

**“GENETIC DIVERGENCE AND STABILITY PERFORMANCE FOR SOME
ECONOMIC TRAITS IN GLADIOLUS (*Gladiolus hybrida* L.)”**

Mohd Qasim Sheikh

Registration No. 99/A/64/D

2004



DIVISION OF FLORICULTURE, MEDICINAL AND AROMATIC PLANTS

FACULTY OF POST-GRADUATE STUDIES SHER-E-KASHMIR

**UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY OF
KASHMIR**

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DIVISION OF FLORICULTURE, MEDICINAL AND AROMATIC PLANTS THESIS

SUBMITTED TO THE FACULTY OF POST-GRADUATE STUDIES

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**IN PARTIAL FULFILMENT OF REQUIREMENTS
FOR AWARD OF THE DEGREE OF**

DOCTOR OF PHILOSOPHY IN AGRICULTURE

[FLORICULTURE]

Sher-e-Kashmir

University of Agricultural Sciences & Technology of Kashmir

Shalimar, Srinagar- 191 121 (J&K)

CERTIFICATE-I

This is to certify that the thesis entitled “**Genetic divergence and stability performance for some economic traits in gladiolus (*Gladiolus hybrida* L.)**” submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in Agriculture (Floriculture), to the faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir is a record of *bona fide* research carried out by **Mr. Mohd Qasim Sheikh** (Registration No. 99/A/64/D) under my supervision and guidance. No part of the thesis has been submitted for any degree or diploma.

It is further certified that such help or information received during the course of investigation have been duly acknowledged.

**Chairman,
Advisory Committee**

Endorsed :

Professor and Head
Division of Floriculture,
Medicinal and Aromatic Plants
SKUAST (K) Shalimar.

**Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar, Srinagar- 191 121 (J&K)**

CERTIFICATE-II

We, the members of Advisory Committee of **Mr. Mohd Qasim Sheikh**, candidate for the degree of **Doctor of Philosophy** in Agriculture (Floriculture), have gone through the manuscript of the thesis entitled “**Genetic divergence and stability performance for some economic traits in gladiolus (*Gladiolus hybrida* L.)**” and recommend that it may be submitted by the student in partial fulfilment of the requirement for the degree.

Advisory Committee

Chairman :- Dr. A.Q.Jhon
Professor and Head
Division of Floriculture, Med. & Arom. Plants

- Members :-
1. Dr. A.A. Siddique
Associate Professor
Division of FMAP
 2. Dr. N.A. Zeerak
Associate Professor
Division of Plant Breeding & Genetics
 3. Dr. M.S Wani
Associate Professor
I/C Fruit Research Station
Balpora, Shopian
 4. Dr. Shafiq-u-Reham
Associate Professor
Division of Environmental Sciences
(**Dean P.G.Nominee**)

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar, Srinagar- 191 121 (J&K)

CERTIFICATE-III

This is to certify that the thesis entitled “**Genetic divergence and stability performance for some economic traits in gladiolus (*Gladiolus hybrida* L.)**” submitted by **Mr. Mohd Qasim Sheikh**, (Registration No. 99/A/64/D) to the Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in Agriculture (Floriculture), was examined and approved by the advisory committee and external examiner on _____ .

Chairman
Advisory Committee

External Examiner

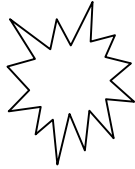
Professor and Head
Division of Floriculture,
Medicinal and Aromatic Plants
SKUAST (K) Shalimar

Director
Resident Instructions-cum -Dean
Post Graduate Studies
SKUAST (K), Shalimar

DEDICATED

TO

MY



MOTHER



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Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Floriculture, Medicinal and Aromatic Plants.
Shalimar, Srinagar-191121

Title of the thesis : “Genetic divergence and stability performance for some economic traits in gladiolus (*Gladiolus hybrida* L.)”.

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Registration No. : 99/A/64/D

Major subject : Floriculture

Minor subject(s) : Pomology/Plant Physiology

Major Advisor : **Dr. A.Q. Jhon**
Professor and Head
Division of Floriculture, Medicinal and Aromatic Plants.

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Abstract

Sixty two gladiolus cultivars were studied for the estimation of their genetic variability and diversity during *Khariief*, 2002 at three random locations (Environments) of Kashmir valley whereas, ten of the genotypes based on *per se* performance were tested at five random locations (Environments) during *Khariief*, 2003 for their stability traits. Analysis of variance revealed presence of significant genetic variability among these cultivars for all the traits. G x E interaction

was also significant, revealing that even the cultivars selected for stability did not perform equally across the random environments. Pooled analysis across locations revealed magnitude of variability for days to sprout ranging from 22.05 to 29.50 days, plant height ranged from 89.84 to 135.28 cm, shoots per plant ranging from 1.11 to 2.36, leaves per plant from 6.92 to 8.70, days to slipping from 68.53 to 110.70, florets open at a time from 2.91-4.64, days to first floret opening from 74.87-118.52, durability of first floret from 3.92-5.65 days, size of floret from 7.87-11.05 cm, spike length from 63.74-112.63 cm, florets per spike from 12.01-18.80, durability of whole spike from 9.18-14.58 days, corms per plant from 1.24-2.43, cormels per plant from 12.53-145.73, size of corm from 3.31-4.96 cm, weight of corm from 17.79-38.82 g, weight of 10 cormels from 2.82-7.45 g. Genotypic coefficient of variance was high for number of cormels per plant, moderate for weight of corm, weight of cormels, number of corms per plant, days to basal floret opening, spike length, floret per spike and days to sprout and low for the rest of the traits.

The heritability was high for all the traits. Correlation was significant and positive for number of florets per plant and spike length with number of florets opening at a time, durability of whole spike, plant height, size of florets, number of corms per plant, weight of corm and size of corm. Days to sprouting had positive and significant correlations with size of florets and number of corms per plant and number of cormels per plant. These traits, besides plant height, contributed significantly and indirectly via each other as well.

