GENOTYPE × ENVIRONMENT INTERACTION IN SESAME

[*Sesamum indicum* (L.)]

by

Mr. Mahajan Raju Pandurang

(Reg. No. 018/41)



DEPARTMENT OF AGRICULTURAL BOTANY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH

RAHURI-413 722, DIST- AHMEDNAGAR

MAHARASHTRA STATE (INDIA)

2021

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A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA.

In partial fulfilment of the requirements for the degree
of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY
(GENETICS AND PLANT BREEDING)



DEPARTMENT OF AGRICULTURAL BOTANY

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2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

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Date : / /2021

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Maharashtra, (INDIA).

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This is to certify that the thesis entitled **"GENOTYPE × ENVIRONMENT INTERACTION IN SESAME [*Sesamum indicum* (L.)]"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING),** embodies the result of a piece of bonafide research work carried out by **Mr. MAHAJAN RAJU PANDURANG** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

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LIST OF ABBREVIATIONS

%	:	Percent
/	:	Per
bi	:	Regression coefficient
C. D.	:	Critical difference
C. V.	:	Coefficient of variance
cm	:	Centimeter
d. f.	:	Degrees of freedom
E	:	Environment(s)
et al.	:	et alli (and others)
etc.	:	Etcetera
Fig.	:	Figure
g	:	Gram(s)
G	:	Genotype(s)
ha.	:	Hectare(s)
i. e.	:	that is
Ij	:	Environmental Index
kg	:	Kilogram(s)
kg/ha	:	Kilogram/hectare
L	:	Linear
M. S. S	:	Mean sum of square
No.	:	Number
S. E.	:	Standard error
S^2di	:	Standard deviation from regression line
spp.	:	Species
viz.,	:	Videlicet (Namely)

ABSTRACT

GENOTYPE × ENVIRONMENT INTERACTION IN SESAME

[*Sesamum indicum* (L.)]

by

Mr. Raju Pandurang Mahajan

A candidate for the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY

(GENETICS AND PLANT BREEDING)

2021

Research Guide	**: Dr. S.D. Rajput**
Department	**: Agricultural Botany**
Major Discipline	**: Genetics and Plant Breeding**

The present investigation entitled "Genotype x environment interaction in Sesame [*Sesamum indicum* (L.)]" was undertaken with a view to estimate G x E interaction for seed yield and its components and to assess the seed yield potential of different genotypes of sesame under different sowing dates and to identify genotypes suitable for different predictable environments. Fourteen genotypes were sown on three different sowing dates in a Randomized Block Design with three replications for measuring stability of genotypes for different characters. The data was subjected to statistical analysis as per Eberhart and Russell model (1966).

The variance due to genotypes were found highly significant when tested against G × E, pooled deviation and pooled error for all the characters *viz.,* days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, length of capsule (cm), number of seeds per capsule, 1000-seed weight (g), seed yield per plant (g) and oil content (%). G × E interaction was found significant for all the characters studied when tested against pooled error.

Both linear and non-linear components of G x E interactions were significant for all the characters indicating that genotypes responded linearly to environmental changes in respect of all the characters except length of capsule for which linear components was non-significant and also length of capsule and 1000 seed weight for which non-linear components was non-significant.

Estimates of environmental indices (Ij) suggested that environment E_1 i.e. sowing on 16th June i.e. 3rd week of June was found to be most favorable for seed yield and yield contributing characters.

Below average stability was observed for JLS-301-24, JLS-710 and GT-10 for days to 50% flowering; JLS-706 and JLS-907 for days to maturity; JLS-301-24 for plant height; JLS-408-2 and JLT-408 for capsules per plant; JLS-120, JLS-408-2, JLS-301-24 and JLT-408 for seeds per capsule; JLS-408-2, JL-708 and JLS-1009-7-1 for 100 seed weight; JLS-120 and JLT-408 for seed yield per plant and JL-708 and PT-1 for oil content indicating their suitability for rich or favorable environments.

The genotypes JLS-302-11 and JLS-706 recorded average stability for days to 50% flowering. The genotype JLS-120, JLS-408-2, JLS-1009-7-1 and JLT-7 exhibited average stability for days to maturity. The genotype JLS-710, JLS-709, JLS-1009-7-1, JLT-408 and JLT-7 exhibited average stability for plant height and genotype JLS-408-2, JLS-302-11, JLS-706 and JLS-907 for branches per plant.The genotypes JLS-120, JL-708, JLS-709 and PT-1 showed average stability for capsules per plant. The genotypes JL-708, JLS-709 and PT-1 showed average stability for seeds per capsule. The genotypes JLS-120, JLS-709, JLS-1009-7-1, PT-1, JLT-408 and GT-10 were recorded average stability for length of capsule. The genotypes JLS-120, PT-1, JLT-408 and GT-10 showed average stability for 1000 seed weight. The genotypes JL-708, JLS-408-2, PT-1 and GT-10 recorded average stability for seed yield per plant. The genotypes JLS-302-11, JLS-907 and JLT-408 showed average stability for oil content.

Above average stability was observed for genotype JL-708for days to 50% flowering; JL-708 and JLT-408 for branches per plant; JLS-907 for length of capsule and JLS-301-24 for 1000 seed weight indicating their suitability for poor or stress environments.

In breeding programme for obtaining stable genotypes for yield, it will be more useful to use the genotypes viz. JLS-120 and JLT-408for rich environment. As stable yield performance is the foremost need for obtaining good yield under varying climatic conditions i.e. early sown, optimum and late sown conditions. Multi-location testing of the genotypes JLS-302-11, JLS-120, JLS-1009-71 & JLS-709 over locations and years is necessary for its release for general cultivation.

1. INTRODUCTION

Sesamum indicum (L.) Syn. *Sesamum orientale* (L.), which is known variously as sesame, til, gingelly, simsim, gergelim etc. Sesame is one of the world's oldest cultivated oilseed crop. North Indian plains, Burma and Abyssinia including Somalia and Eritrea are the basic centers of origin with central Asia as yet another center of origin of sesame.

Sesame is a self-pollinated crop which belongs to family pedaliaceae having (2n = 26) chromosome number. It is cultivated in warm regions of the tropics and sub tropics. It is grown on the plains up to an altitude of 1200 m with an annual rainfall of about 500 mm. It requires average temperature of 25-27° C for rapid germination, initial growth and flowering.

Sesame is an important oilseed crop grown in India next to groundnut, rapeseed and mustard. It is grown in three seasons *viz., kharif,* semi-*rabi* and *summer*. During *kharif* season, sesame is grown in most part of country, while in semi-*rabi*, it is limited to Central India in the states of Maharashtra (Nagpur, Bhandara, Chandrapur districts), Madhya Pradesh and Chhattisgarh. During *rabi* and *summer*, sesame is grown in rice fallow or followed by short duration pulses in the peninsular region and in West Bengal.

The average yield potential of sesame grown in *kharif* season is very low as it has grown mainly as rainfed and it is affected by several biotic and abiotic stresses.

Sesame is better known as "Queen of oilseeds" by virtue of its quality edible oil and protein content. It contains 44-63% oil and 18-20% protein. Sesame oil has long shelf life and rich in linoleic acid. Its protein is rich in sulphur containing amino acid (Methionine). In India nearly 78% of seed production is utilized for oil extraction and 22% for planting purpose. Nearly 73% oil is used for edible purpose, 8.3% hydrogenation, 4.2% industrial purpose in manufacture of paints, pharmaceuticals, and insecticides. It's really the poor man's substitute for 'Ghee', as 100 gm of seeds provides 592 calories energy. Sesame oil cake contains 6.0-6.2% N, 2.0-2.2% P and 1.0-1.2% K.

Sesame is grown in India on an area of 17.06 Lakh hectare with a productivity of 332 kg / ha which is far below than the world average of 389 kg / ha. It is widely cultivated in the states of Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, West Bengal, Bihar and Assam.

Maharashtra, in *kharif* (2018) area under this crop is 52600 ha, from that 18900-ton production is obtained. The productivity of crop during *kharif* (2018) is 360 kg/ha. In *rabi* season it is grown on 2900 ha from which 800-ton production is obtained and the productivity during *rabi* (2018) is 285kg/ha. (Anonymous, 2019)

The development of improved cultivars has made a major contribution to the increased production and quality. The low yield level is attributed to the cultivation of crop on marginal

and sub-marginal land under rainfed condition, low input use, poor plant population, higher cost of seed and labor, lack of plant protection and use of low yielding varieties. Under such situation and in the fluctuating environment, adaptability of varieties became far more important. Thus, ultimately needs to develop stable genotype. Lack of stability in production is perhaps the major factors responsible for low national productivity.

A crop variety developed should show stable performance under different environments, especially in India where wide ranges of environments are prevailing. So, it is need to develop genotypes with higher degree of adaptability levels over a wide range of eco-geographical conditions for successful exploitation of its inherent potential. A variety is said to be stable which can adjust its phenotypic and genotypic status in response to changing environments. The genotype × environment interaction studies are as important as crop improvement.

In any breeding programme, it is necessary to screen and identify phenotypically stable genotypes which could perform more or less uniform in different environments. The phenotype of an individual is determined by G × E interaction. The phenotypic response to change in environment is not same for all the genotypes.

Genotype × Environment interaction is supposed to be one of the genetic parameters responsible for phenotypic stability and adaptation. There are many investigations done in the past and continued till today with a view to identify a stable and adaptable genotype for different yield contributing characters.

Specific varieties can be suggested for specific environments so as to overcome failure of the crop. Therefore, it is necessary to identify the genotype which response to different environments like sowing time or climate change, fertilizer doses etc., and should show stability and high yield potential.

Agriculture is one of the most vulnerable sectors to anticipate climate change. Agriculture in India is extremely diverse in the range of crop grown. The predicted change in climate and their associated impacts are all likely to affect substantially the potential of agriculture. There is variation on adaptic and environmental conditions. Therefore, genotypes those are stable under fluctuating temperature and varied climatic conditions are desirable. Climate change phenomenon now-a-day has forced farmers to adjust or change the sowing time of the crops and Sesame is not an exception. To harvest the economic yield in changing environments, suitable genotypes are enable to such environments is the need of the day

Evolving the high yielding genotypes with better yield by way of tolerance or resistance against biotic or abiotic stresses has been the objective of crop improvement programme in the past and a large number of high yielding varieties suitable for different cropping system have been developed.

Now the major aim of the sesame breeding programme has been to develop new cultivar that fulfill the demand of nation for which the efforts have been made by the Indian Council of

Agricultural Research through the All India Coordinated Research Project on Oilseed and State Agricultural Universities.

The various breeding methods are adopted to evolve the sesame cultivars. The selection methods applied in sesame breeding are routine that include mass selection, pedigree method, back cross method etc. in any breeding programme. It is necessary to screen and identify phenotypically stable genotypes for yield which could perform more or less uniformly under different environmental conditions. It is an established fact that yield is complex character and largely depend on its component characters with an interaction with environment resulting into the ultimate product i.e. yield. So for breeding a stable variety, it is necessary to get the information on the extent of Genotype × Environment interaction for yield and its component character.

Methods such as co-variance, stability variance, coefficient of determination, regression approach (Eberhart and Russell, 1966) etc. with suitable parameters are available to provide necessary criteria to rank varieties for stability. Eberhart and Russell's Model (1966) is the most popular.

The present investigation, consist of 14 genotypes evaluated at three different sowing dates with following objectives.

1. To identify stable genotypes of sesame.
2. To estimate the stability parameters for grain yield and its component.

2. REVIEW OF LITERATURE

Stability analysis has become one of the important tools for plant breeders in predicting the response of various genotypes over changing environments. It is imperative to have stable performing cultivars across environment to realize higher seed yield. The interaction of genotype with environment has an important bearing in breeding improved varieties. G × E interaction has a masking effect on the performance of a genotype and hence the relative ranking of the genotypes do not remain the same over different environments. Adaptability of genotypes to environmental fluctuation is important for the stable crop production over the environments. Several methods such as regression analysis, multivariate clustering analysis, multiplicate formulations such as additive main effects and multiplicative interaction besides non-parametric method may be used for the G × E interaction. Among all, the Eberhart and Russell (1966) model is widely used for stability parameters. The genotypes with high mean ($\bar{X}$), regression coefficient (bi) close to unity and less/no deviation from regression (S^2di) are found to be stable. Literature on this aspect has been reviewed and presented under the following subheads.

2.1 Genotype and Environment (G × E) Interactions

Environment is the sum total of physical, chemical and biological factors. G × E interaction has major importance to plant breeder in developing improved varieties. Low levels of interactions are useful for some characters so as to maximize the stability of performance over a number of environments. However, for some situation, high interactions are beneficial and can be explored.

Comstock and Moll (1963) had classified it in two categories.

i. Macro environment

ii. Micro environment

Micro environment is the environment of a single organism as opposed to that of another growing organism at the same time and same place. Whereas macro environment which is associated with a general location and period of time and is a collection of microenvironments. They have shown statistically, the effect of large genotype × environment interaction in reducing the process of selection.

Allard and Bradshaw (1964) coined the terms predictable and unpredictable environments. The predictable environment includes the permanent features of environments such as climate, soil type and day length etc. It also includes control variables *viz.,* level of fertilizer application, sowing dates, irrigated and unirrigated conditions and plant population densities etc. The unpredictable environment includes factors beyond the control of human beings i.e. amount and distribution of rainfall and the prevailing temperature. They further

suggested that heterozygous and heterogeneous population offers the best opportunity to produce variety, which shows small genotype × environment interaction.

2.2 Statistics and Genetics of G × E Interactions

Jinks and Mather (1955) reported the relationship of stability to genic balance in the development or developmental homeostasis which is produced by selective action. They stated that there is no property of stability that requires its interpretation as an innate consequence of heterozygosity *per se*. At the most such effect can only be of minor importance in the control of stability.

