is an oldest natural dye widely used as a textile dye and as a medicine for centuries in Southeast Asia and India. It had been cultivated and highly valued for centuries as the primary source of indigo dye (Duke, 1981). So it is commonly called as true indigo or common indigo. The dye present in the leaves of *I. tinctoria* is indigotin which is a glycoside with a blue colour. It is highly stable. It also contain other dyes like Indirubine, Indigorubine or red indigo, Indirenine, Indihumine or brown indigo.

I. tinctoria is one of the important plants used in traditional medicine. It is used in constipation, liver disease, heart palpitation and gout (Amrithpal, 2006). The roots, stems and leaves are bitter, thermogenic, laxative, trichogenous, expectorant, anthelminthic, tonic, naturopathy, splenomegaly, echolalia, cardiopathy, chronic bronchitis, asthma, ulcers, skin diseases, diuretic and are useful for promoting growth of hair. It is one of the major ingredients of hair tonics. The leaf extract is used for the treatment of hydrophobia. The plant possesses anti-toxic property (Warrier *et al.*, 2007). The plant is a stimulant, deobstruent and purgative. An Infusion of root is given as an antidote in cases of poisoning by arsenic (Gaurav *et al.*, 2011).

Plant derived molecules are part of traditional medicines in all parts of the world. Also plant derived dyes are more beneficial than synthetic dyes. *I. tinctoria* is a plant used as a source for dye as well as medicine. So finding a high yielding genotype of *I. tinctoria* is beneficial. Phenotype of an individual is determined by both genotype and environment. The association between the environment and the phenotypic expression of a genotype constitute the genotype x environment (G X E) interaction. The G X E interaction determines if a genotype is widely adapted for an entire range of environmental conditions or separate genotypes must be selected for different sub-environments (Bondari, 1999). So for finding a high yielding genotype, plant breeders have to evaluate the stability of performance of different genotypes in different environments. Breeding plans may focus on the G X E interaction to select the best genotype for a target population of environments. Some genotypes perform well in one environment and not so well in others (Dhillon *et al.*, 1999). The adaptability of a variety over different environments is tested by its degree of interaction with different environments under which it is planted. A genotype is said to be stable if it has a high mean yield and a low degree of fluctuation in yield over diverse environments.

The present investigation was conducted to study the stability of neelamari mutant genotypes for yield and yield components under four different locations. The main objectives of the present study was

- To evaluate nine promising mutants of neelamari obtained through mutation breeding along with one local variety as check for yield, stability and indigotin content over various locations.

Review of Literature

2. REVIEW OF LITERATURE

I. tinctoria (L.), a medicinal plant is widely used as a source for blue dye *i.e.,* indigotin. The hazardous effect of synthetic dye has encouraged the use of natural dyes, which are mainly produced from plant extracts. The leaf extract of *I. tinctoria* contains a high percentage of indigotin dye. In this context a study on the stability analysis of nine mutant genotypes over four locations along with a check during summer season was done for identifying a high yielding genotype.

I. tinctoria belongs to the family Leguminoceae commonly called as true indigo. *Indigofera* is the largest genus of the family Leguminoceae containing 700 species distributed in tropics and subtropics (Puy *et al.,* 2002). Out of this 40 species and 3 varieties are found in India (Hooker, 1876). The chromosome no. of *I. tinctoria* is 2n=16 (Duke, 1981; Flora of China Editorial Committee, 2014).

It is the primary source of the dye indigo and here it is widely used as a traditional medicine. *I. tinctoria* was widely used as a textile dye and a medicine for centuries in Southeast Asia and India (Armitage, 2008).

According to Benson (1957) the systematic position of *Indigofera* is as follows

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Fabales

Family: Fabaceae or Leguminoceae

Subfamily: Faboideae or Papilionidae

Genus: *Indigofera*

Species: *tinctoria*

Plant is an erect shrub having 1.5 m tall, many-branched from base, leaves are imparipinnate, leaflets are opposite, oblong, elliptic or oblanceolate, membranous, puberulent on lower surface. The apex are mucronulate, rounded or seldom obtuse, the base tapering to obtuse, the margins are entire, petioles are 1-1.5 mm long; stipules are 2-3 mm long and persistent. Axillary racemes with many-flowers, bracts are minute and persistent. Calyx are bell-shaped and having 1-1.5 mm long. Corollas are pink in colour, tomentose without the standard petal, broadly elliptic, the wings and keel as long as the standard petal. Pods are 3-3.5 cm long, curved at apex, cylindrical, becoming glabrous, tardily dehiscent. Seeds are 2 mm long, square-shaped to oblong (Acevedo, 1996).

2.1 MEAN PERFORMANCE

Prakash (1996) observed a non-significant difference among the genotypes of coleus for the character *viz.,* tuber yield plant^{-1}, tuber length, tuber girth and tuber length to girth ratio.

Samuel (2000) observed that in *Mucuna pruriens* the fresh and dry weight of leaves increased during earlier growth stages and declined during the later growth stages.

Nair (2000) and Resmi (2001) conducted a study in *Clitoria ternatea* which revealed that the performance of different accessions vary during different growth stages. They also reported that the character leaf area increased during pre-flowering and flowering stage but decreased during pod maturation stage. The character shoot yield increased throughout the growth stages.

Neema (2004) reported that the mean performance of growth parameters found to increase throughout the growth stages in neelamari.

Number of branches showed non-significant difference in open field condition during pre-flowering stage in neelamari (Sarada, 2004).

Kumanan (2009) reported that in neelamari a significant difference among the mutants for the characters length of leaves, width of leaves, leaf area, leaf area index, internodal length, harvest index and indigotin content at pre-flowering, flowering and pod maturation stages.

2.2 STABILITY ANALYSIS

Availability of adequate genetic variability, knowledge about criteria for screening and selection of desirable genotypes were pre-requisite for any breeding programme aimed at development of ideal varieties for a given environment. Varieties showed variable genotypic adaptability over varying environment. An ideal variety must showed stability in yield and performance over varying environment.

A genotype-environment interaction had been of concern to plant breeders for many years. Various procedures had been used to characterize individual varieties for behaviour in varying environmental conditions. Performance tests over a series of environments, when analysed in the conventional manner, give information on genotype-environment interactions, but gave no measurement of stability of individual entries. Stability in performance of individual entries was studied by various measurements. According to Wricke (1962) the ecovalenc was genotype x environment interaction effects for genotype, which is squared and summed across all environments, was the stability measure for genotype. Finlay and Wilkinson (1963) carried out the stability analysis using the regression coefficient of genotypes. The residual mean square (MS) of deviation from the regression coefficient was the measure of stability for each genotype (Eberhart and Russell, 1966). Stability can be measured using the variance of a genotype across environments (Shukla, 1972). Francis and Kannenberg (1978) used the conventional coefficient of variation per cent of each genotype as a stability measure.

According to Eberhart and Russell (1966) stable genotype was the one with unit regression coefficient and minimum deviation from regression. In the stability analysis, the regression of a genotype mean yield on the environmental index resulted in regression coefficients ranging from 0.800 to 1.514.

There were no significant differences in morphine content due to varying application of water. However, rates of application of N and P_2O_5 fertilizers did result in differences in the plant's morphine content was observed in poppy by Turkhede *et al.* (1976).

Another study was conducted by Kaicker *et al.* (1978) in 10 cultivars of poppy tested for morphine content for five years at the Indian Agricultural Research Institute (IARI), New Delhi. The mean, grand mean and standard error of the mean suggested wide varietal significant differences in the range of morphine content and the phenotypic stability of cultivars. The linear components were significant. Positive environment index gave better morphine content. The cultivar which has given the least deviation from regression (0.08) is the best adapted cultivar, having absolute genotypic stability.

According to Gauch and Zobel (1989) the IPCA scores of a genotype in the AMMI analysis was considered as the indication of stability of a genotype across environments. The closer the IPCA values to zero, the more stable the genotypes across their testing environments.

A study conducted by Balakrishnan *et al.* (1993) in garlic revealed that a non-linear method is needed for stability studies in garlic varieties.

Six accessions of neem seeds were taken for genotype x environment interaction study over three different locations. The characters studied were height, collar diameter and survival rate. The stability analysis using regression coefficient revealed that the accessions with a lower slope of regression than the average had superior height at the stress site and average or poor performance on optimal or intermediate site. Accessions with significantly steeper average slopes had poor survival rates at stress site (Kundu *et al.,* 1998).

Yield stability analysis and drought susceptibility index estimation in sesame indicated that the genotypes which had poor yield potential under non stress condition were more resistant to moisture stress. However, the wide range of yield stability index suggested that breeding objective should be to combine the high yield potentiality of genotypes with stability (Srivastava and Kamalesh, 1998).

In AMMI Stability Value (ASV) method, a variety with high pooled mean and least ASV score was the most stable (Purchase *et al.*, 2000).

The stability parameters were governed by different genes or genes in combination and the linear components were larger in magnitude than the non-linear components in niger was observed by Hegde *et al.* (2000).

Manomohandas *et al.* (2000) studied the stability of ten genotypes of ginger (*Zingiber officinale*) and observed that all the genotypes differed significantly for tiller number, leaf number and yield. Stability analysis revealed the superiority of Ernadan and Kuruppampady as they expressed high mean yield, non-significant deviation from regression values and a regression coefficient nearing unity. Out of these two varieties, the variety Ernadan was the most promising as it exhibited high mean yield (37 t ha^{-1}) with non-significant deviation from regression value and a regression value nearing unity.

Shinoj (2001) studied about the stable performance of eleven promising mutants, two released varieties and one local accession of coleus for many of the economic traits over different environments. The study was conducted in four districts namely Palakkad, Thrissur, Malappuram and Ernakulam. The study revealed that two mutants, which scored high values for the relative contributions to stability parameters, were '641' and '352', but while considering the most economic character, that is the yield, mutant '641' was the best and hence the mutant '641' can be selected as the most stable, high yielding and well adapted for locations followed by '352' and then by '61-a' and '412'.

Kumar *et al.* (2004) studied stability parameters of 23 genotypes of turmeric for three consecutive years for plant height, rhizome girth, rhizome length, length of primary fingers, dry matter recovery and fresh rhizome yield. The joint regression analysis showed a non- significant difference among genotypes which indicating the uniformity of the genotypes. However the linear components of G×E interaction were significant for four traits studied revealing the profound influence of environment on phenotypes. Based on individual parameters of stability, genotypes GL-Puram and Thoubal Local (a local genotype of Manipur) was found stable in performance over the years. Other genotypes, *viz.*, Duggirala No. 325, Armoor, PCT - 11 and Chayapasupu were found to have significantly higher regression coefficients along with mean values higher than the general mean for dry matter recovery and fresh rhizome yield showing an improved performance under favourable farming conditions.

Twenty two pure selections obtained through different intraspecific hybridization followed by rigorous selections up to 8 years including BROP-1 as check, were used for genotype x environmental interaction in relation to stable genotypes in opium poppy *(Papaver somniferum* L.) by Singh *et al.* (2005) showed a significant difference among genotypes for all characters. Linear component of environmental interaction is significant for opium yield and morphine content. Those genotypes having significant non-linear component are very sensitive and unpredictable to environmental changes. Those genotypes having non-significant deviation from regression and high regression coefficient were stable genotypes and responsive to favourable environment.

Twenty genotypes of white mustard (*Brassica alba* L.) were evaluated under four environments in two seasons for characters *viz.*, plant height, number of primary branches, number of secondary branches, number of pods on main branch and seed yield were studied by Abou *et al.* (2006). The above study revealed a significant genotype x environment interaction among all the traits. Wider ranges of regression coefficient values were observed from the studied stability methods suggesting the possibility of selection for specific genotype patterns. Four genotypes (No. 6, 10, 12 and 13) were most stable for studied characters in four environments.

Stability parameters were analysed for five quantitative characters of three roselle (*Hibiscus sabdariffa* L.) cultivars sudani, masri and white with seven nitrogen fertilizer treatments (environments) during two successive seasons. Significant cultivar environmental interactions were detected for most of the roselle traits during both seasons. Dried and fresh sepal yield plant^{-1} were sensitive to environmental changes. According to stability parameter sudani cultivar were more stable for dry sepal yield, fresh sepal yield and number of bolls plant^{-1}, masri cultivar was stable for plant height while white was stable for number of branches plant^{-1} (Ottai *et al.*, 2006).

Stability in seed yield of nine *Vernonia galamensis* genotypes were conducted in six locations in two seasons. AMMI analysis showed that the first interaction of IPCA I was highly significant ($P < 0.01$), while the subsequent ones were not. The IPCA 1 explained 79.23 per cent of the G-E interaction sum of squares, whereas IPCA 2 explained 9.60 per cent (Tsige, 2006).

Lee (2006) studied the genotype x environment interaction of ten fenugreek genotypes over different agro ecological locations in the world. The multi environment study was conducted over two cropping years at three locations and in both rainfed and irrigated growing conditions. The characters studied were thousand seed weight (g), seed yield (kg ha^{-1}), galactomannan content (%), galactomannan productivity (kg ha^{-1}), diosgenin content (%), diosgenin productivity (kg ha^{-1}), 4-hydroxyisoleucine content (%) and 4-hydroxyisoleucine productivity (kg ha^{-1}). The study revealed that only 14-19 per cent is contributed by genotype x environment effect and the main effect environment had the highest contribution to the total variation due to treatments for all the traits tested, which varied from 63 per cent to 78 per cent. The contribution of genotype for tested traits varied from 7 per cent to 24 per cent of the total variation due to treatment.

Ann *et al.* (2006) conducted a study on genotype by environment interaction for seed yield $plant^{-1}$ in rapeseed using AMMI model. They selected eight genotypes and eleven inbreeds of rapeseed and the result obtained that the three sources of variation were highly significant and the environmental and genotype by environmental interaction had the highest influence in formation of good seed yield in rapeseed.

Drazic *et al.* (2007) studied stability of productive traits (fruit yield, essential oil content) of varieties of cultivated medicinal plants belonging to the species of the family Apiaceae (anise, coriander, dill, parsley and fennel) in five locations following the method of Eberhart and Russell (1966). Least stable yield was recorded in coriander and least stable essential oil content was found in fennel.

Yadav *et al.* (2007) studied the genotype - environmental interactions and phenotypic stability analysis of eleven pure breeding lines of opium poppy (*Papaver somniferum* L.) for five years for the characters *viz.,* seed, opium and morphine content. The combined analysis of variance and AMMI analysis showed that all the main as well as interaction effects were statistically significant for all traits.

Eight varieties of Japanese mint were evaluated for stability for essential oil yield. The variety Himalaya had high oil yield with regression coefficient more than one and hence suitable for high yielding environment and the varieties Kosi and Sangam having high oil yield and unit regression coefficient was suitable for medium yielding environment. Damroo was the variety suitable for low yielding environment (Birendra *et al.,* 2008).

A wide variations in the traits like seed yield, plant height, plant structural components and secondary metabolites like dyes, essential oils etc. within species due to the genotypic differences was observed by Amar *et al.*, (2008).

Basu *et al.* (2009) studied the genotype x environment interaction of 83 accessions of fenugreek under rainfed and irrigated condition during 2004 and 2005 to study the impact of growing conditions on genotypic performance. The result revealed that seed yield of fenugreek was influenced significantly by genotype and environmental factors such as year and interaction effects of year x location, and year x genotype. In another study he took five accessions of fenugreek namely F70, F80, F86, Tristar and Amber to evaluate the genotype x environment interaction over different locations. That is for five years at six different environments or locations. The study revealed a significant effect of genotype ($P < 0.05$), year, location and genotype x location interaction ($P < 0.01$) on forage yield. For seed yield, genotype, year, location and genotype x location interaction effects were found to be highly significant ($P < 0.01$).

Mahesh and Sathyanarayana (2011) studied the genotype x environment interaction and stability analysis for L-Dopa trait in velvet bean (*Mucuna pruriens*) seeds and revealed that all the accessions under study were stable across varying environments as the values for regression co-efficient close to unity and mean square deviation from regression value also near to zero. 500149AP and 500150AP were genotypes with high L-Dopa content, unit regression coefficient and a non-significant deviation from regression indicating that these accessions are adaptable to high performing environments.

Yousefi *et al.* (2011) conducted a study on the stability parameters for discrimination of stable, adaptable and high flower yielding landraces of *Rosa damascene.* They studied six characters of 35 landraces in 8 locations for two years. The existence of genetic variation in responses to environmental changes among genotypes or significant genotype x environment interaction was the primary basis for stability analysis had been reported for many traits such as morphology, oil content and flower yield in Iranian Damask rose populations (Tabaei, *et al.,* 2007).

Panwar *et al.* (2011) conducted stability analysis on 30 accessions of basil germplasm (exotic as well as indigenous) in four diverse environment comprising two different locations and two years. The characters studied were number of primary branches plant^{-1}, lamina length (cm), lamina width (cm), leaf-stem ratio, plant height (cm), fresh herbage yield plant^{-1} (g), dry herbage yield plant^{-1} (g), essential oil content (%) and essential oil yield plant^{-1} (ml). All 30 genotypes had a non-significant deviation from regression showing consistent performance of the genotypes among all the environments. Five genotypes viz. EC388788, IC333332, IC336833, IC388891 and EC338773 were identified as desirable and stable in relation to essential oil yield plant^{-1}. The genotype EC388788 was found stable for most of the traits and had wider adaptability.

Stability analysis was carried out with 36 genotypes of isabgol (*Plantago ovata* Forsk) under three environments to identify stable genotypes that could be cultivated uniformly under varied environmental conditions for yield and yield attributing traits. Seed yield shows stability over diverse environment as indicated by their non-significant deviation from regression values. The linear genotype x environment component was significant for all the traits. Linear component of G x E interaction were relatively larger than non-linear component for almost all the traits indicating that the performance of genotypes for traits could be reliable and predictable (Sharma 2013).

Stability parameters of 25 populations of *Rauwolfia serpentina* were evaluated in three locations to assess genotype x environment interaction and to determine stable plant population for reserpine in root (%). They showed significant G X E interaction for all the characters studied. According to the stability analysis, population 25 was the most stable variety which had regression coefficient unity and had lowest deviations from regressions. The population had deviations from regression values around zero, suggesting that they were responsive to changing environments and could be recommended for favourable environments (Usmani and Mohamed, 2013).

Sangwan *et al.* (2013) conducted an experiment to study the genotype x environment interaction and stability of 26 ashwagandha (*Withania somnifera* (L) Dunal) genotypes and effect of different environments on fresh root yield to understand its adaptation to six varying environments. The study showed a significant genotype x environment interaction for all the six characters. Considering all the parameters of stability together, the maximum number of desirable genotypes for general environment was there for plant height, followed by six for seed yield plant^{-1}, eight for root length, five for root diameter, six for fresh root yield plant^{-1} and six for total alkaloid content. Fresh root yield being the most important character, thirteen genotypes exhibited high mean performance for this trait and out of which only nine genotypes were stable. Genotypes WS-224 was suitable for poor environment, WS-205 and WS-90-100 for favourable environment and WS-210, WS-90-104, WS-90-135, WS-90-136, JA-20 and Adinath were suitable for all environments.

Another study on identification of adaptable and stable genotype for seed and opium yield in opium poppy (*P. somniferum* L.) based on various stability models conducted by Rawli *et al.*, (2014) revealed significant difference between genotypes. Linear components of genotype x environment interaction as well as pooled deviation mean squares are also significant. This gives the presence of predictable and non-predictable components. Also mean yield performance and stability parameters had positive association.

Singh and Anil (2014) studied the stability of *Macuna* species over four environments for various characters using three models of stability analysis, (1) linear sensitivity coefficient i.e. regression coefficient of an individual mean on environment index to evaluate cultivars response (2) non-linear sensitivity coefficient i.e. mean square deviation from the linear regression to measure the cultivar stability (3) AMMI analysis. Genotypes screened through all the three models and those which showed common in all the three models were sorted out as the most desirable stable genotypes over all the four environments.

Thirteen genotypes of fenugreek (*Trigonella foenum-graecum* L.) were evaluated over three environments during rabi season to estimate stability parameters for days to 50 per cent flowering, plant height, branches plant^{-1}, days of 75 per cent pod maturity, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, test weight, biological yield and seed yield plant^{-1} and revealed that genotype x environment interaction was significant for all the characters. Environment + (variety x environment) component was significant for most of the traits *viz.*, plant height, number of branches, days to 50 per cent flowering, number of pod plant^{-1}, biological yield and seed yield plant^{-1}. The pooled analysis was significant for all the traits except branches plant^{-1}, days of 50 per cent flowering and days of 75 per cent pod maturity. Stability parameters showed that genotypes C-1-32-17 was the stable genotype and genotype AFg-3, AFg-6 and AM-413 were suitable for favourable environment (Kakani *et al.*, 2014).

Jyothsna *et al.* (2014) studied stability of thirty genotypes of roselle in three environments during kharif season. The study revealed significant differences for all the characters, indicating wide differences between environments and differential behaviour of genotypes in different environments. The linear and non-linear G × E components were non-significant for all the characters except fibre yield plant^{-1}. The genotypes R-78, JRR-9 and AHS-162 were found to be stable for favourable environmental conditions for plant height, basal stem diameter, green plant weight and fibre yield plant^{-1}, whereas HS-4288 and AR-12 were stable for poor environmental conditions for all the characters under study. The genotypes HS-4288 and CRIJAFR-2 were considered to be stable for fibre yield plant^{-1} in poor environmental conditions. The genotypes HS-4288, AMV-4, CRIJAFR-2, AS-80-29, JRR-9, R-83 and R-78 were found to be stable over environments.

Mishra *et al.* (2014) conducted a study in opium to find out the variations in seed and opium yield due to the effect of genotype, environment and their interaction using the different stability models for GEI revealed that linear genotype x environment interaction as well as pooled deviation mean squares were significant, indicating the presence of both predictable and non-predictable components. The five genotypes LT31, BR231, BR233, BR242 and BR234 were identified as ideal and stable through Eberhart and Russell model and also confirmed by other stability models.

Mubashir *et al.* (2015) studied stability performance of nine genotypes of sesame over two years. Amongst, the nine genotypes average yielding genotypes NS-44-SP1 and SV-III were stable genotypes as their regression coefficient values were within the range of 0.95 to 1.05, small deviation from regression value for NS-44-SP1 and a little high for SV-III and high R^2 values.

Abbas *et al.* (2015) studied the oil yield and stability of 20 genotypes of thyme over eleven environments. The genotypes 5, 56, 70 had higher oil yield than the average and regression coefficient were near unity and therefore they were stable for all environments. The genotypes of G5 (Ghazvin 2), G56 (Zarand) and G70 (Oromiea 2) with average values of 1.66 to 1.70 Kg ha^{-1} had higher performance over all environments. The genotypes G54 (Nagade) and G58 (Sanandaj 2) with average values of 1.685 and 1.499 Kg ha^{-1} had specific stability for poor environments. The genotypes G22 (Ghazvin 3) and G50 (Zanjan 4) with average values of 1.776 and 1.737 Kg h^{-1}, respectively had specific stability for rich areas.

Mohammed and Firew (2015) studied the phenotypic stability analysis of oil yield in Sesame in three locations over two seasons. Stability analysis using biplot graph and AMMI was done which revealed that AMMI with only two IPCA was the best predictive model to reveal the maximum GEI for oil yield in sesame.

Preeti and Solanki (2015) studied the stability of eleven genotypes of fennel (*Foeniculum vulgare* M) for yield and yield contributing characters. The study revealed that in fennel considerable amount of genetic stability with respect to environmental interactions were exists and based on the mean performance, regression coefficient and deviation from regression values, it could be concluded that the stability of yield was imparted in the genotypes UF 281, AF 1, GF 11, JF 586 2/5, HF 131 and NDF 16 through the stability of major yield contributing traits like primary and secondary branches, number of umbels and umbellets, number of seeds plant^{-1} and test weight.

The years and locations with different climatic and geographic characters had significant effects in coriander genotypes for yield, yield components and essential oil content was observed in a study conducted by Duran *et al.* (2015) while determing the performance and stability of coriander genotypes for yield and yield components and essential oil content.

Pankhuri *et al.* (2015) conducted a study to find out the stable genotypes in Vetiver (*Veteveria zizanioides* L. Nash) from the 40 genetic stocks assembled from different states of India, with exotic collections from Indonesia, Reunion Island, Haiti, and Thailand using AMMI analysis. The study revealed that four clones/genotypes of vetiver were found to have highly stable essential oil yield performance over years. The four genotypes were G-1, G-5, G-16, and G-34, performed well for stability due to their ability to tolerate a wide range of environmental conditions.

Rajendra *et al.* (2015) studied stability analysis for biomass and essential oil yields of fifteen genotypes of five ocimum species. The results showed that the genotypes OCS-2 and OCB-9 with high essential oil yield and high values of deviation from regression were suitable for under favourable environmental conditions. Genotype OCG-14 produced more essential oil yield than average yield and had low deviation from regression, thereby exhibiting less sensitivity to environmental changes. The genotype OCS1 produced below average essential oil yield and had regression coefficient close to 1.0 and low deviation from regression revealing stability for poor yield. The genotypes OCS-3, OCS-4, OCS-5, OCS-6, OCB-10, OCG-13 and OCK-15 produced below average herb yield and had significant regression coefficient from unity or high value for deviation from regression, hence considered as unstable.

Materials and Methods

3. MATERIALS AND METHODS

The present work on "Stability analysis of selected mutants of neelamari (*Indigofera tinctoria* L.)" was conducted at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram during 2014-2016. The field experiment was conducted at four locations in farmer's field at Thiruvananthapuram (Vellanad & Kalliyoor), Kottarakara and Kayamkulam. The stability analysis of selected mutants was made for identifying the best mutant showing stable performance in yield and glycoside content. The details of materials used and the techniques adopted for the study are presented in this chapter.

The experiment was conducted in one season at four locations. The seeds of neelamari were collected from the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani. The growth and yield analysis of nine mutants and one local accession (Vellanikara local) as check were done.

3.1 EXPERIMENTAL SITE

The present investigation was carried out in four locations during summer season.

Location I: Farmer's field, Vellanad.

Location II: Farmer's field, Kalliyoor.

Location III: Farmer's field, Kottarakkara.

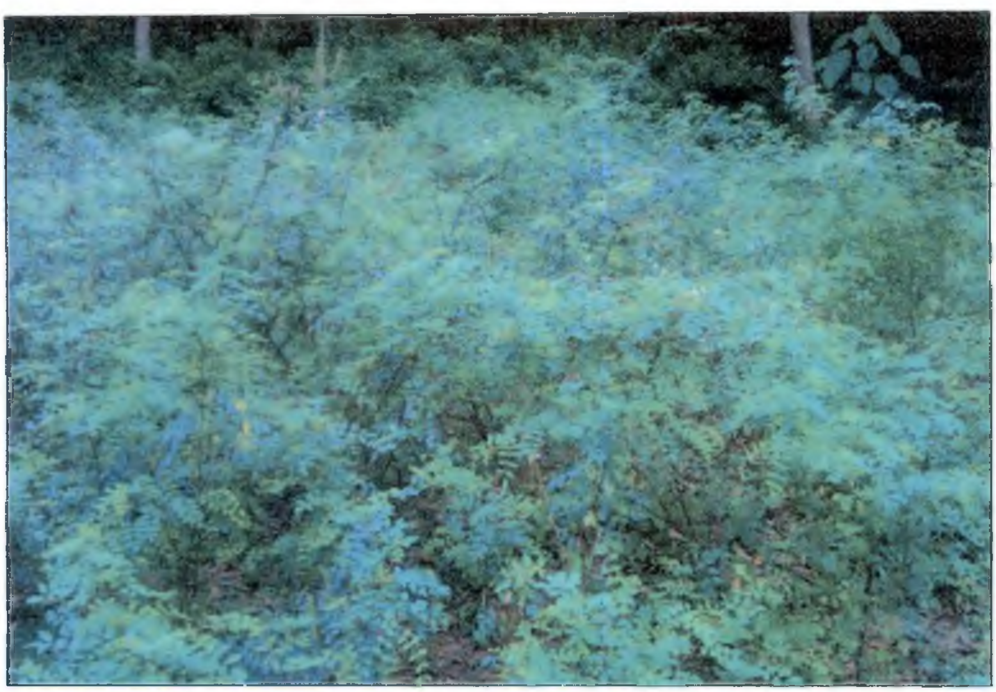
Location IV: Farmer's field, Kayamkulam.

3.2 EXPERIMENTAL DESIGN

The experiment was laid out in Randomized Block Design (RBD) with ten treatments and three replications. The spacing of 60 cm x 30 cm with a plot size of 4.2 x 3 m² was adopted as per package of practice (POP).

Plate 1. General view of experimental plot at Vellanad

Plate 2. General view of experimental plot at Kalliyoor



3.3 FIELD PREPARATION, SOWING AND CULTURAL OPERATIONS

Seeds of nine mutants and one local accession (Vellanikara local) as check were first sown in grow bags containing sand and watered daily. After two weeks, the seedlings were transplanted in to polythene bags of 250 gauge and 15 x 10 cm size, filled with potting mixture. After two months, the seedlings were transplanted to the main field. The land was prepared thoroughly by digging and levelling. Trenches were taken at a spacing of 60 cm. Dried and powdered cowdung was incorporated at the rate of 1 kg m^{-2}. Sixty days old seedlings were transplanted into the trenches in the main field at a spacing of 30 cm between plants. The crop received management practices as per package of practice recommendations of Kerala Agricultural University (KAU, 2011).

3.4 OBSERVATIONS

3.4.1 Growth Attributes

3.4.1.1 Plant Height (cm)

The height of the plant was measured from the base of the plant to the tip of the tallest branch using measuring scale during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) from ten observational plants in each replication and the mean values were taken.

3.4.1.2 Plant Spread (cm)

The distance occupied by the plant in the north-south and east-west direction from its axis was measured during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) from ten observational plants in each replication and average was measured out.

3.4.1.3 Number of Branches

The total number of branches in a plant was counted and recorded during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation

Plate 3. General view of experimental plot at Kottarakara

stage (220 DAS) from ten observational plants in each replication and the mean values were taken.

3.4.1.4 Girth of Stem (cm)

The girth of the main stem at the collar region was taken using a thread and measuring scale during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) from ten observational plants in each replication and the mean values were taken.

3.4.1.5 Number of Leaves Plant^{-1}

The total number leaves produced in a plant was counted and recorded during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) from ten observational plants in each replication and the mean values were taken.