The estimation of genetic divergence among test cultivars was highly significant, which got grouped into several clusters in the individual environments. However, in the pooled analysis 62 cultivars got grouped into XII Clusters, with Cluster- I comprising 50 cultivars and Cluster- VIII with two cultivars. Rest of the clusters had only one cultivar each. The checks in the individual environments were grouped into single clusters. Inter- cluster distances were maximum in the individual environments and in pooled analysis between the Cluster(s), revealing ample possibility for developing superior cultivars through hybridization. Maximum inter-cluster

distances were observed between Cluster-II and Cluster VIII, VII and VIII and I and VIII. The maximum contribution to divergence came from number of cormels per plant, weight of corm and number of florets opening at a time, hence need to be given due weightage, while, selecting parents for hybridization programme. The divergent genotypes from the clusters thus identified for the hybridization programme for a transgressive segregant with high economic yield are White Prosperity, Regency, Aarti, CPG-6, Sapna, Amsterdam, Jester Gold, Red Majesty, Sunny Boy, Sunset Jubilee, Jester and Jackson Villa Gold. Stability analysis of 10 elite cultivars for most important traits of florets per spike across five random locations (Environments) revealed that mean square deviation from regression was non-significant except for Apple Blossom, Moralla and Sanceree and hence prediction for stability was precise and reliable. The linear regression was non-significant revealing that most of the cultivars except Apple Blossom and Big Time Supreme were average in stability. Comparing their performance with the mean, it was observed that Friendship Pink, Jackson Villa Gold, Peter Pears, Traderhorn, White Prosperity and Yellow Stone were well adapted to favourable environments only.

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Place : Shalimar

Mohd Qasim Sheikh

Dated :

CHAPTER-I

INTRODUCTION

Gladiolus is one of the most important bulbous ornamental crop, occupying fifth place in the international floriculture trade (Sharma and Sharga, 1994) ; valued for its majestic flower spike with massive florets of brilliant colours, attractive shapes, varying sizes and excellent keeping quality. It belongs to the family iridaceae and includes more than 150 species, most of them are native to Africa (South, eastern and western), with only about twelve originating from Mediterranean areas, western Asia and Europe. South Africa, particularly the cape of Good Hope, is considered to be the center of diversity of the genus (Delpierre and Du Plessis, 1973 ; Lewis *et al.*, 1972 ; Ohri and Khoshoo, 1985a). Cultivars found in this area are diploid species ($2n = 30$) that flower from autumn to spring, whereas, the rest flower during the hot dry summer. All modern cultivars of summer flowering types (*G. grandiflorus* Hort.) have originated from complex

crosses made since the middle of the last century (Anderton and Park, 1989 ; Buch 1972 ; Ohri and Khoshoo, 1985b).

Species found in the countries bordering the Mediterranean sea in the western Asia and Europe are all polyploids. The available cultivars offer a tremendous diversity for colour, size, shape and flowering time and have arisen from complex crosses among several botanical species originating mainly in south Africa. Breeding and improvement in the flower species has started in the first part of the 19th century and led to the evolution of the modern cultivars that are very different from the parental stocks.

To make further improvement for the economic traits, there have been consistent efforts on the part of breeders and floriculturists to bring about variations in the cultivated gladiolus cultivars for the characters attributed to economic traits. But, the progress in gladiolus improvement has remained more or less stationary in India in the recent past due to non-availability of diverse germplasm.

In order to sustain the potential of genotypes to produce flowers of high commercial quality and also possess good corm production under various soil and climatic conditions, the genetic diversity existing in nature or created through crop breeding is of immense value. Genetic uniformity within a crop is readily brought about by using the same gene or gene complexes during reproduction and also by large-scale extrusion of the genetically unrelated cultivars. When uniformity becomes the cause of genetic vulnerability, genetic diversity is the only insurance against it. To

overcome the menace of this uniformity, it is essential that genetic diversity, present in both the cultivated and wild species, is systematically exploited and used to generate new gene complexes for improvement in quantitative and qualitative traits and resistance or tolerance to biotic and abiotic stresses. The effectiveness of selection depends upon the range of genetic diversity existing already in the population in respect of important economic characters. The progress of breeding in such a population is primarily conditioned by the magnitude, nature, inter-relationship and genetic variations for various plant characters. Genetic parameters therefore, help in partitioning the overall variability into its heritable and non-heritable components. Evolution of flowers of high commercial quality is an ultimate criterion which a plant breeder has always to keep in view in his attempt to breed improved cultivars of any ornamental crop species. However, inheritance of flowers of high commercial value is a polygenic character and highly influenced by environment. A knowledge of the association of quantitative characters, specifically for flowers of high commercial quality and its attributes, is of immense practical value during selection. The selection of one character will lead to the indirect change(s) of other character(s) if the two are correlated. Therefore, the knowledge of phenotypic and genotypic correlation among the economic traits and analysis of the cause and effect relationship (path analysis) is important for a flower breeder. Path co-efficient analysis developed and described by

Wright (1921) and used by Dewey and Lu (1959) measures the direct and indirect effects of various characters.

The principles of Gladiolus breeding are simple. The breeder wants to identify exceptional genotypes that may be present among progenies of crosses between good commercial cultivars possessing complementary qualities. Breeder's constraints are often related to the biological characters of the genes.

Modern cultivars are the result of complex interspecific crosses. They are heterozygous and tetraploid, and the knowledge of the hereditary transmission of numerous characteristics is inadequate. As a result, rational bases for the choice of parents to be crossed are generally not available. Therefore, for the effective breeding programme the knowledge of genetic diversity among the parents is essential to exploit the resulting hybrid vigour and help in convergence of elite gene pools in the desired genotypes.