Jones (1958) attributed stability to the homeostatic effect of genetic heterogeneity and suggested that such stability permits double crosses to produce high yields over many years.

Plaisted and Peterson (1959) developed a method to characterize the stability of yield performance when several varieties were tested at number of locations within one year. A combined analysis was computed for each pair of varieties, n (n-1)/2 pairs for 'n' varieties and estimate of σ^2v was obtained from each variety. The variety with the smallest mean value would be one that contributes the least to variety × location interactions and thus would be considered as the most stable genotype in the tests.

Finlay and Wilkinson (1963) utilized technique to compare the performance of a set of cultivars grown at many sites for each variety. Varietal mean yield over all environments and regression coefficients were used to classify the cultivars specially adopted at poor and better yielding environments and average responsive for general adaptability. They have indicated average phenotypic stability by a regression coefficient of unit (bi = 1). A cultivar with bi < 1 has above average stability, bi > 1 has below average stability and bi = 0 has absolute phenotypic stability which means a constant gain in all environments. The ideal cultivar is one that possesses genetic potential in highest yielding environment and maximum phenotypic stability.

Eberhart and Russell (1966) observed that the corn hybrids with a regression coefficient less than 1.00 usually had mean yields that were below average. Accordingly, they suggested that a desired variety should have high mean, regression coefficient equal to 1.00 and variance due to regression as small as possible. Thus, they modified the regression technique, which enables partitioning of genotype × environment interaction of each variety into two parts (bi), the variation due to response of variety to varying environmental indices (sum of squares due to regression) and the unexplainable deviation from the regression on the environmental index. They defined both the linear (bi) and non-linear (S^2di) components as stability parameters. They compared two types of crosses in maize. They reported that hybrid × year interactions were significantly greater for single crosses than for three way or double crosses. They further stated that some single crosses may show much or more phenotypic stability than most stable three way or double crosses.

The approach of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) are purely statistical and component of these analysis have not been related to the parameters in biometrical genetic model, Perkins and Jinks (1968) performed the second approach which was based on fitting of model which specify the contribution of genetic, environmental and G × E interaction to generation mean and variances allowing for the contribution of additive, dominance and epistatic gene effects to the genetic and interaction components.

Knight (1970) reviewed regression analysis developed by Finlay and Wilkinson (1963) to investigate genotype × environment interactions to assess genotypes for their adoption to a range of environments. The conclusions were extended to consider variation in several environmental factors.

Tai (1971) presented a method of genotypic stability based on principle structure relationship analysis where a G × E interaction of a particular variety is partitioned into two components *viz.,* the linear response to environment effects (α) and a deviation from linear response.

Bains and Gupta (1972) proposed that, if the linear regression of above average genotypes upon the environmental means is less than 1.00 with comparatively small deviation mean square, an agreeable compromise between the two definitions of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) is essential.

Thus, the evaluation of genotype × environment interaction gives an idea of stability of the population under study.

2.3 Stability of Sesame Genotypes under Different Seasons

Krishnaswami and Appaduri (1985) made an investigation on sesame Twenty genotype were tested for yield and yield attributes over three seasons. The material was sown in a RBD with four replications. Data on plant height, number of branches, number of capsules per plant and seed yield per hectare were collected and subjected to analysis of variance to test the significance of genotype × environment interactions.

Henry and Daulay (1987) conducted experiment on 14 genotypes of sesame under rainfed conditions over four years revealed significant genotype × environment interaction for seed yield. Both linear and nonlinear interaction components were significant. ‘TC-25’ gave the maximum mean yield and showed an average response to fluctuating environmental conditions, N-32 perform relatively well under drought conditions.

Kumar (1988) studied phenotypic stability of five quantitative traits in sesame by growing ten genotypes under rainfed condition Genotype × environment interaction was present, and large portion of these was accounted by linear component. Non- linear component was also significant yet magnitude was smaller than the linear component. The strain 4-2 and T-13 were the most stable for seed yield in better environment whereas TC-171 and C-6 exhibited maximum stability yield in poor environment.

Osman (1989) conducted a study for the stability of seed yield in 20 sesame cultivar and selection which were grown in replicated trials at three locations in the Central Rainland of Sudan in three years. Two stability parameters were obtained (1) as the linear regression of an entry mean on an environmental index and (2) the deviation from regression (s^2di). Stability was tested with the hypothesis that b=1.0 and s^2di =0.The material studied differed significantly for seed yield and genotype × environment (G × E) interaction.

Laurentin and Montilla (1999) exhibited eight genotypes of white-grain sesame were evaluated for yield in 1995, 1996 and 1998 in Turen, Portuguese State, Venezuela. Genotype environment interaction and stability were determined by regression, principal component axis (PCA) and additive main and multiplicative interaction (AMMI) models, none of which coincided in the information provided. The AMMI model was more reliable because it explained 97% of the variation and considered both the additive and multiplicative effects for genotype, environment and G × E interaction respectively.

Solanki and Deepak Gupta (2000) studied G × E Interaction for seed yield in 18 genotypes of sesame during *kharif* 1995 to 1997. Significant genotype × environment interaction was observed. Both linear and nonlinear components of interaction were significant. On this basis of stability parameters, RMT-2 was considered to be an ideal genotype.

Kang Bo *et al.* (2000) observed sesame varieties with high cultural stabilities by comparing several yield components under different environments. Cultural stability of yield components was analyzed by the Eberhart and Russel regression model. Studied genotype show more stable regression coefficient values for number of capsules per plant, number of seeds per capsule and seed weight per plant.

Upadhyay *et al.* (2000) studied nine genotypes of sesame grown under 24 environments. They observed highly significant genotype s environment interaction for all the characters except capsule length, while the linear component of genotype × environment interaction was highly significant except number of seed per capsule. They reported PTS-2 gave significant highest mean seed yield.

Subbaraman and Jebbaraj (2001) conducted investigation conducted on twenty-five sesame genotypes grown in three different seasons and evaluated for the stability of seed yield. Genotype × environment interaction and stability were determined by additive main effects and multiplicative interaction model (AMMI).The genotypes EC 357017, EC 357020, EC 351905 and EC 357022 were stable across environments. The summer season was identified as being the best environment for growing the present set of genotypes.

Kumaresan and Nadarajan (2002) studied sixty-four genotypes comprising of 48 hybrid and 16 parents and evaluated for stability parameters for days to 50% flowering, number of branches, number of capsules and single plant yield over three environments. The analysis of

mean squares due to genotype × environment (linear) and nonlinear deviation were significant for all the characters studied.

Anuradha and Reddy (2005) conducted a study was conducted on genotypic × environment interaction of 71 diverse genotypes of sesame. It revealed that substantial portion of the interaction was due to linear components and peddapuram location was most favored for sesame production. None of the genotypes exhibited stable performance for all the traits. However, other genotypes were stable for seed yield per plant.

Velu and Shunmugavalli (2005) recorded data of forty sesame genotypes for ten characters. The variance estimated for all the characters under different environments brought out the differential response of characters to varied environmental effects. The phenotypic and genotypic variances were comparatively high for number of capsules, plant height and number of seed/capsule indicating wide range of variability in these characters. Significant genotype × environment interaction effects were observed for all characters except for capsule length. Single plant yield showed almost similar estimates of coefficient of genetic variation, heritability and genetic advance under the three environments indicating that it is a stable character and least influenced by environment. Number of capsules, number of branches, number of seeds/capsule and single plant yield should be given due importance in selection programs.

Raghuwanshi and Duhoon (2005) assessed genetic variability for eight characters in 100 genotypes of sesame. A wide range of variability was observed for yield and its components in all environments. However, high variability was observed for all characters except for 1000-seed weight which showed low to moderate variability. Genotype × environment interaction had significant effect on seed yield. The genotypic variance was lower than the phenotypic variance.

Kumar *et al*. (2006) carried out an investigation was to assess the stability among six sesame genotypes in three different environments from Dec. 2002 to Feb. 2003. Observations were recorded from ten randomly selected plants for several biometrical characters *viz*. plant height, seed yield per plant, test weight. The result revealed most stable genotype among the six genotypes recorded high mean and low variability for almost all the characters.

Senthil Kumar *et al*. (2006) carried out an investigation to assess the stability among six genotypes in three different environments from December 2002 to February 2003. The results revealed that AUS-122 could be rated as most stable genotype as it recorded high mean and low variability for almost all the characters.

Mekonnen and Mohammad (2009) studied seed yield stability of 20 sesame genotypes from different sources of origin were studied for genotype × environment interaction in randomized complete block design with three replications across six environments. The objective was to estimate the nature and magnitude of genotype × environment interaction for seed yield and to identify stable sesame genotypes for general adaptation.

Adebisi (2009) carried out the work was carried out to determine the stability fortwo seed quality traits in 14 sesame genotypes that were grown in three environments in Abeokuta, South West Nigeria in each of two seasons. The genotypes varied considerably to seed quality traits and genotype × environment interaction was significant.

Bhandarkar and Kumar (2010) studied stability parameters of six promising sesame [*Sesamum indicum* (L.)] genotypes for plant height, number of primary branches per plant and seed yield along with per plant performance under three environmental conditions. The significant genotype × environment interaction was recorded for number of primary branches and seed yield. The variance due to pooled deviation was highly significant for seed yield only, which reflect diversity in seed yield.

Chowdhury *et al.* (2010) studied stability considering seven yield related traits by multi-location trial under four different agro climatic conditions and the result obtained are discussed and better plant type are predicted.

Mekonnen and Mohammad (2010) studied oil content stability of twenty sesame genotypes from different sources of origin for genotype × environment interaction in randomized complete block design with three replications across six environments in 2007. Combined analysis of variance showed highly significant difference between genotypes, location and genotype × environment interaction, suggesting differential response of genotypes across testing location and need for stability analysis.

Kumaresan and Nadarajan (2010) conducted study to analyze the genotype environment (genotype × environment) interaction effect on yield and its components in sesame grown in three environments by using AMMI analysis. The mean square was significant for genotypes, environments, genotype × environment interaction for the characters viz., number of capsules, 1000 seed weight and single plant yield. The genotypes namely PSR 2007 × Co1, Si 42 × Co 1, Si 42 × VRI 1, AHT 123 × VRI 1, B 203 × SVPR 1 and YLM 4030 × SVPR 1 recorded high mean but low interaction effect which are desirable for releasing as stable hybrids. The genotypes OMT 30 × VRI 1, OMT 30 × SVPR 1 and DPI 1424 × VRI 1 exhibited high interaction effect and are suitable for specific environments.

Jhansi Rani and Ramkumar (2013) carried out investigation to assess the genetic parameters i.e. variability, heritability and genetic advance for nine characters viz., plant height, days to 50% flowering, number of primary branches, number of secondary branches, number of capsules per plant, number of seeds per capsule, 1000 seed weight, oil content and seed yield per plant in 10 genotypes over six environments during *Kharif* 2010 and *Rabi* 2010-11. Significant differences were observed for all the characters among the genotypes studied for pooled analysis of six environments.

Diana Sagolsem *et al.* (2013) conducted investigation during *Rab*i season of 2009-10 and 2010-11 to assess the stability for yield and its attributes along with oil content of twelve

genotypes of Indian mustard (*Brassica juncea* L. Czern and Coss) at two locations with two different dates of sowing creating eight artificial environments. Variance due to genotype × environment interaction was significant for all the character except for days to 50% flowering, while genotype × environment (linear) was found to be significant for number of secondary branches per plant, number of siliquae per plant, siliqua length, seed yield per plot and 1000 seed weight. Genotypes, GM-2, JD-6 and Pusa Bold could be recommended for general cultivation and their utilization in future breeding programme.

Narendra Kumar *et al.* (2013) carried study using thirty-six sesame genotypes under four environments to assess the genotype × environment interaction and their stability across the environments for seed yield and physiological traits.

Mali *et al*. (2015) Study Genotype × Environment interaction of 30 genotype of sesame over one check JLT-8 were studied at Oil Seed Research Station Latur, the experimental material was evaluated in Randomized Block Design (R.B.D.) with 3 replications under different seasons during Summer 2013, *Kharif* 2013 and Rabi 2013-2014. Stability analysis was carried out as per model of Eberhart and Russell (1966) for knowing causes of stability. The stability of 30 genotype of sesame for yield and yield components in sesame were significant for seeds yield per plant while number of capsules per plant, number of branches per plant also exhibit positive significantly association with seed yield per plant. Out of 30 genotype GT-02, RT-46 showed wide adaptability to all environments.

Walter Okello Anyanga *et al.* (2016) Study is carried out to identify high yielding and stable sesame genotypes across environments, field experiments were conducted with 16 genotypes for four seasons (2011-2013) at three locations *viz.,* Serere, Kaberamaido and Ngetta. The objective of the study was to use additive main effects and multiplicative interaction (AMMI) and genotype by genotype environment interaction (GGE) biplot statistical analysis to identify the stability and yield potential of sixteen sesame genotypes.

Boureima Seyni *et al.* (2017) Carried out an investigation in the central south of Niger in 2015 and 2016 under rainfed conditions across ten environments. The objective of the study was to evaluate the adaptability and stability of ten sesame genotypes across locations and years. The experimental design was a completely randomized block design with 5 replicates in each environment. Genotypes grain yields (averaged across environments) ranged from 722 kg ha-1 for 38-1-7 to 1095 kg ha-1 for SN403 and Environment grain yields (averaged across genotypes) ranged from 473 kg ha-1 at Bande 2016 (Ban16) to 1414 kg ha-1 at Gounaka 2015 (Gou15). The combined ANOVA for grain yield showed significant effects of the genotypes, environments and genotype × environment interaction. According to the Genotype × Environment interaction biplot (GGE bi-plot), genotypes 10 (SN403), 6 (SN-01-06) and 1 (38-1-7) were highly stable while the unstable genotype was 4 (HB168).