3.4.1.6 Length of Leaves (cm)

The average length of leaves selected at random from ten observational plants in each replication during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) and the mean values were recorded.

3.4.1.7 Width of Leaves (cm)

The average width of leaves selected at random from ten observational plants in each replication during (1) pre-flowering stage (90 DAS) (2) flowering stage (150 DAS) (3) seed maturation stage (220 DAS) and the mean values were recorded.

3.4.1.8 Internodal Length (cm)

The distance between the point of attachment of the first fully opened leaf and that of the next lower leaf was measured at pre-flowering, flowering and pod

Plate 4. General view of experimental plot at Kayamkulam

maturation stage from ten observational plants and the mean values were recorded as internodal length in cm.

3.4.1.9 Leaf Area (cm^2)

Leaf area was calculated by adopting punch method (Watson, 1952). Leaves of the plants earmarked for destructive sampling were separated and 50 punches were made out of them. The discs as well as the leaves were dried in a hot air oven at 70^0C and their respective dry weights were recorded. From the data leaf area per plant was computed.

3.4.1.10 Harvest Index

Harvest index was calculated at final harvest using the formula

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

Where,

Economic yield – dry weight of officinal part

Biological yield – total dry weight of plant

3.4.2 Yield Attributes

3.4.2.1 Fresh and Dry Weight of Shoots (g)

Fresh weight of shoot along with leaves of ten observational plants from each replication was measured using a counterpoise balance. The samples were then dried in a hot air oven at 70^0C until consistent dry weight was obtained.

3.4.2.2 Fresh and Dry Weight of Leaves (g)

Fresh weight of leaves of ten observational plants from each replication was measured using a counterpoise balance. The samples were then dried in a hot air oven at 70^0C until consistent dry weight was obtained.

3.4.3 Biochemical Analysis

3.4.3.1 Glycoside Estimation

Glycoside content in all the mutants was estimated using the method suggested by Wu *et al.* (1999) with certain modifications using the following treatments.

Leaves taken from the observational plants in each replication were kept inside brown paper covers and shade dried for 1 or 2 days and then dried in hot air oven at 70^{0}C till the leaves became completely dried. One gram leaf from each replication was crushed in a mortar. It was mixed with 15 ml of 80 % methanol. The solution was heated at 70^{0}C for 5 minutes in a water bath. The solution was then stirred for 20 minutes and filtered through a glass funnel. The filterate was then read at 280 nm in a Spectronic Genesys 5 Spectrophotometer. Indoxyl β-D-glucoside (indicant) standard (sigma Aldrich) solutions of 0.5 ppm, 1 ppm, 1.5 ppm and 2 ppm were prepared. These were also read at 280 nm in the Spectrophotometer. From the standard values, the amount of indigotin per gram of fresh leaf was calculated.

3.4.4 Physiological Characters

3.4.4.1 Dry Matter Production (g plant^{-1})

Shoot, leaves and roots of ten observational plants from each replication were uprooted, separated and dried to a constant weight at 70^{0}C in a hot air oven during the seed maturation stage. The sum of these individual components gave the total dry matter production.

3.4.4.2 Leaf Area Index

Leaf area of observational plants, were calculated by adopting punch method. Leaf area index was worked out using the formula proposed by Watson (1952).

$$LAI = \frac{\text{Leaf area of the plant } (cm^2)}{\text{Ground area occupied } (cm^2)}$$

3.4.4.2 Net Assimilation Rate ($gm^{-2}day^{-1}$)

Net assimilation rate (NAR) refers to the change in dry weight of the plant per unit leaf area per unit time. The procedure given by Buttery (1970) was followed for calculating NAR.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)\ \frac{(A_1 + A_2)}{2}}$$

W_1 – dry weight of plant (g) at time t_1

W_2- dry weight of plant (g) at time t_2

$t_2 - t_1$:– time interval in days

A_1- leaf area (m^2) at t_1

A_2- leaf area (m^2) at t_2

3.5 STATISTICAL ANALYSIS

The data recorded on different traits were subjected to the following statistical analysis.

1. Analysis of variance
2. Stability Analysis.

3.5.1 Analysis of Variance

3.5.1.1 Analysis in Randomized Block Design (RBD)

The adopted design was Randomized Block Design (RBD) with four replications. The analysis of variance was carried out as per the method outlined by Panse and Sukhatme (1985) using fixed effect model.

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

Where,

Y_{ij} = Phenotypic observation of i^{th} genotype in j^{th} replication

m = General mean

g_i = True effect of i^{th} genotype

r_j = True effect of j^{th} replication

e_{ij} = Random error associated with i^{th} genotype and j^{th} replication

The significance of mean sum of squares for each character was tested against the corresponding error degrees of freedom using 'F' test (Fisher and Yates, 1967).

Standard Error Mean S.E (m) = $\sqrt{\frac{Mse}{r}}$

Where,

Mse = Error mean of squares

r = Number of replications

$$C.D = t\sqrt{\frac{2Mse}{r}}$$

't' = t Table value at error degrees of freedom

C.V = $(SD/\bar{Y}) \times 100$

Where,

S.D = Standard deviation of the population

$\bar{Y}$ = Population mean

3.5.2 Stability Analysis

3.5.2.1 Methods to Measure Stable Performance of Genotypes:

Analysis of variance of genotypic mean was computed for each agronomic variable in each environment. The data were pooled over environments as the coefficient of variation values in each environment were generally low.

3.5.2.2 Eberhart and Russell's Model (1966)

Following the methodology of Eberhart and Russell's model (1966), three parameters namely (i) overall mean of each genotype over a range of environments, (ii) the regression of each genotype on the environmental index and (iii) a function of the squared deviation from the regression were estimated. Eberhart and Russell (1966) used to study the stability of genotypes under different environments.

$$Y_{ij} = m + B_i I_j + \delta_{ij}$$

(i= 1, 2...., g and j=1, 2 ......, e)

Where, Y_{ij} = mean of i^{th} genotype in j^{th} environment.

m = mean of all genotype over all the environments

B_i = regression coefficient of the i^{th} genotype on the environmental index which measures the response of this genotype to varying environments

I_j = environmental index which is defined as the deviation of the mean of all the genotypes at a given location from overall mean

$$= \frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ge}$$

With $\sum_j I_j = 0$

δ_{ij} = The deviation from regression of the i^{th} genotype at j^{th} environment

3.5.2.3 *Analysis of Variance for Stability*

The analysis of variance proposed by Eberhart and Russell (1966) is given below.

ANOVA to estimate stability parameters (Eberhart and Russell, 1966)

Source	d.f	sum of squares	mean sum of squares
Total	(ge-1)	$\sum\sum Y_{ij}^2 - CF$	
Genotype	(g-1)	$\frac{\sum Y_i^2.}{e} - CF$	MS_1
Environment + (Genotype x Environment)	g(e-1)	$\sum\sum Y_{ij}^2 - \frac{Y_i^2.}{e}$	
Environment Linear	1	$\frac{\sum(Y_{ij}I_j)^2}{g(\sum I^2_j)}$	
Genotype + Environment (Linear)	(g-1)	$\sum\left[\frac{(\sum Y_{ij}I^2_j)}{\sum I^2_j}\right] - \left[\frac{\sum Y_j I^2_j}{g\sum I^2_j}\right]$	MS_2
Pooled Deviation	g (e-2)	$\sum\sum\delta^2_{ij}$	MS_3
genotype 1	(e-2)	G_1	
genotype 2	(e-2)	G_2	
genotype 3	(e-2)	G_3	
.			
.			
.			
.			
genotype g	(e-2)	G_g	
Pooled Error	ge (r-1)		S_e^2

g = No. of genotypes, r = No. of replications, e = No. of environments

Deviation due to genotype, $G_i = [\sum Y_{ij}^2 - \frac{Y_i^2.}{e}] - [\frac{(\sum Y_i I_j)^2}{\sum I_j^2}]$

Where i= (1, 2, 3….,g)

3.5.2.4 Estimation of Stability Parameters

The two stability parameters, regression coefficient (b_i) and deviation from regression (S^2_{di}) were estimated as follows :

3.5.2.5 Computation of Regression Coefficient (bi) for Each Genotype

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

Where,

b_i = regression coefficient of i_{th} genotype

$\sum I_j^2$ = The sum of squares of environmental indices (I_j) which are common to each value of b_i.

$\sum_j Y_{ij} I_j$ = (for each genotype) = The sum of products of environmental index (I_j) and the corresponding means of that genotypes at each environment (Y_{ij}).

3.5.2.6 Computation of Mean Square Deviation S^2di from Linear Regression

In a regression analysis, it is possible to partition the variance of dependent variable (Y) into two parts, the one which explains the linearity between dependent and independent variables (variance due to regression) and the other which explains the variance due to deviations from linearity symbolically.

$\sigma^2 y = \sigma^2$ (regression) + σ^2 (deviation from regression)

Obviously, by subtracting the variance due to regression from $\sigma^2{}_Y$, the variance due to deviation from regression can be obtained which in turn can be used for estimating S^2_{di} values. The variance of means over different locations with regard to individual genotypes may be obtained in the following way.

$$\sigma_i^2 = \sum_j Y_{ij}^2 - \left(\frac{Y_i^2.}{g}\right)$$

Where, Y_{ij} and $Y_{i.}$ are the mean values of genotypes in each location and total value of a variety in all the locations respectively.

The variance due to deviations from regression $\left(\sum_j \delta_{ij}^2\right)$ for a genotype being:

$$\sum_j \delta_{ij}^2 = \left[\sum_j Y_{ij}^2 - \frac{Y_i^2.}{g}\right] - \frac{\left(\sum_j Y_{ij} I_j\right)^2}{\sum_j I_j^2}$$

Where,

$$\sum_i Y_{ij}^2 - \left(\frac{Y_i^2.}{g}\right) = \text{The variance due to dependent variable and}$$

$$\frac{\left(\sum Y_{ij} I_j\right)^2}{\sum_j I_j^2} = \text{The variance due to regression}$$

From which it can be obtained as

$$S^2 d_i = \left[\frac{\sum_j \delta_{ij}^2}{e-2}\right] - \left(\frac{S_e^2}{r}\right)$$

3.5.2.7 Test of Significance

The mean sum of squares due to genotypes and environments were tested against pooled deviation. Whereas, mean sum of squares due to G x E interaction was tested against pooled error. Environment (linear) and G x E (linear) were tested against pooled deviation, if pooled deviation is non-significant both these linear components were tested against pooled error. Mean sum of squares due to pooled deviations were tested against pooled error.

The following tests of significance were carried out:

1. To test the significance of the difference among genotype means i.e., $H_o = \mu_1 = \mu_2 = \mu_3 = \ldots \mu_g$

$$F = \frac{MS_1}{MS_3}$$

2. To test that the genotypes did not differ for their regression on environmental index, i.e. $H_o = b_1 = b_2 = b_3 \ldots\ldots\ldots B_e$,

$$F = \frac{MS_2}{MS_3}$$

3. Individual deviation from linear regression was tested as follows:

F= $[(\sum_j \delta_{ij}^2)/(e-2)]/$ pooled error

Against F table value at (e-2), ge (r-1), at 5% or 1% probability level.

3.5.2.8 Stable Genotype

A genotype with unit regression coefficient (bi=1) and deviation not significantly different from zero (S^2_{di}=0) was taken to be a stable genotype with unit response.

Results

4. RESULTS

The present study was conducted to evaluate the performance of nine mutants of neelamari along with one local accession (Vellanikara local) as check over four different locations *viz.,* Thiruvananthapuram (Vellanad and Kalliyoor), Kottarakara, Kayamkulam and to study the stability of genotypes for yield and yield governing characters during summer season. The results obtained from the experiments are presented below under the following headings

1. Analysis of variance
2. Mean performance
3. Stability parameters (Eberhart and Russell, 1966)

4.1 ANALYSIS OF VARIANCE

Analysis of variation showed significant difference among the genotypes for all the characters under study in all the four locations. (Table 1.1 – 1.4)

4.2 MEAN PERFORMANCE

The mean performance of ten genotypes at different locations during pre-flowering, flowering and pod maturation stages are given in the Tables.

4.2.1 Performance of Neelamari Mutants at Vellanad

The mean values of each of 10 neelamari genotypes for the characters studied are presented in Table 2.

4.2.1.1 Plant Height (cm)

The mutants differed significantly for plant height with a general mean of 28.37 cm during pre-flowering stage. The mutant It-5 recorded the lowest value of 25.93 cm. The height of 32.20 cm was recorded for It-8 followed by It-4. It-5 was on par with It-2, It-3 and Vellanikara local. During flowering stage mutants showed significant difference in plant height with an average of 87.08 cm.

Table 1. Analysis of variance (mean square) for individual locations of neelamari

Table 1.1 Location 1: Vellanad

Source of variation	df	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	0.54	0.63	14.43	0.26	3.51	1.36	1.75	1.09	1.82	0.01	0.03	1.95
Genotype	9	14.89**	137.81**	1769**	48.73**	92.63**	1954**	2.10*	11.52**	49.50**	0.19**	0.30**	3.44**
Error	18	1.45	2.21	10.06	2.33	1.68	1.03	0.79	1.17	2.65	0.006	0.01	0.55

Source of variation	df	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	2.33	365.12	416.21**	0.007	0.03*	0.02	0.0009	0.0008	0.01	0.01	0.03*	0.71
Genotype	9	17.20**	22314**	34327**	0.07**	0.07**	0.12**	0.07**	0.03*	0.02*	0.03**	0.07**	1.61**
Error	18	1.10	105.93	68.55	0.01	0.007	0.01	0.006	0.01	0.007	0.007	0.007	0.52

Table 1.1 (continued…..)

Source of variation	df	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index
Replication	2	7260	1.19	187.16	228.46	1.81	0.001
Genotype	9	305620**	63.10**	70780.82**	12291.51**	417.39**	0.83**
Error	18	5100	1.11	152.85	78.86	2.21	0.01

Source of variation	df	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Replication	2	0.04	120.00	16.06	50.03	131.07	0.008
Genotype	9	1.81**	8378.24**	1115.26**	22278.82**	11504.02**	1.86**
Error	18	0.04	116.29	11.06	122.44	103.76	0.007

* & ** - significant at 1 & 5 per cent respectively

Table 1.2 Location 2: Kalliyoor

Source of variation	df	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	0.01	0.97	3.45	3.11	1.95	1.87	0.05	1.86	0.93	0.006	0.01	0.91
Genotype	9	13.28**	150.83**	2111**	33.97**	92.84**	1903**	3.12*	8.84**	35.36**	0.19**	0.30**	3.02**
Error	18	1.64	3.39	13.20	2.10	1.13	1.47	0.96	1.04	2.60	0.01	0.01	0.48

Source of variation	df	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	1.40	87.03	105.70	0.005	0.01	0.004	0.003	0.02	0.007	0.009	0.01	1.17
Genotype	9	15.82**	21395**	34966**	0.08**	0.06**	0.08**	0.05**	0.02	0.07**	0.03**	0.06**	2.45**
Error	18	0.70	100.78	85.47	0.007	0.009	0.006	0.006	0.01	0.005	0.008	0.009	0.39

Table 1.2 (continued…..)

Source of variation	df	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index
Replication	2	128.47	0.03	200.83	0.19	0.09	0.004
Genotype	9	269663**	53.82**	73838.51**	10194.92**	388.60**	0.96**
Error	18	4607	0.57	113.79	85.78	2.83	0.009

Source of variation	df	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Replication	2	0.01	0.04	0.83	34.53	16.26	0.002
Genotype	9	1.62**	7957.03**	1244.82**	23719.64**	11261.77**	1.82**
Error	18	0.03	150.92	7.15	177.86	70.91	0.006

* & ** - significant at 1 & 5 per cent respectively

Table 1.3 Location 3: Kottarakara

Source of variation	df	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	0.14	0.30	5.27	1.73	5.37*	0.59	0.11	1.43	1.80	0.01	0.005	1.01
Genotype	9	15.09**	123.44**	1962**	27.44**	68.97**	1939**	1.27	10.38**	45.46**	0.14**	0.31**	3.69**
Error	18	0.97	1.25	4.59	2.49	1.36	2.40	0.90	1.56	2.30	0.01	0.01	0.62

Source of variation	df	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	0.34	0.41	72.40	0.008	0.01	0.01	0.005	0.03*	0.01	0.001	0.01	0.12
Genotype	9	17.23**	22931**	35262**	0.10**	0.07**	0.14**	0.04**	0.03**	0.04**	0.04**	0.07**	2.04**
Error	18	0.73	36.33	108.06	0.008	0.01	0.01	0.006	0.008	0.003	0.008	0.01	0.53

* & ** - significant at 1 & 5 per cent respectively

Table 1.3 (continued…..)

Source of variation	df	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index
Replication	2	86308	1.53	69.73	142.84	0.41	0.0008
Genotype	9	154846**	61.00**	62309.27**	12492.74**	443.35**	0.86**
Error	18	140673	0.94	129.02	77.95	1.16	0.007

Source of variation	df	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Replication	2	0.01	255.83	10.92	339.60*	84.52	0.003
Genotype	9	1.74**	8877.87**	1196.49**	22140.77**	10914.75**	1.58**
Error	18	0.01	153.98	8.67	76.00	75.37	0.005

* & ** - significant at 1 & 5 per cent respectively

Table 1.4 Location 4: Kayamkulam

Source of variation	df	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	1.61	0.64	11.67	0.96	3.30	0.71	2.25	0.02	0.53	0.007	0.02	0.25
Genotype	9	28.70**	131.09**	2178**	50.72**	78.47**	1865**	5.01**	10.35**	45.92**	0.19**	0.22**	3.32**
Error	18	0.92	2.50	14.72	2.09	1.63	3.06	0.85	1.04	1.79	0.01	0.01	0.57

Source of variation	df	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
		90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
Replication	2	2.07	145.97	36.97	0.007	0.04**	0.01	0.003	0.008	0.02	0.004	0.04**	0.47
Genotype	9	29.72**	23238**	34434**	0.12**	0.08**	0.16**	0.12**	0.04**	0.03*	0.02	0.08**	4.59**
Error	18	1.06	129.38	25.48	0.005	0.006	0.01	0.006	0.01	0.009	0.008	0.006	0.37

* & ** - significant at 1 & 5 per cent respectively

Table 1.4 (continued….)

Source of variation	df	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index
Replication	2	28250	0.19	291.60	13.73	22.81	0.006
Genotype	9	283674**	68.47**	67959.17**	14409.22**	435.41**	0.90**
Error	18	6667	0.64	543.19	132.65	9.31	0.004

Source of variation	df	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Replication	2	0.006	87.30	4.32	41.59	61.86	0.006
Genotype	9	1.12**	9393.83**	1235.10**	25984.45**	11929.63**	1.58**
Error	18	0.03	99.89	7.81	85.10	74.44	0.006

* & ** - significant at 1 & 5 per cent respectively

It-8 showed the highest plant height and Vellanikara local showed the lowest plant height. It-2, It-3, It-5, It-6, It-8 and It-9 showed above average performance in plant height. During flowering stage the plant height differed from 211.25 cm (It-8) to 138.75 cm (Vellanikara local).

4.2.1.2 Plant Spread (cm)

The plant spread ranged from 21.67 cm (It-5) to 33.76 cm (It-8). Minimum plant spread was recorded by It-5, which was on par with It-2, It-6 and Vellanikara local during pre-flowering stage. During flowering stage the plant spread ranged from 58.43 cm (It-8) to 42.38 cm (Vellanikara local). The minimum plant spread was showed by Vellanikara local and it was on par with It-1. During pod maturation stage plant spread varied from 197.52 cm (It-8) to 125.99 cm (It-4) with an average of 164.95 cm. The mutant genotypes It-3, It-5, It-6, It-8, It-9 and It-10 showed above average performance.

4.2.1.3 Number of Branches

Significant difference was noticed for number of branches among the mutants with the Vellanikara local registering the lowest number of branches of 6.33 and It-8 showed the highest number of branches of 9.00 during pre-flowering and flowering stages. It-8 was on par with It-3, It-5, It-9 and It-10. Vellanikara local was on par with all the genotypes except It-8 and It-3. During flowering stage It-8 was on par with It-5 and Vellanikara local which was on par with It-1. During pod maturation stage the highest number of branches was shown by It-8 (43.66), it was on par with It-6. The lowest number of branches was shown by It-4 (31.66) and it was on par with It-5, It-9 and It-10.

4.2.1.4 Girth of Stem (cm)

The plant with maximum stem girth was produced by It-6 (1.87 cm) and it was on par with It-8 (1.86 cm), It-3 (1.84 cm) and It-2 (1.83 cm). The girth of

Table 2. Mean performance of neelamari at Vellanad

Genotype	Plant height(cm)			Plant spread(cm)			Number of branches			Girth of stem(cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	29.05	85.55	183.93	28.00	44.60	144.01	7.33	23.75	36.00	1.20	4.86	6.88
It-2	26.25	88.07	155.87	22.33	46.95	134.87	6.66	24.50	39.33	1.83	5.08	8.51
It-3	26.73	92.43	199.09	26.67	55.73	194.60	8.66	24.33	39.00	1.84	4.60	8.98
It-4	31.62	86.03	154.48	28.52	55.79	125.99	7.00	26.33	31.66	1.36	4.63	7.76
It-5	25.93	92.30	174.74	21.67	45.68	185.72	7.76	27.33	33.66	1.48	4.83	8.43
It-6	28.84	87.81	139.80	22.59	48.52	166.89	7.00	25.00	41.00	1.87	4.72	9.66
It-8	32.20	97.16	211.25	33.76	58.43	197.52	9.00	28.00	43.66	1.86	5.65	9.83
It-9	28.77	87.36	183.67	29.31	53.98	184.40	7.66	26.00	33.00	1.51	4.63	7.00
It-10	28.31	82.07	178.11	29.47	47.32	166.32	7.66	25.00	32.33	1.32	4.70	8.26
Vellanikara local(check)	26.05	72.05	138.75	22.70	42.38	149.23	6.33	23.00	35.33	1.52	4.76	7.01
Mean	28.37	87.08	171.97	26.50	49.94	164.95	7.51	25.47	36.50	1.58	4.84	8.23
S. E (m)	0.69	0.85	1.83	0.88	0.74	0.58	0.51	0.62	0.93	0.04	0.05	0.42
C. D (5%)	2.06	2.54	5.43	2.61	2.22	1.74	1.52	1.85	2.79	0.13	0.17	1.27

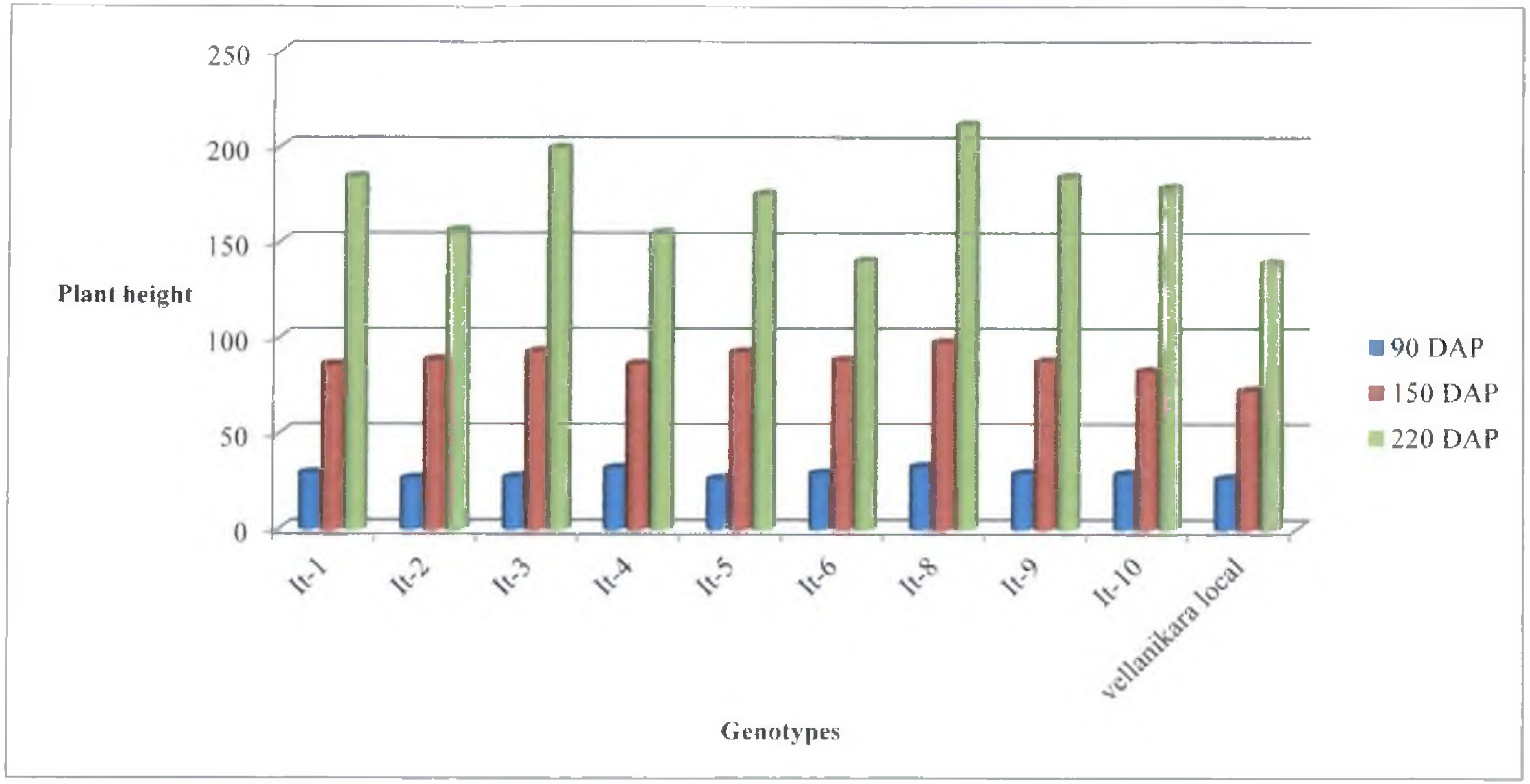


Fig 1. Mean performance of neelamari at Vellanad

stem was lowest in It-1 (1.20 cm) and it was on par with It-10 during pre-flowering stage. During flowering stage the girth of stem ranged from 4.60 cm to 5.65 cm. The girth of stem was highest for It-8 and lowest for It-3, which was on par with It-4, It-6, It-9, It-10 and Vellanikara local. During pod maturation stage the stem girth ranged from 9.83 cm to 6.88 cm. The maximum stem girth was shown by It-8 which was on par with It-6 and It-3 respectively. The minimum stem girth was shown by It-1 which was on par with It-4, It-9 and Vellanikara local.

4.2.1.5 Number of Leaves Plant^{-1}

Number of leaves plant^{-1} varied from a minimum of 23.00 (It-2) to a maximum of 30.50 (It-8) and the difference was significant during pre-flowering stage. It-2 was on par with It-1, It-6 and Vellanikara local. During flowering stage minimum number of leaves was produced by It-5 (263.36) and maximum number of leaves was produced by It-8 (528.00) with an average performance of 388.39. It-3, It-4, It-5, It-8, It-9 and It-10 showed above average performance. Number of leaves varied from 1144.20 (It-1) to 1473.33 (It-8). It-1 was on par with It-5 during pod maturation stage.

4.2.1.6 Length of Leaves (cm)

The length of leaves exhibited significant variation among the various mutants. The longest (2.66 cm) and shortest (2.14 cm) leaves were produced by It-8 and It-6 respectively during pre-flowering stage. The length of leaves It-8 was on par with It-10 and It-4, whereas It-6 was on par with It-5 and Vellanikara local. During flowering stage the longest (2.81 cm) and the shortest (2.30 cm) leaves were produced by It-8 and Vellanikara local respectively. It-8 was on par with It-2 and Vellanikara local was on par with It-1 and It-3. During pod maturation stage the longest (3.06 cm) and the shortest (2.38 cm) leaves were produced by It-8 and Vellanikara local respectively. Vellanikara local was on par with all the mutants except It-8 and It-4.

4.2.1.7 Width of Leaves (cm)

The width of leaves exhibited significant variation among the various mutants. The wide (1.75 cm) and narrow (1.20 cm) leaves were produced by It-5 and It-9 respectively during pre-flowering stage. It-5 (1.75 cm) was on par with It-8 (1.63 cm), whereas It-9 (1.20 cm) was on par with It-6 (1.32 cm). During flowering stage the wide (1.66 cm) and the narrow (1.27 cm) leaves were produced by Vellanikara local and It-9, respectively. Vellanikara local (1.66 cm) was on par with It-10 (1.58 cm) and It-6 (1.51 cm), It-9 was on par with all the mutant genotypes except Vellanikara local, It-10 and It-6. During pod maturation stage the wide (1.53 cm) and the narrow (1.23 cm) leaves were produced by It-8 and It-2 respectively. It-8 (1.53 cm) was on par with mutant It-1 (1.51 cm).

4.2.1.8 Internodal Length (cm)

The internodal length exhibited significant variation among the various mutants. The longest (1.46 cm) and shortest (1.16 cm) internodal length were produced by It-4 and It-8 respectively during pre-flowering stage. The internodal length of It-4 was on par with It-6 and It-9, whereas It-8 was on par with It-10, Vellanikara local and It-1. During flowering stage the longest (2.81 cm) and the shortest (2.30 cm) internodal length were produced by Vellanikara local and It-8 respectively. Vellanikara local was on par with It-2 and It-8 was on par with It-1 and It-3. During pod maturation stage the longest internodal length was shown by It-5 (7.67 cm) and the shortest was shown by Vellanikara local (4.83 cm). It-5 (7.67 cm) was on par with It-10 and It-3, whereas Vellanikara (4.83 cm) was on par with all the genotypes except It-10, It-8 and It-3.

Table 2. (Continued….)