Floriculture is one sector where India has a very good opportunity to boost up exports. The country has an annual growth potential of 25 to 30 per cent and capable of earning foreign exchange many times more than it presently gets from the export of cereals or any other agricultural crops. The government of India has identified "Floriculture as a thrust area for export". It is highly suitable for cultivation under agro-climatic conditions of J&K state.

Among the vast number of florist crops available for exploitation on commercial scale, gladiolus is the premier one. Although gladiolus is so widely cultivated yet only a limited reliable statistics are available.

In India, cultivation of gladiolus has gained popularity in the recent years for cut flower trade. According to 1987 production statistics (Kolavalli *et al.*, 1991), about 289 hectares of land were under commercial gladiolus cultivation producing 459 lakh spikes annually in India. However, the pace of improvement for evolving varieties with highly desirable traits is at a low ebb mainly due to the non-availability of the diverse germplasm resources (Misra and Saini, 1990).

Multivariate analysis using Mahalanobis's D^2 statistic has been reported as a powerful tool in quantifying the degree of divergence among biological populations at genotypic level.

The information on these aspects in gladiolus under the climatic conditions of Kashmir valley is lacking. The present investigation is therefore, planned to gather information on i) genetic divergence among the available cultivars, ii) relationship of genetic diversity with the geographical and ecological background and environmental factors influencing the divergence, iii) identification of diverse clusters for subsequent hybridization, and iv) estimation of stability of some promising cultivars across random environments. The main objectives of the study were as under :

1. To study the genetic variability for different traits in the available germplasm resources,
2. To estimate the direct and indirect components of genetic parameters,
3. To estimate the genetic divergence among the available genotypes,
4. To estimate the magnitude of G x E interaction for the quantitative/qualitative traits, and
5. To study the stability of performance of some elite genotypes across random environments.

CHAPTER-II

REVIEW OF LITERATURE

A brief account of pertinent literature on different aspects of the present study is described in the following chapter.

2.1 Phenotypic variability and components of direct selection

The success of any breeding programme depends on the presence of sufficient genetic variability to help in effective selection. It is important to assess the relative magnitude of components of variability in order to use such information, together with other selection parameters for improvement of the plant type through adoption of effective breeding methods (Johnson, *et al.*, 1955 ; Hanson *et al.*, 1956 ; Williams 1964 ; Briggs and Knowle's 1967). It is necessary to divide the total phenotypic variance of the entire

characters into its components, as these are the basis for a genetic analysis and the dimensions of these components divide the breeding behaviour of the populations. Such selection parameters, particularly genetic variability (GCV), helps to choose a potential genotype; whereas, heritability (h^2) along with genetic advance as percentage of mean (GA) are more useful in predicting the resultant effect from selection of best genotypes.

Robinson (1966) recommended that germplasm pools be created to provide a reservoir of gene complexes and to form new bases for profitable selection studies. Infact such germplasm offers an array of materials for incorporation into breeding programmes with the possibility of extending economic production from a wider genetic base. Since most of the characters considered are quantitatively inherited and are subject to different degrees of non-heritable variability, the magnitude of heritable variability, more particularly its genetic component, is the most important aspect of the genetic constitution of the breeding materials, which has a close bearing on the response to selection.

Genetic variability studies of some important quantitative and qualitative characters in gladiolus were carried out in 30 cultivars by Lal *et al.*, (1985). A wide range of phenotypic variability was observed for some of the characters like days to flower, plant height, spike length and spike weight. All the characters under study showed high values of heritability. Number of florets per spike, spike length and spike weight had high heritability along with high genetic advance and thus, showed additive gene

effects, whereas, plant height, number of leaves per spikelet and days to flower exhibited heritability with lower genetic advance thereby indicating non-additive gene effects. It was therefore, advocated that selection for improvement in gladiolus could be based on number of florets per spike, spike length and spike weight.

Arora and Khanna (1986) evaluated thirty one cultivars of gladiolus to study the genotypic and phenotypic variability for six important characters, viz., number of days taken to spike emergence, number of days taken to basal floret to open, length of spike, number of florets open at one time, total number of florets per spike and number of cormels produced. High heritability with high expected genetic gain was observed for number of cormels produced and number of days taken for spike emergence. The characters like length of spike and number of florets per spike that had high heritability but lower expected genetic gain revealed that high heritability for such characters was due to non additive gene effects. However, Negi *et al.* (1982) reported high expected genetic gain for three characters, viz., weight and number of cormels produced per corm and weight of corm. It was recommended that selection based on these characters will be very effective.

Assessment of genetic performance of 45 gladiolus cultivars was carried out in another study by Khanna and Arora (1986). High genotypic and phenotypic coefficient of variation was observed for number of cormels per corm, total number of florets per spike and number of florets per spike,

and number of florets open at one time. For other characters studied (number of days taken to spike emergence, days taken to basal floret to open and spike length) the variation was observed to be low. However, heritability was recorded high in all the characters studied. Six cultivars for cormel production per corm and five for taller spikes were identified as putative parents for planning a breeding programme in gladiolus improvement.

Studies on sixty varieties of gladiolus consisting of three indigenous and 57 belonging to different agro-climatic conditions of the world were under taken to find out the extent of genetic variability *viz-a-viz*, the magnitude of genetic coefficient of variation, heritability estimates and genetic advance for twenty characters (Misra and Saini, 1988). The differences among the varieties were observed to be significant for all the characters except spike length. The higher values of GCV were observed for the characters like 10 cormel weight and number of cormels produced per plant. Most of the characters including number of florets open at first exhibited high heritability. The highest genetic advance was expressed by number of cormels produced per plant followed by number of shoots per plant. In a similar study Gowda (1989) reported that genetic variability in gladiolus showed high value of heritability. Number of florets, spike length and spike weight showed high heritability together with high genetic advance with additive gene effects. Plant height, number of leaves and days taken to flowering showed lower genetic advance with non-additive gene

effects. Hence selection of the cultivars based on number of florets, spike length and weight of spike would be effective. Singh and Singh (1983) while studying the correlation and path analysis in 41 varieties on different characters included that selection in this crop be based on the number of shoots and length of spike. High estimates of components of variance indicated that there was a high degree of genetic variability present in the majority of the characters (Gowda. 1991).