Manal Hefny *et al*. (2017) studied seed yield stability of 12 sesame [*Sesamum indicum* (L.)] genotypes evaluated across six environments (two growing years × three irrigation intervals). Data on seed yield were subjected to additive main effects and multiplicative interaction (AMMI) and genotype main effect and genotype × environment interaction (GGE) analyses using Gen Stat software.

Fiseha Baraki*et al*. (2018) Conducted experiment comprised of 13 sesame genotypes, laid out in a randomized complete block design of three replications with the objective of determining the magnitude of Genotype × Environment Interaction (GEI) and oil content. The mean of the oil content was 53.9%, with genotypes G4 and G11 with the highest oil content (55.1%) each, and G8 with the lowest oil content (51.4%). G4 was the exceptional genotype with the highest oil content (55.1%) and oil yield (512.9 kg/ha).Genotypes G4, G13 and G10 with oil the content of 55.1%, 54.7 and 54.2 respectively, were stable genotypes. On the other hand, genotypes G2, G8, G9, G3 and G1 were unstable genotypes in most of the environments.

Fiseha Baraki*et al*. (2019) Conducted study to estimate the stability of sesame genotypes and to determine the association of the stability parameters and sesame seed yield. Grain yield was positively associated with all of the ranks of stability parameters at different significance levels. According to the total rank value (TR), G12, G11 and G4 were the furthermost stable and widely adapted genotypes respectively, whereas G8 and G9 were the furthermost unstable genotypes.

3. MATERIALS AND METHODS

The investigation entitled "Genotype × Environment interaction in sesame [*Sesamum indicum* (L.)]" was undertaken at Post Graduate Institute Research Farm, MPKV, Rahuri. Sowing was made during *Kharif* 2019. The experimental details regarding materials and methods used are described in following lines.

3.1 Experimental material

The 14 Promising genotypes of sesame were obtained from Oil Seed Research Station, Jalgaon. Including four check varieties viz., PT-1, JLT-408, JLT-7 and GT-10 were sown in three different Sowing Dates *viz.,*16 June 2019, 1 July 2019 and 16 July 2019 in *Kharif* 2019. The details of varieties included in the experiment have been shown in Table 1.

Table 1 List of sesame genotypes

Name of Genotypes	Name of Genotypes
1. JLS-120	2. JL-708
3. JLS-408-2	4. JLS-302-11
5. JLS-710	6. JLS-709
7. JLS-706	8. JLS-1009-7-1
9. JLS-907	10. JLS-301-24
11. PT-1 (Check)	12. JLT-408 (Check)
13. JLT-7 (Check)	14. GT-10 (Check)

The experiment was conducted during *kharif* season of 2019 with three different sowing dates as below.

1. 16/06/2019 (E_1)
2. 01/07/2019 (E_2)
3. 16/07/2019 (E_3)

3.2 Methods

3.2.1 Experimental Design

The experimental material was evaluated in Randomized Block Design (R.B.D.) with 3 replications under three different sowing dates at Post Graduate Institute Research Farm, MPKV Rahuri. The sowing was carried out at the spacing of 30 cm and 15 cm between the rows and plants, respectively. The method of sowing followed was dibbling. One plant per hill was maintained by thinning 15 days after sowing. The recommended dose of fertilizer 50 kg N + 0 kg P_2O_5 + 0 kg K_2O per hectare was applied at time of sowing. All other cultural practices were undertaken to maintain healthy crop.

3.2.2 Observations recorded

Five plants were selected from each treatment randomly for recording observations. Average value of each character was determined from these observational plants. Observations were recorded on following biometrical traits.

1. Days to 50 per cent flowering (days): Number of days required from sowing to the flowering of approximately 50 per cent plants in each genotype were recorded.

2. Number of branches per plant: Number of branches on main shoot per plant was counted. Total number of branches includes primary as well as secondary branches.

3. Plant height at maturity (cm): The height of the mature plant was recorded in centimeter from the base of plant to tip of main shoot.

4. Number of capsules per plant: Number of capsules on main shoot and on all branches were counted and summed up and average worked out for per plant.

5. Number of seeds per capsule: Average number of seeds from selected capsules were counted.

6. Length of capsule (cm): Capsule length was recorded in centimeter from tip of the capsule to the base of the capsule.

7. Days to maturity (days): The procedure followed for 50 per cent flowering was considered as an index of maturity Seeding of yellow leaves, yellowing of capsules on stem are the symptoms of the crop attaining maturity.

8. 1000-seed weight (g): Weight of randomly sampled 1000 seeds from each of the genotype was recorded in gram.

9. Seed yield per plant (g): Yield in gram of plant selected for above observation was recorded and average value was calculated.

10. Oil content (%): A random bulk sample of filled seeds was drawn from the selected plants produced weighing 15g. The Oil percentage was estimated using NMR (Nuclear Magnetic Resonance) spectrometer from facility available at Post Graduate Institute, MPKV, Rahuri.

11. Phyllody incidence (%): To study the Phyllody incidence on sesame plants, five plants per treatment was selected and observation was recorded applying 0-9 grade disease rating scale (Mayee and Datar, 1986). The Incidence was calculated by using following formula.

$$\text{Incidence (\%)} = \frac{\text{No. of plants showing disease symptoms}}{\text{Total number of plants observed}} \times 100$$

3.3 Statistical analysis

The data was collected on randomly selected five plants of each genotype per replication in each plot for each character except phyllody incidence (%). The collected data was subjected for testing the genotypic differences (Panse and Sukhatme, 1967).

Stability analysis was performed as per Eberhart and Russell (1966) by considering three stability parameters to describe the performance of genotypes over different environments. According to them the regression of each variety on an environmental index and a function of square deviation from this regression provide estimates of stability parameters.

For each genotype stability was described by three parameters *viz*., mean performance ($\bar{X}$), regression coefficient (bi) and the squared deviation from the regression (S^2di).

These parameters are defined by using the following model.

$Yij = \mu + \beta iIj + \delta ij$ (I= 1, 2 ……, t and j = 1, 2 ….. s)

Where,

Yij = Mean of ith genotype in j^{th} environment

μ = Mean of all genotypes over all environments

βi = The regression coefficient of ith genotype on the environmental index, which measures response of genotype to varying environments

Ij = The environmental index which is defined as deviation of the mean of all the genotypes at a given environment from the overall mean.

$$\frac{\sum_j Yij}{t} - \frac{\sum_j \sum_j Yij}{ts} \quad \text{with } \sum Ij = 0$$

δij = The deviation from regression of the ith genotype of jth environment.

3.3.1 The Stability Parameters

a. The regression coefficient (bi) is described as under

$$bi = \sum_j YijIj / \sum_j I^2j$$

Where,

$\sum_j YijIj$ is the sum of products

$\sum_j I^2j$ is the sum of squares of environmental index

b. Mean square deviation (S^2di) from linear regression is calculated as

$$S^2di = \frac{\sum_j \delta^2 ij}{(s-2)} - \frac{S^2e}{r}$$

Where,

$$\sum_j \delta^2 ij = \left(\sum_j Y^2 ij - \frac{Y^2 i}{t} \right) - \frac{(\sum_j Yij \,.\, Ij)^2}{\sum_j Ij}$$

and

S^2e = The estimate of pooled error

t = Number of genotypes

s = Number of environments

r = Number of replications

1. Computation of environmental index (Ij)

I_j is defined as

$$Ij = \frac{\sum_j Yij}{t} - \frac{\sum_i \sum_j Yij}{ts}$$

$$= \frac{\text{Total of all genotypes at } j^{th} \text{ location}}{\text{Number of genotypes}} - \frac{\text{Grand total}}{\text{Total number of observations}}$$

2. Computation of regression coefficient (bi) for each genotype

$$bi = \frac{\sum_j Yij.Ij}{\sum_j I^2 j}$$

i. For each value of regression coefficient $\sum I^2 j$ is common, equal to sum of squares of environmental indices.

$$\sum_j I^2 j = (I^2_1 + I^2_2 + \ldots . + I^2 j)$$

ii. The $\sum_j Yij.Ij$ for each genotype of environmental index (Ij) with corresponding mean ($\bar{X}$) of that genotype at each environment.

These values were obtained in the following manner

$$(\bar{X})\ (I_j) = (\sum_j Yij.Ij) = (S)$$

($\bar{X}$) = Matrix of means

(I_j) = Vector of environmental index

(S) = Vector for sum of products i.e., $\sum_j Yij.Ij$

iii. The bi value for each genotype was thus calculated by dividing $\sum_j Yij.Ij$ [as calculated above in (ii)] by $\sum_j I^2$ obtained above under (i)

Thus, $bi = \sum_j YijIj \,/\, \sum_j I^2 j$

3. Computation of S^2di

In regression analysis it is possible to partition the variance of the 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

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

By subtracting the variance due to regression from σ^2y one can get the variance due to deviation from regression which in turn can be used for estimating S^2di values. The variance of means over different environments was obtained as follows.

$$\sigma^2V_i = \sum_j Yij^2 - (Yi^2/s)$$

Where,

$\sum_j Yij^2$ = Sum of squares of mean of ith genotype over j^{th}environment

Yi = Sum of means of ith genotype over environments.

s = Number of environments

The variance due to deviations from regression $\sum_j \sigma^2ij$ for a genotype being.

$$\text{Where, } \sum_j \sigma^2ij = \left[\sum_j Yij^2 - \frac{Yi^2}{s}\right] - \frac{(\sum_j Yij.\ Ij)^2}{\sum_j I^2j}$$

Where,

$(\sum_j Yij - Yi^2/s)$ = The variance due to dependent variable and

$(\sum_j Yij.\ Ij)^2 / \sum I^2j$ = The variance due to regression

Because,

$$\frac{(\sum_j Yij.\ Ij)^2}{\sum_j I^2j} = \frac{(\sum_j Yij\ .\ Ij)(\sum_j Yij\ .Ij)}{\sum_j I^2\ j} = bi \sum_j Yij.\ Ij$$

Where,

bi values have been calculated in (2) and

$\sum_j Yij\ .Ij$ value in 2 (ii)

The $\sum_j \sigma^2$ ij values may be computed as

$$\sum_j \sigma^2ij = \sigma^2Vi - bi\sum_j Yij\ .\ Ij$$

From $\sum_j \sigma^2ij$, the stability parameter S^2di for each genotype was computed as follows.

$$S^2di = [\sum_j \sigma^2ij/ (s-2)] - (S^2e/r)$$

3.3.2 Analysis of Variance

The analysis of variance partitioned into three main parts.

a. Sum of squares due to genotypes.

b. Sum of squares due to environment + (genotype × environment)

c. Pooled error

The sum of squares due to genotype × environment is further partitioned into two parts.

i. S.S. due to genotype × environment (linear) which is in fact S.S. due to regression.

ii. S.S. due to deviation from linearity of response (i.e., S.S. due to pooled deviation).

The latter can be further partitioned into as many components as the number of genotypes with (s-2) degrees of freedom (s represents number of environments).

The analysis of variance table for stability parameter was constructed in tabulated form as,

Sources	d.f.	S.S.	M.S.S.
Genotypes	(t-1)	$1/s\sum_i Y_i^2$ - C.F.	MS_1
Environments	(s-1)	$1/t \sum_i Y_i^2$ - C.F.	MS_2
Genotypes × Environments	(t-1)(s-1)	$\sum_i\sum_j Y_i^2$ - C.F.-G.S.S.-E.S.S.	MS_3
Environments + (Genotypes × Environments)	t(s-1)	$\sum_i\sum_j Y_{ij}^2 - Y_i^2/s$	MS_4
Environments (linear)	1	$1/t[\sum_i Yij\ I_j)^2/\sum_j I^2_i]$	
Genotypes × Environments (linear)	(t-1)	$\sum_i\sum_i Yij\ I_j)^2/\sum_j I^2_i$ - E(1)S.S.	MS_5
Pooled deviation	t(s-1)	$\sum_i\sum_i \sigma^2 ij$	MS_6
Pooled error	s(r-1)(t-1)		MS_7

Where,

t = Number of genotypes

s = Number of environments

r = Number of replications

G.S.S. = S.S. due to genotypes

E.S.S. = S.S. due to environments

C.F. = Correction factor

S.S. due to genotypes, environment and genotypes × environments were calculated as per the method of pooled analysis.

The M.S. pooled error was calculated as

$$\frac{(n_1 - 1)(\text{M.S. error } L_1) + \ldots (n_s - 1)(\text{M.S. error } L_s)}{(n_1 - 1) + (n_2 - 1) + \ldots + (n_s - 1)}$$

Where,

M.S. error L_s = Mean sum of square due to error for s^{th} environment

$n_1 - 1$ = Error d.f. in environmental 1

$n_2 - 1$ = Error d.f. in environment 2

The S.S. due to remaining sources were calculated as follows:

S.S. due to environment (Gen. × Env.) = $\sum_{ij} \sum Yij - \sum_i Y^2 i/t$

In fact,

S.S. (E + G × E) = S.S.E. + S.S.G. × E

Where,

S.S.E. = $1/t\ (\sum_j Y_j.Ij)^2 / Ej.I^2 j$

The Yj and Ij values are already computed and by putting appropriate values we can get S.S. environment (linear) which can also be checked as,

S.S. Environment (linear)

= $t \times \sum_j I^2 j$

In fact,

S.S.G. × E (linear)

= $\sum_j [\sum_j (YijIj)^2 / (\sum_j.I_j)^2]$ - S.S.E. (linear)

= bi $\sum_j YijIj$ for each genotype

Thus, by taking simply the sum of these values over all the genotypes, the first part of S.S., G × E (linear) can be obtained.