Genotype	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	24.33	337.00	1144.20	2.38	2.36	2.51	1.40	1.44	1.51	1.24	2.36	5.20
It-2	23.00	479.83	1270.83	2.40	2.76	2.40	1.42	1.38	1.23	1.34	2.76	5.75
It-3	27.00	473.83	1354.33	2.40	2.44	2.46	1.36	1.46	1.40	1.38	2.44	6.46
It-4	27.00	360.66	1241.00	2.46	2.46	2.60	1.40	1.40	1.36	1.46	2.46	5.76
It-5	28.10	263.36	1145.25	2.14	2.55	2.41	1.75	1.43	1.41	1.36	2.55	7.67
It-6	23.33	363.43	1347.33	2.14	2.48	2.40	1.32	1.51	1.48	1.44	2.48	5.96
It-8	30.50	528.00	1473.33	2.66	2.81	3.06	1.63	1.41	1.53	1.16	2.30	5.17
It-9	27.66	414.66	1354.66	2.41	2.47	2.50	1.20	1.27	1.43	1.40	2.47	6.30
It-10	26.33	381.50	1260.66	2.53	2.52	2.56	1.46	1.58	1.40	1.20	2.52	6.49
Vellanikara local (check)	24.16	281.66	1172.66	2.26	2.30	2.38	1.36	1.66	1.38	1.28	2.81	4.83
Mean	26.14	388.39	1276.42	2.38	2.51	2.53	1.43	1.45	1.41	1.32	2.51	6.01
S. E (m)	0.60	5.94	4.78	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.41
C. D (5%)	1.79	17.64	14.19	0.17	0.14	0.17	0.13	0.17	0.14	0.14	0.14	1.23

4.2.1.9 Leaf Area (cm^2)

The maximum leaf area were produced by It-8 (2699.76 cm^2) and it was on par with It-1 (2681.96 cm^2). The leaf area was minimum in It-5 (1625.01 cm^2).

4.2.3.10 Harvest Index

Significant difference was noticed for harvest index among the mutants with the It-6 registering the highest of 29.95 and It-1 showed lowest of 16.11 and was on par with Vellanikara local (16.41), It-3 (17.49) and It-2 (17.79).

4.2.1.11 Total Fresh Weight (g)

The mutants differed significantly for the total fresh weight of plant with a general mean of 787.72 g. The mutant It-8 recorded the highest value of 1081.05 g. The lowest fresh weight of plant of 627.93 g was recorded for It-4 and was on par with Vellanikara local.

4.2.1.12 Total Dry Weight (g)

The total dry weight of the plant ranged from 475.48 g (It-1) to 314.74 g (Vellanikara local). Significantly higher dry weight yield in comparison to other mutants were recorded by top yielder It-1, which was on par with It-3 and It-8. The lowest dry weight yield per plant was for Vellanikara local (314.74 g) which was on par with It-6.

4.2.1.13 Dry Matter Production (g $plant^{-1}$)

The plant with maximum dry matter production (85.87 g $plant^{-1}$) was produced by It-8 and minimum (53.40 g $plant^{-1}$) in Vellanikara local with an average of 69.62 g $plant^{-1}$. It-1, It-2, It-3, It-8 and It-10 were showed above average performance in dry matter production.

4.2.1.14 Leaf Area Index

Leaf area index was varied from a minimum of 3.66 (Vellanikara local) to a maximum of 5.49 (It-8) with an average of 4.78 and the difference was significant. It-8 was on par with It-6 and It-9. It-2, It-3, It-5, It-6, It-8 and It-9 showed above average performance in the character leaf area index.

4.2.1.15 Net Assimilation Rate ($gm^{-2}day^{-1}$)

The mutants differed significantly in net assimilation rate with the general mean of 2.68 $gm^{-2}day^{-1}$. The mutant It-1 registered the minimum net assimilation rate of 1.60 $gm^{-2}day^{-1}$ which was on par with Vellanikara local and It-8 registered the maximum of 3.82 $gm^{-2}day^{-1}$, which was on par with It-4.

4.2.1.16 Fresh Weight of Leaves (g)

The fresh weight of leaves exhibited significant variation among the various mutants. The maximum (280.00 g) and minimum (145.00 g) fresh weight of leaves were produced by It-8 and It-5, respectively. The fresh weight of leaves It-8 was on par with It-6 and It-9, whereas It-5 was on par with Vellanikara local and It-3.

4.2.1.17 Dry Weight of Leaves (g)

The plant with maximum dry weight of leaves was produced by It-8 (118.95 g) and minimum was produced by vellanikara local (51.67 g) with an average of 78.85 g. It-3, It-6, It-8 and It-9 showed above average performance in dry weight of leaves.

4.2.1.18 Fresh Weight of Shoot (g)

Significant difference was noticed for fresh weight of shoot among the mutants with the It-8 registering the maximum fresh weight of shoot of 845.00 g and It-5 showed the minimum fresh weight of shoot of 558.33 g and it was on par with It-2 (568.33 g).

4.2.1.19 Dry Weight of Shoot (g)

Dry weight of shoot ranged from 427.43 g (It-8) to 217.66 g (Vellanikara local) with an average of 310.59 g. Significantly highest dry weight of shoot in comparison to other mutants was recorded by top yielder It-8 and the lowest dry weight of shoot was for Vellanikara local. It-1, It-3, It-8, It-9 and It-10 showed above average performance in dry weight of shoot.

4.2.1.20 Indigotin Content (%)

The mutants differed significantly for the indigotin content with a general mean of 3.65 per cent. The control Vellanikara local recorded the minimum value of 1.90 per cent. The maximum indigotin content of 4.56 per cent was recorded for It-8 followed by It-9, It-4 and It-2. It-2, It-4, It-8, It-9 and It-10 mutants showed above average performance in indigotin content.

4.2.2 Performance of Neelamari Mutants at Kalliyoor

The mean performances of 10 genotypes for different characters are given in Table 3.

4.2.2.1 Plant Height (cm)

The plant height showed significant difference during pre-flowering, flowering and pod maturation stages. The plant height ranged from 25.23 cm to 31.55 cm during pre-flowering stage (90 DAP) with an average of 27.98 cm and during flowering stage (150 DAP) it ranged from 71.38 cm to 97.82 cm with an

Table 2. (Continued….)

Genotype	Leaf area(cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves(g)	Dry weight of leaves(g)	Fresh weight of shoot(g)	Dry weight of shoot(g)	Indigotin content (%)
It-1	2681.96	16.11	845.86	475.48	77.98	4.75	1.60	245.00	76.60	657.00	358.33	3.17
It-2	2273.25	17.79	687.17	380.69	72.41	4.98	2.21	240.00	67.72	568.33	286.33	4.18
It-3	2174.52	17.49	786.89	475.24	78.35	4.80	3.29	150.00	83.12	726.66	329.89	3.43
It-4	1941.23	21.40	627.93	366.42	56.71	4.41	3.66	241.66	78.37	663.33	262.33	4.26
It-5	1625.01	18.31	719.84	341.65	55.96	4.84	3.08	145.00	62.56	558.33	267.66	3.47
It-6	2089.83	29.95	655.64	323.46	63.86	5.18	2.40	270.00	96.81	645.00	273.66	3.25
It-8	2699.76	25.42	1081.05	468.08	85.87	5.49	3.82	280.00	118.95	845.00	427.43	4.56
It-9	2072.98	24.51	977.55	357.15	68.52	5.28	2.76	263.33	87.53	723.33	313.33	4.38
It-10	2215.51	19.09	861.60	341.39	83.17	4.40	2.28	180.00	65.14	650.00	369.26	3.85
Vellanikara local (check)	2141.47	16.41	633.69	314.74	53.40	3.66	1.68	160.00	51.67	588.33	217.66	1.90
Mean	2191.55	20.65	787.72	384.43	69.62	4.78	2.68	217.50	78.85	662.53	310.59	3.65
S. E (m)	41.23	0.60	7.13	5.12	0.85	0.05	0.11	6.22	1.92	6.38	5.88	0.04
C. D (5%)	122.44	1.80	21.19	15.22	2.54	0.17	0.34	18.49	5.70	18.97	17.46	0.14

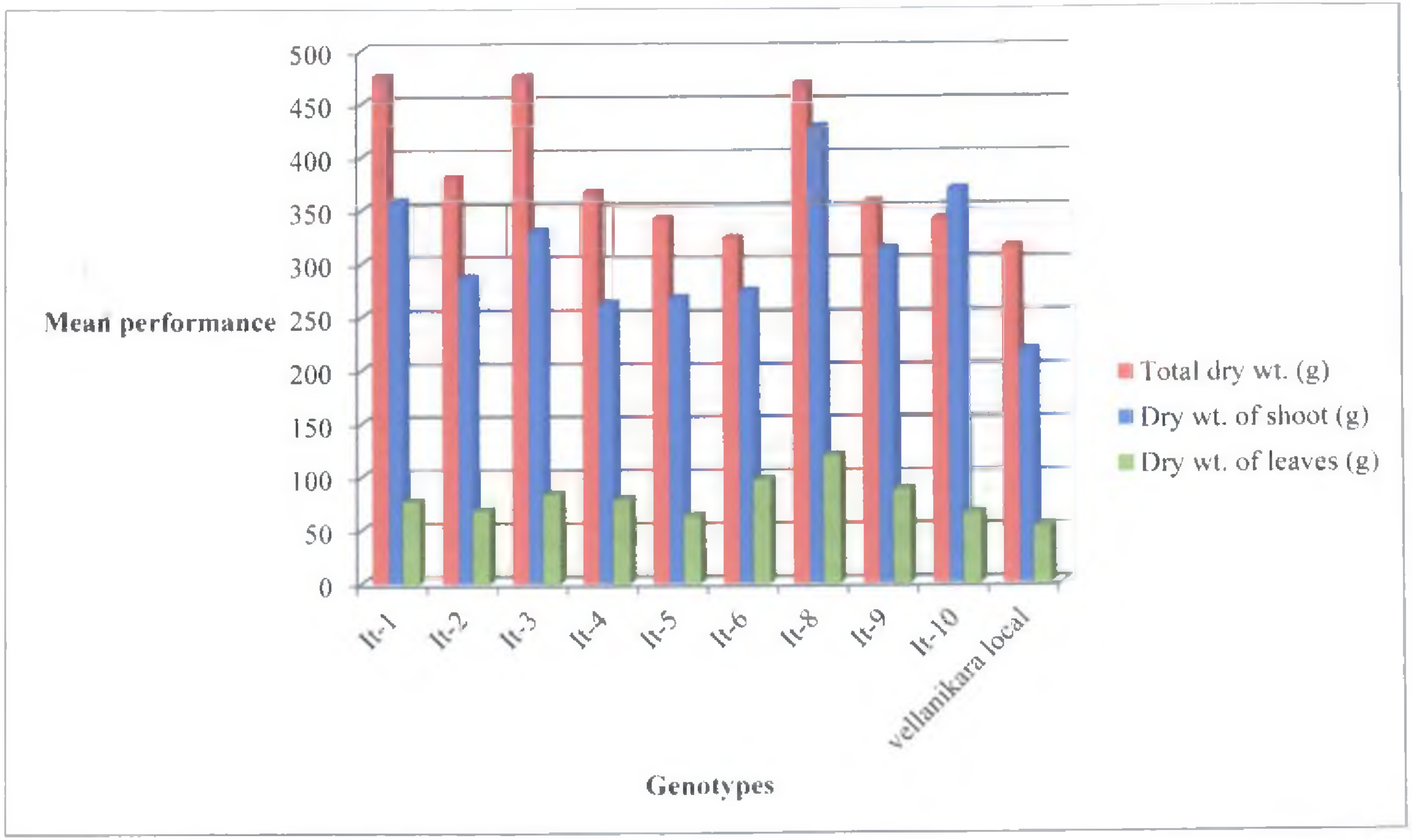


Fig 2. Mean performance of neelamari at Vellanad

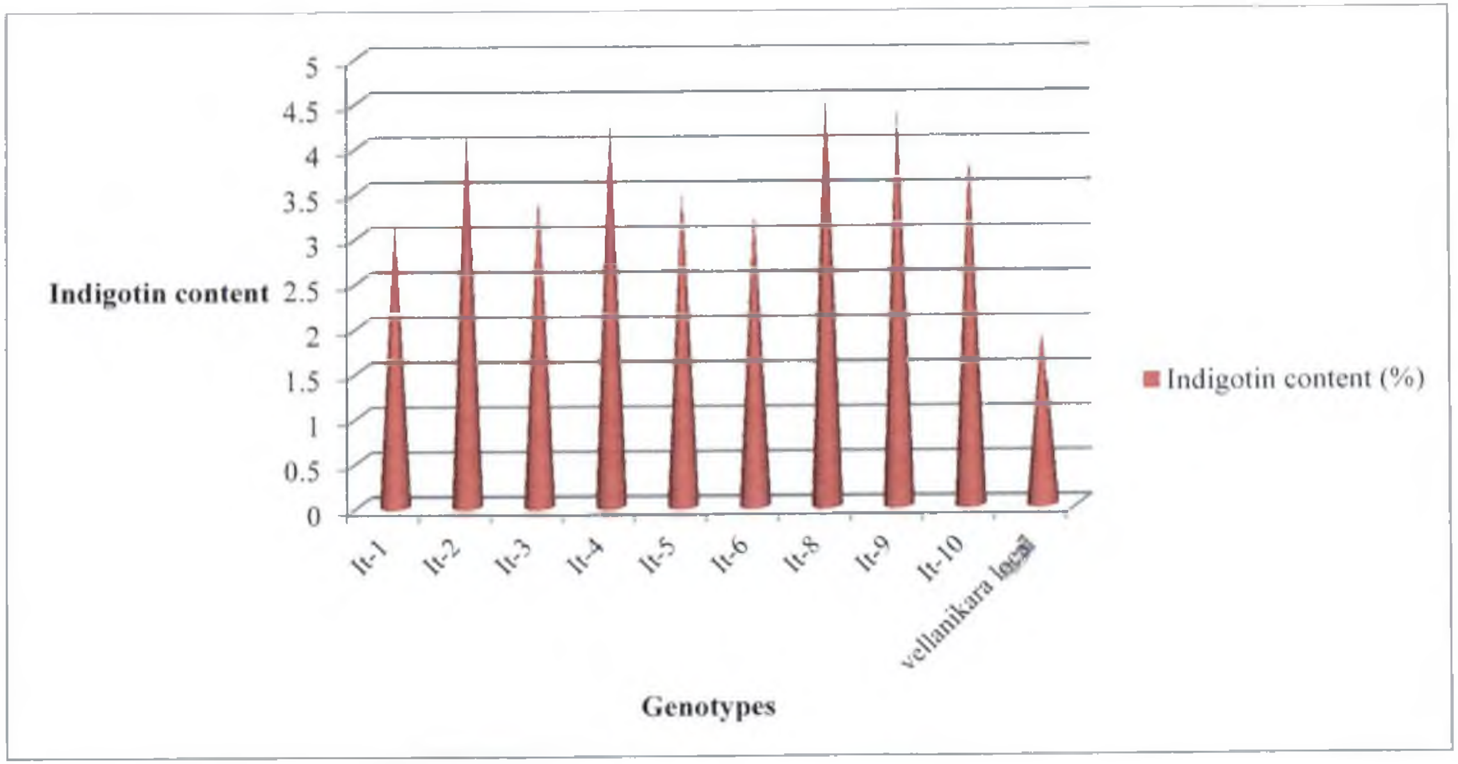


Fig 3. Mean performance of neelamari at Vellanad

average of 87.52 cm. During pod maturation stage plant height ranged from 135.53 cm to 214.87 cm with an average of 172.47 cm. In all the three stages It-8 (31.55 cm, 97.82 cm, and 214.87 cm) showed maximum plant height and was on par with It-6 and It-4 during pre-flowering stage. Vellanikara local (25.23 cm, 71.38 cm, and 135.53 cm) showed the minimum plant height which was on par with It-3 during pre-flowering stage and It-6 during pod maturation stage.

4.2.2.2 Plant Spread (cm)

The maximum plant spread was shown by It-8 (31.37 cm) during all the three stages. The lowest performance was shown by It-2 (22.43 cm) during pre-flowering stage. It-8 was on par with It-10, It-1 and It-9 during pre-flowering stage and the lowest performed mutant It-2 was on par with It-5, Vellanikara local and It-6 during pre- flowering stage. During flowering stage It-8 (57.52 cm) and was on par with It-3 (55.93 cm), while the minimum plant spread was showed by Vellanikara local (41.23 cm). During pod maturation stage the plant spread varied from 124.69 cm (It-4) to 195.74 cm (It-8) with an average of 164.28 cm. It-3, It-5, It-6, It-8 and It-9 showed above average performance with regard to plant height.

4.2.2.3 Number of Branches

Number of branches ranged from 6.00 (It-5, It-9 and Vellanikara local) to 8.66 (It-3) during pre-flowering stage with an average of 7.16. It-3 was on par with It-8 and It-4 whereas It-7 was on par with all the genotypes except It-3, It-8 and It-4. During flowering stage It-8 showed the highest number of branches (29.16), which was on par with It-5 and Vellanikara local which showed the lowest number of branches. Number of branches ranged from 32.00 (It-4) to 42.66 (It-8) with an average of 37.03 during pod maturation stage. It-8 (42.66) was on par with It-6 and It-3, whereas It-4 (32.00) was on par with It-10 and Vellanikara local.

4.2.2.4 Girth of Stem (cm)

The stem with maximum girth were produced by It-8 (1.90 cm, 5.66 cm, 9.96 cm) during all the three stages and It-8 was on par with It-2 (1.90 cm) and It-6 (1.76 cm) during pre-flowering stage. The girth of stem was minimum for It-1 (1.24 cm) and exhibited homogeneity with It-10, Vellanikara local and It-5 during pre-flowering stage. During pod maturation stage girth of stem ranged from 7.16 cm (It-9) to 9.96 cm (It-8). Maximum stem girth was showed by It-8 (9.96 cm) and was on par with It-6 and It-2 and the minimum stem girth was showed by It-9 (7.16 cm) and was on par with It-1, It-3, It-4, It-10 and Vellanikara local.

4.2.2.5 Number of Leaves plant^{-1}

During pre-flowering stage number of leaves plant^{-1} varied from 21.16 (It-6) to 28.88 (It-8) and the difference was significant. It-8 was on par with It-5 (28.33). During flowering stage the highest number of leaves was produced by It-8 (523.33) and the lowest number of leaves was produced by It-5 which was on par with Vellanikara local. During pod maturation stage the number of leaves per plant ranged from 1134.66 (It-1) to 1484.00 (It-8) with an average of 1274.00. It-1 was on par with It-5.

4.2.2.6 Length of Leaves (cm)

The length of leaves exhibited significant variation among the various mutants. The longest leaf (2.60 cm) was produced by It-8 during all the three stages and shortest leaves (2.08 cm) was produced by It-6 during pre-flowering and pod maturation stage respectively. The length of leaves It-8 was on par with It-9 (2.51 cm) and It-10 (2.60 cm), whereas It-6 (2.08 cm) was on par with It-5 (2.22 cm) during pre-flowering stage. During flowering stage length of leaves varied from 2.31 cm to 2.76 cm. The mutant It-8 (2.76 cm) produced the longest leaves and was on par with It-2. The shortest leaf for Vellanikara local (2.31 cm) and it was on par with It-1, It-3, It-4, It-5 and It-10. During pod maturation stage

Table 3. Mean performance of neelamari at Kalliyoor

Genotype	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	27.84	86.59	185.40	29.34	44.01	144.39	6.33	24.75	37.00	1.24	4.98	8.31
It-2	27.48	88.13	153.77	22.43	45.54	134.27	7.33	24.16	38.00	1.90	4.93	9.51
It-3	25.24	93.02	202.79	27.63	55.93	192.35	8.66	24.00	40.66	1.70	4.56	7.80
It-4	29.60	86.44	157.49	28.83	55.32	124.69	8.00	26.00	32.00	1.51	4.60	7.36
It-5	26.63	93.02	177.62	22.48	45.72	184.69	6.00	28.41	35.66	1.33	4.87	8.50
It-6	30.54	87.58	136.38	24.44	47.89	166.53	7.33	25.00	40.66	1.76	4.73	9.58
It-8	31.55	97.82	214.87	31.37	57.52	195.74	8.33	29.16	42.66	1.90	5.66	9.96
It-9	27.21	87.32	185.68	29.01	51.32	185.61	6.00	26.66	35.33	1.59	4.73	7.16
It-10	28.45	83.38	175.24	29.85	47.06	164.15	7.66	25.33	33.66	1.30	4.63	8.26
Vellanikara local (check)	25.23	71.38	135.53	23.28	41.23	150.37	6.00	22.33	34.66	1.33	4.81	7.40
Mean	27.98	87.52	172.47	26.87	49.15	164.28	7.16	25.43	37.03	1.55	4.85	8.38
S. E (m)	0.73	1.06	2.09	0.83	0.61	0.7	0.56	0.58	0.93	0.05	0.05	0.4
C. D (5%)	2.19	3.15	6.22	2.48	1.82	2.07	1.68	1.74	2.76	0.17	0.17	1.18

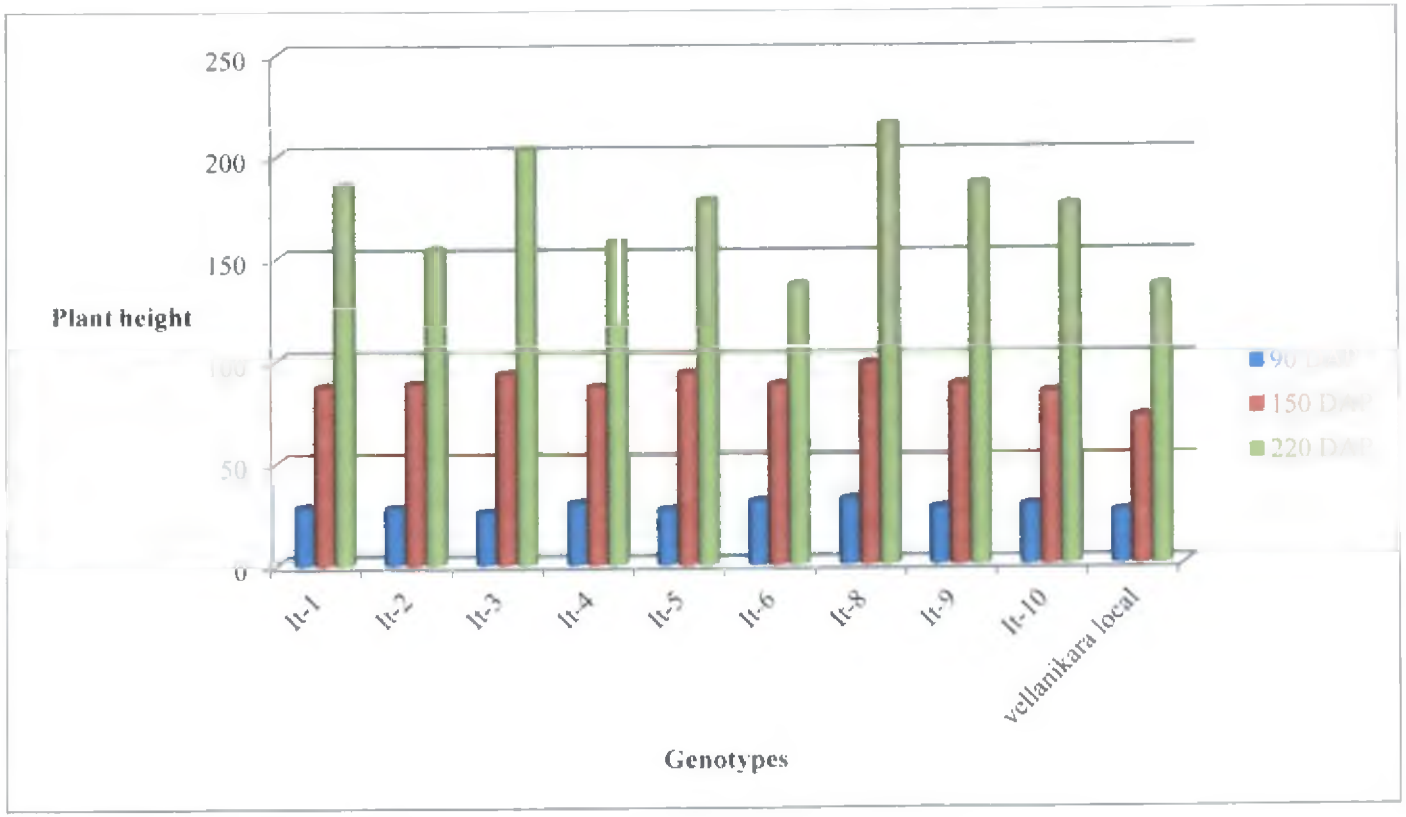


Fig 4. Mean performance of neelamari at Kalliyoor

the minimum leaf length was shown by It-6 (2.21 cm) and it was on par with It-1 and It-2.

4.2.2.7 Width of Leaves (cm)

The mutants differed significantly in leaf width with the general mean of 1.40 cm during pre-flowering stage. The mutants It-6 and Vellanikara local registered the minimum leaf width of 1.30 cm and It-5 registered the maximum of 1.70 cm, which was on par with It-8 (1.60 cm). Vellanikara local was on par with all the genotypes except It-5 and It-8. During flowering stage leaf width ranged from 1.33 cm (It-8 and It-9) to 1.56 cm (Vellanikara local). It-3 (1.50 cm), It-4(1.50 cm), It-5(1.49 cm) and It-10 (1.43cm) showed above average performance for the leaf width. During pod maturation stage It-8 (1.70 cm) showed the maximum width of leaves and Vellanikara local (1.20 cm) showed minimum width of leaves which was on par with It-2, It-4 and It-5.

4.2.2.8 Internodal Length (cm)

The internodal length exhibited significant variation among the various mutants. The highest (1.46 cm) and lowest (1.13 cm) internodal length were shown by It-4 and It-6 respectively during pre-flowering stage. The internodal length of It-4 was on par with It-3, It-5 and It-8. During flowering stage internodal length ranged from 2.31 cm (It-8) to 2.76 cm (Vellanikara local) with an average of 2.49 cm. Vellanikara local (2.76 cm) was on par with It-2 and It-8 (2.31 cm) was on par with It-1, It-3 and It-4. During pod maturation stage the highest internodal length was recorded by Vellanikara local (7.63 cm), it was on par with It-3 and the lowest internodal length was recorded by It-8 (4.80 cm).

4.2.2.9 Leaf Area (cm^2)

The mutants differed significantly for leaf area with a general mean of 2190.07 cm^2. The mutant It-5 recorded the lowest value of 1622.29 cm^2. The

Table 3. (continued....)

Genotype	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	25.00	344.20	1134.66	2.34	2.42	2.31	1.33	1.40	1.50	1.20	2.42	5.25
It-2	23.00	477.50	1269.00	2.43	2.73	2.31	1.41	1.36	1.21	1.31	2.73	5.65
It-3	25.00	474.33	1341.66	2.31	2.41	2.60	1.35	1.50	1.50	1.40	2.41	7.26
It-4	26.00	354.33	1238.33	2.41	2.46	2.40	1.38	1.50	1.23	1.46	2.46	5.95
It-5	28.33	275.25	1149.33	2.22	2.47	2.40	1.70	1.49	1.31	1.46	2.47	5.06
It-6	21.16	350.66	1342.33	2.08	2.51	2.21	1.30	1.43	1.35	1.13	2.51	6.06
It-8	28.88	523.33	1484.00	2.60	2.76	2.80	1.60	1.33	1.70	1.40	2.31	4.80
It-9	27.00	411.33	1343.00	2.51	2.48	2.43	1.33	1.33	1.50	1.31	2.48	6.13
It-10	25.66	374.00	1266.00	2.60	2.43	2.60	1.36	1.50	1.43	1.23	2.43	6.28
Vellanikara local (check)	25.50	276.07	1171.66	2.25	2.31	2.36	1.30	1.56	1.20	1.31	2.76	7.63
Mean	25.55	386.09	1274.00	2.37	2.49	2.44	1.40	1.44	1.39	1.32	2.49	6.01
S. E (m)	0.48	5.79	5.33	0.04	0.05	0.04	0.04	0.05	0.04	0.05	0.05	0.36
C. D (5%)	1.43	17.21	15.85	0.14	0.16	0.13	0.13	0.17	0.12	0.15	0.16	1.07

highest leaf area of 2664.55 cm^2 was recorded for It-8 followed by It-1, It-10, It-2, It-3 and Vellanikara local.

4.2.2.10 Harvest Index

The harvest index ranged from 15.75 (It-1) to 28.92 (It-6) with an average of 20.83. It-4 (21.83), It-6 (28.92), It-8 (26.51) and It-9 (23.28) showed above average performance for character harvest index.

4.2.2.11 Total Fresh Weight (g)

Total fresh weight of plant among the various mutants ranged from 640.00 g to1120.00 g. The mutant with highest total fresh weight of plant was It-8 and lowest fresh weight of plant was for It-4 which was on par with Vellanikara local (650.00 g).

4.2.2.12 Total Dry Weight (g)

Total dry weight of plant showed wide range of variation among the mutants from 319.53 g (Vellanikara local) to 484.32 g (It-1). Mutant It-1 (484.32 g) was on par with It-8 (473.00 g).

4.2.2.13 Dry Matter Production (g plant^{-1})

The plant with maximum dry matter production (83.40 g plant^{-1}) was produced by It-10 and it was on par with It-8 (83.02 g plant^{-1}). Dry matter production was minimum (53.73 g plant^{-1}) in It-5, which was on par with Vellanikara local (54.34 g plant^{-1}).

4.2.2.14 Leaf Area Index

Leaf area index was varied from a minimum of 3.53 (Vellanikara local) to a maximum of 5.49 (It-8) with an average of 4.77 and the difference was significant. It-2, It-3, It-5, It-6, It-8 and It-9 showed above average performance in the character leaf area index.

4.2.2.15 Net Assimilation Rate ($gm^{-2}day^{-1}$)

The mutants differed significantly in net assimilation rate with a general mean of 2.63 $gm^{-2}day^{-1}$. Vellanikara local registered the minimum net assimilation rate of 1.53 $gm^{-2}day^{-1}$ and It-8 registered the maximum of 3.83 $gm^{-2}day^{-1}$, Vellanikara local was on par with It-1.

4.2.2.16 Fresh Weight of Leaves (g)

The fresh weight of leaves exhibited significant variation among the various mutants. The highest (276.66 g) and lowest (150.00 g) fresh weight of leaves were produced by It-8 and It-5 respectively. It-8 was on par with It-6 and It-9, whereas It-5 was on par with Vellanikara local and It-3 respectively for fresh weight of leaves.

4.2.2.17 Dry Weight of Leaves (g)

The plants with highest dry weight of leaves were produced by It-8 (125.44 g) and lowest was produced by Vellanikara local (55.26 g) with an average of 80.12 g. It-3, It-6, It-8 and It-9 showed above average performance in dry weight of leaves.