Soorianathasundaram and Nambisan (1991) studied the genetic variability and certain other genetic parameters in seventy five cultivars of gladiolus. A wide range of phenotypic variability was recorded for all the seven characters studied. Characters like spike weight, number of florets per spike, spike length and floret size exhibited greater variability coupled with higher heritability and genetic advance. The study also indicated that these characters could be relied upon for effective selection. In a similar study, genetic variability, heritability and expected genetic advance were estimated for some quantitative characters in forty varieties of gladiolus (Pant and Lal, 1991). A wide range of variation was observed for days to sprout, plant height, days to flower, spike length, number of cormels. Weight of corm, weight of cormels and spike weight exhibited high heritability along with high genetic advance indicating the importance of additive gene effects, and therefore, greater emphasis would need to be laid on these characters while selecting the superior genotypes.

Mahanta and Paswan (1993) studied the variability and heritability of twenty two characters in 10 cultivars of gladiolus. Significant differences were observed among the cultivars for the characters studied. The genotypic variances were however, low for certain traits indicating thereby, the influence of environment on the expression of genetic effect. The study revealed that the characters like weight of the daughter corms and number of sprouts and cormels exhibited greater genetic variability and high heritability coupled with high genetic advance. It indicated that selection based on these characters could be relied upon in gladiolus for future improvement.

In another experiment Sarangi *et al.* (1994) studied genetic variance, genotypic and phenotypic coefficient of variation, heritability (in broad sense) and genetic advance for fifteen characters in 47 varieties of gladiolus. High genotypic variance was observed for length of spike followed by corm weight per plant. Highest genotypic and phenotypic coefficients of variation were noted in floret size. The heritability (broad sense) ranged from 98.0 (corm weight) to 47.7 per cent (Vase life of cut flower). The weight of cormels per plant had highest genetic advance. It was suggested that corm weight having high heritability and genetic advance was the most important character for selection.

In a two year experiment on heritability estimates using fifteen exotic gladiolus varieties, Prasad *et al.* (1994) reported higher estimates of GCV for number of bulbs per plant in both the years. They further reported that

neck diameter showed the highest heritability estimate and days for blooming exhibited high heritability coupled with high genetic advance in one year of the experiment. Number of corms per plant recorded the highest genetic advance as percentage of mean. However, in the second year of the experiment the data revealed high heritability with high genetic advance for days to blooming of spike. Cormlet diameter exhibited highest genetic advance (per cent of mean). They also suggested that conventional selection procedures would bring about considerable improvement for various desirable characters in this crop. In a similar study, Anuradha and Gowda (1994) using 25 genotypes of gladiolus recorded considerable variation among the varieties for twenty four characters studied. A narrow difference between phenotypic and genotypic coefficients of variation was noticed for floret length, number of leaves, plant height, days to spike emergence and spike length indicating less environmental interference on the expression of these characters. High heritability with high genetic advance was exhibited by number of cormels and 10 cormel weight. Selection based on phenotypic observations would be effective for these traits, which appeared to be controlled by additive gene effects.

Ashwath and Parthasarthy (1994) carried out genetic variability studies for fourteen quantitative characters using 16 varieties of gladiolus. The varietal differences in respect of all the characters were observed to be significant. Variation was high for weight of cormels per plant, weight of main corm and weight of cormels per plant. Weight of main corm and

weight of single cormel per plant had high values of heritability along with high GCV. The characters plant height, length and weight of the main corm and weight of the single cormel per plant revealed high expected genetic gain and high heritability values. It was suggested that these characters were controlled by additive genes and thus, were amenable to selection. Genetic advance estimates clearly indicated scope for improving economically important traits like weight of mean corm, rachis length and spike length.

Sheikh *et al.* (1995) observed high heritability for plant height, spike length, floret per spike, floret size, corm and cormel production and weight per cormel ranging from 58.75 to 99.0 and low values for days to flower and weight per corm. However, genetic advance was high in case of cormels per plant, plant height, days to flower and spike length.

Desh Raj and Misra (1996) studied genetic variability in gladiolus under three locations for two years and reported high phenotypic and genotypic co-efficient of variation for number of cormels per plant. Heritability in broad sense was highest for days to first floret opening and plant height. Number of cormels per plant showed high to moderate heritability along with high genetic advance, indicating additive gene effects.

Sharief-ud-Din *et al.* (2000) also reported considerable genetic variability together with high estimates of broad sense heritability for the different traits which ranged from 18.30 to 99.8%. High heritability with

high expected genetic gain was observed for spike weight, corm weight, corm size and number of corms and cormels per plant. High heritability with moderate expected genetic gain was recorded for vase life, plant height, spike length, number of florets per spike and different other flowering traits. Katwate *et al.* (2002) studied variability for various characters involving 101 hybrids including 14 parents of gladiolus and observed high genotypic and phenotypic coefficient of variation along with heritability estimates for majority of the characters. Among the 101 crosses evaluated, 12 hybrids appeared to be the best as they exhibited high performance for more than 10 characters.

Patil *et al.* (2002) reported considerable genetic variability and heritability in 40 diverse lines of gladiolus for various characters. The phenotypic and genotypic variance estimates were highest for number of cormels and lowest for number of spikes. High to very high heritability estimates were recorded for all the characters.