S.S. due to pooled deviation is simply the sum of S.S. due to deviation for individual genotype for (s-2) degrees of freedom each.

3.3.3 Test of Significance

a. The significance of difference among genotypes were tested against the M.S.S. due to G × E interaction (MS_3). The genotypic differences were also tested against pooled deviation (MS_6) and pooled error (MS_7).

b. The G × E interaction (MS_3) was tested against effective pooled error.

c. The components, environment (linear) as well as G × E (linear) was tested against pooled deviation (MS_6) and pooled error (MS_7).

d. Pooled deviation was tested against effective pooled error (PE/r). Individual deviation from linear regression was tested as follows.

$$F = \frac{[(\sum_j \sigma^2 ij) / (s - 2)]}{\text{Pooled error}}$$

e. Stable genotype i.e., test of significance for regression coefficient.

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

$$\text{'t' test bi} = \frac{|bi-1|}{\text{S.E. (bi)}}$$

Where,

$$\text{SE bi} = \sqrt{\frac{\text{MSS due to pooled deviation}}{\sum_j I^2 j}}$$

The significance of bi values was tested by 't' test as against unity.

Mean of bi = $\sum_i bi/t$

Population mean and standard error are calculated as,

$$\text{Population mean } (\mu) = \frac{\text{Grand Total}}{\text{Number of observations}}$$

$$\text{S.E. (Mean)} = \sqrt{\frac{\text{M.S. due to pooled deviation}}{\text{Number of environments -1}}}$$

4. RESULTS AND DISCUSSION

In the present investigation entitled "Genotype × Environment interaction in Sesame [*Sesamum indicum* (L.)]" using fourteen promising genotypes were evaluated over three diverse environments to estimate the stability parameters for seed yield and its components in sesame genotypes and to identify most stable genotypes under different environments.

4.1 Analysis of Variance

The analysis of variance for ten characters *viz*., days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, length of capsule (cm), number of seeds per capsule, 1000 seed weight (g), seed yield per plant (g) and oil content (%) was done. The analysis revealed that 14 genotypes were highly significant for all the characters under study in all the sowing dates i.e. E_1 (16th June 2019), E_2 (1st July 2019) and E_3 (16th July 2019) (Table 13).

The pooled analysis of variance for phenotypic stability as per Eberhart and Russel (1966) indicated that mean differences due to genotypes were statistically significant for the characters, days to 50% flowering, days to maturity, plant height, branches per plant, capsules per plant, length of capsule, seeds per capsule, 1000-seed weight, seed yield per plant and oil content when tested against G × E interaction (Table 2). This observation suggested that there is substantial variability in the genotypes evaluated. Similarly, the mean differences among the genotypes were found to be significant for the characters, days to 50% flowering, days to maturity, plant height, branches per plant, capsules per plants, length of capsule, seeds per capsule, 1000-seed weight, seed yield per plant and oil content when tested against pooled deviation and pooled error.

The highly significant G × E interaction observed for the characters, days to 50% flowering, days to maturity, plant height, branches per plant, capsules per plant, length of capsule, seeds per capsule, 1000-seed weight, seed yield per plant and oil content indicated that various genotypes showed varied response to different environments.

4.2 Response of Various Sesame Genotypes to Changing Environments

The mean values of the genotypes for different characters studied under three sowing dates are presented in Tables 2 to 11.

1. Days to 50% flowering

The genotype JLS-706 (40.67 days) was the earliest than rest of all genotypes over the three environments, followed by GT-10 (41.56 days) and JLS-301-24 (41.67 days).

In E_1, the genotype JLS-706 (42.67 days) was earliest to flower followed by JLS-1009-7-1 (43.00 days) and GT-10 (43.33 days) while the genotype JLT-7 (45.67 days) flowered later among all the genotypes. In E_2, the genotype JLS-706 (41.00 days) was earliest to flower followed by PT-1 (41.33 days) and JLS-709 (44.67 days) flowered later among all the genotypes. In E_3, genotype JLS-706 (38.33 days) was earliest to flower followed by JLS-709 (39.00 days) with JLS-408-2 and JLT-408 (42.33 days) flowered later among all the genotypes.

Table 2 Mean performance of Sesame genotypes for days to 50% flowering over three different sowing dates

Sr. No.	Genotypes	Days to 50% flowering			
		E1	E2	E3	Mean
1	JLS-120	43.67	44.00	41.00	42.89
2	JL-708	43.33	42.33	41.00	42.22
3	JLS-408-2	44.00	44.33	42.33	43.56
4	JLS-302-11	43.33	41.67	40.67	41.89
5	JLS-710	44.00	43.00	40.00	42.33
6	JLS-709	44.00	44.67	39.00	42.56
7	JLS-706	42.67	41.00	38.33	40.67
8	JLS-1009-7-1	43.00	44.33	41.67	43.00
9	JLS-907	45.33	44.00	42.00	43.78
10	JLS-301-24	43.67	42.33	39.00	41.67
11	PT-1	43.67	41.33	40.33	41.78
12	JLT-408	45.67	44.00	42.33	44.00
13	JLT-7	45.67	42.00	39.00	42.22
14	GT-10	43.33	42.00	39.33	41.56
	Mean	43.95	42.93	40.43	42.44
	S.E.±	0.43	0.50	0.66	0.59
	CD at 5 %	1.25	1.43	1.92	1.66
	CV (%)	1.689	1.989	2.833	-

It is revealed that the mean number of days required for 50% flowering was greatly influenced by different dates of sowing. The genotype JLS-706 recorded lowest number of days to 50% flowering i.e. 40.67 days. In last sowing date (16th July) all the genotypes has recorded lowest number of days to 50% flowering.

2. Days to maturity

The genotype JLT-7 (81.22 days) was earliest to maturity among all the genotypes over the three environments followed by genotype JLS-1009-7-1 (82.22 days). The genotype JLT-7 recorded the maturity time 84.00 days in E_1, 80.00 days in E_2, and 79.67 days in E_3.

In E_1, genotype JLT-7 (84.00 days) was earliest for maturity, while the genotype JLT-408 (89.00 days) was late to mature among all the genotypes. In E_2, the genotype JLT-7 (80.00 days) matured earlier followed by JLS-907 (81.00 days), while JLS-710 (87.33 days) was late to mature among all the genotypes. The genotype JLT-7 (79.67 days) matured earlier in E_3 followed by JLS-907 (80.00 days) and genotype JLS-710 (86.67 days) was matured late among all the genotypes.

Table 3 Mean performance of Sesame genotypes for days to maturity over three different sowing dates

Sr. No.	Genotypes	Days to Maturity			
		E1	E2	E3	Mean
1	JLS-120	85.67	82.67	82.00	83.44
2	JL-708	88.67	85.67	84.33	86.22
3	JLS-408-2	86.00	84.00	83.67	84.56
4	JLS-302-11	86.00	84.67	81.33	84.00
5	JLS-710	88.67	87.33	86.67	87.56
6	JLS-709	87.33	85.00	83.67	85.33
7	JLS-706	88.00	87.00	85.67	86.89
8	JLS-1009-7-1	84.67	81.67	80.33	82.22
9	JLS-907	87.00	81.00	80.00	82.67
10	JLS-301-24	88.33	84.00	84.00	85.44
11	PT-1	86.67	84.00	83.67	84.78
12	JLT-408	89.00	84.67	83.67	85.78
13	JLT-7	84.00	80.00	79.67	81.22
14	GT-10	87.67	83.33	83.00	84.67
	Mean	86.98	83.93	82.98	84.63
	S.E.±	0.42	0.70	0.78	0.44
	CD at 5 %	1.23	2.03	2.25	1.24
	CV (%)	0.844	1.440	1.619	-

The environment E_3 was earliest for maturity followed by environment E_2 and environment E_1. Present study revealed that under late sowing condition, all the varieties took less number of days to mature. This was due to availability of optimum sowing conditions which resulted into early flowering and early maturity.

3. Plant height (cm)

In E_1, the genotype PT-1 (110.67 cm) was the tallest and genotype JLS-706 (98.83 cm) was the shortest among all the genotypes.

In E_2, the genotype PT-1 (108.60 cm) was the tallest followed by genotype JLT-7 (108.20 cm), while genotype JLS-120 (86.20 cm) was the shortest genotype. In E_3, the genotype JLT-408 (96.77 cm) was tallest and genotype JLS-708 was shortest with height of 86.67 cm among all the genotypes.

The genotype JLT-7 (104.96 cm) was the tallest among all the genotypes followed by PT-1 (104.76 cm), while JLS-120 (92.14 cm) was the shortest among all the genotypes over the three environments. The mean plant height was maximum in E_1 environment (105.26 cm) followed by E_2 (100.68 cm) and E_3 (92.73 cm)

Table 4 Mean performance of Sesame genotypes for Plant height (cm) over three different sowing dates

Sr. No.	Genotypes	Plant height (cm)			
		E1	E2	E3	Mean
1	JLS-120	99.77	86.20	90.47	92.14
2	JL-708	106.37	102.43	86.67	98.49
3	JLS-408-2	108.80	107.00	93.13	102.98
4	JLS-302-11	100.67	92.300	96.00	96.32
5	JLS-710	105.53	102.57	92.60	100.23
6	JLS-709	106.83	103.57	92.53	100.98
7	JLS-706	98.83	89.43	89.40	92.56
8	JLS-1009-7-1	104.10	101.77	93.23	99.70
9	JLS-907	99.87	100.47	91.37	97.23
10	JLS-301-24	110.23	104.73	94.60	103.19
11	PT-1	110.67	108.60	95.00	104.76
12	JLT-408	107.50	106.80	96.77	103.69
13	JLT-7	110.17	108.20	96.50	104.96
14	GT-10	104.30	95.50	89.97	96.59
	Mean	105.26	100.68	92.73	99.60
	S.E.±	1.27	1.46	1.39	2.50
	CD at 5 %	3.68	4.23	4.05	7.02
	CV (%)	2.084	2.504	2.602	-

It is seen from the mean data presented for plant height that the highest mean plant height was recorded in environment E_1 (16th June). Considering the mean of the three different environments, JLT-7 (104.96 cm) was the tallest among all the genotypes.

4. Number of branches per plant

The genotype JLS-120 (4.40) had recorded maximum mean number of branches per plant followed by genotype JLT-408 (4.23) over three different environments.

In E_1, genotype JLS-706 (4.53) had maximum number of branches per plant, while genotype JLS-709 (3.80) had recorded minimum number of branches per plant. In E_2, genotype JLS-120 (4.60) had a greater number of branches per plant than other genotypes. In E_3, genotype JLS-120 (4.27) had recorded highest number of branches per plant, while the genotype JLS-709 (3.13) had recorded lowest number of branches per plant. Highest number of branches recorded in E_1 (4.26) followed by E_2 (3.99).

Table 5 Mean performance of Sesame genotypes for Number of branches/plant over three different sowing dates

Sr. No.	Genotypes	Number of branches/plant			
		E1	E2	E3	Mean
1	JLS-120	4.33	4.60	4.27	4.40
2	JL-708	4.30	4.13	3.93	4.12
3	JLS-408-2	4.50	4.23	3.73	4.16
4	JLS-302-11	4.20	3.90	4.03	4.04
5	JLS-710	4.23	3.47	3.23	3.64
6	JLS-709	3.80	3.33	3.13	3.42
7	JLS-706	4.53	4.40	3.83	4.26
8	JLS-1009-7-1	4.10	4.20	3.70	4.00
9	JLS-907	4.40	4.13	3.93	4.16
10	JLS-301-24	4.30	3.93	3.70	3.98
11	PT-1	4.50	4.00	4.10	4.20
12	JLT-408	4.40	4.20	4.10	4.23
13	JLT-7	3.97	3.53	3.17	3.56
14	GT-10	4.00	3.80	3.43	3.74
	Mean	4.26	3.99	3.74	3.99
	S.E.±	1.13	0.09	0.10	0.11
	CD at 5 %	0.36	0.26	0.30	0.31
	CV (%)	5.092	3.844	4.728	-

5. Number of capsules per plant

In E_1, the genotype JLS-708 (66.37) produced maximum number of capsules per plant followed by JLS-408-2 (65.63), while JLT-7 (50.30) produced minimum number of capsules per plant.

In E_2 the genotype JL-708 (63.93) produced highest number of capsules per plant followed by JLS-120 (63.30) and in E_3 the genotype JL-708 (54.63) produced maximum number of capsules per plant followed by JLS-120 (54.50).

In all the three environments the genotype JL-708 (61.64) produced highest number of capsules per plant while JLS-710 (46.46) produced lowest number of capsules per plant. Number of capsules per plant was maximum in E_1 (58.47) followed by E_2 (57.17) and E_3 (48.71).

Table 6 Mean performance of Sesame genotypes for Number of Capsules/plant over three different sowing dates

Sr. No.	Genotypes	Number of Capsules/plant			
		E1	E2	E3	Mean
1	JLS-120	62.90	63.30	54.50	60.23
2	JL-708	66.37	63.93	54.63	61.64
3	JLS-408-2	65.63	63.13	53.00	60.59
4	JLS-302-11	55.83	48.50	45.93	50.09
5	JLS-710	51.500	46.03	41.83	46.46
6	JLS-709	61.77	60.97	51.90	58.21
7	JLS-706	51.83	54.67	41.27	49.26
8	JLS-1009-7-1	57.13	57.77	48.43	54.44
9	JLS-907	55.37	54.23	43.63	51.08
10	JLS-301-24	59.03	56.97	48.20	54.73
11	PT-1	61.57	60.97	52.20	58.24
12	JLT-408	63.37	62.40	52.27	59.34
13	JLT-7	50.30	52.63	43.10	48.68
14	GT-10	55.10	54.90	51.10	53.70
	Mean	58.47	57.17	48.71	54.76
	S.E.±	136	1.21	1.15	1.35
	CD at 5 %	3.96	3.54	3.35	3.79
	CV (%)	4.036	3.663	4.098	-

6. Length of capsule (cm)

In E_1, the genotype JLS-120 (4.07 cm) having maximum length of capsule while JLS-302-11 (3.80 cm) having minimum length of capsule.