4.2.2.18 Fresh Weight of Shoot (g)

Significant difference was noticed for fresh weight of shoot among the mutants with the It-8 registering the highest fresh weight of shoot of 845.00 g and It-5 showed the lowest fresh weight of shoot of 551.66 g and it was on par with It-2 (557.00 g).

4.2.2.19 Dry Weight of Shoot (g)

Dry weight of shoot ranged from 217.66 g (Vellanikara local) to 413.33 g (It-8) with an average of 308.13 g. Significantly highest dry weight of shoot in comparison to other mutants was recorded by top yielder It-8 and the lowest dry weight of shoot was for Vellanikara local. It-1, It-3, It-8, It-9 and It-10 showed above average performance in dry weight of shoot.

4.2.2.20 Indigotin Content (%)

The mutants differed significantly for the indigotin content with a general mean of 3.61 per cent. The control Vellanikara local recorded the least value of 1.86 per cent. The highest indigotin content of 4.55 per cent was recorded for It-8 followed by It-9, It-4 and It-2. It-2, It-3, It-8, It-9 and It-10 mutants showed above average performance in indigotin content.

4.2.3 Mean Performance of Neelamari in Kottarrakkara

The mean values of each of 10 neelamari genotypes for the characters studied are presented in Table 4.

4.2.3.1 Plant Height (cm)

The mutants differed significantly for the plant height with a general mean of 28.73 cm during pre-flowering stage. The mutant It-3 recorded the minimum value of 25.98 cm. The maximum height of 32.72 cm was recorded for It-8 followed by It-9 (30.68 cm). It-3 was on par with It-2, It-5 and Vellanikara local. During flowering stage mutants showed significant difference in plant height with an average of 87.58 cm. The genotype showed maximum plant height was It-8 (98.84 cm) and the minimum plant height was Vellanikara local (73.98 cm). It-2, It-3, It-5, It-8 mutants showed above average performance in plant height. During pod maturation stage plant height varied from 136.08 cm (Vellanikara local) to 214.62 cm (It-8). Vellanikara local was on par with It-6.

Table 3. (continued….)

Genotype	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
It-1	2598.28	15.75	843.33	484.32	76.61	4.73	1.75	230.00	76.31	666.66	351.66	3.16
It-2	2262.63	18.47	680.00	375.25	75.16	4.94	2.12	245.00	69.28	557.00	289.66	4.14
It-3	2229.46	19.70	770.00	434.13	77.83	4.84	3.13	156.66	85.50	726.66	326.89	3.49
It-4	2048.60	21.83	640.00	353.52	58.26	4.41	3.38	245.00	77.17	663.33	255.66	4.21
It-5	1622.29	18.12	713.33	345.10	53.73	4.83	3.07	150.00	62.51	551.66	259.26	3.46
It-6	1970.29	28.92	661.66	340.58	64.13	5.32	2.42	273.33	98.53	646.66	263.66	3.24
It-8	2664.55	26.51	1120.00	473.00	83.02	5.49	3.83	276.66	125.44	845.00	413.33	4.55
It-9	2076.26	23.28	950.00	367.70	67.31	5.25	2.76	265.00	85.65	720.00	329.23	4.29
It-10	2267.09	18.80	875.00	348.48	83.40	4.41	2.32	183.33	65.53	646.66	374.33	3.75
Vellanikara local (check)	2161.31	17.27	650.00	319.53	54.34	3.53	1.53	155.00	55.26	581.66	217.66	1.86
Mean	2190.07	20.83	790.33	384.16	69.38	4.77	2.63	218.00	80.12	660.53	308.13	3.61
S. E (m)	39.18	0.43	6.15	5.34	0.97	0.05	0.1	7.09	1.54	7.69	4.86	0.04
C. D (5%)	116.36	1.29	18.29	15.88	2.88	0.16	0.29	21.06	4.58	22.86	14.43	0.13

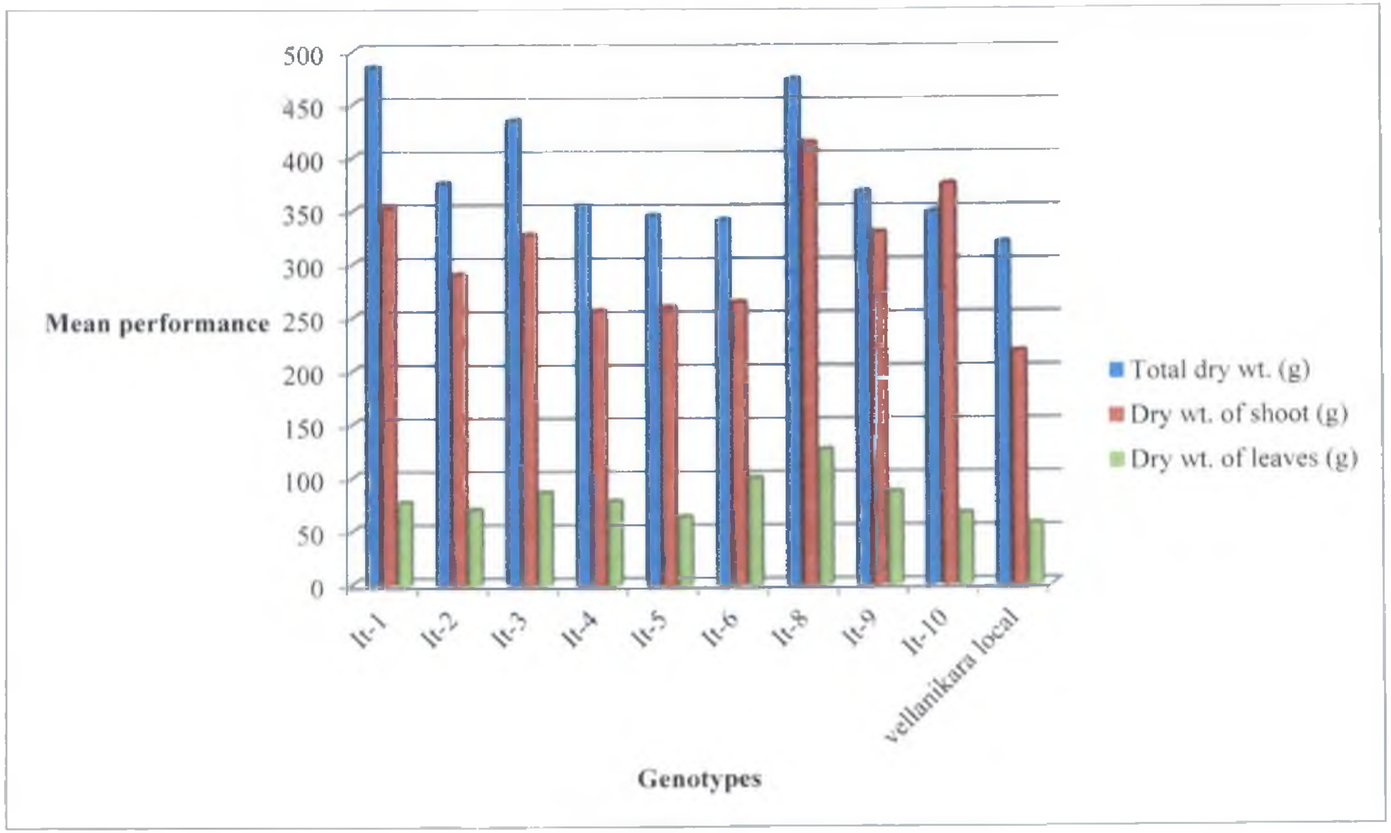


Fig 5. Mean performance of neelamari at Kalliyoor

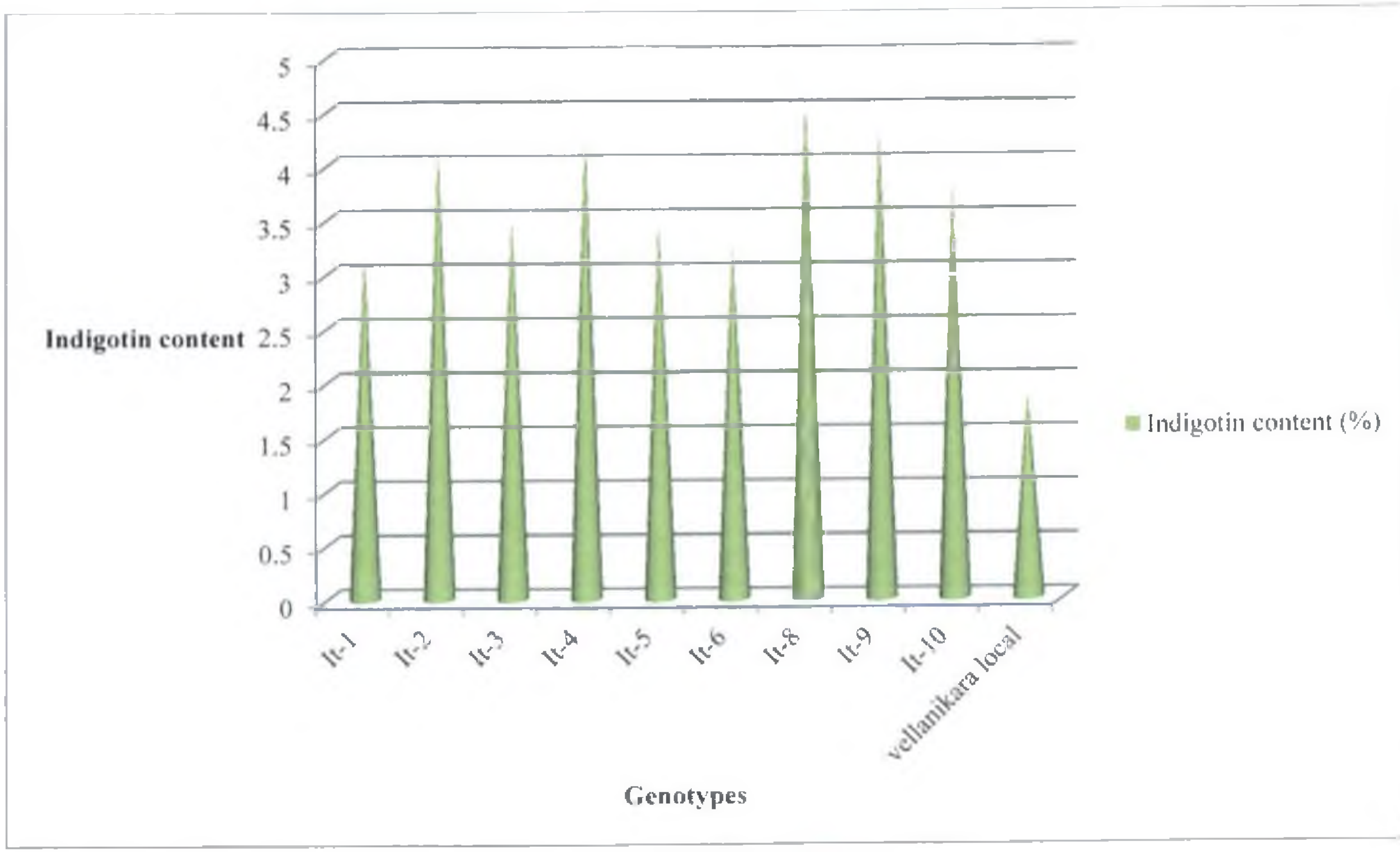


Fig 6. Mean performance of neelamari at Kalliyoor

4.2.3.2 Plant Spread (cm)

During pre-flowering stage the mean value of plant spread ranged from 23.19 (Vellanikara local) to 32.34 cm (It-8) with an average of 26.63 cm. The minimum plant spread was shown by Vellanikara local and it was on par with It-2, It-5 and It-6. The plant spread showed significant variation from (It-8) 43.98 cm (Vellanikara local) to 56.84 cm during flowering stage. The mutant showed maximum plant spread was It-8 and it was on par with It-4 and the minimum plant spread was shown by Vellanikara local and it was on par with It-2 and It-1. During pod maturation stage the mean value of plant spread varied from 126.31 cm (It-4) to 198.40 cm (It-8) with an average of 165.32 cm. The genotype It-3, It-5, It-6, It-8 and It-9 showed above average performance.

4.2.3.3 Number of Branches

There was no significant variation among the mutants for number of branches during pre-flowering stage. During flowering stage the maximum number of branches was shown by It-8 and the minimum no of branches was shown by Vellanikara local which was on par with It-1, It-2, It-3 and It-4. During pod maturation stage number of branches ranged from 31.66 to 43.66. The maximum number of branches was shown by It-8 and it was on par with It-6. The minimum number of branches was shown by It-4 and it was on par with It-5, It-9 and It-10.

4.2.3.4 Girth of Stem (cm)

The plant with maximum stem girth was produced by It-8 (1.90 cm) and it was on par with It-2 (1.85 cm), It-6 (1.73 cm) and It-3 (1.70 cm). The girth of stem was minimum in It-1 (1.25 cm) and exhibited on par with the control (1.35 cm), It-10 (1.40 cm) and It-5 (1.40 cm) during pre-flowering stage. During flowering stage the highest performance was shown by It-8 (5.73 cm) and the least performance of stem girth was shown by It-6 (4.66 cm) which was on par with all the genotypes except It-8 and It-2. The stem girth during pod maturation

Table 4. Mean performance of neelamari at Kottarakkara

Genotype	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	29.02	86.82	184.53	27.98	45.82	143.10	7.17	24.50	36.33	1.25	4.78	7.55
It-2	26.72	88.32	154.54	23.70	44.43	137.04	7.33	25.00	38.33	1.85	5.05	8.18
It-3	25.98	92.81	199.34	27.15	53.98	193.48	7.33	25.00	38.66	1.70	4.70	8.31
It-4	30.47	86.22	156.14	29.19	55.88	126.31	8.00	25.16	31.66	1.53	4.75	7.10
It-5	27.11	91.40	175.16	23.38	46.74	187.63	7.64	27.66	34.00	1.40	4.83	8.43
It-6	29.69	86.02	138.47	23.88	48.02	168.45	8.33	26.33	42.00	1.73	4.66	9.66
It-8	32.72	98.84	214.62	32.34	56.84	198.40	9.33	30.00	43.66	1.90	5.73	10.60
It-9	30.68	87.10	184.34	27.77	52.62	184.64	7.50	27.16	34.00	1.56	4.70	8.00
It-10	28.92	84.29	177.71	27.73	47.77	164.09	7.83	26.83	33.33	1.40	4.68	9.36
Vellanikara local (check)	26.04	73.98	136.08	23.19	43.98	150.08	7.33	23.66	35.33	1.35	4.73	7.35
Mean	28.73	87.58	172.09	26.63	49.61	165.32	7.78	26.13	36.73	1.56	4.86	8.45
S. E (m)	0.56	0.64	1.23	0.91	0.67	0.89	0.54	0.72	0.87	0.05	0.05	0.45
C. D (5%)	1.68	1.91	3.67	2.70	1.99	2.65		2.14	2.60	0.17	0.17	1.35

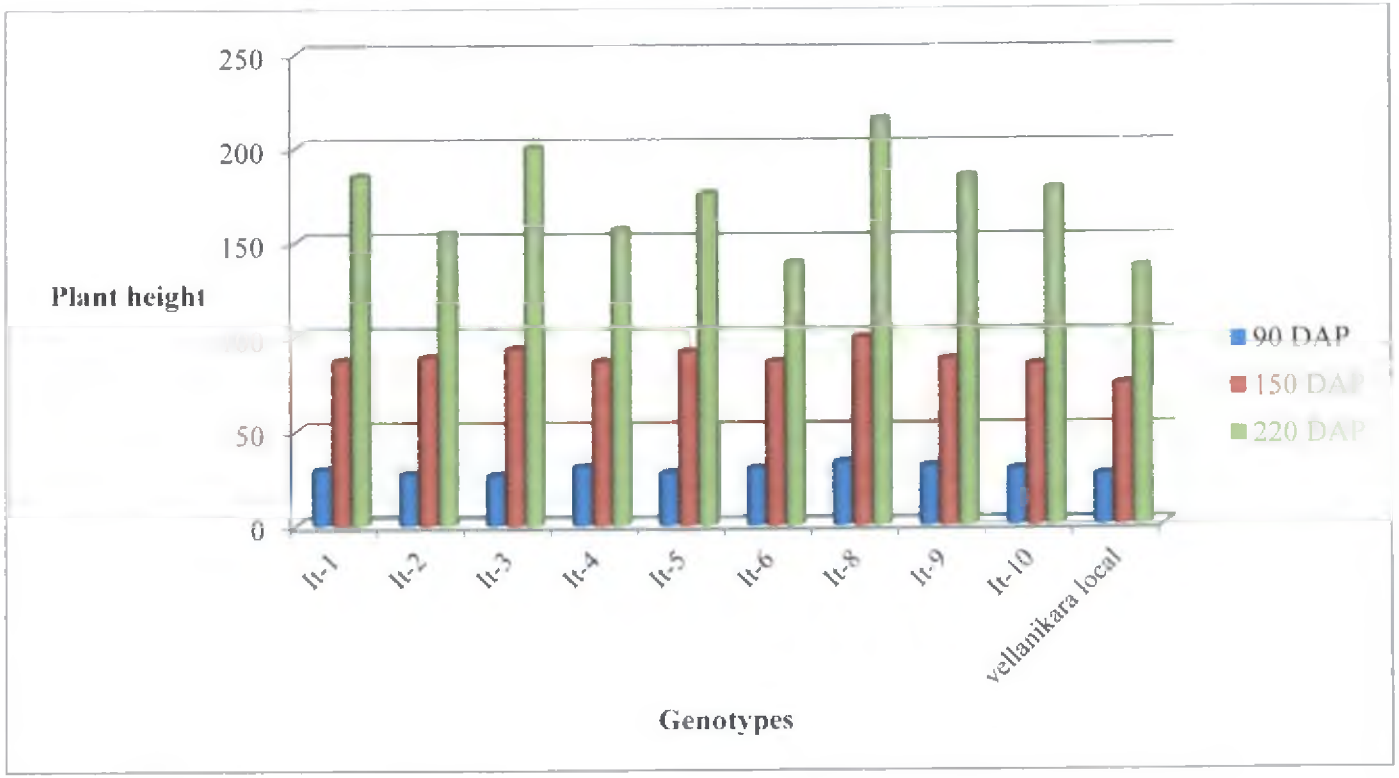


Fig 7. Mean performance of neelamari at Kottarakara

stage ranged from 7.10 cm to10.60 cm. The maximum stem girth was shown by It-8 and it was on par with It-6 and It-10. Also minimum stem girth was performed by It-4 and it was on par with all the mutant genotypes except It-8, It-6 and It-10.

4.2.3.5 Number of Leaves plant^{-1}

Number of leaves plant^{-1} varied from a minimum of 23.20 (It-6) to a maximum of 29.85 (It-8) and the difference was significant during pre-flowering stage. It-8 was on par with It-5 and It-6 was on par with Vellanikara local and It-2. During flowering stage the number of leaves plant^{-1} varied from 264.10 (It-5) to 523.66 (It-8). The mutant showing lowest performance was on par with Vellanikara local. Number of leaves plant^{-1} varied from 1141.66 (It-1)to 1475.33 (It-8) during pod maturation stage. The genotype showing minimum no of leaves i.e., It-1 was on par with It-5 (1146.33).

4.2.3.6 Length of Leaves (cm)

The length of leaves exhibited significant variation among the various mutants. The longest (2.66 cm) and the shortest (2.10 cm) leaves were produced by It-8 and It-5 respectively during pre-flowering stage. The length of leaves It-8 was on par with It-10 and It-9, whereas It-5 was on par with It-6. During flowering stage the longest (2.8 cm) and the shortest (2.3 cm) leaves were produced by It-2 and Vellanikara local respectively. It-2 was on par with It-8 and It-5 and Vellanikara local was on par with It-9. During pod maturation stage the length of leaves varied from 2.38 cm to 3.13 cm. The longest leaves were shown by It-8 and the shortest leaves were shown by Vellanikara local and it was on par with all the mutant genotypes except It-8, It-4 and It-10.

4.2.3.7 Width of Leaves (cm)

The width of leaves exhibited significant variation among the various mutants. The wide (1.70 cm) and narrow (1.30 cm) leaves were produced by It-8 and It-6 respectively during pre-flowering stage. The length of leaves It-8 was on par with It-5, whereas It-9 was on par with all the mutant genotypes except It-8, It-5 and It-2. During flowering stage the wide (1.63 cm) and the narrow (1.30 cm) leaves were produced by control and It-2 respectively. Vellanikara local was on par with It-8, It-6 and It-10, while It-2 was on par with It-1, It-3, It-4, It-5 and It-9. During pod maturation stage the wide (1.63 cm) and the narrow (1.16 cm) leaves were produced by It-8 and It-2 respectively with an average width of 1.43 cm. It-1, It-4, It-6, It-8 and It-9 showed an above average performance in width of leaves.

4.2.3.8 Internodal length (cm)

The internodal length exhibited significant variation among the various mutants. The longest (1.5 cm) and shortest (1.17 cm) internodal length were produced by It-4 and It-8 respectively during pre-flowering stage. The internodal length of plant It-4 was on par with It-6, It-9, It-5 and It-2, whereas It-8 was on par with It-10, control, It-3 and It-1. During flowering stage the longest (2.80 cm) and the shortest (2.30 cm) internodal length were produced by control and It-8 respectively. Vellanikara local was on par with It-8 and It-5 whereas It-8 was on par with It-9. During pod maturation stage the internodal length varied from 4.83 cm to7.67 cm. The longest internodal length was shown by control and it was on par with It-10 and It-3. The shortest internodal length was shown by It-8 and it was on par with It-1, It-2, It-4, It-5 and It-6.

4.2.3.9 Leaf Area (cm^2)

Leaf area ranged from 1952.00 cm^2 to 2668.50 cm^2. Maximum leaf area was shown by It-1 and the minimum leaf area was shown by It-6.

Table 4. (Continued…..)

Genotype	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	24.66	341.85	1141.66	2.36	2.48	2.51	1.34	1.40	1.51	1.27	2.48	5.20
It-2	23.33	472.00	1274.66	2.41	2.80	2.43	1.46	1.30	1.16	1.40	2.80	5.75
It-3	26.66	474.00	1350.00	2.36	2.48	2.40	1.33	1.41	1.38	1.30	2.48	6.46
It-4	26.00	352.16	1234.66	2.50	2.51	2.66	1.40	1.45	1.43	1.50	2.51	5.76
It-5	29.77	264.10	1146.33	2.10	2.63	2.51	1.61	1.43	1.41	1.41	2.63	5.17
It-6	23.20	354.53	1348.33	2.13	2.51	2.43	1.30	1.53	1.51	1.43	2.51	5.96
It-8	29.85	523.66	1475.33	2.66	2.80	3.13	1.70	1.56	1.63	1.17	2.30	4.83
It-9	27.11	418.77	1353.00	2.54	2.41	2.46	1.37	1.34	1.46	1.47	2.41	6.30
It-10	25.50	377.50	1267.00	2.61	2.50	2.63	1.40	1.50	1.40	1.26	2.50	6.49
Vellanikara local (check)	24.00	265.00	1163.00	2.30	2.30	2.38	1.43	1.63	1.38	1.20	2.80	7.67
Mean	26.01	384.36	1275.40	2.39	2.54	2.55	1.43	1.45	1.43	1.34	2.54	5.96
S. E (m)	0.49	3.47	6.00	0.05	0.05	0.05	0.04	0.05	0.03	0.05	0.05	0.42
C. D (5%)	1.46	10.33	17.82	0.15	0.17	0.17	0.13	0.15	0.09	0.15	0.17	1.24

4.2.3.10 Harvest Index

Significant difference was noticed for harvest index among the mutants with the It-6 registering the maximum of 30.22 and It-1 showed minimum of 16.36 and was on par with control (17.47) and It-2 (17.75).

4.2.3.11Total Fresh Weight (g)

The mutants differed significantly for the total fresh weight of plant with a general mean of 778.53 g. The mutant It-8 recorded the maximum value of 1028.33 g. The minimum fresh weight of plant of 627.33 g was recorded for It-4 and was on par with control and It-6.

4.2.3.12 Total Dry Weight (g)

The total dry weight of the plant ranged from 313.54 g (control) to 486.53 g (It-8). Significantly higher dry weight yield in comparison to other mutants were recorded by top yielder It-8, which was on par with It-1. The lowest dry weight yield per plant was for control.

4.2.3.13 Dry Matter Production (g plant^{-1})

The plant with minimum dry matter production (53.66 g plant^{-1}) was produced by It-5, it was on par with Vellanikara local (53.93 g plant^{-1}) and maximum dry matter production (85.71 g plant^{-1}) was produced by It-8, it was on par with It-10 (85.45 g plant^{-1}) and

4.2.3.14 Leaf Area Index

Leaf area index varied from a minimum of 3.58 (control) to a maximum of 5.45 (It-8) with an average of 4.77 and the difference was significant. It-I, It-2, It-3, It-5, It-6, It-8 and It-9 showed above average performance in the character leaf area index.

4.2.3.15 Net Assimilation Rate ($gm^{-2}day^{-1}$)

The mutants differed significantly in net assimilation rate with the general mean of 2.69 $gm^{-2}day^{-1}$. The mutant It-1 registered the lowest net assimilation rate of 1.50 $gm^{-2}day^{-1}$ and It-8 registered the highest of 3.87 $gm^{-2}day^{-1}$. It-3, It-4, It-5, It-8 and It-9 showed above average performance in net assimilation rate.

4.2.3.16 Fresh Weight of Leaves (g)

The fresh weight of leaves exhibited significant variation among the various mutants. The lowest (145 g) and highest (286.66 g) fresh weight of leaves were produced by It-3 and It-8 respectively. The fresh weight of leaves It-8 was on par with It-6, whereas It-5 was on par with It-3.

4.2.3.17 Dry Weight of Leaves (g)

The plant with lowest dry weight of leaves were produced by Vellanikara local (54.67 g) and highest was produced by It-8 (122.33 g) with an average of 79.61 g. It-3, It-6, It-8 and It-9 showed above average performance in dry weight of leaves.

4.2.3.18 Fresh Weight of Shoot (g)

Significant difference was noticed for fresh weight of shoot among the mutants with It-5 showed the lowest fresh weight of shoot of 550.00 g and It-8 registering the highest fresh weight of shoot of 840.00 g with an average of 658.30 g. It-1, It-3, It-4, It-6, It-8 and It-9 showed above average performance in fresh weight of shoot.

4.2.3.19 Dry Weight of Shoot (g)

Dry weight of shoot ranged from 209.05 g (Vellanikara local) to 411.47 g (It-8) with an average of 309.12 g. Significantly highest dry weight of shoot in comparison to other mutants was recorded by top yielder It-8 and lowest dry weight of shoot was for Vellanikara local. It-1, It-3, It-8, It-9 and It-10 showed above average performance in dry weight of shoot.

4.2.3.20 Indigotin content (%)

The mutants differed significantly for the indigotin content with a general mean of 3.5 per cent. The control vellanikara local recorded the lowest value of 1.97 per cent. The highest indigotin content of 4.35 per cent was recorded for It-8, which was on par with It-9 and It-4. It-1, It-3, It-8, It-9 and It-10 mutants showed above average performance in indigotin content.

4.2.4 Performance of Neelamari at Kayamkulam

The mean performances of 10 genotypes for different characters are given in Table 5.

4.2.4.1 Plant Height (cm)

The plant height showed significant difference during pre-flowering, flowering and pod maturation stages. The plant height ranged from 24.55 cm to 33.33 cm during pre-flowering stage (90 DAP) with an average of 27.84 cm and during flowering stage (150 DAP) it ranged from 73.60 cm to 98.35 cm with an average of 87.77 cm. During pod maturation stage, performance of plant height ranged from 135.76 cm to 217.85 cm with an average of 173.02 cm. In all the three stages mutant It-8 showed maximum plant height. It-1, It-4, It-6, It-8 and It-10 genotypes showed above average performance during pre-flowering stage. It-2, It-3, It-5, It-8 and It-9 genotypes showed above average performance during flowering stage and the genotypes It-1, It-3, It-5, It-8, It-9 and It-10 showed above average performance during pod maturation stage. Mutant It-8 was on par with It-4, It-5 and It-3 during 90, 150 and 220 DAP respectively.

Table 4. (Continued…..)