2.2 Interrelationship among quantitative traits and cause and effect analysis.

In gladiolus, ideotype breeding is believed to offer great opportunities to enhance performance of number of florets per spike and rachis length (Misra *et al.*, 2001). In order to achieve the objectives, understanding of relationship between the component characters and their relative contribution to economic yield (number of florets per spike and rachis length) is critical so that these are used effectively (Desh Raj *et al.*, 1997 ;

Sirohi *et al.*, 2000 ; Misra *et al.*, 2001). Information obtained from correlation coefficients could be augmented by partitioning the correlations into direct and indirect contributions (effects) for the most important traits. In such a situation the correlation coefficients may be confounded with indirect effects due to common association inherent in the trait. Interrelationships, Path coefficient analysis has proven useful in providing additional information that describes cause and effect relationship (Desh Raj *et al.*, 1997 ; Sirohi *et al.*, 2000; Neeraj *et al.*, 2001 ; Sakkeer Hussain *et al.*, 2001).

Lal *et al.* (1985) studied correlation between important yield contributing characters in thirty cultivars of gladiolus and noticed that all the genotypic correlation coefficients were higher than the phenotypic correlation coefficients. The results further depicted significant positive correlations between characters like plant height and spike length ; leaf number and spike length ; leaf number and spike weight, and number of florets per spike and spike weight. Few positive correlations were also observed at the environmental levels. Plant height and leaf number correlated positively with the number of florets and spike weight, days to flower also correlated at the environmental level with spike length and spike weight, spike length also correlated with number of florets per spike.

Gowda (1989) studied the coefficient of correlations at both the genotypic and phenotypic levels for both qualitative and quantitative characters in twenty cultivars of gladiolus and observed positive

correlations between plant height and spike length, and spike weight and number of leaves. Misra and Saini (1990) worked out the coefficient of correlations at genotypic and phenotypic levels among twenty cultivars. Positively significant correlations of number of florets per spike with height of plant, number of leaves per shoot, number of florets remaining open at one time, durability of spike, number of capsules per shoot, weight of one daughter corm and 10 cormel weight were recorded. It indicated that single plant selection would be effective for its improvement since these characters had positive direct effects also. The number of shoots per planted corm was the only character, which showed negative correlation with days to flowering. The highly positive correlations was found between number of shoots per planted corm and number of daughter corms produced and equatorial diameter and weight of one daughter corm.

Positive correlations were observed for corm size with plant height, number of leaves per plant, length of flower stalk and the number of buds per stalk (Gil *et al.*, 1978).

Genotypic and phenotypic correlations along with direct and indirect effects were studied by Sandhu *et al.* (1990) for days taken to open first floret, vase life, duration of flowering, spike length, number of florets per spike and size of floret in fifteen genotypes of gladiolus. Number of florets per spike exhibited moderate to low correlations with most of the characters, whereas, spike length had significant correlation with number of florets per spike. Duration of flowering exhibited significant correlations

with spike length and number of florets per spike. Path analysis revealed that size of flower and duration of flowering were the direct components at genotypic level. Therefore, the selection for these characters could be effective. In general, it was observed that the direct effects of associated traits towards number of florets per spike were lower than that of their respective correlation (except for days taken by the first floret to open and the size of the floret).

Pant and Lal (1992) worked out correlation for fourteen component characters. The results revealed that plant height, number of leaves, leaf size, floret length, floret width, number of florets and weight of corms exhibited positive significant correlations with the spike weight. Anuradha and Gowda (1994) estimated the degree of association among some important yield contributing characters in twenty five varieties of gladiolus. The results revealed that all the genotypic correlation coefficients were higher in magnitude than their phenotypic ones. The number of florets per spike recorded a positive and highly significant association with rachis length, spike length and durability of spike. Spike length had a highly significant and positive association with plant height, rachis length and number of florets per spike. Floret diameter also had highly significant and positive correlation with floret length, spike length and plant height. Selection of parents based on characters such as rachis length, spike length and plant height would be useful in a breeding programme.

Hedge *et al.* (1997) studied path analysis in gladiolus and observed that days for first bud to loosen and number of marketable spikes per plant had the highest positive direct effects and days for spike emergence had the highest negative direct effect on spike length. Corm size, rachis length, daughter corm weight, total cormels and dormancy period had positive direct effects on spike length,

Desh Raj *et al.* (1997) studied the genetic relationship among component characters through character association and path-coefficient analysis in gladiolus and reported positive and significant associations for number of florets per spike with durability of whole spike, rachis length and plant height. It is suggested that single plant selection would be more effective for gladiolus improvement since these characters showed positive direct effects.

Correlation and path co-efficient analysis was carried out in twenty five diverse genotypes in gladiolus at 3 locations (Desh Raj *et al.*, 1998). Florets per spike observed significant positive association with rachis length in the all 3 environments and pooled values. It also showed positive significant association with plant height in all the 3 environments. Florets per spike showed positive significant correlation with durability of whole spike. However, results of pooled analysis revealed that plant height, rachis length and durability of whole spike had direct effects on florets per spike. Therefore, single plant selection for these traits will be useful for improvement of florets per spike.

Path coefficient analysis of floret traits with 10 quantitative characters was investigated in gladiolus by Anuradha *et al.* (2000). Plant height and rachis length exhibited direct effect on spike length, while floret length and plant height had direct influence on floret diameter in gladiolus.

In an another study Anuradha *et al.* (2000) recorded significant positive association for number of florets per spike with all the eight quantitative characters under study. Direct effects of spike length and rachis length were high and positive and selection based on these two characters would be useful for improvement of the trait i.e number of florets per spike.

Sirohi *et al.* (2000) studied inter-relationship and path-coefficient analysis among 17 characters of 20 varieties of gladiolus and observed that plant height, spike length, rachis length and number of florets remain open at a time had significant positive correlation with number of florets per spike, which indicated selection based on these characters would be effective in gladiolus breeding.