In E_2 the genotype PT-1 (3.83 cm) recorded highest length of capsule while JLS-408-2 (3.37 cm) recorded lowest length of capsule.

In E_3 the genotype JLS-120 (3.67 cm) recorded highest length of capsule while JLS-301-24 (3.17) recorded lowest length of capsule.

The genotype JLS-120 (3.84 cm) recorded maximum length of capsule followed by the genotype JLS-907 (3.77 cm) over all the three environments. For length of capsule E_1 was superior (3.91 cm) followed by E_2 (3.64 cm).

Table 7 Mean performance of Sesame genotypes for length of capsule (cm) over three different sowing dates

Sr. No.	Genotypes	Length of capsule (cm)			
		E1	E2	E3	Mean
1	JLS-120	4.07	3.80	3.67	3.84
2	JL-708	3.97	3.50	3.23	3.57
3	JLS-408-2	4.03	3.37	3.30	3.57
4	JLS-302-11	3.80	3.63	3.23	3.56
5	JLS-710	3.83	3.50	3.43	3.59
6	JLS-709	3.93	3.63	3.40	3.66
7	JLS-706	3.83	3.77	3.23	3.61
8	JLS-1009-7-1	3.97	3.57	3.43	3.66
9	JLS-907	3.90	3.77	3.63	3.77
10	JLS-301-24	3.77	3.67	3.17	3.53
11	PT-1	3.90	3.83	3.43	3.72
12	JLT-408	4.00	3.63	3.53	3.72
13	JLT-7	3.77	3.63	3.33	3.58
14	GT-10	4.03	3.60	3.40	3.68
	Mean	3.91	3.64	3.38	3.65
	S.E.±	007	0.08	0.10	0.09
	CD at 5 %	0.21	0.22	0.28	0.25
	CV (%)	3.138	3.656	4.960	-

7. Number of seeds per capsule

InE_1, the genotype JLT-408 (72.70) produced highest number of seeds per capsule followed by JL-708 (72.03), while JLS-710 (60.77) produced lowest number of seeds per capsule.

In E_2, JL-708 (65.90) produced maximum number of seeds per capsule followed by JLS-408-2 (64.57), while JLS-907 (57.07) produced minimum number of seeds per capsule. In E_3, JL-708 (61.07) produced maximum number of seeds per capsule followed by JLS-408-2 (60.83), while JLS-706 (54.67) produced minimum number of seeds per capsule.

The genotype JL-708 (66.33) produced highest number of seeds per capsule followed by the genotype JLS-408-2 (65.44), while JLS-907 (59.09) produced lowest number of seeds per capsule over all the three environments. The highest number of seeds per capsule were recorded in E_1 (66.67) followed by E_2 (60.96)

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Table 8 Mean performance of Sesame genotypes for number of seeds/capsule over three different sowing dates

Sr. No.	Genotypes	Number of seeds/capsule			
		E1	E2	E3	Mean
1	JLS-120	71.77	61.30	56.90	63.32
2	JL-708	72.03	65.90	61.07	66.33
3	JLS-408-2	70.93	64.57	60.83	65.44
4	JLS-302-11	62.20	62.07	57.07	60.44
5	JLS-710	60.77	59.67	57.13	59.19
6	JLS-709	67.77	62.70	59.43	63.30
7	JLS-706	62.80	60.50	54.67	59.32
8	JLS-1009-7-1	64.17	58.40	55.77	59.44
9	JLS-907	62.53	57.07	57.67	59.09
10	JLS-301-24	67.77	60.63	57.63	62.01
11	PT-1	69.23	61.07	58.93	63.08
12	JLT-408	72.70	62.83	57.80	64.44
13	JLT-7	63.43	58.63	58.33	60.13
14	GT-10	65.27	58.17	55.27	59.57
	Mean	66.67	60.96	57.75	61.79
	S.E.±	0.41	1.17	0.78	0.88
	CD at 5 %	1.18	3.40	2.27	2.47
	CV (%)	1.056	3.320	2.339	-

8. 1000-seed weight (g)

In E_1, the genotype JLS-120 (3.43 g) recorded highest 1000-seed weight followed by the genotype JLS-1009-7-1 (3.33 g), while JLT-7 (2.70 g) recorded lowest 1000-seed weight.

In E_2, the genotype JLT-408 (3.20 g) recorded highest 1000-seed weight followed by JLS-301-24 (3.13 g), while JLS-710 (2.40 g) recorded lowest 1000-seed weight. In E_3 the genotype JLS-301-24 (2.90 g) recorded highest 1000-seed weight followed by JLT-408 (2.87 g), while JLS-907 (2.40 g) recorded lowest 1000-seed weight. The genotype JLS-120 (3.10 g) and JLT-408 (3.10 g) recorded highest 1000-seed weight while JLS-710 (2.58 g) recorded lowest 1000-seed weight than other genotypes in all the three environments. On the basis of mean performance over the three environments maximum 1000-seed weight was recorded in E_1 (3.09 g) followed by E_2 (2.89 g) and E_3 (2.65 g).

Table 9 Mean performance of Sesame genotypes for 1000 seed weight (g) over three different sowing dates

Sr. No.	Genotypes	1000 seed weight (g)			
		E1	E2	E3	Mean
1	JLS-120	3.43	3.03	2.83	3.10
2	JL-708	3.20	2.93	2.63	2.92
3	JLS-408-2	3.23	2.93	2.53	2.90
4	JLS-302-11	2.87	2.57	2.63	2.69
5	JLS-710	2.83	2.40	2.50	2.58
6	JLS-709	2.87	2.83	2.63	2.78
7	JLS-706	3.13	2.87	2.57	2.86
8	JLS-1009-7-1	3.33	3.03	2.60	2.99
9	JLS-907	2.80	2.77	2.40	2.66
10	JLS-301-24	3.23	3.13	2.90	3.09
11	PT-1	3.10	3.07	2.80	2.99
12	JLT-408	3.23	3.20	2.87	3.10
13	JLT-7	2.70	2.80	2.47	2.66
14	GT-10	3.30	2.93	2.70	2.98
	Mean	3.09	2.89	2.65	2.88
	S.E.±	0.05	0.06	0.06	0.08
	CD at 5 %	0.14	0.19	0.18	0.22
	CV (%)	2.689	3.889	4.124	-

9. Seed yield per plant (g)

In E_1, the genotype JLS-120 (12.70 g) recorded highest seed yield per plant followed by the JLT-408 (11.80 g) and JL-708 (11.07 g), while JLS-302-11 (9.00 g) recorded lowest seed yield per plant.

In E_2, the genotype JLS-120 (11.43 g) gave highest seed yield per plant followed by JLT-408 (10.83 g), while JLS-302-11 (7.97 g) recorded lowest seed yield per plant. In E_3, the genotype JLS-408-2 (9.17 g) recorded maximum seed yield per plant followed by JLS-120 (8.97 g).

The genotype JLS-120 (11.03 g) recorded highest seed yield per plant over all the three environments followed by genotype JLT-408 (10.37 g), while JLS-706 (8.04 g) recorded lowest seed yield per plant. The mean seed yield per plant was maximum in E_1 (10.22 g) followed by E_2 (9.43 g) and E_3 (8.11 g). Almost all the genotypes had recorded higher seed yield per plant in E_1 than E_2 and E_3.

Table 10 Mean performance of Sesame genotypes for seed yield/plant (g) over three different sowing dates

Sr. No.	Genotypes	Seed yield/plant (g)			
		E1	E2	E3	Mean
1	JLS-120	12.70	11.43	8.97	11.03
2	JL-708	11.07	9.97	8.93	9.99
3	JLS-408-2	10.87	10.70	9.17	10.24
4	JLS-302-11	9.00	7.97	7.30	8.09
5	JLS-710	9.23	8.27	7.73	8.41
6	JLS-709	9.90	9.50	8.63	9.34
7	JLS-706	9.37	8.10	6.67	8.04
8	JLS-1009-7-1	9.77	9.50	7.83	9.03
9	JLS-907	9.03	8.03	7.77	8.28
10	JLS-301-24	10.07	9.10	8.03	9.07
11	PT-1	10.43	10.03	8.37	9.61
12	JLT-408	11.80	10.83	8.47	10.37
13	JLT-7	9.37	8.47	6.90	8.24
14	GT-10	10.47	10.17	8.77	9.80
	Mean	10.22	9.43	8.11	9.25
	S.E.±	0.18	0.19	0.21	0.19
	CD at 5 %	0.52	0.55	0.62	0.53
	CV (%)	3.024	3.478	4.546	-

From the results, it is observed that seed yield per plant was affected due to different sowing dates. Maximum seed yield per plant was produced by the genotype JLS-120 (11.03 g) over all the three environments. The maximum seed yield was recorded in E_1 (3rd week of June) environment and decreased drastically for E_2 (1st week of July) and E_3 (3rd week of July) environments. This is might be due to the availability of more congenial growing conditions of photoperiod, temperature etc., in optimum sowing environment i.e. E_1 as compared to other sowing dates.

10. Oil content (%)

In E_1, the genotype JLS-706 (51.70%) recorded highest oil content followed by JLS-907 (50.93%). In E_2, the genotype JLS-907 (51.03%) recorded highest oil content followed by JLS-706 (50.37%) and in E_3 the genotype JLS-706 (50.60%) recorded highest oil content than other genotypes. The genotype JLS-706 (50.89%) recorded highest oil content among all the

genotypes over all the three environments followed by JLS-907 (50.80%), while JLS-1009-7-1 (43.37%) recorded lowest oil content.

Table 11 Mean performance of Sesame genotypes for oil content (%) over three different sowing dates

Sr. No.	Genotypes	Oil content (%)			
		E1	E2	E3	Mean
1	JLS-120	49.60	50.13	48.33	49.36
2	JL-708	49.30	48.97	47.87	48.711
3	JLS-408-2	47.17	47.00	46.63	46.93
4	JLS-302-11	48.00	48.17	46.37	47.51
5	JLS-710	44.50	44.933	44.47	44.63
6	JLS-709	44.23	43.63	43.20	43.69
7	JLS-706	51.70	50.37	50.60	50.89
8	JLS-1009-7-1	43.70	43.53	42.87	43.37
9	JLS-907	50.93	51.03	50.43	50.80
10	JLS-301-24	45.37	45.167	45.33	45.29
11	PT-1	48.90	48.67	47.03	48.20
12	JLT-408	49.13	48.80	47.93	48.62
13	JLT-7	46.60	46.93	46.13	46.56
14	GT-10	45.37	45.13	44.57	45.02
	Mean	47.46	47.32	46.56	47.11
	S.E.±	0.25	0.25	0.29	0.24
	CD at 5 %	0.667	0.724	0.61	0.67
	CV (%)	0.540	0.603	0.744	-

4.3 Stability Analysis

4.3.1 Genotype × Environment Interaction Studies

Productivity of the population is the function of its adaptability. Significant achievement in crop production may be possible by breeding varieties for their stability for seed yield and yield components. Plant breeding is said to be the management of genetic variability. Plant breeders look for greater variability in crop plants for evolving strains which give maximum yield over the environments and show consistent performance. There is no direct measurement for genetic variability. However, the same can be inferred from the phenotype, which is a linear function of genotypes, environment and their interaction. Phenotype usually gets changed when a genotype is grown over varying environments. It has been shown that interactions are widely

present irrespective of nature of genetic material. This sets limits to the expected progress. The interactions of genetic and non-genetic factors on phenotypic expression is called genotype × environment (G × E) interaction which is widely present and substantially contributes to the non-realization of expected gain from selection (Comstock and Moll, 1963).

A population which can adjust its genotypic or phenotypic state in response to environmental fluctuations in such a way that it gives high and stable economic returns, can be termed as "well buffered" (Singh and Singh, 1980). Stable genotypes are particularly of great importance in the country like India, where the crops are grown as a risk under varied environmental conditions. G × E interaction certainly plays an important role in the evaluation and execution of breeding programs. Allard and Bradshaw (1964) critically reviewed this phenomenon and brought out its implications in applied plant breeding. Thus, G × E interaction is important in the expression of quantitative characters, which are controlled by polygenic systems and largely influenced by environmental fluctuations.

The process of identification of stable genotype is difficult because of G × E interaction. Although the plant breeders have observed genetic differences for adaptability, they have been unable to fully exploit these differences in breeding stable genotypes. This has been largely due to problem of defining and measuring phenotypic stability. Various attempts were made to characterize the behavior of genotypes in response to varying environments. Statistical approach of Finlay and Wilkinson (1963) proved considerably useful to measure the phenotypic stability in the performance of genotype. They considered linear regression slope (bi) as a measure of stability. This regression analysis proposed by Finlay and Wilkinson (1963) was improved upon by Eberhart and Russell (1966). They introduced one more parameter, deviation from regression (S^2di) which accounts for unpredictable irregularities in the response of genotypes to varying environments.

Mechanism of stability falls into four general categories:

1. Genetic heterogeneity
2. Yield component compensation
3. Stress tolerance
4. Capacity to recover rapidly from stress

Growing a set of genotypes under a large number of environments and combined analysis is useful in assessing the G × E interaction and comparing different types of populations, but it did not go any further towards dynamic interpretation of the stability of individual genotypes. The most widely used approach in this respect is the regression technique in which G × E interaction component of variability partitioned into its linear and non-linear portions for assessing the stability of genotypes over a range of environments. This is known as joint regression analysis.