Genotype	Leaf area (cm²)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production (gplant^{-1})	Leaf area index	Net assimilation rate (gm^{-2}day^{-1})	Fresh weight of leaves(g)	Dry weight of leaves(g)	Fresh weight of shoot(g)	Dry weight of shoot(g)	Indigotin content (%)
It-1	2668.5	16.36	841.66	476.00	77.28	4.83	1.50	240.00	77.93	663.66	358.97	3.16
It-2	2300.45	17.75	671.66	373.89	74.69	4.90	2.10	241.66	66.39	568.33	282.94	4.18
It-3	2225.21	18.37	776.66	447.53	78.56	4.81	3.34	145.00	82.24	725.00	321.60	3.48
It-4	2018.93	21.84	627.33	352.67	59.15	4.41	3.49	235.00	77.04	662.33	265.24	4.23
It-5	2289.58	18.60	728.33	334.70	53.66	4.84	3.09	145.00	62.22	550.00	266.72	3.50
It-6	1952	30.22	642.66	330.52	64.55	5.23	2.47	275.00	99.89	650.00	276.84	3.21
It-8	2558.56	25.15	1028.33	486.53	85.71	5.45	3.87	286.66	122.33	840.00	411.47	4.35
It-9	2074	25.44	970.00	342.76	65.11	5.23	2.86	263.33	87.20	700.00	327.43	4.26
It-10	2238.35	19.22	865.33	344.41	85.45	4.40	2.35	173.33	66.17	650.33	371.00	3.61
Vellanikara local(check)	2121.83	17.47	633.33	313.54	53.93	3.58	1.88	166.66	54.67	573.33	209.05	1.97
Mean	2244.74	21.04	778.53	380.02	69.81	4.77	2.69	217.16	79.61	658.30	309.12	3.59
S. E (m)	21.65	0.55	6.55	5.09	0.62	0.04	0.05	7.16	1.7	5.03	5.01	0.04
C. D (5%)	64.30	1.66	19.47	15.13	1.84	0.14	0.17	21.27	5.04	14.94	14.88	0.12

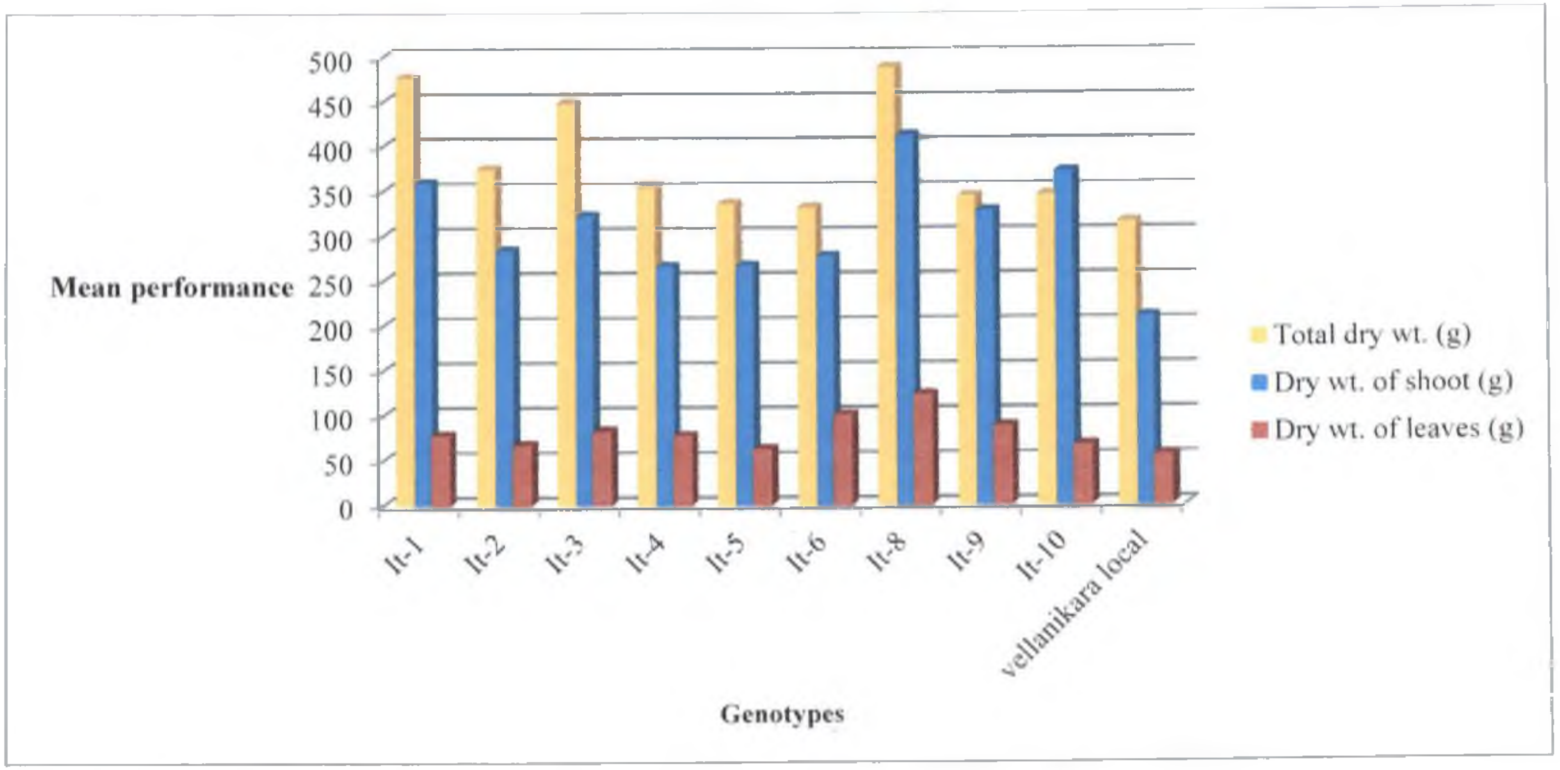


Fig 8. Mean performance of neelamari at Kottarakara

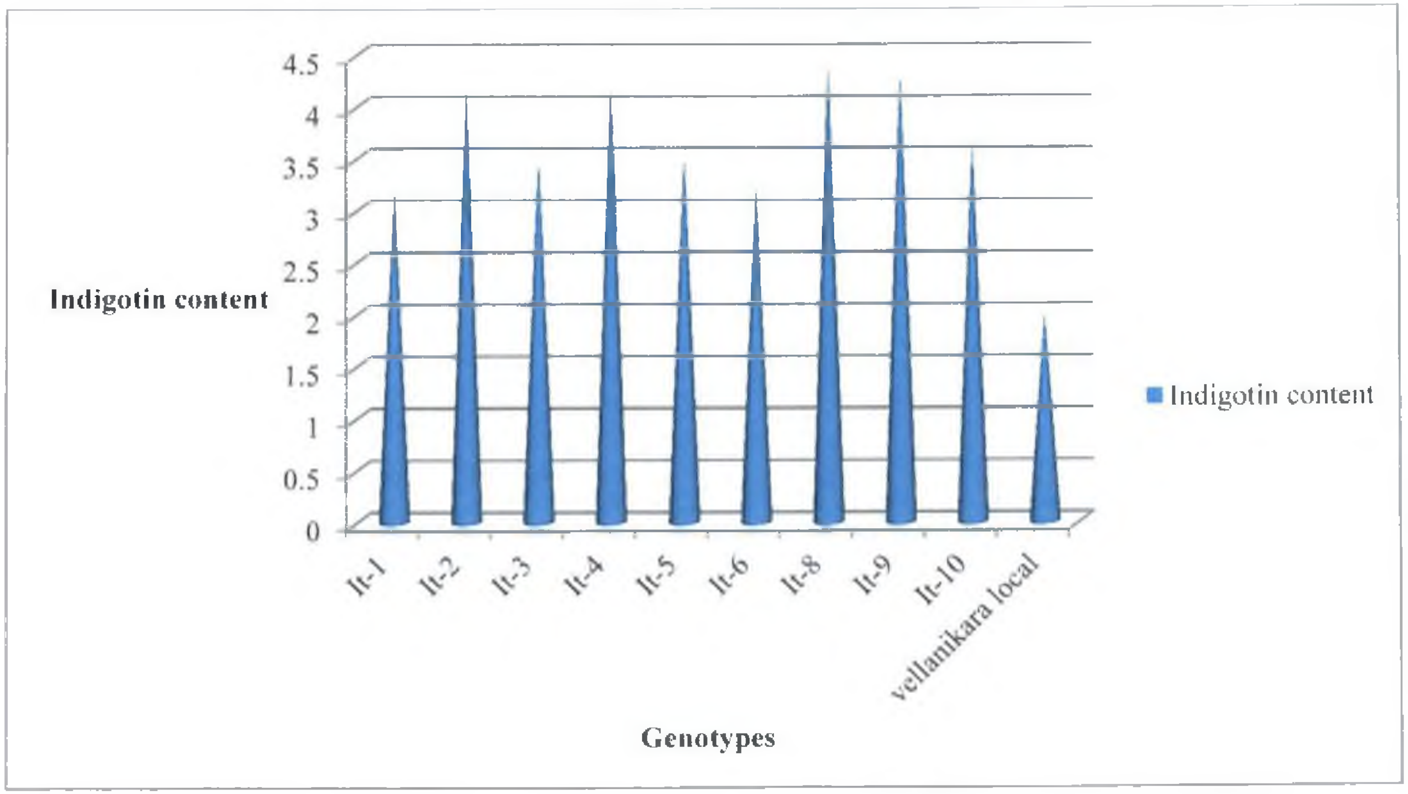


Fig 9. Mean performance of neelamari at Kottarakara

4.2.4.2 Plant Spread (cm)

The minimum plant spread was showed by It-2 (21.00 cm), Vellanikara local (42.04 cm) and It-4 (127.73 cm) during 90, 150 and 220 DAP respectively. The maximum plant spread was showed by It-8 (33.42 cm, 57.71 cm, 195.40 cm) during pre-flowering, flowering and pod maturation stages. It-8 was on par with It-10, It-4 and It-3 during 90, 150 and 220 DAP respectively.

4.2.4.3 Number of Branches

Number of branches ranged from 5.00 to 9.00 during pre-flowering stage and during flowering stage it ranged from 23.44 to 29.16. During pod maturation stage it ranged from 33.00 to 43.66. The genotype It-8 showed highest performance in all stages of plant growth which was on par with It-6 during pre-flowering stage and pod maturation stage, while it was on par with It-5 during flowering stage.

4.2.4.4 Girth of Stem (cm)

Girth of stem showed significant difference among genotypes. It ranged from 1.20 cm to 1.88 cm during pre-flowering stage. The maximum girth of stem was showed by It-8 which was on par with It-6. During flowering stages it ranged from 4.54 cm to 5.52 cm with an average of 4.84 cm. During flowering and pod maturation stages It-8 showed maximum girth of stem which was on par with It-2 and It-10 respectively. It-4 showed the lowest girth of stem and it was on par with It-1 and Vellanikara local during pod maturation stage.

4.2.4.5 Number of Leaves Plant^{-1}

The observation for number of leaves plant^{-1} was taken during pre-flowering, flowering and pod maturation stages. The lowest number of leaves per plant was observed in It-6, Vellanikara local and It-1 during 90, 150 and 220 DAP. The genotype It-8 (515.33, 1470.00) showed highest number of leaves per

Table 5. Mean performance of neelamari at Kayamkulam

Genotype	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	29.58	85.91	183.42	29.33	43.64	142.15	6.11	25.16	38.66	1.20	4.92	7.50
It-2	25.00	88.56	153.97	21.00	44.93	136.02	6.33	24.72	40.33	1.83	5.02	9.40
It-3	24.55	92.19	205.83	26.01	53.82	193.98	5.00	25.88	40.33	1.62	4.54	8.93
It-4	30.46	87.02	155.33	28.52	54.36	127.73	6.50	24.33	33.33	1.48	4.64	7.30
It-5	24.74	93.61	176.65	21.67	46.29	185.44	7.00	28.68	36.00	1.30	4.87	9.33
It-6	29.94	86.36	139.80	23.25	49.46	165.44	8.33	24.63	42.33	1.80	4.65	8.36
It-8	33.33	98.35	217.85	33.42	57.71	195.40	9.00	29.16	43.66	1.88	5.52	10.30
It-9	26.17	88.76	`184.94	28.64	50.44	186.88	5.00	26.66	35.33	1.61	4.74	8.06
It-10	29.54	83.38	176.74	29.47	46.96	165.46	6.00	26.00	33.00	1.22	4.76	9.80
Vellanikara local (check)	25.11	73.60	135.76	22.70	42.04	151.40	6.00	23.44	33.66	1.42	4.79	7.53
Mean	27.84	87.77	173.02	26.40	48.96	164.99	6.57	25.87	37.66	1.53	4.84	8.65
S. E (m)	0.55	0.91	2.21	0.83	0.73	1.01	0.53	0.58	0.77	0.06	0.06	0.43
C. D (5%)	1.65	2.71	6.58	2.48	2.19	3.00	1.58	1.75	2.29	0.17	0.18	1.29

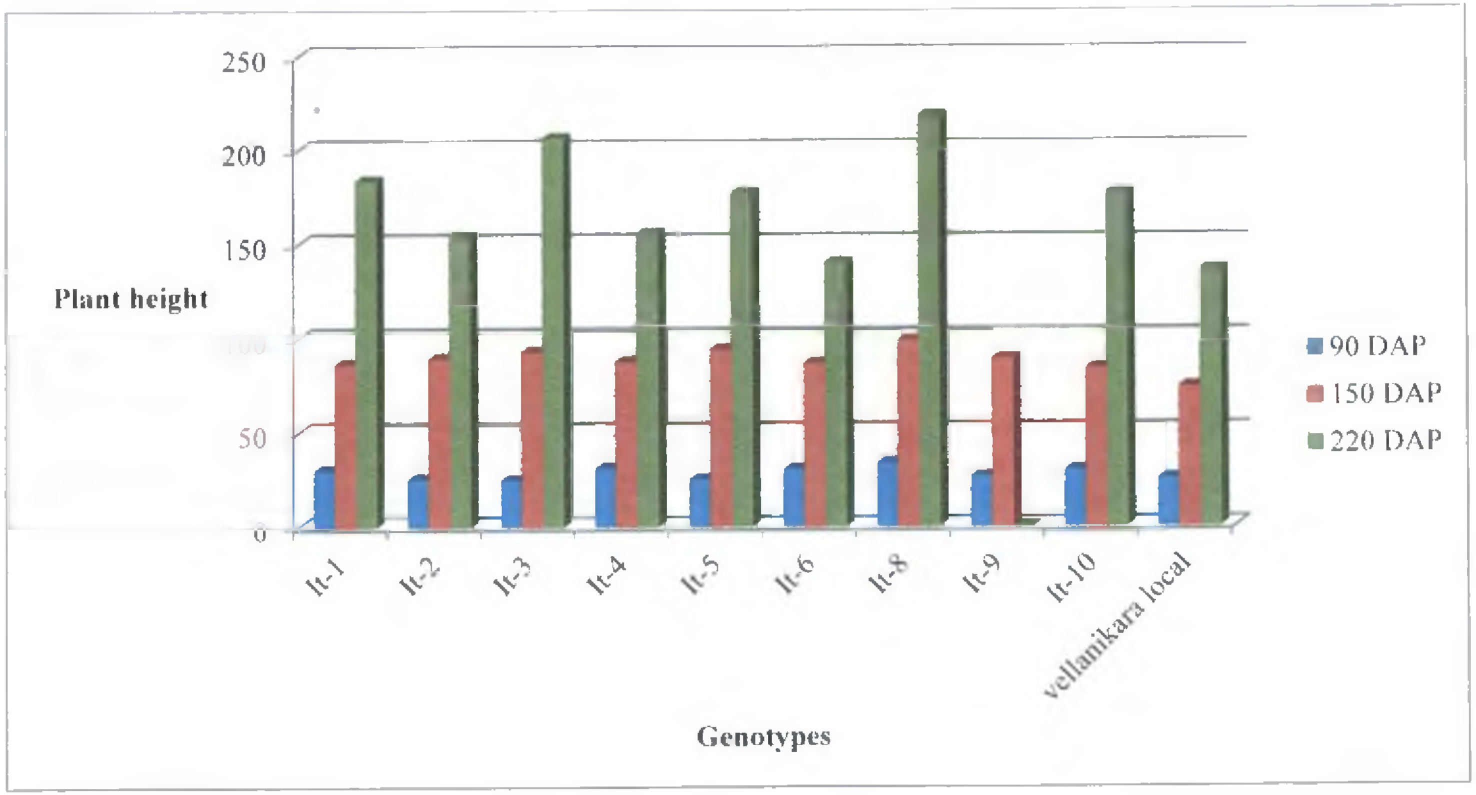


Fig 10. Mean performance of neelamari at Kayamkulam

pant during flowering and pod maturation stages and was on par with It-3, It-6 and It-9.

4.2.4.6 Length of Leaves (cm)

During pre-flowering and flowering stages It-8 showed the lowest was shown by It-6 (2.03 cm and 2.36 cm) of leaf and the highest length (2.77 cm and 3.16 cm) with an average of 2.5 cm and 2.39 cm. During pod maturation stage the minimum length of leaves was showed by Vellanikara local (2.29 cm).The mutant It-2 (2.83 cm) showed the highest performance and was on par with It-8 (2.78 cm).

4.2.4.7 Width of Leaves (cm)

The genotypes showed significant difference in width of leaves with a general mean of 1.45 cm during pre-flowering and flowering stages and 1.48 cm during pod maturation stage. The minimum performance in the character width of leaves was shown by the genotype It-9 (1.20 cm) and the highest was shown by It-5 (1.89 cm) during pre-flowering stage. During flowering stage, the maximum width of leaves was shown by It-10 (1.69 cm) and was on par with It-4 and It-5. Mutant It-8 (1.66 cm) showed the maximum width of leaves and was on par with It-1, It-4, It-9 and It-10 during pod maturation stage.

4.2.4.8 Internodal Length (cm)

During pre-flowering stage the genotypes showed non-significant variation. But at flowering stage It-2 (2.29 cm) showed the least internodal length and was on par with It-4, It-9 and It-1. Vellanikara local (2.83 cm) showed the highest internodal length which was on par with It-8. During pod maturation stage It-8 (4.4 cm) showed the lowest internodal length and Vellanikara local (8.20 cm) showed the highest internodal length. The genotype Vellanikara local which showed highest internodal length was on par with It-3 while It-8 which showed least internodal length was on par with It-5, It-1, It-9 and It-4.

Table 5. (continued….)

Genotype	Number of leaves plant⁻¹			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP	90 DAP	150 DAP	220 DAP
It-1	24.16	333.61	1141.85	2.40	2.41	2.42	1.41	1.38	1.58	1.37	2.42	5.27
It-2	25.50	474.66	1262.00	2.46	2.41	2.83	1.58	1.30	1.35	1.32	2.29	5.5
It-3	25.00	484.20	1354.00	2.38	2.41	2.54	1.47	1.47	1.45	1.44	2.54	7.5
It-4	27.16	364.66	1252.16	2.42	2.40	2.38	1.31	1.55	1.56	1.47	2.38	5.4
It-5	30.30	263.83	1150.77	2.23	2.46	2.54	1.89	1.56	1.38	1.40	2.54	4.6
It-6	21.00	344.44	1355.86	2.03	2.36	2.54	1.24	1.46	1.48	1.44	2.54	5.8
It-8	30.25	515.33	1470.00	2.77	3.16	2.78	1.61	1.31	1.66	1.18	2.78	4.4
It-9	29.00	406.33	1355.11	2.43	2.43	2.41	1.20	1.31	1.50	1.40	2.41	5.2
It-10	26.00	370.33	1254.16	2.60	2.53	2.50	1.36	1.69	1.53	1.38	2.50	6.7
Vellanikara local (check)	25.16	263.00	1166.33	2.21	2.41	2.29	1.42	1.50	1.35	1.32	2.83	8.2
Mean	26.05	382.04	1276.22	2.39	2.50	2.52	1.45	1.45	1.48	1.37	2.52	5.89
S. E (m)	0.59	6.56	2.91	0.04	0.07	0.04	0.04	0.06	0.05	0.05	0.04	0.35
C. D (5%)	1.76	19.51	8.66	0.12	0.23	0.13	0.13	0.18	0.17		0.13	1.05

4.2.4.9 Leaf Area (cm^2)

Leaf area showed significant difference among the genotypes. The mean value of leaf area ranged from 1623.54 cm^2 (It-5) to 2674.43 cm^2 (It-8). The mutant It-8 showed maximum leaf area and it was on par with It-1.

4.2.4.10 Harvest Index

The mean of harvest index was lowest for It-1 (15.94) and highest for It-6 (30.69) with an average of 20.83. It-9 (25.64) was on par with It-8. It-1 was on par with It-2 and Vellanikara local.

4.2.4.11 Total Fresh Weight (g)

The mutants differed significantly in total fresh weight of plant with a general mean of 787.60 g. The mutant It-4 registered the minimum total fresh weight of 630.00 g and It-8 registered the maximum of 1076.66 g, It-4 was on par with It-6 and Vellanikara local.

4.2.4.12 Total Dry Weight (g)

Total dry weight of plant exhibited significant variation among the various mutants. Minimum total dry weight was shown by Vellanikara local (316.98 g) and maximum by It-8 (487.90 g). The total dry weight of plant of It-8 was on par with It-1 and It-3, whereas Vellanikara local was on par with It-6, It-5 and It-10.

4.2.4.13 Dry Matter Production (g $plant^{-1}$)

Dry matter production varied from a minimum of 52.05 g $pant^{-1}$ (Vellanikara local) to a maximum of 83.97 g $plant^{-1}$ (It-8) with an average of 69.06 and the difference was significant. It-8 was on par with It-10.

4.2.4.14 Leaf Area Index

The mutants differed significantly in leaf area index with the general mean of 4.77. The mutant Vellanikara local registered the minimum leaf area index of 3.56 and It-8 registered the maximum 5.44.

4.2.4.15 Net Assimilation Rate ($gm^{-2}day^{-1}$)

The net assimilation rate exhibited significant variation among the various mutants. The minimum (1.74 $gm^{-2}day^{-1}$) and maximum (3.51 $gm^{-2}day^{-1}$) net assimilation rate were showed by It-1 and It-8 respectively. The net assimilation rate of It-8 (3.51 $gm^{-2}day^{-1}$) was on par with It-3 (3.26 $gm^{-2}day^{-1}$), whereas It-1 (1.74 $gm^{-2}day^{-1}$) was on par with Vellanikara local (1.76 $gm^{-2}day^{-1}$).

4.2.4.16 Fresh Weight of Leaves (g)

Significant difference was noticed for fresh weight of leaves among the mutants with the It-5 registering the minimum fresh weight of leaves of 145.00 g and It-6 showed the maximum fresh weight of leaves of 284.33 g. It-6 was on par with It-8. It-5 was on par with It-3 and Vellanikara local.

4.2.4.17 Dry Weight of Leaves (g)

The dry weight of leaves ranged from 54.64 g (Vellanikara local) to 122.67 g (It-8) with an average of 79.78 g. Significantly maximum dry weight of leaves in comparison to other mutants was recorded by It-8 (122.67 g). The minimum dry weight of leaves was for Vellanikara local (54.64 g).

4.2.4.18 Fresh Weight of Shoot (g)

The mutants differed significantly for the fresh weight of shoot with a general mean of 659.24 g. The mutant It-5 recorded the minimum value of 548.33 g. The maximum fresh weight of leaves of 852 g was recorded for It-8 which was on par with It-3. It-5 was on par with It-2.

Table 5. (continued…..)

Genotype	Leaf area (cm^2)	Harvest index	Total fresh weight (g)	Total dry weight (g)	Dry matter production ($gplant^{-1}$)	Leaf area index	Net assimilation rate ($gm^{-2}day^{-1}$)	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
It-1	2625.85	15.94	851.66	485.63	78.41	4.78	1.74	233.33	77.45	651.66	342.63	3.07
It-2	2347.39	16.89	674.66	388.86	72.77	4.94	2.37	241.66	65.70	555.00	272.43	4.11
It-3	2172.45	17.96	790.00	470.63	77.65	4.87	3.26	146.66	84.57	733.33	334.44	3.47
It-4	2079.48	20.45	630.00	375.31	57.94	4.41	3.18	245.00	76.75	656.00	252.61	3.94
It-5	1623.54	18.90	728.33	330.59	53.62	4.77	3.05	145.00	62.38	548.33	258.01	3.50
It-6	1980.37	30.69	660.00	327.05	63.53	5.25	2.78	284.33	100.36	658.33	265.52	3.21
It-8	2674.43	25.15	1076.66	487.90	83.97	5.44	3.51	283.33	122.67	852.00	417.93	4.34
It-9	2061.77	25.64	961.66	343.11	66.74	5.29	2.68	258.33	87.89	724.32	315.10	4.13
It-10	2275.34	19.46	865.33	336.15	83.95	4.41	2.36	173.33	65.44	640.76	373.06	3.66
Vellanikara local(check)	2152.40	17.22	637.66	316.98	52.05	3.56	1.76	155.00	54.64	572.66	213.08	1.86
Mean	2199.30	20.83	787.60	386.22	69.06	4.77	2.67	216.60	79.78	659.24	304.48	3.53
S. E (m)	47.14	0.46	13.45	6.64	1.76	0.03	0.10	5.77	1.61	5.32	4.98	0.04
C. D (5%)	139.98	1.37	39.98	19.75	5.23	0.11	0.32	17.13	4.79	15.81	14.79	0.13

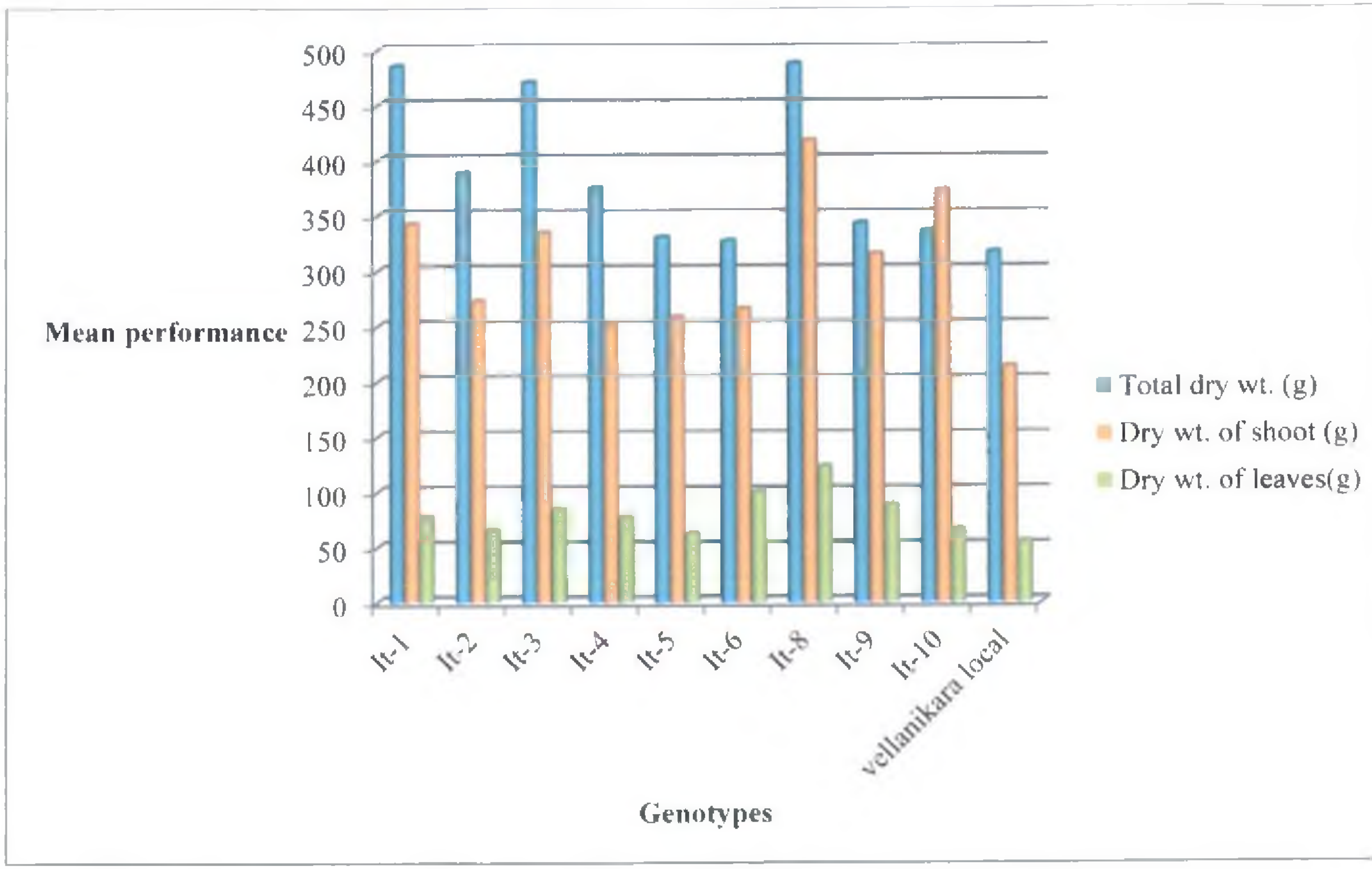


Fig11. Mean performance of neelamari at Kayamkulam

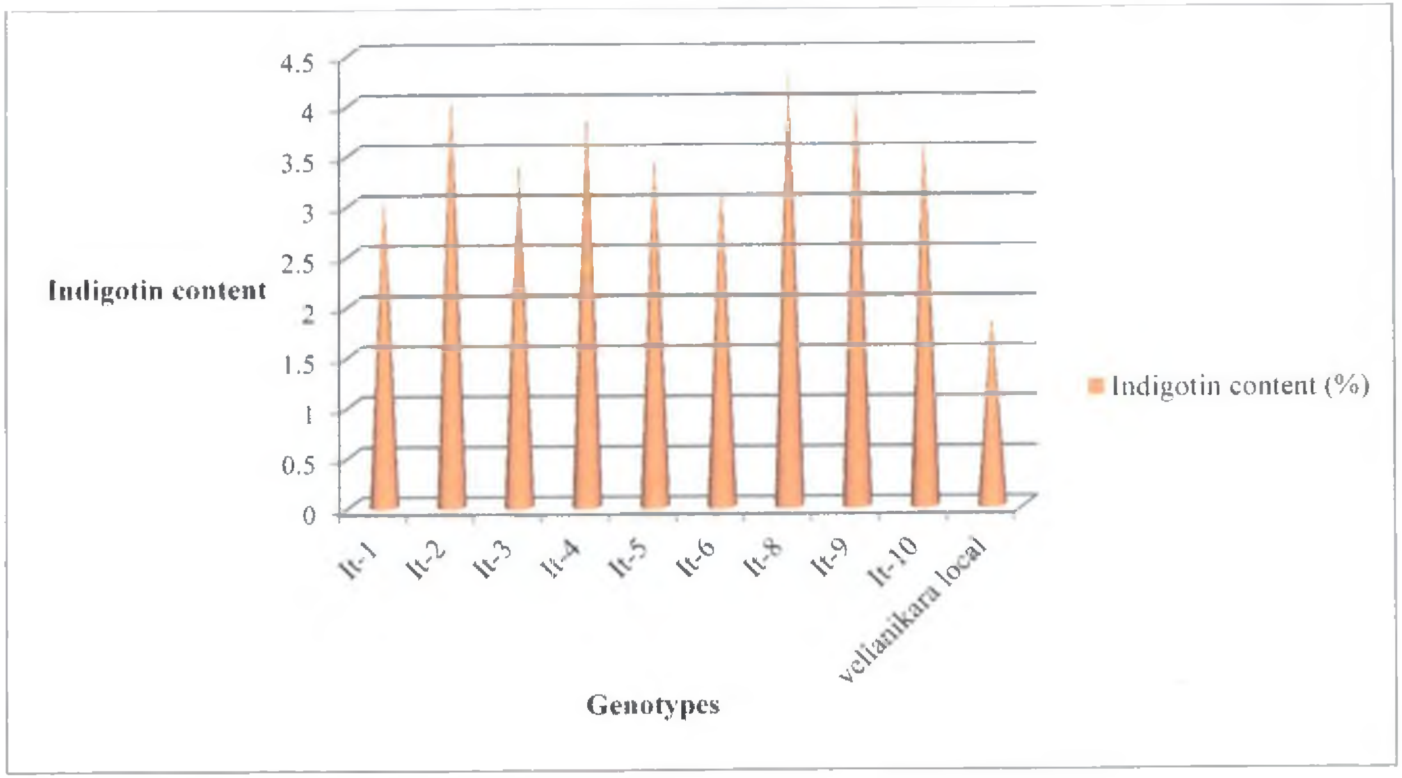


Fig12. Mean performance of neelamari at Kayamkulam

4.2.4.19 Dry Weight of Shoot (g)

Dry weight of shoot among the various mutants ranged from 213.08 g to 417. 93 g with an average of 304.48 g. The mutant with maximum dry weight of shoot was It-8 (417.93 g) and minimum dry weight of leaves was Vellanikara local (213.08 g). It-1(342.63 g) was on par with It-3 and It-2 (272.43 g) was on par with It-6 and It-5.