Sakkeer Hussain *et al.* (2000) studied correlation and path coefficient analysis of florets per spike with different characters in 25 genotypes of gladiolus. Characters like durability of whole spike, number of florets remaining open at a time, rachis length, plant height and number of cormels per plant showed a significant positive correlation with number of florets per spike. Among the characters studied, days to 50 per cent heading recorded maximum positive direct effect towards number of florets per

spike while days to first floret showing colour showed maximum indirect positive effect. In another study Neeraj *et al.* (2001) carried out correlation and path co-efficient studies in 26 genotypes of gladiolus and reported significant positive correlation of number of florets per spike with plant height, size of first floret, length of rachis, length of spike, duration of flowering, number of florets remain open at a time and size of corm. However, a significant negative correlation of number of corms per plant and number of spikes per plant was observed with number of florets per spike. The maximum positive direct effect on number of florets per spike was shown by days to first floret showing colour followed by duration of flowering, length of rachis and days to spike initiation, while maximum negative direct effect was shown by days to first floret opening.

Katwate *et al.* (2002) studied correlation and path analysis in 101 cultivars of gladiolus and observed that rachis length, plant height, spike length, interfloret length, size of second floret, number of leaves per plant, number of days to flowering and weight of corms and cormels per plant had significant positive correlation with number of florets per spike. Path analysis revealed that length per spike had the highest positive direct effect on the number of florets per spike, followed by rachis length and number of days to flowering. The workers further reported that the number of florets per spike was positively correlated with plant height, length of spike, size of second floret, number of leaves per plant, weight of corms, diameter of corm, vase life of spike and length of rachis. The maximum positive direct

effect on number of florets per spike was shown by the length of rachis followed by diameter of corm, days to flowering and vase life, suggesting the importance of these characters in gladiolus improvement. Plant height, days to flowering and inter-floret length could be indirectly used as indirect parameters for selecting high yielding types in gladiolus.

2.3 Genetic divergence studies

De and Misra (1993) assessed the nature and magnitude of genetic divergence in 25 genotypes of gladiolus using D^2 statistics. Days taken to flowering and last flowering, leaf area, number of corms and propagation coefficient constituted maximum contribution to divergence and assessment of general diversity was likely found to be more useful in elite genotypes. Selection for divergent characters would be useful for producing spectrum of new variability through hybridization.

Similarly, Arya *et al.* (1999) carried out genetic divergence studies in 25 genotypes of gladiolus using D^2 statistic and grouped the genotypes into different clusters. Cluster I and II comprised of 7 genotypes while the remaining clusters had only one or two genotypes. Intra-cluster distance was maximum (134.098) in cluster-I. While inter-cluster distance was maximum (543.084 and 4518.084) between cluster-I and cluster-VI and cluster-II and VII, respectively.

Avishai and Zohary (1980) evaluated the nature and magnitude of genetic divergence in the crosses that were performed among 33 species representing 7 recognized trends of divergence in section Oncocycles of the

genus *Iris*. All tested combinations were cross-compatible and the various F_1 inter-specific hybrids were fully fertile. It was concluded that speciation in this group did not involve the buildup of internal reproductive isolation barriers. Various species of the highly specialized insect-pollinated *Oncocyclus* irises are isolated from one another by geographic, ecological and temporal mechanisms and by the preferences of their pollinators.

Desh Raj and Misra (1999) studied genetic divergence for 20 quantitative characters in gladiolus and grouped twenty five cultivars into five clusters on the basis of D^2 statistics. Genetic divergence was not related to geographic distribution. In another study using multivariate analysis (Mahalanobis's D^2 statistics) for 20 quantitative characters in 25 cultivars of gladiolus under three environment Desh Raj and Misra (2000) observed that the cultivars got grouped into five clusters on the basis of relative magnitude of D^2 values at individual environment and pooled analysis. The maximum number of cultivars was in cluster-I at E_1 and E_3 (16 and 11), respectively and in cluster-III at E_1 (11), whereas, in the pooled analysis it was maximum in cluster-I (12). Based on cluster means the characters like days to 30 per cent heading, first floret colour showing, first floret opening, last floret opening, number of florets per spike, average weight of a corm and propagation coefficient contributed maximum towards differentiation among the 25 cultivars. Maximum genetic distance was observed between cluster IV and V (E_1 and E_3) II and V (E_2) and II and IV (pooled). However, no close correspondence was evident between

geographical distribution and genetic divergence. The study also revealed that clustering behaviour and mean performance of cultivars of individual clusters were not consistent over the environments because of larger genotype x environment interactions. It was therefore, suggested that for effecting hybridization and desired improvement the cultivars should be selected randomly from divergent clusters possessing good economic traits.

The nature and magnitude of genetic divergence was assessed in 101 genotypes of gladiolus using Mahalanobis D^2 statistics for 13 characters (Nimbalkar *et al.*, 2002). The genotypes were grouped into 12 clusters. Cluster-I was largest with 27 genotypes followed by cluster-II (24), cluster -III (19), cluster-IV (14), cluster-V (7), cluster-VI (3) and cluster-III (2). The remaining five were single genotype clusters. The maximum intra-cluster distance was exhibited by the genotypes of the cluster-III, while the lowest by the genotypes of the cluster-VII. The inter-cluster distance was maximum between the cluster-VIII and cluster-XI. The traits viz., number and weight of corms and cormels per plant, number of florets/spike, and plant height contributed considerably to divergence. No parallelism was observed between geographic diversity and genetic diversity. Based on the D^2 values and *per se* performance, divergent pairs for hybridization programme and other genotypes in possible combinations were suggested to obtain superior types with yield improvement and also remove yield constraints in gladiolus.