The information on the relative stability of the genotypes for different yield components is essential. In the present investigation, fourteen genotypes of sesame were studied through genotype × environment interaction and stability analysis. Since the sesame is the short duration crop, the material was sown on three different dates *viz.*, 16th June, 1st July and 16th July,2019 and stability of genotypes assessed by following Eberhart and Russell (1966) model. The results obtained on different stability parameters estimated for different characters separately with a view to identify suitable conditions.

4.3.2 Analysis of Variance (Pooled)

Analysis of variance representing the mean sum of squares due to different sources of variation as per Eberhart and Russell (1966) for ten characters is presented in Table 13.

Pooled analysis of variance over three different environments showed that genotypes differed significantly for the characters *viz*., Days to 50% flowering, Days to maturity, Plant height, Number of branches per plant, Number of capsules per plant, Length of capsule, Number of seeds per capsule, 1000-seed weight, Seed yield per plant and Oil content when tested against G × E interaction, pooled deviation and pooled error indicating the presence of variability in the material. Similarly, environments in which genotypes were grown also differed significantly for the characters *viz*., days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, length of capsule, number of seeds per capsule, 1000-seed weight, seed yield per plant and oil content when tested against G × E interaction, pooled deviation and pooled error. The earlier workers Henry *et al*. (1987), Upadhyay *et al*. (2000), Bhandarkar *et al.* (2010), Kumaresan *et al*. (2010), Mekonnen *et al*. (2009), Mali *et al*. (2015) also observed significant differences among the genotypes, environments and G × E interaction for all the characters studied in sesame.

Variance due to G × E interaction was found significant for the traits *viz*., days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, seed yield per plant and oil content except length of capsule and 1000 seed weight when tested against pooled error. This indicated differential response of genotypes in expression of characters to varying environments. Similar results were found in comments of Mali *et al.* (2015), Solanki and Gupta (2000) and Kumaresan and Nadarajan (2005).

Partitioning of G × E interaction showed that G × E (linear) effect was significant for the characters *viz*., days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight, seed yield per plant and oil content except length of capsule when tested against pooled error. G × E (linear) effect was also significant for the characters *viz.,* days to maturity, no. of seeds per capsule and seed yield per plant when tested against pooled deviation and pooled error, indicating the predictability of the performance of genotypes over environments. Both linear and

non-linear components of G × E interactions were significant for all the characters indicating that genotypes responded linearly to environmental changes in respect of these characters except length of capsule for which linear components was non-significant and also length of capsule and 1000 seed weight for which non-linear components was non-significant. Similar results were found in comments of Osman (1989), Solanki and Gupta (2000), Velu and Shunmugavalli (2005) and Bhandarkar and Kumar (2010).

Environment (linear) effects were significant for the traits *viz*., days to 50 % flowering, days to maturity, plant height, no. of branches per plant, no. of capsules per plant, no. of seeds per capsule, length of capsule, 1000 seed weight, seed yield per plant and oil content (%) when tested against pooled deviation and pooled error.

4.4 Estimation of Environmental Indices

Estimates of environmental indices (Ij) are presented in Table 3, which revealed that environment E_1 (3rdweek of June) was favorable for most of the characters under study *viz*., plant height, number of branches/plant, number of capsule/plant, Length of capsule, number of

seeds/capsule, 1000 seed weight, seed yield/plant and Oil content (%) except days to 50% flowering and days to maturity.

Table 12 Estimation of environment index (Ij) under different environments

Sr. No.	Genotypes	Environmental index (Ij)		
		E1	E2	E3
1	Days to 50 % flowering	1.52	0.49	-2.01
2	Days to maturity	2.35	-0.70	-1.65
3	Plant height (cm)	5.70	1.13	-6.83
4	Number of branches per plant	0.26	-0.00	-0.26
5	Number of capsules per plant	3.64	2.41	-6.05
6	Number of seed per capsule	4.88	-0.83	-4.04
7	Length of capsule (cm)	0.27	-0.01	-0.26
8	1000 seed weight (g)	0.21	0.02	-0.23
9	Seed yield per plant (g)	0.96	0.18	-1.14
10	Oil content (%)	0.35	0.21	-0.56

Environment E_2 (1stweek of July) was favorable for some of the characters *viz*., days to maturity, plant height, number of capsules per plant, 1000 seed weight, seed yield per plant and oil content (%).Environment E_3 (3rdweek of July) was unfavorable for most of the characters *viz*., plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, length of capsule, 1000 seed weight, seed yield per plant and oil content. In general

environment E_1 (3rdweek of June) was the most favorable for yield and yield contributing characters.

4.5 Stability Parameters for Individual Character

Since G × E interaction was detected for all the characters, the stability parameters in respect of these traits were estimated and were presented in Tables 14 to 18. The non-significant bi values were considered as around unity irrespective of their high or low numerical values.

These points are considered for deciding stability of genotypes i.e. the genotypes with at least mean performance greater than population mean and S^2di low or non-significant and (1) 'bi' approaching to unity or not significantly deviating from unity are regarded with general adaptability or average stability. (2) 'bi' significantly greater than unity is considered as better adaptable to rich or favorable environments (below average stability). (3) 'bi' significantly less than unity and or having lower magnitude than unity is considered as better adaptable to poor or unfavorable environments (above average stability).

The genotype with significant S^2di component is considered as highly unpredictable. In some cases, relative 'bi' of Eberhart and Russell (1966) method was preferred because of its explicit nature.

The stability parameters estimated for different traits are presented in Table 4. Yield is the end product depends on holding certain morphological and physiological attributes and allowing others to vary resulting in predictable G × E interaction for ultimate character i.e. seed yield. The study of stability in yield components in this respect, therefore, is of great importance. The results of the present investigation carried in this direction are discussed below.

4.5.1 Days to 50% flowering

The mean number of days required for 50% flowering ranged from 40.67 days (JLS-706) to 44.00 days (JLT-408) with a population mean of 42.44 days. Two genotypes JLS-302-11 (41.89 days) and JLS-706 (40.67 days) recorded low mean than population mean (42.44 days) with non-significant regression coefficient (0.69 and 1.20, respectively) and non-significant deviation from regression (0.22 and -0.17, respectively) indicating its average stability for this trait i.e. genotype performed better under all environments, in respect of earliness which is desirable.

For this trait, the genotype JLS-301-24 (41.67 days), JLS-710(42.33 days) and GT-10 (41.56 days) recorded lower mean, significant regression coefficient (bi=1.33**, 1.15*and 1.12*, respectively) greater than unity with non-significant deviation from regression (S^2di= -0.28,-0.26 and -0.26) exhibited below average stability i.e. suitable for rich environment (Fig. 1).

The genotype JL-708 (42.2 days) had recorded mean lower than population mean (42.44 days) with significant regression coefficient (bi=0.64**) less than unity and non-significant

Table 13 ANOVA for stability as per Eberhart and Russell Model (1966) in Sesame

Sr. No.	Sources	G	E	E + (G × E)	G × E	E (L)	G × E (L)	P.D. (Pooled deviation)	P.E. (Pooled error)
1	Days to 50 % flowering	2.62$^{+*\#\#}$	46.00$^{++**\#\#}$	4.08$^{++**\#\#}$	0.86$^{\#\#}$	92.00$^{**\#\#}$	0.94$^{\#\#}$	0.77**	0.280
2	Days to maturity	9.64$^{++**\#\#}$	61.11$^{++**\#\#}$	5.06$^{++**\#\#}$	0.75*$^{\#\#}$	122.23$^{**\#\#}$	1.07*$^{\#\#}$	0.39	0.420
3	Plant height at maturity (cm)	53.17$^{++**\#\#}$	562.66$^{++**\#\#}$	51.17$^{++**\#\#}$	11.82$^{\#\#}$	1125.32$^{**\#\#}$	9.71$^{\#\#}$	12.94**	1.890
4	Number of branches per plant	0.26$^{++**\#\#}$	0.94$^{++**\#\#}$	0.09$^{++**\#\#}$	0.03$^{\#\#}$	1.89$^{**\#\#}$	0.03$^{\#\#}$	0.02*	0.010
5	Number of capsules per plant	75.98$^{++**\#\#}$	389.66$^{++**\#\#}$	31.06$^{++**\#\#}$	3.47$^{\#\#}$	779.33$^{**\#\#}$	3.00$^{\#\#}$	3.67**	1.550
6	Number of seed per capsule	19.05$^{++**\#\#}$	285.66$^{++**\#\#}$	24.15$^{++**\#\#}$	4.03**$^{\#\#}$	571.32$^{**\#\#}$	6.40**$^{\#\#}$	1.54*	0.710
7	Length of capsule (cm)	0.03 $^{++\#\#}$	0.97$^{++**\#\#}$	0.08$^{++**\#\#}$	0.01	1.94$^{**\#\#}$	0.01	0.02*	0.010
8	1000 seed weight (g)	0.10$^{++**\#\#}$	0.69$^{++**\#\#}$	0.06$^{++**\#\#}$	0.01	1.3$^{**\#\#}$	0.02$^{\#\#}$	0.01**	0.001
9	Seed yield per plant (g)	2.76$^{++**\#\#}$	15.91$^{++**\#\#}$	1.35$^{++**\#\#}$	0.18*$^{\#\#}$	31.83$^{**\#\#}$	0.29**$^{\#\#}$	0.07*	0.040
10	Oil content (%)	18.23$^{++**\#\#}$	3.34$^{++**\#\#}$	0.39$^{++**\#\#}$	0.16$^{\#\#}$	6.69$^{**\#\#}$	0.19$^{\#\#}$	0.11*	0.050

+, ++ : Significant at 5 and 1 % level of significance, respectively against G × E

*, ** : Significant at 5 and 1% level of significance, respectively against the pooled deviation (PD)

#, ## : Significant at 5 and 1% level of significance, respectively against the pooled error (PE)

deviation from regression (S^2di= -0.21) shows above average stability i.e., suitable for poor or stress environment.

The genotype JLS-709, JLS-1009-7-1, PT-1 and JLT-7 had significant value of deviation from regression (S^2di=2.55**, 1.59*, 0.90* and 1.61**, respectively) indicating its unpredictability for this trait.

4.5.2 Days to maturity

The days to maturity ranged from 81.22 days (JLT-7) to 87.56 days (JLS-710) with population mean of 84.63 days.

The genotype JLS-120 (83.44 days), JLS-408-2 (84.56 days), JLS-1009-7-1 (82.22 days) and JLT-7 (81.22 days) recorded lower mean value than population mean (84.63 days) with non-significant regression coefficient (0.93, 0.6, 1.06 and 1.14, respectively) and non-significant deviation from regression (-0.40, -0.40, -0.37and -0.13, respectively) indicating its average stability for this trait i.e. this genotype performed better under all environments in respect of earliness which is desirable.

Table 14 Estimates of stability parameters for days to 50% flowering and days to maturity

Sr. No.	Genotypes	Days to 50% flowering			Days to maturity		
		$\overline{X}$	Bi	S^2di	$\overline{X}$	Bi	S^2di
1	JLS-120	42.89	0.84	0.50	83.44	0.93	-0.40
2	JL-708	42.22	0.64**	-0.21	86.22	1.06**	-0.37
3	JLS-408-2	43.56	0.53	0.14	84.56	0.60	-0.40
4	JLS-302-11	41.89	0.69	0.22	84.00	0.99	2.59**
5	JLS-710	42.33	1.15*	-0.26	87.56	0.49**	-0.41
6	JLS-709	42.56	1.58	2.55**	85.33	0.88	-0.30
7	JLS-706	40.67	1.20	-0.17	86.89	0.52*	-0.06
8	JLS-1009-7-1	43.00	0.51	1.59*	82.22	1.06	-0.37
9	JLS-907	43.78	0.92	-0.19	82.67	1.80**	-0.16
10	JLS-301-24	41.67	1.33**	-0.28	85.45	1.17**	0.22
11	PT-1	41.78	0.84	0.90*	84.78	0.78*	-0.34
12	JLT-408	44.00	0.89	0.03	85.78	1.36**	-0.38
13	JLT-7	42.22	1.76	1.61*	81.22	1.14	-0.13
14	GT-10	41.56	1.12*	-0.26	84.67	1.23	-0.06
	Mean	42.44			84.63		
	S.E.D±	0.599	0.33		0.44	0.21	

*,** = Significant at 5 and 1% level of significance, respectively.

The genotypes JLS-706 and JLS-907 having regression coefficient (0.52* and 1.80**, respectively) values significantly greater than unity and non-significant deviation from regression value (-0.06 and -0.16, respectively) indicating their below average stability i.e. suitable for favorable or rich environments (Fig. 2).

The genotype JLS-302-11 recorded significant deviation from regression (S^2di=2.59**) indicating its unpredictability for this trait.

Both linear and non-linear components of G × E interaction were found significant for this trait.

4.5.3 Plant height (cm)

Plant height ranged from 92.1 cm (JLS-120) to 105.0 cm (JLT-7) with a population mean of 99.6 cm.