4.2.4.20 Indigotin Content (%)

Average indigotin content showed wide range of variation among the mutants from 1.86 per cent (Vellanikara local) to 4.34 per cent (It-8).

4.3 STABILITY ANALYSIS

4.3.1 Pooled Analysis of Variance

Ten genotypes including nine mutants and one local accession (Vellanikara local) as check were subjected to pooled analysis of variance for characters *viz.,* plant height, plant spread, number of branches, girth of stem, number of leaves plant^{-1}, length of leaves, width of leaves, internodal length, leaf area, harvest index, total fresh and dry weight of plant, net assimilation rate, fresh and dry weight of leaves, fresh and dry weight of shoot and indigotin content over four locations. The analysis revealed that the genotypes and G X E interactions were significant for all the characters at three different stages. The G x E interactions were significant for all characters, therefore, further analysis were done for estimating the stability parameters (Table 6).

The total of sum of squares is partitioned into genotypes, Environments + (Genotype x Environment) and pooled error in the anova. Here mean squares due to Environments + (Genotype x Environment) were significant for the characters girth of stem, length of leaves, leaf area, total fresh weight of plant and indigotin content reemphasizing the existence of GE interactions for these traits. Mean sum

Table 6. Pooled Analysis of Variance (mean square) for different quantitative traits over four locations

Source of variation	df	Plant height (cm)	Plant spread (cm)	Number of branches	Girth of stem (cm)	Number of leaves plant^{-1}	Length of leaves (cm)	Width of leaves (cm)	Leaf area (cm^2)	Internodal length (cm)	Harvest index
Genotype	9	7993**	7651**	170.21**	3.85**	138703**	0.47**	0.13**	893373**	9.86**	242.31**
Environment	3	6.67	5.73	7.65*	61.72**	36.49	0.07**	0.04*	20074	0.08	0.78
Gen. * Env. interaction	27	9.18**	3.82**	2.01**	1.59**	95.36**	0.01**	0.01**	40143**	0.28*	1.36**
Error	80	3.48	0.63	0.74	0.24	26.83	0.004	0.002	12794	0.15	0.26

Source of variation	df	Total fresh weight (g)	Total dry weight (g)	Leaf area index	Net assimilation rate(gm^{-2}day^{-1})	Dry matter production (gplant^{-1})	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Genotype	9	273197**	48507**	3.55**	6.13**	1674.63**	34385**	4775**	93749**	45295**	6.80**
Environment	3	800.53	189.59	0.0004	0.02	3.11	10.36	8.68	100.74	203.46	0.07**
Gen. * Env. interaction	27	563.27**	293.67**	0.004**	0.05**	3.38**	73.76*	5.40**	124.58**	104.73**	0.01**
Error	80	76.60	31.35	0.002	0.01	1.37	42.94	2.87	38.48	26.78	0.002

* & **- significant at 1 & 5 per cent respectivel

Table 7. Analysis of variance (mean square) for mean data of different quantitative traits over four locations

Source of variation	df	Plant height (cm)	Plant spread (cm)	Number of branches	Girth of stem (cm)	Number of leaves $plant^{-1}$	Length of leaves (cm)	Width of leaves (cm)	Internodal length (cm)	Leaf area(cm^2)	Harvest index
Genotype	9	2664**	2550**	56.73**	1.28*	46234**	0.15**	0.04**	3.28**	297791**	80.77**
Env. + (gen. * env.)	30	2.97	1.33	0.85	2.53**	29.82	0.008*	0.005	0.08	12712**	0.43
Env. (Linear)	1	6.67	5.73*	7.65**	61.72**	36.49	0.07**	0.04**	0.08	20074**	0.78
Genotype * env. (linear)	9	5.70**	1.09	1.04*	0.50	50.12*	0.01*	0.004	0.15*	35648**	0.08
Pooled deviation	20	1.56	1.22	0.43	0.48	20.35	0.003	0.003	0.05	2022	0.57
Pooled error	80	3.48	0.63	0.74	0.24	26.83	0.004	0.002	0.15	12794	0.26

* & **- significant at 1 & 5 per cent respectively

Table 7. (Continued…..)

Source of variation	df	Total fresh weight (g)	Total dry weight (g)	Dry matter production (gplant^{-1})	Leaf area index	Net assimilation rate (gm^{-2}day^{-1})	Fresh weight of leaves (g)	Dry weight of leaves (g)	Fresh weight of shoot (g)	Dry weight of shoot (g)	Indigotin content (%)
Genotype	9	91065**	16169**	558.21**	1.18**	2.04**	11461.90**	1591.83**	31249.97**	15098.66**	2.26**
Env. + (gen. * env.)	30	195.66**	94.42	1.11	0.001	0.01	22.47	1.91	40.73	38.20	0.006**
Env. (Linear)	1	800.53**	189.59	3.11	0.0004	0.02	10.36	8.68**	100.74	203.46*	0.07**
Genotype * env. (linear)	9	405.52**	54.08	0.48	0.001	0.01	28.14	3.04*	36.98	32.94	0.008**
Pooled deviation	20	70.98	107.81	1.30	0.001	0.01	20.52	1.06	39.42	32.30	0.002
Pooled error	80	76.60	31.35	1.37	0.002	0.01	42.94	2.87	38.48	26.78	0.002

* & **- significant at 1 & 5 per cent respectively

of squares due to genotype were significant for all the characters (Table 7). Sum of squares due to E + (G x E) was further partitioned into that of Environment (linear), Genotype x Environment (linear) and pooled deviation (Table 7). Variation due to environment (linear) were significant for plant spread, number of branches, girth of stem, length of leaf, width of leaf, leaf area, total fresh weight of plant, dry weight of leaves and shoot and indigotin content. The linear component of G x E were significant for plant height, number of branches, number of leaves plant^{-1}, length of leaves, internodal length, leaf area, total fresh weight of plant, dry weight of leaves and indigotin content.

4.3.2 Environmental Indices

Environmental indices of twenty characters were presented in the Table 8. It was observed that Vellanad was found favourable for most of the characters, while Kayamkulam was unfavourable for all the characters except plant spread, length of leaves, harvest index, dry matter production, net assimilation rate and dry weight of leaves and shoot.

4.3.3 Stability Parameters

According to the Eberhart and Russell (1966) the ideal genotype would be the one which had high mean value, unit regression coefficient (b_i = 1) and minimum deviation from regression (S^2d_i = 0). The linear regression (b_i) is treated as a measure of response of a genotype and deviation from regression (S^2d_i) is considered as a measure of stability. In the present study regression coefficient (b_i) values, b_i=1 are treated as unity. Deviation from regression (S^2d_i) values, if found non-significant, are considered to be within the "minimum deviation" *i.e.*, zero. Hence, the genotypes are considered to be stable. Then the measure of response or sensitivity to environmental changes is decided on regression coefficient and mean values of the genotypes. The genotype with high mean values and regression coefficient (b_i) equal to unity is considered to have "average stability" (the performance does not change with change in

Table 8. Estimates of environmental indices (I_j) for each character under different locations

Sl. No	Character	Vellanad	Kalliyoor	Kottarakara	Kayamkulam
1	Plant height (cm)	-0.42	0.08	0.63	-0.3
2	Plant spread (cm)	0.06	-0.61	0.1	0.43
3	No of branches	-0.48	0.05	0.68	-0.25
4	Girth of stem (cm)	-1.08	1.2	1.27	-1.39
5	No of leaves per plant	0.91	-1.51	0.71	-0.11
6	Length of leaves (cm)	0.03	-0.06	-0.006	0.05
7	Width of leaves (cm)	-0.02	-0.04	0.05	-0.001
8	Internodal length(cm)	0.05	0.05	-0.07	-0.008
9	Leaf area (cm^2)	7.11	3.52	-2.21	-8.43
10	Harvest index	-0.19	0.03	-0.01	0.2
11	Total fresh weight (g)	1.68	4.29	1.56	-7.51
12	Total dry weight (g)	0.67	0.4	2.46	-3.51
13	Dry matter production ($gplant^{-1}$)	0.15	-0.09	-0.41	0.34
14	Leaf area index	0.01	0.002	-0.0009	-0.004
15	Net assimilation rate ($gm^{-2}day^{-1}$)	0.01	-0.04	0.001	0.02
16	Fresh weight of leaves(g)	0.19	0.69	-0.71	-0.15
17	Dry weight of leaves(g)	-0.74	0.53	0.19	0.02
18	Fresh weight of shoot(g)	2.38	0.38	-0.91	-1.85
19	Dry weight of shoot(g)	2.51	0.05	-3.6	1.04
20	Indigotin content (%)	0.06	0.02	-0.06	-0.0005

environment), if b_i is more than unity, it is suggested to have "less than average stability" (sensitive to environmental changes but adaptable to favourable environment) and if b_i is less than unity, it is reported to have "more than average stability" (adaptable to poor environment). The estimation of stability parameters i.e., mean (μ), regression coefficient (b_i) and deviation from regression (S^2d_i) for twenty characters are furnished below character-wise.

4.3.3.1 Plant Height (cm)

Height of plant ranged from 136.53 cm (Vellanikara local) to 214.65 cm (It-8). The mutant It-6 (μ=176.95, b_i=1.04, S^2d_i=0.43) showed unit regression and non-significant deviation from regression with high mean and hence this was the stable genotype over all environments. The mutants It-3, It-5, It-8 and It-9 with regression greater than unity and non-significant deviation from regression were highly responsive and hence ideal for favourable environment. It-1 had regression less than unity, non-significant deviation from regression and high mean. So they were stable, but adapted for poor environment.

4.3.3.2 Plant Spread (cm)

The mean values of plant spread ranged from 126.18 cm (It-4) to 196.76 cm (It-8). The mutants It-3 (μ=193.60, b_i=1.02, S^2d_i=0.13) and It-6 (μ=166.83, b_i=1.01, S^2d_i=0.2) were considered as stable because they were having high mean with regression coefficient near to unity and non-significant deviation from regression. The mutants It-5 and It-8 having regression greater than unity and non-significant deviation from regression were above average, stable and were adapted for rich environment. The mutants It-9 and It-10 having regression less than one and non-significant deviation from regression revealed that they were low responsive and suitable for poor environment.

4.3.3.3 Number of Branches

Number of branches ranged from 32.16 (It-4) to 43.41 (It-8). It-2 (μ=39.00, b_i=1.03, S^2d_i=0.43), It-3 (μ=39.66, b_i=1.04, S^2d_i=-0.05) and It-6 (μ=41.50, b_i=0.84, S^2d_i=-0.07) were having higher mean, unit regression coefficient and non-significant deviation from regression. These genotypes were stable for all environments. The genotype which were high responsive and suitable for favourable environments was It-1. It-8 was suitable for unfavourable environments with low response.

4.3.3.4 Girth of Stem (cm)

The mean values for girth of stem ranged from 6.44 cm (Vellanikara local) to 8.67 cm (It-8). The genotypes which were stable for all the environments are It-3 (μ=7.84, b_i=1.09, S^2d_i=0.06), It-1 (μ=7.42, b_i=0.88, S^2d_i=0.36) and It-5 (μ=7.45, b_i=0.86, S^2d_i= -0.07). It-2 and It-8 were having high mean, regression coefficient greater than one and non-significant deviation from regression. These genotypes were above average stable and suitable for rich environment.

4.3.3.5 Number of Leaves plant^{-1}

The mean performance of number of leaves per plant ranged from 1120.59 (It-1) to 1475.66 (It-8). It-2 (μ=1269.12, b_i=-1.08) showed high mean, unit regression and non-significant deviation from regression revealed that this genotype was stable for all types of environment. It-3, It-6, It-8, It-9 had high mean, regression coefficient greater than unity and non-significant deviation from regression. So they were suitable for favourable environment and had high responsiveness.

4.3.3.6 Length of Leaves (cm)

Length of leaves ranged from 2.28 cm (Vellanikara local) to 2.57 cm (It-8). It-2 (μ=2.49, b_i=0.97, S^2d_i= -0.004), It-3 (μ=2.47, b_i= -1.03, S^2d_i= -0.001) and

Table 9. Mean performance and stability parameters for yield and its component traits

Genotype	Plant height (cm)			Plant spread (cm)			Number of branches			Girth of stem(cm)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
It-1	184.32	-0.55	-2.50	143.41	-1.41	0.29	37.00	2.33	-0.72	7.42	0.88	0.36
It-2	154.51	-1.56	-2.89	135.55	2.48	-0.13	39.00	1.03	0.43	7.65	1.44	-0.18
It-3	201.76	6.72	-3.26	193.60	1.02	0.13	39.66	1.04	-0.05	7.84	1.09	0.06
It-4	155.86	1.09	0.45-	126.18	1.92	0.63	32.16	1.50	-0.67	7.21	0.80	0.90
It-5	176.04	1.98	-2.13	185.87	2.48	-0.07	34.83	2.10	-0.38	7.45	0.86	-0.07
It-6	176.95	1.04	0.43	166.83	1.01	0.20	41.50	0.84	-0.07	7.32	1.31	0.22
It-8	214.65	5.19	-1.56	196.76	2.17	1.08	43.41	-0.06	-0.37	8.67	1.21	0.35
It-9	184.66	1.16	-2.83	185.38	-0.66	1.14	34.41	1.90	-0.20	6.80	0.65	-0.05
It-10	138.61	-1.48	-1.78	165.00	0.44	1.06	33.08	0.35	-0.30	7.34	1.13	1.08
Vellanikara local(check)	136.53	-2.05	-1.53	150.27	-0.17	0.54	34.75	-1.53	-0.71	6.44	0.58	-0.23
Grand mean	172.39			164.89			36.98			7.41		

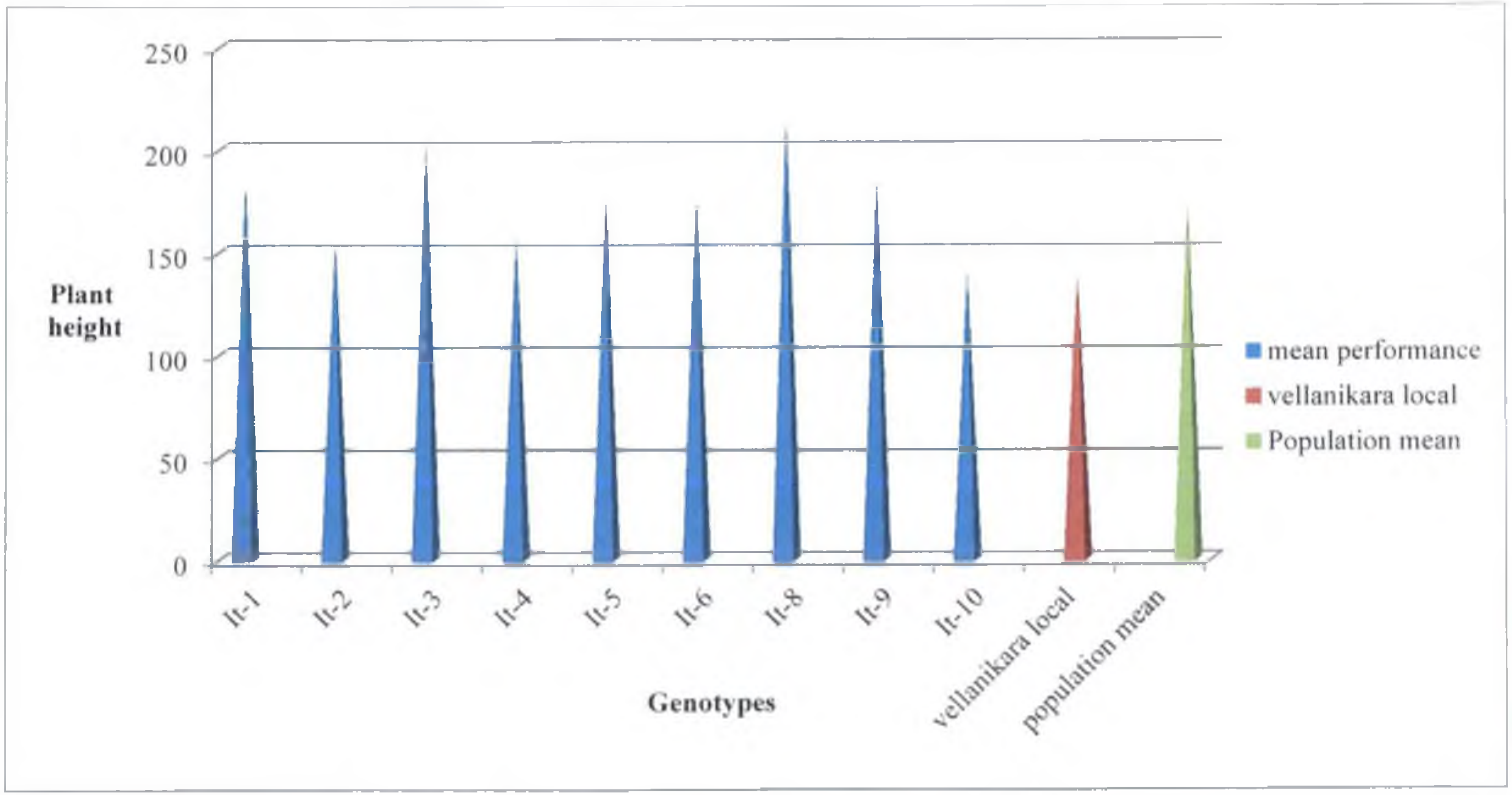


Fig 13. Comparison of plant height with the check (vellanikara local) and population mean of the 9 mutants

It-6 (μ=2.45, b_i=1.03, S^2d_i= -0.004) were the stable genotypes with regression coefficient one and had non-significant deviation from regression. The genotypes which had regression coefficient greater than one and non-significant deviation from regression were It-1, It-4 and It-8. These genotypes were stable and suitable for rich environment. The genotypes which were stable and adapted for poor environment had regression less than one and non-significant deviation from regression. It-5 and It-9 were suitable for poor environment.

4.3.3.7 Width of Leaves (cm)

The mean value of width of leaves ranged from 1.32 cm (Vellanikara local) to 1.63 cm (It-8). It-1 (μ=1.52, b_i=0.92, S^2d_i=-0.002) and It-6 (μ=1.45, b_i=1.08, S^2d_i=0.003) were the stable genotypes with unit regression coefficient and non-significant deviation from regression. It-2 and It-10 were suitable for favourable environment because they had regression coefficient greater than one and non-significant deviation from regression. These genotypes were high responsive in rich environment. It-8 and It-9 were suitable for poor environment and having less response in performance. Vellanikara local had significant deviation from regression. So the performance of vellanikara local cannot be predictable and it was unstable.

4.3.3.8 Internodal Length (cm)

The mean character for this trait varied from 4.79 cm (It-8) to 7.76 cm (Vellanikara local). For the character internodal length plant with lowest internodal length was selected. The mutants It-3 (μ=5.07, b_i=0.93, S^2d_i=0.001), It-8 (μ=4.79, b_i=0.98, S^2d_i= -0.0007), It-9 (μ=5.25, b_i=1.07, S^2d_i=0.002) were the stable genotypes having low mean, unit regression coefficient and non-significant deviation from regression. It-10 mutant had regression coefficient greater than unity and non-significant deviation from regression. So it was adapted for rich environment or for favourable environment. It-6 was adapted for poor

Table 9. (Continued….)

Genotype	Number of leaves plant^{-1}			Length of leaves (cm)			Width of leaves (cm)			Internodal length (cm)		
	Mean	bi	s^2di	Mean	bi	s^2di	Mean	bi	s^2di	Mean	bi	s^2di
It-1	1120.59	3.57	-24.71	2.44	1.91	-0.003	1.52	0.92	-0.002	5.98	3.26	-0.002
It-2	1269.12	-1.08	13.22	2.49	0.97	-0.004	1.44	1.52	0.001	6.52	-0.12	-0.0005
It-3	1310.00	5.32	-26.44	2.47	-1.03	-0.001	1.43	-0.22	0.001	5.07	0.93	0.001
It-4	1241.54	3.48	36.37	2.51	2.46	0.002	1.40	3.43	-0.0007	5.96	0.69	-0.002
It-5	1147.92	-0.64	-17.70	2.45	0.79	-0.002	1.38	0.42	0.0005	6.96	-0.30	0.0001
It-6	1328.46	3.71	-5.10	2.45	1.03	-0.004	1.45	1.08	0.003	5.78	-0.36	-0.002
It-8	1475.66	-5.13	-21.44	2.57	2.80	0.009	1.63	0.19	0.005	4.79	0.98	-0.0007
It-9	1351.44	4.97	-23.27	2.45	0.43	-0.003	1.47	0.23	-0.001	5.25	1.07	0.002
It-10	1261.95	-3.67	0.53	2.38	0.18	-0.002	1.44	1.30	-0.0004	5.61	3.45	-0.002
Vellanikara local(check)	1168.41	-0.52	3.82	2.28	0.12	-0.004	1.32	1.10	0.006*	7.76	0.38	0.002
Grand mean	1267.51			2.44			1.44			5.96		

environment due to regression less than unity and non-significant deviation from regression.

4.3.3.9 Leaf Area (cm²)

The mean performance in leaf area ranged from 1780.11 cm² (It-5) to 2649.32 cm² (It-8). It-1 (μ=2643.93, b_i=0.92) and It-6 (μ=2249.07, b_i= -1.07) were the stable genotypes with unit regression coefficient and non-significant deviation from regression. The genotypes which had unit regression showed average response towards the environmental factors. It-8 was the mutant genotype which show high response towards environmental factors and performed well under rich environment. It-8 had regression coefficient greater than unity and non-significant deviation from regression. It-2 performed well under unfavourable environment with regression less than unity and non-significant deviation from regression.

4.3.3.10 Harvest Index

The mean value for harvest index ranged from 16.04 (It-1) to 21.56 (It-8). It-3 (μ=21.38, b_i=1.04, S^2d_i=0.29) and It-6 (μ=20.94, b_i=0.94, S^2d_i=0.56) were the stable genotypes with high mean, unit regression coefficient and non-significant deviation from regression. It-8 and It-10 were suitable for unfavourable environment with regression coefficient less than one and non-significant deviation from regression i.e., zero. The mutants It-4 and It-9 had regression coefficient greater than unity but they were significantly deviated from zero. So these two genotypes were unstable and the performance cannot be predicted.

4.3.3.11Total Fresh Weight (g)

Total fresh weight of the plant ranged from 631.31 g (It-4) to 1076.5 g (It-8). The stable genotypes for this character were It-5 (μ=822.46, b_i= -0.98), Vellanikara local (μ=838.67, b_i=0.98), It-9 (μ=964.80, b_i= -1.07) with high mean, unit regression and non-significant deviation from regression. It-8 had high mean,

Table 9. (Continued…..)

Genotype	Leaf area (cm²)			Harvest index			Total fresh weight (g)			Total dry weight (g)		
	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
It-1	2643.93	0.92	-10954	16.04	0.57	-0.18	845.63	0.37	-53.43	480.36	1.40	-6.86
It-2	2295.93	0.34	-10767	17.72	0.29	0.35	678.37	0.82	-34.76	379.67	2.20	-8.20
It-3	2206.41	0.92	-11619	21.38	1.04	0.29	780.88	0.11	50.51	456.88	1.08	405.65
It-4	2022.06	0.11	-7536	20.72	1.45	0.80*	631.31	0.74	-46.48	361.98	3.43	34.90
It-5	1780.11	12.71	-8740	18.48	0.53	-0.10	822.46	-0.98	-35.59	338.01	-0.07	33.32
It-6	2249.07	-1.07	-8600	20.94	0.94	0.56	654.99	1.62	-71.36	330.40	-0.48	47.91
It-8	2649.32	-2.37	-12371	21.56	-0.32	0.35	1076.5	6.94	107.21	478.88	-0.74	108.83
It-9	2071.25	0.03	-12733	18.38	1.75	1.34**	964.80	-1.07	86.38	352.68	1.06	175.68
It-10	1998.12	-0.19	-11705	19.14	0.16	-0.15	866.81	0.43	-35.13	342.60	-1.09	-2.18
Vellanikara local(check)	2144.25	-0.57	-12693	17.09	2.68	-0.22	838.67	0.98	-24.06	316.20	0.61	-24.46
Grand mean	2206.04			19.14			816.04			383.76		

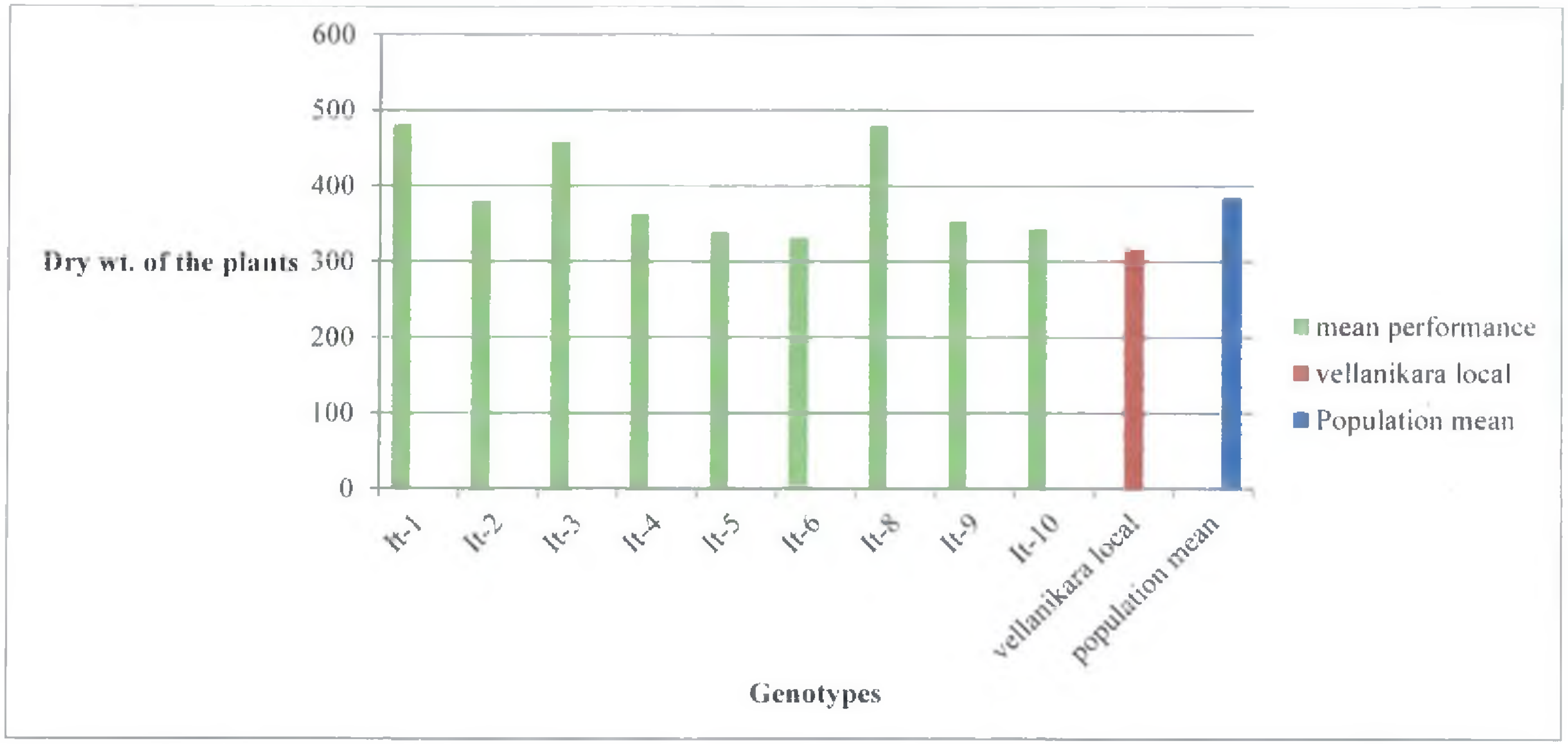


Fig 14. Comparison of dry wt. of plant with the check (vellanikara local) and population mean of the 9 mutants

regression coefficient greater than unity and non-significant deviation from regression, so it was widely suitable for favourable environment. It-1 and It-10 showed high mean, regression coefficient less than unity and non-significant deviation from regression which revealed that these genotypes were adapted for unfavourable environment.

4.3.3.12 Total Dry Weight (g)

Total dry weight of the plant ranged from 316.20 g (Vellanikara local) to 480.36 g (It-1). It-3 (b_i=1.08) was the mutant with unit regression and non-significant deviation from regression, so this was the stable genotypes. It-1 was the genotypes with regression coefficient greater than unity and non-significant deviation from regression indicates high responsiveness towards environmental factors and performs well under rich environment. It-8 was identified for poor environment with regression less than unity and non-significant deviation from regression.

4.3.13 Dry Matter Production (g plant^{-1})

The mean values for dry matter production ranged from 53.43 g plant^{-1} (Vellanikara local) to 84.64 g plant^{-1} (It-8). It-1 (μ=77.57, b_i= -0.92, S^2d_i= -0.56) and It-3 (μ=78.10, b_i=1.08, S^2d_i= -1.35) were identified as stable genotypes with unit regression and non-significant deviation from regression. It-2, It-8, It-10 were identified for rich environment. They were highly responsive in favourable environment.

4.3.3.14 Leaf Area Index

Leaf area index varied from 3.58 (Vellanikara local) to 5.87 (It-8). The genotype It-3 (μ=4.83, b_i= -0.97, S^2d_i= -0.001) showed high mean, unit regression coefficient and non-significant deviation from regression. It-1, It-2, It-6, It-8, It-9 were genotypes identified for favourable environment. These genotypes showed high mean, regression coefficient greater than unity and non-significant deviation.