2.4 Genotype-environment interaction and stability studies

The value of a phenotypic is the resultant of genotype and environment and their interaction. If no genotype-environment (G x E) interactions are present, the average difference between genotypes estimated through phenotypic stability in different environments would be constant. Significant G x E interactions results from changes in the magnitude of the differences among genotypes in different environments or from changes in relative ranking of the genotypes (Allard and Bradshaw, 1964). The G x E interaction reduces the correlation between phenotype and genotype and decreases selection progress (Comstock and Moll, 1963). Success of new varieties is based on the performance for economic yield and other essential agronomic traits over a wide range of different environmental conditions (Becker, 1981). Plant breeders generally agree on the importance of good “phenotypic stability” but there is much less accord on the most appropriate definition of ‘stability’ and on statistical measure of stability in yield traits. The basic concepts of phenotypic stability have been defined as ; i) a stable genotype having a minimal variance under different environmental conditions (biological concept), or ii) a stable genotype showing minimal interaction with environments as measured by the ecovalence (agronomic concept).

A genotype showing a constant performance in most of the environments does not respond to improved growing conditions with regard to increase in yield, therefore, most agronomists no longer regard this type of stability as desirable. Their objectives is a variety which always shows

the yield expected at a level of productivity of the respective environment as measured by the average yield of all treatments in that environment, i.e., a variety that shows no genotype x environment interactions. Yates and Cochran (1938) proposed a method of partitioning the genotype x environment interaction by calculating a regression of yield of a given genotype in the different environments on the respective means of all the genotypes. This procedure, as elaborated by Eberhart and Russell (1966) has been widely used to estimate phenotypic stability and provides two statistical measures to characterize an entry viz. i) the coefficient of regression (b) which measures whether the genotype is better adapted to good environments ($b < 1$) or to most of the environments ($b = 1$) or to poorer environments ($b > 1$), and ii) the mean square for deviation from regression ($S^2 d_i$), a measure of the reliability of the linear responses.

$b < 1$ = good environment

$b = 1$ = average environment

$b > 1$ = poor environment

Lin *et al.* (1986) investigated the statistical relationship among nine stability parameters and classified them into three types. Type I stability is where a stable genotype is characterized by a small variance across all environments. Francis and Kannenberg's (1978) co-efficient of variability (C_{vi}) belongs to type-1. Type-2 stability is where stable genotypes fits a linear regression model and have a much slope. Finlay and Wilkinson's (1963) regression co-efficient (b_i) belongs to type-2, since the

regression analysis uses the mean of all cultivars included in the list as environmental index, it is a stability measure relative to the other cultivars. Eberhart and Russell's (1966) residual mean square of deviation (S^2d_i) belongs to type-3 stability. Although it has been extensively used as a stability measure, its statistical validity has been questioned because S^2d_i is an indication of how well the data fit the regression line and is not an estimate of stability (Lin *et al.*, 1986). However, in the actual experiments carried out by Eberhart and Russell (1966) the inbred lines of maize differed in their average response to varying environments, the variety x environment (linear) sum of squares was not a large proportion of the variety x environmental interaction. Hence the parameter S^2d_i appeared to be very important. However, since the variance of S^2d_i is a function of number of environments, several environments with maximum replications per environment was advocated to be necessary to obtain reliable estimates of S^2d_i .

Identification of the stable genotypes having adaptability over a wide range of agro-climatic conditions is of major significance in crop improvement with the statistical techniques developed to estimate stability parameters (Finlay and Wilkinson, 1963 ; Eberhart and Russell, 1966). It would be possible to detect genotypic differences for wider adaptability in crop improvement.

Arora and Sharma (1991) studied genotype x environment interaction in 7 cultivars to identify a stable cultivar in gladiolus. The cultivars Snow Princess, Melody, Aldebaran, Suchitra, Mayur, G-55 and

CPG-6 were planted on the first day of each month from July to December. The genotype x environment interaction (linear) and the pooled deviation mean squares (non-linear) were significant for number of cormels plant⁻¹, whereas, for the other characters the non-linear component was predominant. Mayur was a good performer as it produced the highest number of florets (16.8) and had average stability for most of the characters studied. Snow Princess took the least number of days for the basal floret to open (63.8). Melody and Suchitra were good performers but lacked stability.

Irones are the major essential aromatic compounds extracted from the rhizomes of *Iris* species (mainly *Iris pallida* and *Iris germanica*) and are used in fragrances for their scent of violets. Jehan *et al.* (1994) with a view to improving productivity and the quality of rhizomes, studied interclonal stability in the plants of single clones of *Iris pallida* and *Iris germanica*. After one year of cultivation in the field the plants averaged 1686 and 1134 mg irones per kg dried matter, respectively. Variance analysis showed that for both species the iron contents of the rhizomes of different plants were not significantly different. For selection of some promising clones with regard to their growth, iron-content and iron yield, a large number of *Iris pallida* clones were evaluated in 2 locations in France comprising Notre-Dame-doel (Oceanic climate) and Allemagneen-provence (Mediterranean climate). After one growth cycle in the field all the 3 plants per clone and per replication were harvested, mixed together and submitted to a microbiological treatment for iron determination. At Notre-Dame-doel the

iron content and iron yield differed significantly among the clones, whereas, no significant differences were observed for growth. At Allemagne-en-provence the yields were also significantly different among the clones, which resulted due to differences in the growth, the iron contents being very similar. These preliminary results indicated that growth and iron yields were higher at Notre-Damed'Oe, whereas, the iron content was higher at Allemagne-en-provence.