Table 15 Estimates of stability parameters for plant height (cm) and number of branches per plant

Sr. No.	Genotypes	Plant height (cm)			No. of branches per plant		
		$\bar{X}$	bi	S^2di	$\bar{X}$	bi	S^2di
1	JLS-120	92.1	0.60	65.5**	4.40	0.12	0.05*
2	JL-708	98.5	1.62	5.1	4.12	0.71*	-0.01
3	JLS-408-2	103.0	1.31	8.2*	4.16	1.47	-0.00
4	JLS-302-11	96.3	0.28	27.10**	4.04	0.33	0.02
5	JLS-710	100.2	1.06	0.20	3.64	1.93	0.03
6	JLS-709	101.0	1.17	0.70	3.42	1.29	-0.00
7	JLS-706	92.6	0.67	21.30**	4.26	1.34	0.02
8	JLS-1009-7-1	99.7	0.89	-0.10	4.00	0.76	0.05*
9	JLS-907	97.2	0.73	7.10*	4.16	0.90	-0.01
10	JLS-301-24	103.2	1.25**	-1.80	3.98	1.16**	-0.01
11	PT-1	104.8	1.30	6.90*	4.20	0.78	0.05*
12	JLT-408	103.7	0.90	5.00	4.23	0.58**	-0.01
13	JLT-7	105.0	1.13	4.20	3.56	1.54**	-0.01
14	GT-10	96.6	1.09	6.50*	3.74	1.09	-0.01
	Mean	99.6			3.99		
	S.E.D±	2.5	0.40		0.11	0.42	

*,** = Significant at 5 and 1% level of significance, respectively.

The genotype JLS-710 (100.2 cm), JLS-709 (101.0 cm), JLS-1009-7-1 (99.7 cm), JLT-408 (103.7 cm) and JLT-7 (105.0 cm) recorded higher mean than population mean (99.6 cm) with non-significant regression coefficient (1.06, 1.17, 0.89, 0.90 and 1.13, respectively) and

non-significant deviation from regression (0.20, 0.70, -0.10, 5.00 and 4.20, respectively) indicating its average stability for this trait.

The genotype JLS-301-24 had regression coefficient (bi=1.25**) significantly greater than unity and non-significant deviation from regression (S^2di= -1.80) exhibited below average stability for this trait i.e. suitability of genotype for favorable or rich environments.

The genotypes JLS-120, JLS-408-2, JLS-302-11, JLS-706, JLS-907, PT-1and GT-10 had significant value of deviation from regression (S^2di=65.5***, 8.2*, 27.10**, 21.30**, 7.10*, 6.90*and 1.61**, respectively) indicating their unpredictability for this trait (Fig. 3).

Both linear and non-linear components of G × E interaction were significant for this trait.

4.5.4 Number of branches per plant

The number of branches per plant ranged from 3.42 (JLS-709) to 4.40 (JLS-120) with a population mean of 3.99.

The genotypes JLS-408-2, JLS-302-11, JLS-706 and JLS-907 (4.16, 4.04, 4.26 and 4.16, respectively) exhibited superior mean than population mean (3.99) with non-significant regression coefficient (bi=1.47, 0.33, 1.34 and 0.90, respectively) and non-significant deviation from regression (S^2di= -0.00, 0.02, 0.02 and -0.01, respectively) indicating its average stability for this trait i.e. suitable for all environments (Fig. 4).

The genotype JL-708 andJLT-408 (4.12 and 4.23, respectively) had recorded mean higher than population mean (3.99) with significant regression coefficient (bi=0.71*and 0.58**, respectively) less than unity and non-significant deviation from regression (S^2di= -0.01 and -0.01, respectively) shows above average stability i.e. suitable for poor or stress environment.

The genotypes JLS-120, JLS-1009-7-1 and PT-1 had significant value of deviation from regression (S^2di=0.05*, 0.05* and 0.05*, respectively) indicating their unpredictability for this trait.

The linear and non-linear components of G × E interaction were significant for this character.

4.5.5 Number of capsules per plant

The stability parameters presented in Table-16 revealed that capsules per plant was ranged from 46.46 (JLS-710) to 61.64 (JL-708) with population mean of 54.76. The genotype JLS-120 (60.23), JL-708 (61.64), JLS-709 (58.21) and PT-1 (58.24) recorded mean higher than population mean (54.76) with non-significant regression coefficient (bi=0.93, 1.17, 1.04 and 0.99, respectively) and non-significant deviation from regression (S^2di= -0.33, -1.05, -1.49 and -1.35, respectively) indicating its average stability for this trait i.e. suitable for all environments.

The genotype JLS-408-2 (60.59) and JLT-408 (59.34) recorded mean higher than population mean (54.76) with regression coefficient (bi=1.27* and 1.17**, respectively) significantly greater than unity and non-significant deviation from regression (S^2di= -1.10 and

-1.43, respectively) indicating their below average stability i.e. genotypes suitable for favorable or rich environments (Fig. 5).

Table 16 Estimates of stability parameters for number of Capsules per plant and number of seed per capsule

Sr. No.	Genotypes	No. of capsules per plant			No. of seed per capsule		
		$\overline{X}$	bi	S^2di	$\overline{X}$	bi	S^2di
1	JLS-120	60.23	0.93	-0.33	63.32	1.69**	-0.11
2	JL-708	61.64	1.17	-1.05	66.33	1.21	-0.20
3	JLS-408-2	60.59	1.27*	-1.10	65.44	1.13**	-0.70
4	JLS-302-11	50.09	0.76	19.19**	60.44	0.51	5.74**
5	JLS-710	46.46	0.81	8.54*	59.19	0.38**	0.27
6	JLS-709	58.21	1.04	-1.43	63.30	0.93	-0.66
7	JLS-706	49.26	1.27	8.29*	59.32	0.85	4.77**
8	JLS-1009-7-1	54.44	0.97	0.16	59.44	0.95	-0.60
9	JLS-907	51.08	1.23	-1.47	59.09	0.59	2.90*
10	JLS-301-24	54.73	1.09**	-1.28	62.01	1.15**	-0.43
11	PT-1	58.24	0.99	-1.35	63.08	1.19	0.92
12	JLT-408	59.34	1.17**	-1.43	64.44	1.68*	-0.63
13	JLT-7	48.68	0.88	4.40	60.13	0.60	0.83
14	GT-10	53.70	0.43**	-1.49	59.57	1.14	-0.38
	Mean	54.76			61.79		
	S.E.D±	1.35	0.26		0.88	0.19	

*,** = Significant at 5 and 1% level of significance, respectively.

The genotypes JLS-302-11, JLS-710 and JLS-706 had recorded significant values for deviation from regression (S^2di=19.19**, 8.54*and 8.29*, respectively) indicating their unpredictability for this trait.

Both linear and non-linear components of G × E interaction were significant for capsules per plant.

4.5.6 Number of Seeds per capsule

The number of seeds per capsule ranged from 59.09 (JLS-907) to 66.33 (JL-708) with a population mean of 59.34.

The genotypes JL-708 (66.33), JLS-709 (63.30) and PT-1 (63.08) had recorded higher mean than population mean (61.79) non-significant regression coefficient (bi=1.21, 0.93and 1.19, respectively) and non-significant deviation from regression (S^2di= -0.20, -0.66 and 0.92, respectively) exhibited average stability i.e. suitable for all environments for this trait (Fig. 6).

The genotype JLS-120 (63.32), JLS-408-2 (65.44), JLS-301-24 (62.01) and JLT-408 (64.44) had recorded higher mean than population mean (61.79) with regression coefficient (bi=1.69**, 1.13**, 1.15** and 1.68* respectively) significantly greater than unity and non-significant deviation from regression (S^2di= -0.11, -0.70, -0.43 and -0.63, respectively) indicating its below average stability i.e. genotype suitable for favorable or rich environments.

The genotypes JLS-302-11, JLS-706 and JLS-907 had recorded significant values for deviation from regression (S^2di=5.74**, 4.77** and 2.90*, respectively) indicating unpredictability of performance for this trait.

Linear and non-linear components of G × E interaction were found significant for this character.

4.5.7 Length of capsule (cm)

The length of capsule ranged from 3.53 cm (JLS-301-24) to 3.84 cm (JLS-120) with population mean of 3.65 cm.

The genotypes JLS-120 (3.84 cm), JLS-709 (3.66 cm), JLS-1009-7-1 (3.66 cm), PT-1 (3.72 cm), JLT-408 (3.72 cm) and GT-10 (3.68 cm) had recorded mean higher than population mean (3.65 cm) with non-significant regression coefficient (bi=0.76, 1.01, 1.02, 0.87, 0.90 and 1.21, respectively) and non-significant deviation from regression (S^2di= -0.00, -0.01, 0.00, 0.01, 0.00 and -0.00, respectively) exhibited average stability i.e. genotypes performed better under all environments for this trait (Fig. 7).

The genotype JLS-907 (3.77 cm) had recorded mean higher than population mean (3.65cm) with significant regression coefficient (bi=0.51**) less than unity and non-significant deviation from regression (S^2di= -0.01) shows above average stability i.e. suitable for poor or stress environment.

The genotype JLS-408-2, JLS-706 and JLS-301-24 exhibited significant value for deviation from regression (S^2di=0.04**, 0.03* and 0.02*) indicating its unpredictability for length of capsule.

4.5.8 1000-seed weight (g)

The range of 1000-seed weight was from 2.58 g (JLS-710) to 3.10 g (JLS-120 and JLT-408) with population mean of 2.88 g.

The genotype JLS-120 (3.10 g), PT-1 (2.99 g), JLT-408 (3.10 g)and GT-10 (2.98 g) had recorded higher mean than population mean (2.88 g), non-significant regression coefficient (bi=1.33, 0.69, 0.85 and 1.34 respectively) and non-significant deviation from regression (S^2di=0.01, 0.00, 0.01 and 0.00) exhibited average stability i.e. suitable for all environments for 1000-seed weight (Fig. 8).

The genotypes JLS-408-2 (2.90), JL-708 (2.92) and JLS-1009-7-1 (2.99) had recorded higher mean than population mean (2.88 g), exhibited regression coefficient (bi=1.58**, 1.28** and 1.66**, respectively) significantly greater than unity and non-significant deviation from

regression (S^2di=-0.00, -0.00 and -0.00 respectively) indicating their below average stability i.e. genotypes suitable for favorable or rich environments for this trait.

Table 17 Estimates of stability parameters for Length of capsule (cm) and 1000 seed weight (g)

Sr. No.	Genotypes	Length of capsule (cm)			1000 seed weight (g)		
		$\overline{X}$	bi	S^2di	$\overline{X}$	bi	S^2di
1	JLS-120	3.84	0.76	-0.00	3.10	1.33	0.01
2	JL-708	3.57	1.40*	-0.00	2.92	1.28**	-0.00
3	JLS-408-2	3.57	1.41	0.04**	2.90	1.58**	-0.00
4	JLS-302-11	3.56	1.07	0.00	2.69	0.50	0.02**
5	JLS-710	3.59	0.77	0.00	2.58	0.71	0.05**
6	JLS-709	3.66	1.01	-0.01	2.78	0.54**	-0.00
7	JLS-706	3.61	1.12	0.03*	2.86	1.28**	-0.00
8	JLS-1009-7-1	3.66	1.02	0.00	2.99	1.66**	-0.00
9	JLS-907	3.77	0.51**	-0.01	2.66	0.93	0.01
10	JLS-301-24	3.53	1.12*	0.02*	3.09	0.76**	-0.00
11	PT-1	3.72	0.87	0.01	2.99	0.69	0.00
12	JLT-408	3.72	0.90	0.00	3.10	0.85	0.01
13	JLT-7	3.58	0.82	-0.00	2.66	0.56	0.02**
14	GT-10	3.68	1.21	-0.00	2.98	1.34	0.00
	Mean	3.65			2.88		
	S.E.D±	0.09	0.33		0.08	0.34	

*,** = Significant at 5 and 1% level of significance, respectively.

The genotype JLS-301-24 (3.09g) had recorded mean higher than population mean (2.88g) with significant regression coefficient (bi=0.76**) less than unity and non-significant deviation from regression (S^2di= -0.00) shows above average stability i.e. suitable for poor or stress environment.

The genotype JLS-302-11, JLS-710 and JLT-7 had recorded significant deviation from regression (S^2di=0.02**, 0.05** and 0.02**, respectively) exhibited unpredictability of performance for this trait.

4.5.9 Seed yield per plant (g)

Seed yield per plant ranged from 8.04 g (JLS-706) to 11.03 g (JLS-120) with population mean of 9.25 g, seven genotypes recorded mean higher than population mean (9.25 g).

The genotype JLS-120 (11.03 g) and JLT-408(10.37) had recorded higher mean than population mean (9.25 g) and exhibited regression coefficient (bi=1.78**and 1.60*, respectively) significantly greater than unity and non-significant deviation from regression (S^2di= -0.04 and

-0.00, respectively) indicating their below average stability i.e., suitability of the genotypes for favorable or rich environments.

Table 18 Estimates of stability parameters for seed yield per plant (g) and oil content (%)

Sr. No.	Genotypes	Seed yield per plant (g)			Oil content (%)		
		$\overline{X}$	bi	S^2di	$\overline{X}$	Bi	S^2di
1	JLS-120	11.03	1.78**	-0.04	49.36	1.71	0.26*
2	JL-708	9.99	0.99	0.01	48.71	1.53**	-0.05
3	JLS-408-2	10.24	0.84	0.09	46.93	0.55	-0.05
4	JLS-302-11	8.09	0.77	0.05	47.51	1.98	0.05
5	JLS-710	8.41	0.68	0.06	44.63	0.23	0.06
6	JLS-709	9.34	0.61**	-0.05	43.69	0.95	0.06
7	JLS-706	8.04	1.26	-0.01	50.89	0.71	0.72**
8	JLS-1009-7-1	9.03	0.95	0.08	43.37	0.90**	-0.05
9	JLS-907	8.28	0.56	0.13*	50.80	0.63	-0.03
10	JLS-301-24	9.07	0.95	-0.02	45.29	-0.05*	-0.03
11	PT-1	9.61	1.01	0.04	48.20	2.08**	-0.05
12	JLT-408	10.37	1.60*	-0.00	48.62	1.26	-0.04
13	JLT-7	8.24	1.17**	-0.05	46.56	0.69	0.04
14	GT-10	9.80	0.83	0.02	45.02	0.83	-0.05
	Mean	9.25			47.11		
	S.E.D±	0.19	0.18		0.24	0.49	

*,** = Significant at 5 and 1% level of significance, respectively.