Table 9. (Continued….)

Genotype	Dry matter production (gplant^{-1})			Leaf area index			Net assimilation rate (gm^{-2}day^{-1})			Fresh weight of leaves (g)		
	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
It-1	77.57	-0.92	-0.56	4.77	-9.51	-0.002	1.65	-3.66	-0.003	237.08	-1.09	24.14
It-2	73.75	1.23	1.20	4.94	7.31	-0.002	2.20	0.17	0.01	242.08	1.90	-38.22
It-3	78.10	1.08	-1.35	4.83	-0.97	-0.001	3.25	1.05	-0.01	149.58	7.42	-31.56
It-4	58.02	0.62	0.10	4.41	-0.49	-0.002	3.43	2.56	0.04	241.66	-8.35	-9.98
It-5	54.24	1.16	0.38	4.82	0.43	-0.001	2.52	0.33	-0.009	146.25	3.29	-39.19
It-6	64.02	1.00	-1.28	5.25	-1.21	0.002	3.07	0.93	0.03	275.66	0.85	-23.26
It-8	84.64	3.12	-0.01	5.47	4.74	-0.002	3.76	0.20	0.03	281.66	-5.46	-30.65
It-9	66.92	-1.07	1.45	5.26	3.44	-0.002	2.76	1.08	-0.003	159.16	4.55	-41.19
It-10	83.99	1.42	-0.10	4.40	0.18	-0.002	2.33	0.27	-0.008	177.50	7.77	-36.74
Vellanikara local(check)	53.43	2.05	-0.54	3.58	5.87	0.0007	1.71	5.04	-0.005	262.50	-0.80	2.55
Grand mean	69.47			4.77			2.67			217.31		

They performed well in rich environment. It-5 showed high mean, regression coefficient less than unity and non-significant deviation from regression which revealed that it was adapted to the unfavourable environment.

4.3.3.15 Net Assimilation Rate ($gm^{-2}day^{-1}$)

The mean value of net assimilation rate ranged from 1.65 $gm^{-2}day^{-1}$ (It-1) to 3.76 $gm^{-2}day^{-1}$ (It-8). The genotypes identified as stable genotypes were It-3 (μ=3.25, b_i=1.05, S^2d_i= -0.01), It-6 (μ=3.07, b_i=0.93, S^2d_i=0.03) and It-9 (μ=2.76, b_i=1.08, S^2d_i= -0.003 with high mean, unit regression coefficient and non-significant deviation from regression. It-4 was identified for favourable or rich environment had high mean, regression coefficient greater than unity and non-significant deviation from regression. Mutant It-8 was suitable for unfavourable environment because it had regression coefficient less than unity with minimum deviation from regression.

4.3.3.16 Fresh Weight of Leaves (g)

The mean value for fresh weight of leaves ranged from 146.25 g (It-5) to 281.66 g (It-8). It-1 (μ=237.08, b_i=-1.09, S^2d_i=24.14), It-6 (μ=275.66, b_i=0.85, S^2d_i= -23.26) and Vellanikara local (μ=262.50, b_i= -0.80, S^2d_i=2.55) were identified as stable genotypes. They had high mean and unit regression with minimum deviation from regression. It-2, It-4, It-8 were the genotypes suitable for favourable environment having high mean and regression greater than unity with minimum deviation from the regression.

4.3.3.17 Dry Weight of Leaves (g)

Dry weight of leaves ranged from 54.06 g (Vellanikara local) to 122.35 g (It-8). Among the mutants It-3 (μ=83.85, b_i=1.06, S^2d_i= -1.02), It-6 (μ=98.90, b_i=0.91, S^2d_i= -0.65) and It-9 (μ=87.07, b_i= -1.07, S^2d_i= -1.90) were stable with regression near to unity and minimum deviation from regression, while It-8 recorded greater than unity of bi with minimum deviation from regression were suited for favourable environment.

4.3.3.18 Fresh Weight of Shoot (g)

The mean value for this trait ranged from 552.08 g (It-5) to 845.50 g (It-8). Among the ten genotypes, all mutants recorded non-significant deviation from regression (S^2d_i) values *i.e.* their performance could be predicted. Table 9 depicted that the mutants It-4 (μ=661.25, b_i=0.84, S^2d_i= -23.38), It-6 (μ=661, b_i= -1.06, S^2d_i=-7.10) and It-9 (μ=716.91, b_i=1.07, S^2d_i=73.75) recorded regression coefficient values of unity and non-significant deviation from regression. The mutant It-3 and It-8 exhibited less than unit value of regression and non-significant deviation from regression, while It-5 and Vellanikara local exhibited more than one b_i value (2.18, 3.92).

4.3.3.19 Dry Weight of Shoot (g)

Dry weight of shoot ranged from 214.36 g (Vellanikara local) to 417.54 g (It-8) in the present study. The mutants, It-3 (μ=328.20, b_i=-1.03, S^2d_i=1.14) and It-8 (μ=417.54, b_i=0.82, S^2_{di}=1.05) had recorded high mean, regression coefficient near 'unity' and non–significant deviation from regression for this trait. The mutant It-10 (μ=371.91, bi=-0.57, S^2d_i=-22.58) was identified for poor environment based on stability parameters. The mutant, It-1 had regression coefficient greater than 'unity' (2.79, 2.29, 1.85, 1.63, 1.57) and non–significant deviations from regression (Table 9). The mutant It-9 with significant deviations from regression exhibited unpredictable performance.

4.3.3.20 Indigotin Content (%)

High indigotin content is the ultimate objective for any breeder. Among the mutants studied, eight mutants revealed non-significant deviations from the regression (S^2d_i) values, which imply that the mutants were within the range of minimum deviation from regression and hence their performance could be predicted. The mutants *viz.*, It-3 (μ=4.15, b_i=-0.96, S^2d_i=-0.001), It-6 (μ=3.63, b_i=0.97, S^2d_i=-0.001) and It-9 (μ=4.27, b_i=1.00, S^2d_i=-0.001) were considered stable as they recorded high mean with regression coefficient near 'unity' and non–significant deviation from regression (Table 9). The mutant It-4 exhibited high mean (4.16) with regression coefficient (2.73) more than 'unity' and non–significant deviation from regression. The mutants showing unpredictable performance with highly significant deviation from regression were It-8 and It-10.

Table 9. (Continued…..)

Genotype	Dry weight of leaves(g)			Fresh weight of shoot(g)			Dry weight of shoot(g)			Indigotin content (%)		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
It-1	77.07	0.04	-2.02	659.75	-0.37	28.83	352.90	2.79	-19.58	3.14	0.83	-0.001
It-2	67.27	0.46	0.78	562.16	0.77	35.53	282.84	2.29	3.16	3.47	0.53	-0.001
It-3	83.85	1.06	-1.02	727.91	-0.29	-18.44	328.20	-1.03	1.14	4.15	-0.96	-0.001
It-4	77.33	-1.12	-2.65	661.25	0.84	-23.38	258.96	1.85	-10.69	4.16	2.73	0.001
It-5	62.42	-0.07	-2.84	552.08	2.18	-33.68	262.91	1.63	-16.88	3.48	-0.34	-0.001
It-6	98.90	0.91	-0.65	661.00	-1.06	-7.10	269.92	1.57	8.08	3.63	0.97	-0.001
It-8	122.35	4.85	-2.51	845.50	0.28	-2.40	417.54	0.82	1.05	4.45	2.01	0.005*
It-9	87.07	-1.07	-1.90	716.91	1.07	73.75	321.27	0.45	72.35*	4.27	1.00	-0.001
It-10	65.57	0.32	-2.63	646.94	0.64	-11.04	371.91	-0.57	-22.58	3.72	1.51	0.006*
Vellanikara local(check)	54.06	2.91	-2.63	579.00	3.92	-32.70	214.36	0.37	-2.34	1.89	0.59	0.002
Grand mean	79.59			661.15			308.08			3.59		

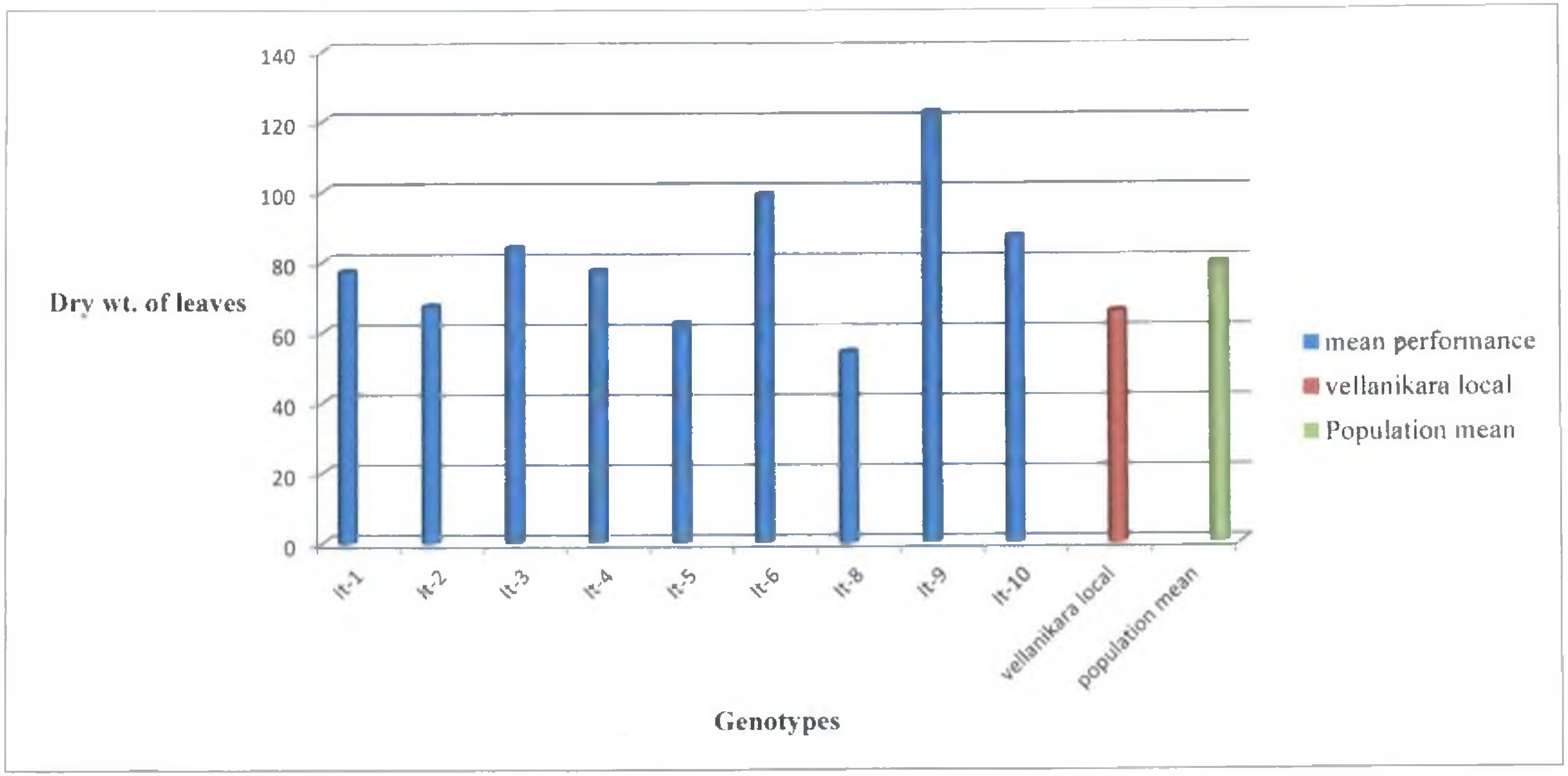


Fig 15. Comparison of Dry wt. of leaves with the check (vellanikara local) and population mean of the 9 mutants

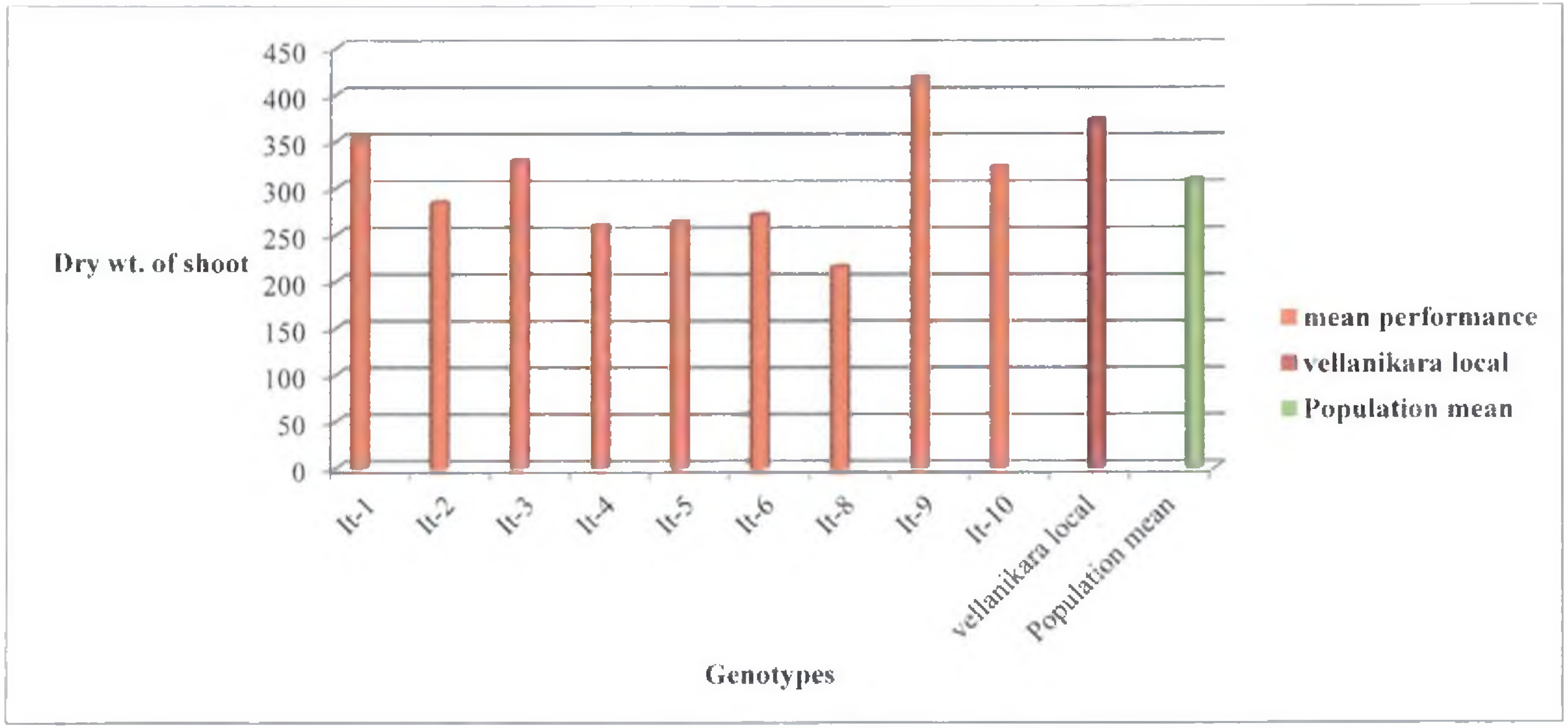


Fig 16. Comparison of Dry wt. of shoot with the check (vellanikara local) and population mean of the 9 mutants

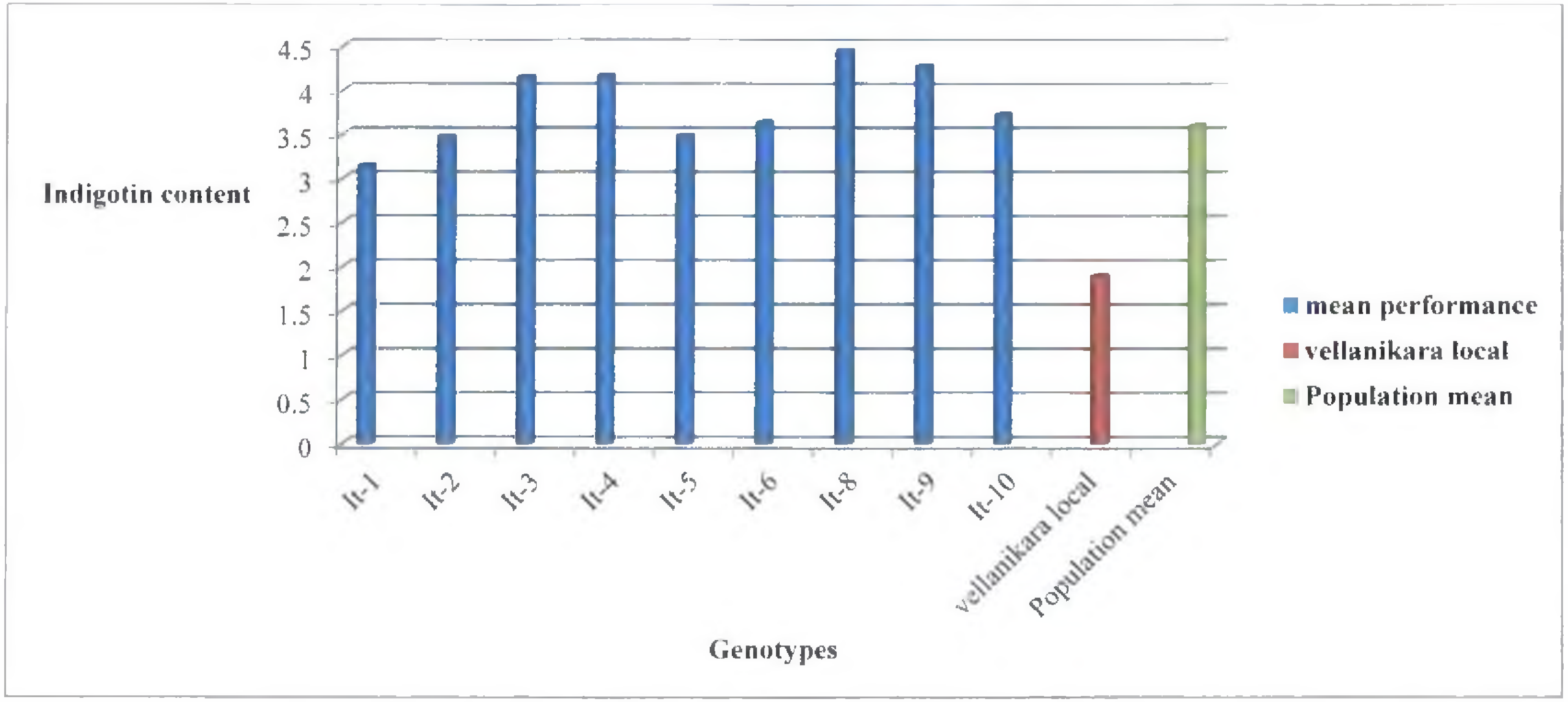


Fig 17. Comparison of indigotin content with the check (vellanikara local) and population mean of the 9 mutants

lt-3

lt-6

lt-9

Plate 5. Mutants stable over all environments

It-1

It-2

It-8

Plate 6. Mutants stable over favourable environment

It-10

Plate 7. Mutant stable over unfavourable environment

Discussion

5. DISCUSSION

Medicinal plants are local heritage with global importance. In Ayurveda about 2000 plant species are considered to have medicinal value (Prajapati *et al.*, 1998). Unlike other economic crops, medicinal plants, with few exceptions, continue to be cultivated in the same way as they were grown thousands of years ago. Very little work has been done with respect to genetic improvement of medicinal crops inspite of the long history of their domestication. *Indigofera tinctoria*, a Leguminous medicinal plant commonly known as neelamari is found throughout India. The roots, stems and leaves of neelamari are having thermogenic, laxative, anthelminthic, hepatoprotective and anticancer property. The extracts from the plant is used for the treatments of different diseases like epilepsy, chronic bronchitis, asthma, ulcers, skin diseases and the leaf extract is an important ingredient in hair tonics which promote the growth of hair (Asuntha *et al.*, 2010). The plant *I. tinctoria* is a rich source of the natural indigo dye. The glycoside present in the plant called indigotin is typically a blue dye with wide importance in the textile industry (Nittaya *et al.*, 2010). Neelamari also contain indirubin, a resinous impurity, indigobrown, indigogluten and indigtone and the leaf extract is used for the treatment of hydrophobia (Muthulingam *et al.*, 2010).

In recent years, the breeding methods and selection techniques have considerably changed in crops under the impact of biometrical genetics. Developments in biometrical genetics have helped in better understanding of the genetic architecture of the quantitative characters of economic importance. The knowledge about the extent of fluctuations of yield and yield attributes over environments is very important to identify genotypes which are widely adapted. Leaf yield and indigotin content is a quantitatively inherited character and there is considerable interaction between genotypes and environments. Some of the crop varieties are widely adapted, where as others are not. Multilocation testing of genotypes provides an opportunity for the plant breeders to study the adaptability of genotypes to a particular environment and also to understand the stability of the genotypes over different environments. The information on genotype x environment interaction is of major importance to the plant breeders in identifying an improved stable variety. Performance of genotypes in terms of productivity without stability serves no purpose.

In the light of the above facts, the salient results obtained from the experiment "Stability analysis of selected mutants in neelamari (*Indigofera tinctoria* L.)" had been critically analyzed and discussed in this chapter under the following subheads.

1. Pooled Analysis of variance
2. Stability analysis for yield and its attributing traits

5.1 POOLED ANALYSIS OF VARIANCE

Genotypes showed highly significant differences for all traits under study in the pooled analysis of variance, which revealed that the presence of wide genetic variability among the genotypes. Highly significant differences among the mutants gave an ample opportunity for selecting suitable mutants with high mean value for all the traits of interest. Environments were highly significant for the traits like number of branches, girth of stem (cm), length of leaves (cm), width of leaves (cm) and indigotin content (%) indicating divergence among growing environments. The highly significant effect of genotype x environment interaction for all the characters indicated differential response of genotypes to various environments. Therefore, for proper evaluation the mutants must be tested over a wide range of environments where these mutants were to be finally cultivated for commercial purposes. Similar findings were also reported by Manomohandas *et al.* (2000) in ginger, Ottai *et al.* (2006) in roselle, Panwar *et al.* (2011) in ocimum, Sangwan *et al.* (2013) in aswagandha, , Sharma (2013) in plantago, and Kakani *et al.* (2014) in fenugreek.

Stability analysis by joint regression analysis revealed that the G x E interaction (linear) was highly significant for plant height (cm), number of branches, number of leaves plant^{-1}, length of leaves (cm), internodal length (cm), leaf area (cm^2), total fresh weight (g), dry weight of leaves (g) and indigotin content (%) indicating that genotypes had divergent linear response to the environmental changes for these characters (Table 7). Those characters showing a non-significant G x E (linear) indicated that the variations in the performance of mutants for those characters were predictable. Similar responses were obtained by Toshniwal (1984) for plant height, pods $plant^{-1}$, grain pod^{-1} and test weight and Kakkani *et al.* (2014) for number of branches and days to 50% flowering in fenugreek.

5.2 STABILITY ANALYSIS

To identify stable genotypes that exhibit least interaction with environments, several workers proposed different models. A dynamic approach to interpretation of varying environments was developed by Finlay and Wilkinson (1963). In this approach the components of a genotype and environment interaction were linearly related to environmental effects, when these effects were measured on the same scale as the genotypic effects. The regression technique of Finlay and Wilkinson was improved upon by Eberhart and Russell (1966) by adding another stability parameter, *viz.*, the deviation from regression and provided a fresh approach to GE interaction analysis. In their model they considered three parameters for stability *viz.*, mean performance (x), regression coefficient (b_i) *i.e.*, regression of means on environmental index and deviation from regression (S^2d_i). Regression coefficient (b_i) is a measure of linear component of GE interaction and gives an idea about response of genotype and S^2d_i is a measure of genotype environment interaction of unpredictable type (*i.e.*, predictable or unpredictable type).

In interpreting the results of the present investigation, the parameters like regression coefficient, mean value and deviation from regression is used. According to Eberhart & Russell (1966), if b_i is equal to unity, a genotype is considered to have stability (same performance in all the environments). If b_i is more than unity, it is suggested to have less than average stability (good performance in favourable environments). If b_i is less than unity, it is said to have above average stability and uniform performance in poor environments. However, Breese (1969) and Paroda *et al.* (1973) opined that regression coefficient is a measure of response to varying environments and the mean square deviation from linear regression is the true measure of stability, the genotypes with the least deviation being the most stable.

5.2.1 Plant Height (cm)

Among the mutants evaluated It-4 had lower mean value than population mean with non-significant deviation from regression and as such their performances can be predicted. The mutant It-6 was well adapted over all the environments as its regression coefficient is around unity. Mutants It-3, It-5, It-8 and It-9 were found to be suitable for better environment. Varied response of genotypes with respect to stability parameters for plant height had been reported by Manomohandas *et al.* (2000) in ginger, Ottai *et al.* (2006) in roselle, Panwar *et al.* (2011) in ocimum, Sangwan *et al.* (2013) in aswagandha, , Sharma (2013) in plantago and Kakani *et al.* (2014) in fenugreek.

5.2.2 Plant Spread (cm)

The mutants *viz.*, It-3 (μ=193.60, b_i=1.02, S^2d_i=0.13) and It-6 (μ=166.83, b_i=1.01, S^2d_i=0.20) were superior to the check and recorded regression coefficient values equal to one. Hence, they were considered to be stable mutants which can be recommended for wider environments. The mutants It-9 and It-10 recorded less than one for b_i value and hence adaptable to poor environments. Similar results were reported by Rajendra *et al.* (2015) in Ocimum and Santosh *et al.* (2014) in elephant foot yam.

5.2.3 Number of Branches

The mutants, It-2 (39.00), It-3 (39.66) and It-6 (41.50) with regression coefficient near to 'unity' and minimum deviation from regression were widely adaptable with average stability and possessing more number of branches than the standard check Vellanikara local. The mutant, It-1 (37.00) had regression coefficient more than 'unity' and non–significant deviation from regression and hence suitable for favourable environment with predictable performance. The mutant, It-8 (43.41) had recorded more number of branches than the standard check recommended for poor environment as regression coefficient was less than 'unity' besides non–significant deviation from linearity (Table 10). The similar variation in stability parameters were observed in the character no of branches, by Ottai *et al.* (2006) in roselle, Abou *et al.* (2006) in white mustard, Panwar *et al.* (2011) in ocimum, Kakani *et al.* (2014) in fenugreek and Rajendra *et al.* (2015) in ocimum.

5.2.4 Girth of Stem (cm)

The mutants with high mean than population mean, check Vellanikara local, regression coefficient near 'unity' and non-significant deviation from regression *viz.*, It-1 (μ=7.42, b_i=0.88, S^2d_i=0.36), It-3 (μ=7.84, b_i=1.09, S^2d_i=0.06) and It-5 (μ=7.45, b_i=0.86, S^2d_i= -0.07) were considered as stable ones for this trait. It-2 and It-8 were superior to the check with regression coefficient more than 'unity' and suitable for favourable environment. Similar result was obtained by Santosh *et al.* (2014) in elephant foot yam.

5.2.5 Number of Leaves Plant^{-1}

The mutants It-2, It-3, It-6, It-8 and It-9 were superior to the check with Vellanikara local having least deviation from regression. The mutant, It-2 (μ=1269.12, b_i= -1.08) was considered as stable because of a regression coefficient around 'unity'. Further, the mutants, It-3 and It-6 were suitable for favourable environments. Similar result in the variation of stability parameters for number of leaves plant^{-1} was reported by Manomohandas *et al.* (2000) in ginger.

5.2.6 Length of Leaves (cm)

The mutants It-2 (2.49), It-3 (2.47) and It-6 (2.45) recorded high mean values than the population mean, regression coefficient around unity and least deviation from regression for yield per plant. They were expected to perform well in all environments. The mutants It-1, It-4 and It-8 whose performance could be well predicted expressed non-significant S^2d_i values. Similar results were reported by Panwar *et al.* (2011) and Rajendra *et al.* (2015) in ocimum.

5.2.7 Width of Leaves (cm)

Mutant It-8 recorded higher mean value than the standard check. The mutants It-1 (1.52) along with It-6 (1.45) also have a regression coefficient around unity and least deviation from regression and thus appeared to be highly stable with respect to width of leaves. The mutants, It-8 and It-9 had regression coefficient less than unity and non–significant deviation from regression and hence were identified as suitable for unfavourable environments. The mutants, It-2 and It-10 with regression coefficient greater than 'unity' (1.52, 1.30) and non–significant deviation from regression (0.001 and -0.0004) were ideal for better environments. Varied response of genotypes due to change in environments is in accordance with the findings of Panwar *et al.* (2011) and Rajendra *et al.* (2015) in ocimum.

5.2.8 Internodal Length (cm)

The mutants It-3 (5.07), It-8 (4.79) and It-9 (5.25) recorded lower mean values for internodal length than the check Vellanikara local and population mean. These mutants also have least deviation from regression. Therefore mutants It-3, It-8 and It-9 performed well under all types of environments due to b_i=1. It-10 performed well under favourable environment due to b_i>1. With respect to internodal length most of the genotypes showed non-significant S^2d_i value which indicated that internodal length did not vary with the growing system.

5.2.9 Leaf Area (cm²)

Among the mutants, It-1 (μ=2643.93, b_i=0.92), It-3 (μ=2206.41, b_i=0.92), It-6 (μ=2249.07, b_i= -1.07) were considered as stable mutants because of a desirable mean than the standard check, regression coefficient around 'unity' and non–significant deviation from regression which can be recommended for wider environments. Further, the mutant It-8 also had high mean, greater than 'unit' regression and non–significant deviation from linearity and it was suitable for favourable environment. The same variation in the stability parameters was reported by Rajendra *et al.* (2015) in ocimum.

5.2.10 Harvest Index

Among the mutants, It-3 (μ=21.38, b_i=1.04, S^2d_i=0.29) and It-6 (μ=20.94, b_i=0.94, S^2d_i=0.56) were considered as stable hybrids because of a desirable mean than the standard check, regression coefficient around 'unity' and non–significant deviation from regression which can be recommended for wider environments. Further, the mutants It-8 and It-10 also had high mean lesser than 'unit' regression and non–significant deviation from linearity. Mutants It-4 and It-9 exhibited significant S^2_{di} values for this trait which indicated their instability. The instability might be due to variation in the existing environment of the growing system.