The genotypes JL-708 (9.99 g), JLS-408-2 (10.24 g), PT-1 (9.61 g) and GT-10 (9.80 g) had recorded higher mean than population mean (8.97 g) with regression coefficient (bi=0.99, 0.84, 1.01 and 0.83, respectively) non-significant and non-significant deviation from regression (S^2di=0.01, 0.09, 0.04 and 0.02, respectively) exhibited average stability i.e. suitable for all environments for seed yield per plant (Fig. 9).

The genotype JLS-709 (9.34 g) had recorded mean higher than population mean (9.25 g) with significant regression coefficient (bi=0.61**) less than unity and non-significant deviation from regression (S^2di= -0.05) shows above average stability i.e. suitable for poor or stress environment.

The genotypes JLS-907 had significant values for deviation from regression (S^2di=0.13*) indicating its unpredictability for this trait.

Both linear and non-linear components of G × E interaction were found to be significant for seed yield per plant.

4.5.10 Oil content (%)

The values for oil content ranged from 43.37% (JLS-1009-7-1) to 50.89% (JLS-706) with population mean of 47.11%. Seven genotypes recorded mean higher than population mean (47.11%).

The genotype JLS-302-11 (47.51%), JLS-907 (50.80%) and JLT-408 (48.62%) had higher mean than population mean (47.11%), non-significant regression coefficient (bi=1.98, 0.63 and 1.26, respectively) and non-significant deviation from regression (S^2di=0.05, -0.03 and -0.04, respectively) exhibited average stability i.e. suitability of genotype for all environments for oil content (Fig. 10).

The genotype JL-708 (48.71 %) and PT-1 (48.20 %) had recorded higher mean than population mean (47.11% g) with regression coefficient (bi=1.53** and 2.08**, respectively) significantly greater than unity and non-significant deviation from regression (S^2di= -0.05 and -0.05, respectively) indicating their below average stability i.e. suitable for favorable or rich environments for this trait.

The genotypes JLS-120 and JLS-706 had recorded significant values for deviation from regression (S^2di=0.26*and 072**, respectively) indicating their unpredictability for the trait oil content.

The linear and non-linear components of G × E interaction were found significant for oil content in sesame.

Table 19. Nature of stability of Sesame genotypes under different environments

Sr. No.	Character	Genotypes showing stability			Unstable (S^2di significant and High mean)	Stable but Low/high mean
		Average stability (suitable for all environments)	Below average stability (bi>1) (suitable for rich environment)	Above average stability (bi<1) (suitable for poor environment)		
1	Days to 50% flowering	JLS-302-11 JLS-706	JLS-301-24 JLS-710 GT-10	JL-708	JLS-709 JLS-1009-7-1 PT-1 JLT-7	JLS-120 JLS-408-2 JLS-907 JLT-408
2.	Days to maturity.	JLS-120 JLS-408-2 JLS-1009-7-1 JLT-7	JLS-706 JLS-907		JLS-302-11	JLS-709 GT-10
3	Plant height (cm).	JLS-710 JLS-709 JLS-1009-7-1 JLT-408 JLT-7	JLS-301-24		JLS-120, JLS-408-2, JLS-302-11, JLS-706, JLS-907, PT-1, GT-10	JL-708
4.	No. of branches per plant.	JLS-408-2 JLS-302-11 JLS-706 JLS-907		JL-708 JLT-408	JLS-120 JLS-1009-7-1 PT-1	JLS-710 JLS-709 JLS-301-24 GT-10
5	No. of capsules per plant.	JLS-120 JL-708 JLS-709 PT-1	JLS-408-2 JLT-408		JLS-302-11 JLS-710 JLS-706	JLS-1009-7-1 JLS-907 JLT-7
6	No. of seed per capsule.	JL-708 JLS-709 PT-1	JLS-120 JLS-408-2 JLS-301-24 JLT-408		JLS-302-11 JLS-706 JLS-907	JLS-1009-7-1 JLT-7 GT-10
7	Length of capsule (cm).	JLS-120 JLS-709 JLS-1009-7-1 PT-1 JLT-408 GT-10		JLS-907	JLS-408-2 JLS-706 JLS-301-24	JLS-302-11 JLS-710 JLT-7
8	1000 seed weight (g).	JLS-120 PT-1 JLT-408 GT-10	JLS-408-2 JL-708 JLS-1009-7-1	JLS-301-24	JLS-302-11 JLS-710 JLT-7	JLS-907

Table 19 contd...

Sr. No.	Character	Genotypes showing stability			Unstable (S^2di significant and High mean)	Stable but Low/high mean
		Average stability (suitable for all environments)	Below average stability (bi>1) (suitable for rich environment)	Above average stability (bi<1) (suitable for poor environment)		
9	Seed yield per plant (g).	JL-708 JLS-408-2 PT-1 GT-10	JLS-120 JLT-408	JLS-709	JLS-907	JLS-302-11 JLS-710 JLS-706 JLS-1009-7-1 JLS-301-24
10	Oil content (%).	JLS-302-11 JLS-907 JLT-408	JL-708 PT-1		JLS-120 JLS-706	JLS-408-2 JLS-710 JLS-709 JLT-7 GT-10

4.6 Study of Phyllody incidence:

To study the Phyllody incidence on sesame plants, five plants per treatment was selected and observation was recorded applying 0-9 grade disease rating scale (Mayee and Datar, 1986). The Incidence was calculated by using following formula.

$$\text{Incidence (\%)} = \frac{\text{No. of plants showing disease symptoms}}{\text{Total number of plants observed}} \times 100$$

Standard Disease rating scale (0-9 grade) scale

Rating scale	Description
0	No symptoms of infection
1	1-10% infection
3	10.1-25% infection
5	25.1-50% infection
6	50.1-75% infection
7	>75% infection

Table 20 Phyllody incidence under different environments:

Sr.No.	Genotypes	E_1		E_2		E_3	
		Percent Disease Incidence (%)	Rating Scale	Percent Disease Incidence (%)	Rating Scale	Percent Disease Incidence (%)	Rating Scale
1	JLS-120	0	0	0	0	0	0
2	JL-708	0	0	0	0	3.2	1
3	JLS-408-2	0	0	0	0	0	0
4	JLS-302-11	0	0	0	0	0	0
5	JLS-710	0	0	0	0	8.6	1
6	JLS-709	0	0	0	0	0	0
7	JLS-706	0	0	0	0	6.4	1
8	JLS-1009-7-1	0	0	0	0	0	0
9	JLS-907	0	0	0	0	4.2	3
10	JLS-301-24	0	0	0	0	9.3	1
11	PT-1	0	0	0	0	0	0
12	JLT-408	0	0	0	0	0	0
13	JLT-7	0	0	0	0	5.3	1
14	GT-10	0	0	0	0	0	0

From the table 6.2 we observed that in environment E_1 i.e. sowing of sesame on 16th June shows all of the genotypes had zero percent incidence of phyllody. In environment E_2 i.e. sowing of sesame on 1st July all the genotype had zero percent incidence of phyllody. In environment E_3 i.e. sowing of sesame on 16th July the genotypes JLS-120, JLS-408-2, JLS-302-11, JLS-709, JLS-1009-7-1, PT-1, JLT-408 & GT-10 had zero percent incidence of phyllody while genotypes JL-708, JLS-710, JLS-706, JLS-907, JLS-301-24 & JLT-7 (rating scale value= 1, 1, 1, 3, 1 and 1, respectively) exhibit phyllody incidence.

5. SUMMARY AND CONCLUSION

The present investigation entitled "Genotype × Environment interaction in Sesame [*Sesamum indicum* (L.)]" was carried out with the objectives of determining the suitable genotypes for different environments under varied sowing conditions. The field experiment was conducted to evaluate fourteen genotypes of sesame under three sowing dates viz., E_1 (16th June, 2019), E_2 (1st July, 2019), and E_3 (16th July, 2019) at Post Graduate Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) during *kharif* 2019 in a randomized block design with three replications. The data from each of these three environments was collected on days to 50 % flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, length of capsule (cm), number of seeds per capsule, 1000-seed weight (g), seed yield per plant (g) and oil content (%). Stability analysis was done following the approach given by Eberhart and Russel (1966).

5.1 Response of Genotypes to Changing Environments

Mean performance of different genotypes over three environments indicated that the genotype JLS-706 was the earliest for days to 50 % flowering (40.67 days) and genotype JLT-7 was the earliest for days to maturity (81.22 days).

The genotype JLT-7 was the promising for plant height (104.96 cm) and the genotype JLS-120 recorded maximum number of branches (4.40), genotype JL-708 for number of capsules per plant (61.64), genotype JLS-120 recorded maximum length of capsule (4.07 cm) and genotype JLS-706 for highest oil content (50.89%).

The genotype JL-708 produced maximum number of seeds per capsule (66.33) and both genotypes JLS-120 and JLT-408 recorded highest 1000-seed weight (3.10 g).

The genotype JLS-120 was good for seed yield per plant (11.03 g).

5.2 Pooled Analysis of Variance and G × E Interaction

Pooled analysis of variance showed that genotypes differed significantly for days to 50 % flowering, days to maturity, plant height, branches per plant, capsules per plant, length of capsule, seeds per capsule, 1000-seed weight, seed yield per plant and oil content when tested against G x E interaction, pooled deviation and pooled error. Environmental variance was significant for all the characters when tested against G × E interaction, pooled deviation and pooled error.

Linear components of G × E interaction were found significant for the characters *viz.,* days to 50 % flowering, days to maturity, plant height, branches per plant, capsules per plant, seeds per capsule, 1000-seed weight, seed yield per plant and oil content while found non-significant for the character length of capsule when tested against pooled error.

Non-linear component of G × E interaction was found significant for the traits *viz.* days to 50 % flowering, days to maturity, plant height, branches per plant, capsules per plant, seeds per capsule, seed yield per plant and oil content while found non-significant for the traits *viz.* length of capsule and 100 seed weight when tested against pooled error.

5.3 Estimation of Environmental Index

The environment E_1 (3rd week of June) was favorable for most of the characters under study (except days to 50% and days to maturity) *viz.,* branches per plant, capsules per plant, length of capsule, seeds per capsule, 1000-seed weight, seed yield per plant and oil content. Environment E_2 (1st week of July) was favorable for the characters *viz*., days to maturity, plant height, capsules per plant, 1000 seed weight, seed yield per plant and oil content. Environment E_3 (3rd week of July) was unfavorable for most of the characters (except days to 50% flowering and days to maturity).

In general environment E_1 (3rd week of June) was the most favorable for seed yield and yield contributing characters.

5.4 Stability Parameters

The genotypes JLS-302-11 and JLS-706 recorded average stability for days to 50% flowering. The genotype JLS-120, JLS-408-2, JLS-1009-7-1 and JLT-7 exhibited average stability for days to maturity. The genotype JLS-710, JLS-709, JLS-1009-7-1, JLT-408 and JLT-7 exhibited average stability for plant height and genotype JLS-408-2, JLS-302-11, JLS-706 and JLS-907 for branches per plant. The genotypes JLS-120, JL-708, JLS-709 and PT-1 showed average stability for capsules per plant.

The genotypes JL-708, JLS-709 and PT-1 showed average stability for seeds per capsule. The genotypes JLS-120, JLS-709, JLS-1009-7-1, PT-1, JLT-408 and GT-10 were recorded average stability for length of capsule. The genotypes JLS-120, PT-1, JLT-408 and GT-10 showed average stability for 1000 seed weight. The genotypes JL-708, JLS-408-2, PT-1 and GT-10 recorded average stability for seed yield per plant. The genotypes JLS-302-11, JLS-907 and JLT-408 showed average stability for oil content.

Below average stability was observed for JLS-301-24, JLS-710 and GT-10 for days to 50% flowering; JLS-706 and JLS-907 for days to maturity; JLS-301-24 for plant height;JLS-408-2 and JLT-408 for capsules per plant; JLS-120, JLS-408-2, JLS-301-24 and JLT-408 for seeds per capsule; JLS-408-2, JL-708 and JLS-1009-7-1 for 100 seed weight; JLS-120 and JLT-408 for seed yield per plant and JL-708 and PT-1 for oil content indicating their suitability for rich or favorable environments.

Above average stability was observed for genotype JL-708for days to 50% flowering; JL-708 and JLT-408 for branches per plant; JLS-907 for length of capsule and JLS-301-24 for 1000 seed weight indicating their suitability for poor or stress environments.

None of the genotype was found stable for all the characters under study.

5.5 Conclusions

1. It is revealed that an environment E_1 i.e. sowing of sesame on 16th June was found most favorable for expression of most of the characters including grain yield.

2. Linear and non-linear component of G × E interactions were found significant for all the characters under study.

3. None of the genotype was found average stable for all the characters.

4. Above average stability exhibited by few genotypes i.e. JL-708 (days to 50% flowering), JL-708, JLT-408 (no. of branches per plant), JLS-907 (length of capsules), JLS-301-24 (1000 seed weight) & JLS-709 (seed yield per plant).

5. The genotypes under study showed differential stability performance for all the characters.

6. Considering the mean yield performance, the genotype JLS-120 and JLT-408 found suitable to grow under rich environment i.e. 16th June (E_1) and none of the other genotype except JLS-709 were found suitable to grow under poor environment i.e. 16th July (E_3).

7. Genotypes JLS-302-11, JLS-120, JLS-1009-71, JLS-709, JLT-408 and PT-1 Shows average stable performance for most of the characters.

8. The genotype JLS-120, JLS-408-2, JLS-302-11, JLS-709, JLS-1009-7-1, PT-1, JLT-408& GT-10 do not exhibit symptoms of phyllody in all three environments i.e. E_1, E_2 & E_3.

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