5.2.11 Total Fresh Weight (g)

The mutants It-5 (μ=822.46, b_i= -0.98), It-9 (μ=964.80, b_i= -1.07) and Vellanikara local (μ=838.67, b_i=0.98) possessed higher fruit yield than the population mean and were considered as ideal, highly adaptable mutants having average stability and was expected to perform well in all the environment. Mutants It-1 (845.63 g) and It-10 (866.81 g) with regression coefficient less than unity and non–significant deviation from regression were found suitable for poor environment.

5.2.12 Total Dry Weight (g)

The mutants It-1, It-3 and It-8 had highest mean performance in total dry weight than the population mean and check Vellanikara local. The mutant It-3 was stable with regression coefficient near 'unity' and non-significant deviation from regression. The mutant It-1 with regression coefficient higher than 'unity' and non–significant deviation from regression was suitable for favourable environment. With respect to poor environment, the mutant It-8 which recorded high mean with less than 'unity' regression coefficient and non–significant deviation from linearity was suitable.

5.2.13 Dry Matter Production (g plant^{-1})

The stable mutants observed for this trait were It-1 (μ=77.57, b_i= -0.92, S^2d_i= -0.56) and It-3 (μ=78.10, b_i=1.08, S^2d_i= -1.35) with regression coefficient near to 'unity' and non–significant deviation from regression. The mutants It-2, It-8 and It-10 were having high mean value than population mean and check vellanikara local. These results were in accordance with the findings of Santosh *et al.* (2014) in elephant foot yam.

5.2.14 Leaf Area Index

Only one mutant, It-3 (μ=4.83, bi= -0.97, S^2d_i= -0.001) was stable with b_i value near to unity and non-significant deviation from the regression for the character leaf area index. The mutants It-1, It-2, It-6, It-8 and It-9 were identified for favourable environment as they recorded b_i more than unity and non–significant S^2d_i value. Mutant It-5 was suited for poor environment.

5.2.15 Net Assimilation Rate (gm^{-2}day^{-1})

Among the mutants evaluated It-3, It-6 and It-9 were having higher mean value than population mean with non-significant deviation from regression and as such their performances can be predicted. The above mentioned mutants were well adapted for all the environments as its regression coefficient was around unity. Mutant It-4 was found to be suitable for better environment and It-8 was suitable for poor environment for this trait.

5.2.16 Fresh Weight of Leaves (g)

The mutants, It-1 (237.08 g), It-6 (275.66 g) and Vellanikara local (262.5 g) with regression coefficient near to 'unity' and minimum deviation from regression were widely adaptable with average stability. The mutants, It-2 (242.08 g), It-4 (241.66 g) and It-8 (281.6 6 g) having regression coefficient more than 'unity' and non–significant deviation from regression were suitable for favourable environment with predictable performance.

5.2.17 Dry Weight of Leaves (g)

The mutants with high mean than population mean, regression coefficient near 'unity' and non-significant deviation from regression *viz.,* It-3 (μ=83.85, b_i=1.06, S^2d_i= -1.02), It-6 (μ=98.90, b_i=0.91, S^2d_i= -0.65) and It-9 (μ=87.07, b_i= -1.07, S^2d_i= -1.90), were finally considered as stable ones for this trait. Only one mutant It-8 was superior to the check, regression coefficient more than 'unity' and suitable for favourable environment.

5.2.18 Fresh Weight of Shoot (g)

The mutants It-4, It-6 and It-9 were superior to the check Vellanikara local with least deviation from regression. These mutants were considered as stable because of regression coefficient around 'unity'. Further, the mutants, It-3 and It-8 were observed to be suitable for un-favourable environment with lesser than 'unit' regression.

5.2.19 Dry Weight of Shoot (g)

For dry weight of shoot the mutant It-9 exhibited significant S^2d_i values and the performance cannot be predicted. The mutants It-3 and It-8 were superior to the check Vellanikara local with least deviation from regression.

These mutants were considered as stable because of a regression coefficient around 'unity'. Further, the mutant, It-10 was observed to be suitable for un-favourable environment with lesser than 'unit' regression, It-1 was suitable for favourable environment.

5.2.20 Indigotin Content (%)

For indigotin content It-8 and It-10 genotypes, exhibited significant S^2d_i values whose performance cannot be predicted. The mutants It-1, It-3, It-6 and It-9 were superior to the check Vellanikara local with least deviation from regression.

These mutants were considered as stable because of a regression coefficient around 'unity'. Further, the mutant, It-4 was suitable for favourable environment. These findings are agreement with those of Lee (2006) in fenugreek, Panwar *et al.* (2011), Sangwan *et al.* (2013) in awagandha and Rajendra *et al.* (2015) in ocimum.

Table 10. Comparison of mutants on the basis of mean performance and stability parameters

	Character	Stable	Favourable environment	Poor environment	Mean value of checks	Population mean
1	Plant height (cm)	It-6 (176.95)	It-3 (201.76), It-5 (176.04), It-8 (214.65), It-9 (184.66)	It-1(184.32)	Vellanikara local (136.53)	172.39
2	Plant spread (cm)	It-3 (193.60), It-6 (166.83)	It-5 (185.87), It-8 (196.76)	It-9 (185.38), It-10 (165.00)	Vellanikara local (150.27)	164.89
3	No of branches	It-2 (39), It-3 (39.66), It-6 (41.50)	It-1(37.00)	It-8 (43.41)	Vellanikara local (34.75)	36.98
4	Girth of stem (cm)	It-1 (7.42), It-3 (7.84), It-5 (7.45)	It-2 (7.65), It-8 (8.67)		Vellanikara local (6.44)	7.41
5	No of leaves per plant	It-2 (1269.12)	It-3 (1310.00), It-6 (1328.46),		Vellanikara local (1168.41)	1267.51
6	Length of leaves (cm)	It-2 (2.49), It-3 (2.47), It-6 (2.45)	It-1(2.44), It-4 (2.51), It-8 (2.57)	It-5 (2.45), It-9 (2.45)	Vellanikara local (2.28)	2.44
7	Width of leaves (cm)	It-1 (1.52), It-6 (1.45)	It-2 (1.44), It-10 (1.44)	It-8 (1.63), It-9 (1.47)	Vellanikara local (1.32)	1.44
8	Intermodal length (cm)	It-3 (5.07), It-8 (4.79), It-9 (5.25)	It-10 (5.61)	It-6 (5.78)	Vellanikara local (7.76)	5.96
9	Leaf area (cm^2)	It-1(2643.93), It-3 (2206.41),It-6 (2249.07)	It-8 (2649.32)	It-2 (2295.93)	Vellanikara local (2144.25)	2206.04
10	Harvest index	It-3 (21.38), It-6 (20.94)		It-8 (21.56), It-10 (19.14)	Vellanikara local (17.09)	19.14

Table 10. (Continued……)

11	Total fresh weight (g)	It-5 (822.46),vellanikara local (838.67), It-9 (964.80)	It-8 (1076.50)	It-1 (845.63), It-10 (866.81)	Vellanikara local (838.67)	816.04
12	Total dry weight (g)	It-3 (456.88)	It-1 (480.36)	It-8 (478.88)	Vellanikara local (316.20)	383.76
13	Dry matter production (gplant^{-1})	It-1 (77.57), It-3 (78.10)	It-2 (73.57), It-8 (84.64), It-10 (83.99)		Vellanikara local (53.43)	69.47
14	Leaf area index	It-3 (4.83)	It-1 (4.77), It-2 (4.94), It-6 (5.25) It-8 (5.47), It-9 (5.26)	It-5 (4.82)	Vellanikara local (3.58)	4.77
15	Net assimilation rate (gm^{-2}day^{-1})	It-3 (3.25), It-6 (3.07), It-9 (2.76)	It-4 (3.43)	It-8 (3.76)	Vellanikara local (1.71)	2.67
16	Fresh weight of leaves(g)	It-1(237.08), It-6 (275.66), vellanikara local (262.50)	It-2 (242.08), It-4 (241.66), It-8 (281.66)		Vellanikara local (262.50)	217.31
17	Dry weight of leaves(g)	It-3 (83.85), It-6 (98.90), It-9 (87.07)	It-8 (122.35)		Vellanikara local (54.06)	79.59
18	Fresh weight of shoot(g)	It-9 (716.91) , It-4 (661.25), It-6 (662.00)		It-3 (727.91), It-8 (845.50)	Vellanikara local(579.00)	661.15
19	Dry weight of shoot(g)	It-3 (328.20), It-8 (417.54)	It-1 (352.90)	It-10 (371.91)	Vellanikara local (214.36)	308.08
20	Indigotin content (%)	It-3 (4.15), It-6 (3.63), It-9 (4.27)	It-4 (4.16)		Vellanikara local (1.89)	3.59

Summary

6. SUMMARY

The present investigation on "Stability analysis of selected mutants in neelamari (*Indigofera tinctoria* (L.)" was carried out to study the performance of yield and stability of nine mutants and one check variety (Vellanikara local) in four locations (Vellanad, Kalliyoor, Kottarakkara, and Kayamkulam).

The highly significant mean squares due to genotypes for yield and all other component characters revealed the presence of high variability among the tested genotypes. The mean squares due to G x E interactions were significant for all the characters indicating that the genotypes responded differently to the change in the environment. Thus further analysis was done to test the stability of the genotypes.

In the stability analysis, the mean squares due to Environments + (Genotype x Environment) were significant for the characters girth of stem, length of leaves, leaf area, total fresh weight of the plant and indigotin content emphasizing the existence of G x E interactions for these traits. Sum of squares due to E + (G x E) was further partitioned into Environment (linear), Genotype x Environment (linear) and pooled deviation. Environment (linear) was significant for the characters plant spread, number of branches, girth of stem, length of leaves, width of leaves, leaf area, total fresh weight of plant, dry weight of leaves, dry weight of shoot and indigotin content. Genotype x Environment (linear) was significant for the characters plant height, number of branches, number of leaves plant^{-1}, length of leaves, internodal length, leaf area, total fresh weight of the plant, dry weight of leaves and indigotin content. This indicated that the major component for differences in stability was due to both linear and nonlinear component.

Estimation of environmental index for all characters in all the four locations revealed that out of the four locations Vellanad was the most favourable or suitable environment for the cultivation of neelamari and Kayamkulam was the least favourable location for the cultivation of neelamari.

The mean performance of a genotype along with two parameters viz., regression coefficient (bi) and deviation from regression (S^2d_i) considered simultaneously represents a measure of stability of the genotype.

Mutants It-3, It-6 and It-9 were identified as stable mutants having regression coefficient near 'unity' and non–significant deviation from regression with wider adaptability over environments for yield along with other yield contributing characters. It-1, It-2 and It-8 were identified as stable for favourable environments with regard to plant height, plant spread, number of branches, girth of stem, number of leaves plant^{-1}, length of leaves, width of leaves, leaf area, total fresh weight of the plant, total dry weight of the plant, dry matter production, leaf area index, fresh weight of leaves, dry weight of leaves and dry weight of shoot as indicated from high mean values, regression coefficient greater than unity and non-significant deviation from regression equal to zero. The mutant It-10 was observed suitable for poor environments for characters plant spread, harvest index, total fresh weight of plant and dry weight of shoot.

The present study showed that mutant populations show not only increased yield, but also greater stability in yield across environments. Mutants as a whole exhibited higher mean values and regression coefficients near to unity and non-significant deviation from regression which indicated that the stability parameters for yield lead to the interpretation of greater production and stability of mutants. The superior mutants identified in the present study can be further promoted to farm trials before releasing them as a variety.

References

7. REFERENCE

Abbas, P., Ali, A. J., Hasan, M. A., Sepideh, T., and Mahdi, M. 2015. Essential oil yield stability of 20 populations of thyme (*Thymus kotschyanus*) across 11 environments of Iran. *J. Bio. & Environ. Sci.* 7(1): 31-37.

Abou El-Nasr, T. H. S., Ibrahim, M. M., and Aboud, K. A. 2006. Stability parameters in yield of white mustard (*Brassica alba* L.) in different environments. *World J. of Agric. Sci.* 2 (1): 47-55.

Acevedo-Rodriguez, P. 1996. Flora of St. John, U.S. Virgin Islands. Memoirs of the New York Botanical Garden, 78: 1-581.

Amar, S., Becker, H. C., and Mollers, C. 2008. Genetic variation and genotype x environment interactions of phytosterol content in three doubled haploid populations of winter rapeseed. *Crop Sci.* 48: 1000-1006.

Amrithpal Singh. 2006. Medicinal plants of the World Oxford & IBH. Co.Pvt .Ltd publishers, New Delhi, 168p.

Ann, M. J., Neven, N., Jelica, G. V., Nikola, H., Ankica, K. S., Mirjana, V., and Radovan, M. 2006. Genotype by environment interaction for seed yield per plant in rapeseed using AMMI model. *Pesq. agropec. bras.* 46(2): 129-136.

Armitage, A. M. 2008. Herbaceous perennial plants: A treatise on their identification, culture, and garden attributes. Champaign, IL, USA: Stipes Publishing.

Asuntha, G., Prasannaraju, Y., and Prasad, G. 2010. Effect of ethanol extract of *Indigofera tinctoria* Linn (Fabaceae) on lithium / pilocarpine-induced status epilepticus and oxidative stress in Wistar Rats. *Trop. J. of pharma. Res.* 9(2): 149-156.

Balakrishnan, K. A., Tomar, B. S. and Verma, R. 1993. Stability analysis of garlic varieties. *Veg. Sci.* 20: 166-168

Basu, S. K., Acharya, S. N., Bandara, M. S., Friebel, D., and Thomas, J. E. 2009. Effects of genotype and environment on seed and forage yield in fenugreek (*Trigonella foenum-graecum* L.) grown in western Canada. *Aust. J. of Crop Sci. Southern Cross J.* 3(6): 305-314.

Benson, L. 1957. Manual of the orders and families of dicotyledons. *Plant classification.* Oxford & IBH publishing Co., New Delhi, p. 688.

Birendra, K., Singh, H. P., and Patra, N. K. 2008. Stability analysis for essential oil yield and quality traits in Japanese mint. *Indian J. Hort.* 65(2): 245-247.

Bondari, K. 1999. Statistical analysis of genotype x environment interaction in Agricultural Research. *J. of Entomol. Sci.* 34: 57-71.

Breese, E. I. 1969. The measurement and significance of genotype x environment interaction in grasses. *Heredity* 24: 27-44.

Buttery, B. R. 1970. Effect of variation in leaf area index on growth of maize and soyabean. *Crop Sci.* 10: 9-13.

Dhillon, S. S., Sing, K., and Bar, K. S. 1999. Stability analysis of elite strain in Indian mustard. Proc. 10th Intl. Rapeseed Congress held at Canberra, Aust.

Drazic, S., Zivanovic, T., and Prodanovic, S. 2007. Stability of productive traits of genotypes of cultivated medicinal plants of the family Apiaceae. *Biotechnol. & Biotechnol. Eq.* 21(1): 100-106.

Duke, J. A. 1981. Handbook of legumes of world economic importance. Plenum press, New York, USA Frankel, OH, Brown and Burdon, J.J. 1995. The conservation of plant biodiversity, Cambridge Univ. press. Cambridge. UK. pp 29-33.

Duran, K., Kara, N., and Katar, N. 2015. Yields and quality performance of coriander (*Coriandrum sativum* L.) genotypes under different ecological conditions. *Field crops* 21(1): 79-87.

Eberhart, S. A. and Russell, W. A. 1966. Stability parameter for comparing varieties. *Crop sci.* 6: 36-40.

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

Fisher, R.A. and Yates, F. 1967. Statistical tables for biological, agricultural and medical research. Olive and Boyd, Edinburgh

Flora of China Editorial Committee. 2014. Flora of China. St. Louis, Missouri and Cambridge, Massachusetts, USA: Missouri Botanical Garden and Harvard University,Herbaria. http://www.efloras.org/flora_page.aspx?flora_id=2

Francis, T. R. and Kannenberg, L. W. 1978. Yield stability studies in short season maize. A descriptive method for grouping genotypes. *Can. J. Plant Sci.* 58:1029-1034.

Gauch, J. R. and Zobel, R. W. 1989. Using interaction in two-way tables. Proceedings of the 1989 Kansas State University Conference on Applied Statistics in Agriculture (G. A. Milliken and J. R. Schwenke, Editors): 205-213.

Gaurav, K. L., Karthik, K., and Bhaskararao, V. 2011. A review on pharmacological and phytochemical properties *zingier officinale Roscoe* (Zingiberaceae). *J. of Pharmacy.* 4(9): 2963-2966.

Hegde, D.M., Patil, H.S., Singh, B.R. and Goswami, U. 2000. Phenotypic stability in niger (*Guizotia abyssinica* (ass)). *Crop Res.* 19: 97-101

Hooker, J. D. 1876. Flora of Birtish India. Volume II. L. Reeve & Co. Ltd., Kent, London, p. 792.

Jyothsna, S., Appalaswamy, A., and Lal Ahamed, M. 2014. Stability analysis in roselle (*Hibiscus sabdariffa* L.) by Eberhart-Russell model. *Int. J. of Food, Agric. and Vet. Sci.* 4 (3): 151-155.

Kaicker, U. S., Saini, H. C., Singh, H. P., and Choudhury, B. 1978. Environmental effects on morphine content in opium poppy (*Papaver somniferum* L.). UNODC. p69-74.

Kakani, R. K., Saxena, S. N., Meena, S. S., and Chandra, P. 2014. Stability analysis for yield and yield attributes in fenugreek under water limiting conditions (*Trigonella foenum-graecum* L.). *Int. J. Seed Spices.* 4(2): 47-52.

Kerala Agricultural University (KAU) 2011 Package of Practices Recommendations. Kerala Agricultural University, Trichur.

Kumanan, E. 2009. Introduction of variability through mutagenesis in Neelayamari (*Indigofera tinctoria* L.) M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 3-26pp

Kumar, K., Sunil1, Yadav, D. S., Durai, A., and Anna. 2004. stability analysis in turmeric (*Curcuma* spp.) genotypes. *Indian J. of Hortic.* 61(1): 71-73.

Kundu, S. K., Islamz, Q. N., Emmanuelb, C. J. S. K., and Tigerstedt, P. R. I. A. 1998. Observations on genotype x environment interactions and stability in the international neem (*Azadiractha indica* A. JUSS.) provenance trials in Bangladesh and India. *For. Genet.* 5(2): 85-96.

Lee. L. E. 2006. Genotype X Environment impact on selected bioactive compound of fenugreek (*Trigonella foenumgraecum* L.). M.Sc. (Agri.) Thesis, University of Saskatchewan, Canada.

Mahesh, S. and Sathyanarayana, N. 2011. The genotype x environment interaction and stability analysis for L-Dopa trait in Velvetbean (*Mucuna pruriens*) seeds. *Indian J. Genet.* 71(3): 279-282.

Manomohandas, T. P., Pradeepkumar, T., Mayadevi, P., Aipe K. C., and Kumaran, K. 2000. Stability analysis of ginger (*Zingiber officinale* Rose.) genotypes. *J. of Spices and Aromat. Crops* 9 (2): 165-167.

Mishra, B. K., Rastogi, A., Verma, N., Prasad, B., Parmar, D., Parmar, N. C., and Shukla. S. 2014. Effect of genotype, environment and their interaction on seed and opium yield in opium poppy (*Papaver somniferum* L.) and comparison of different stability models for GEI. *Acta Hort.* 10: 164-168.

Mohammed, A. and Firew, M. 2015. Phenotypic stability analysis of oil yield in sesame (*Sesamum indicum* L.) varieties across the Awash Valleys in Ethiopia. *J. of Adv. in Agric.* 5(2): 650-657.

Mubashir, A. K., Nazakat, N., Abdul, R., Tahira, M., and Amjad, M. 2015. Genotype environment interaction and stability analysis for seed yield in sesame (*Sesamum indicum* L.). *Sky J. of Agric. Res.* 4(6): 110 – 113.

Muthulingam, M., Mohandoss, P., Indra, N., and Sethupathy, S. 2010. Antihepatotoxic efficacy of *Indigofera tinctoria* (Linn.) on paracetamol induced liver damage in rats. *Indian J. Plant Biol. Res.* 1(1): 13-18.

Nair, D. S. 2000. Evaluation of genetic stock of sanghupushpam (*Clitoria ternatea* L.) for yield, alkaloid content and nitrogen fixing potential. M.Sc. (Horti.) thesis. Kerala Agricultural University, Thrissur, p. 110.

Neema, M. 2004. Genetic variability analysis in Indian indigo (*Indigofera tinctoria* L.) using RAPD technique. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 49p.

Nitya, J., Harish, S. P., and Premalatha, D. 2010. Phytochemistry and antimicrobial efficacy of *Indigofera tinctoria* L. (Fabaceae). *Int. J. of Pharmacy and Pharmaceutical Sci.* 6(1): 158-160.

Ottai, M. E. S., Aboud, K. A., Mahmoud, I. M., and El-hariri, D. M. 2006. Stability analysis of roselle cultivars (*Hibiscus sabdariffa* L.) under different nitrogen fertilizer environments. *World J. of Agric. Sci.* 2(3): 333-339.

Pankhuri, G., Raj, K. L., and Nisha, B. 2015. Stable genotype selection in vetiver (*Veteveria zizanioides* L. Nash). *J. of Herbs, Spices & Med. Plants*. 21:392–409.

Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods Agricultural Workers. ICAR, New Delhi. pp. 235-246.

Panwar, N. S., Kumar, A., Malik, S. S., Dwivedi, V. K., Singh, P. B., and Kumar, G. 2011. Stability analysis for biomass and essential oil yield in basil (*Ocimum basilicum*) germplasm. *Indian J. Plant Genet. Resour.* 25(2): 180-182.

Paroda, R. S., Panwar, D. V. S., and Sharma, G. D. 1973. Genotype x environment interaction for fodder yield in sorghum. *Indian J. Agric. Sci.* 43: 386-388.

Prajapati, S., Purohit, J., Sharma, R. B., and Kumar, S. 1998. Medicinal Plants: An overview. In: A handbook of medicinal plants, a complete source book. Agrobios Publication (India) 1-3.

Prakash, K.M. 1996. Biometrical analysis of yield and other attributes in coleus (*Coleus parviflorus* Benth.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Trichur, p.133

Preeti, V. and Solanki R. K. 2015. Stability of seed yield and its component traits in fennel (*Foeniculum vulgare*). *Indian J. of Agric. Sci.* 85 (11): 1504–7.

Purchase, J. L., Hatting, H., and Vandenventer, C. S. 2000. G x E interaction of wheat: stability analysis of yield performance. *S. Afr. J. Pl. Sci.* 17: 101-107.

Puy, D., Labat, J. N., Rabevohitra, R., Villiers, J. F., Bosser, J., and Moat, J. 2002. The Leguminosae of Madagascar. Richmond, UK: Royal Botanic Gardens, 737 pp.

Rajendra, P., Patela, Rakshapal, S., Shilpi, K., Saikiab, B. R., Rajeswara, R., Sastryc, M., Zaimd, R., and Lale, K. 2015. Phenotypic characterization and stability analysis for biomass andessential oil yields of fifteen genotypes of five *Ocimum* species. *Ind. Crops and Products.* 77: 21–29.

Rawli, P., Brij, K. M., Nidhi, V., Ameena, S., and Sudhir, S. 2014. Identification of adaptable and stable genotype for seed and opium yield in opium poppy (*Papaver somniferum* L.) based on various stability models [abstract]. In: *Abstacts*, 2nd International Conference on Agricultural & Horticultural Sciences; 3-5 February, 2014, Hyderabad. Radisson Blu Plaza Hotel, Hyderabad, India, p. 219. Abstract No. 51.

Resmi, C. R. 2001. Evaluation of selected sanghupushpam (*Clitoria ternatea* L.) lines for yield, alkaloid content and nodulation. M.Sc (Horti.) thesis. Kerala Agricultural University, Thrissur, p. 129.

Samuel, A. 2000. Evaluation of genetic stock of *Macuna puriens* Baker non DC. For yield, L-Dopa content and nitrogen fixing potential in coconut garden. M.Sc. (Horti.) thesis. Kerala Agricultural University, Thrissur. P.126.

Sangwan, O., Avtar, R., and Amit, S. 2013. Stability analysis in some ashwagandha (*Withania somnifera* (L.) DUNAL) genotypes. *Indian J. of Plant Sci.* 2 (1): 66-71

Santosh, K., Singh, P. K., Solankey, S. S., and Singh, B. K. 2014. Genotypic × environment interaction and stability analysis for yield and quality components in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst) Nicolson). *Afr. J. of Agric. Res.* 9(7): 707-712.

Sarada, S. 2004. Evaluation of neelayamari (*Indigofera tinctoria* L.) for yield and glycoside content under open and shaded conditions. Ph.D thesis, Kerala Agricultural University, Thrissur, 165p.

Sharma, A. K. 2013. Stability analysis for economic traits in blond psyllium (*Plantago ovata* Forsk.). *Indian J. Genet.* 73(2): 225-227.

Shinoj, P. 2001. Stability analysis of selected mutants of coleus (*Solenostemon rotundifolius* (poir) J K Morton. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur.

Shukla, G. K. 1972. Some statistical aspects of partitioning genotypes – environmental components of variability. *Heredity*. 29:237–245.

Singh, and Anil, K. 2014. Genetic variability and stability analysis in *Macuna* species. M.Sc. (Ag.) thesis, Chaudhary Charan Singh University.

Singh, S. P., Shukla, S., Yadav, H. K., and Chatterjee, A. 2005. Genotype x environmental interaction in relation to stable genotypes in opium poppy (*Papaver somniferum* L.). *Indian J. Genet.* 65(2): 153-154.

Srivastava, J.P. and Kamalesh, R. 1998. Analysis of yield stability in sesame (*Sesamum indicum* L.). *Indian J. Plant Physiol.* 3: 256-259.

Tabaei-Aghdaei, S. R., Babaei, A., Khosh-Khui, M., Jaimand, K., Rezaee, M. B., Assareh,M . H., and Naghavi, M. R. 2007. Morphological and oil content variations amongst Damask rose (*Rosa damascena* Mill.) landraces from different regions of Iran. *Scientia Horticulturae* 113 (1): 44–48.

Toshniwal, R. P. 1984. Stability analysis in fenugreek (*Trigonella foenum-graecum* L.) M.Sc. (Ag.) thesis, Sukhadia University, Udaipur.

Tsige, G. 2006. Genotype-Environment interactions in *Vernonina galamensis*. *Eth.J. Sci. & Technol.* 3(2): 1-14.

Turkhede, B. B., De, R., and Singh, R. K. 1976. Mimeographed Proc. 2nd Workshop on medicinal and aromatic plants 23.

Usmani, and Mohamed, G. 2013. Studies on reproductive biology and genetic variation for chemoagronomic traits in (*Rauwalfia serpentine* L. Benth. Ex. Kurz). Ph. D. thesis. Forest Research Institute University, Deharadun.

Warrier, P. K., Nambiar, V. P. K., and Ramankatty, C. 2007. Indian medicinal plants. Published by Orient Longman Private Limlited Chennai. 3: 210-213.

Watson, D. J. 1952. The physiological basis of variation of yield. *Ann. Bot.* 4: 101-145.

Wricke, G. 1962. Beerin e Methode zur Erfassung de okologischen Streubreite in Feldversuchen. Zeitschrift fur. Pflanzenziichtung 47:92-96.

Wu, E., Komolpis, K., and Wang, H. Y. 1999. Chemical extraction of indigo from *Indigofera tinctoria* while attaining biological integrity. *Biotech. Tech.* 13: 567-569.

Yadav, H. K., Sudhir, S., Anu, R., Singh, M. P., and Singh, S. P. 2007. Genotype - Environmental interactions and phenotypic stability analyses of opium poppy (*Papaver somniferum* L.) for seed, opium and morphine content. *Indian J. Genet*. 67(2): 166-168.

Yousefi, B., Seyed, R. T., Farrokh, D., and Mohammad, H. A. 2011. Flower yield performance and stability of various *Rosa damascena* Mill. Landraces under different ecological conditions. *Scientia Horticulturae.* 121: 333–339.

STABILITY ANALYSIS OF SELECTED MUTANTS IN NEELAMARI (*Indigofera tinctoria* L.)

SARANYA, V. S.
(2014 - 11 - 127)

ABSTRACT

of the thesis submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM – 695 522
KERALA, INDIA

2016

ABSTRACT

The research work on "Stability analysis of selected mutants in neelamari (*Indigofera tinctoria* L.)" was carried out with nine mutants and one local accession as check over four locations *viz.*, farmer's fields at Kalliyoor, Vellanad, Kayamkulam and Kottarakara during summer season of 2015-2016 with the objective of studying the performance of superior mutants for yield and indigotin content over different locations.

In the pooled analysis of variance for evaluation of mutants over locations, significant differences among the genotypes were noticed for all the characters studied and significant differences among environments were noticed for the characters number of branches, girth of stem, length of leaves, width of leaves and indigotin content suggesting that genotypes interacted significantly with environments.

Stability analysis revealed that the mutants It-3, It-6 and It-9 were stable over all locations for different characters like net assimilation rate, dry weight of leaves and indigotin content. The mutant It-3 was stable for plant spread, number of branches, girth of stem, length of leaves, internodal length, leaf area, harvest index, total dry weight of plant, dry matter production, leaf area index and dry weight of shoot, while mutant It-6 was stable for plant height, plant spread, number of branches, length of leaves, width of leaves, leaf area, harvest index, fresh weight of leaves and fresh weight of shoot. The mutant It-9 was stable for the characters like internodal length, total fresh weight of the plant and fresh weight of shoot.

It-1, It-2 and It-8 were identified as stable mutants for favourable environments. Mutant It-8 showed stable performance for most of the characters. Mutant It-1 was stable in favourable environment for number of branches, length of

leaves, total dry weight of the plant, leaf area index and dry weight of shoot whereas mutant It-2 was stable for girth of stem, width of leaves, dry matter production, leaf area index and fresh weight of leaves.

The mutant It-10 was found to be stable for the characters plant spread, harvest index, total fresh weight of the plant and dry weight of shoot in poor environments.

The present investigation revealed that the mutants It-3, It-6 and It-9 were stable over different locations during the summer season. It-1, It-2 and It-8 were the mutants which performed well under favourable environment and It-10 was the mutant suitable for unfavourable environment.