Desh Raj and Misra (1998a) tested twenty five genotypes of gladiolus for 8 vegetative traits over three locations in Himachal pradesh (Palampur, Shimla and Kulu) for two years (1993 and 1994). Significant mean squares due to genotype x environment interaction (linear) were observed for propagation coefficient, whereas for all the other characters mean squares due to pooled deviation were significant. 'Dhanvantari' and 'Legend' showed average stability for four characters. 'Australian Fair', showed above average stability for average weight of corm and was suitable for growing in poor environments. 'Peter pears', showed below average stability for plant height and was recommended for growing in favourable environments. By considering the stability parameters simultaneously for all the vegetative characters, three genotypes (Dhanvantari, Legend and American Beauty) were identified as being most suitable across all the six environments. In an another study, Desh Raj *et al.* (1998b) reported performance of 25 genotypes of gladiolus for stability in six environments. Significant mean squares due to genotype x environment (linear) for characters including florets per spike and rachis length indicated that a

significant portion of these interactions was due to the linear component. Mean squares due to pooled deviation were significant for all the characters, indicating the predominance of non-linear components. 'Red softglow' and 'Viola', showed high mean performance, unit regression coefficient and least deviation from regression coefficient for most of the economic characters under all the six environments.

Jhon *et al.* (1999) reported phenotypic stability for thirteen promising cultivars of gladiolus for some floral and corm traits on the basis of mean performance, regression coefficient and deviation from regression. The genotype 'Apple Blossom' had better phenotypic stability. Genotype 'Classic' was more stable for weight per corm, 'Apple Blossom' for corms per plant and 'Rose Supreme' for cormles weight per plant.

Sun-yanzhi *et al.* (2002) studied 21 gladiolus cultivars to ascertain eight qualitative binary characters, 47 qualitative polymorphic characters and 24 quantitative characters in order to set up a scientific and reasonable DUS test guide. Uniformity, stability and distinctiveness of these characters were analysed by using coefficient of variation, t-test and systematic cluster analysis. Results showed that the uniformity of all quantitative binary characters and most of the qualitative polymorphic ones were good for all cultivars, while the quantitative ones were influenced by the environment significantly and their uniformity were bad. The stability of the qualitative binary characters were relatively good. While those quantitative ones were the worst. On the basis of uniformity and stability characters, 26 relatively poor ones and 11 bad ones were screened. The first category of characters

could be used for comparing distinctiveness of cultivars, distinguishing one DUS test cultivar from another correctly and efficiently.

CHAPTER-III

MATERIALS AND METHODS

Sixty two gladiolus cultivars, obtained from the Division of Floriculture, Medicinal and Aromatic Plants, SKUAST-K, Shalimar and other parts of the Kashmir Valley were evaluated for vegetative, floral, corm and cormel production traits at three locations in the Kashmir valley in a randomized block design with three replications at each location during *Kharif*, 2002. The random locations were i) Experimental fields of the Division of Floriculture, Medicinal and Aromatic Plants, SKUAST-K, Shalimar, Srinagar, ii) Rice Research and Regional Station, SKUAST-K, Anantnag, and iii) High Altitude Rice Research Sub-station, Larnoo, SKUAST-K Anantnag. Each experimental plot consisted of 2 rows each of 4 m length. In each row 28 corms were planted with plant to plant spacing of 15 cm and rows were spaced 30 cm apart.

The experimental fields were well prepared and standard recommended package of practices followed to raise a good crop.

The geographical details of the three locations were :

- i) Experimental Farm of the Division of Floriculture, Medicinal and Aromatic Plants SKUAST-K, Shalimar.

The farm is located at the main campus, Shalimar Srinagar which is 15 km away from Srinagar city on the foot hills of Mahadev. The altitude of the location is 1685 meter above mean sea level and situated 34.0° N of latitude and 74.89° E of longitude.

- ii. Rice Research and Regional Station, Khudwani, SKUAST-K, Anantnag.

The research station is located in south Kashmir 5 km away from Anantnag town. The location is 1700 m a.m.s.l and situated $34\frac{1}{2}^{\circ}$ N of latitude and 74.0° E of longitude

- iii. High Altitude Rice Research Sub-station Larnoo, Anantnag.

The research station is located in south Kashmir 45 km away from Anantnag town. The location is 2250 m a.m.s.l and situated 34° N of latitude and 74° E of longitude.

The three locations will be referred to here in after as E_1 , E_2 and E_3 , respectively.

3.1 Materials used

The cultivars used in the present study are given in the Table 1. Besides, two local checks viz., ‘Priscilla’ and ‘Wig’s Sensation’ were used for all the locations E_1 , E_2 and E_3 .

3.2 Methodology adopted

Characters studied and observational procedures

Observations were recorded on the various vegetative, floral, corm and cormel traits in order to study the magnitude of genetic variability and level of genetic divergence in the materials. Five competitive plants were selected at random from each experimental plot in a replication and tagged for recording the biometrical observations.

Mean values for all the characters were worked out. Observations were recorded at the appropriate developmental stages of plant growth as per the description given below. The characters included for the study were:

3.2.1 Vegetative and floral traits

3.2.1.1 Days to sprout

Days taken from corm planting till the shoot emergence were recorded for each cultivar.

3.2.1.2 Plant height (cm)

Height of the tagged plants was measured in centimeter as the distance from ground level to the tip of the top most floret.

3.2.1.3 Number of leaves per plant

Total number of leaves per plant was counted and recorded for each cultivar.

3.2.1.4 Number of shoots per plant

The number of shoots per plant was counted and recorded from each cultivar.

3.2.1.5 Days to slipping (Spike emergence)

Days to slipping were recorded as number of days taken from corm planting to the slipping stage (emergence of spike) in each cultivar.

3.2.1.6 Spike length (cm)

Spike length was recorded in centimeters from the 4th leaf above to the top most floret from each representative plant in each treatment.

The test cultivars were classified on the basis of spike length as per the standards given by Wilfret (1980)

Spike length (cm)	Grade
> 107	Fancy
≤ 107	Special
≤ 97	Standard
≤ 81	Utility

3.2.1.7 Days to basal floret opening

Days taken from corm planting to the basal floret opening were recorded for each cultivar. The test cultivars were classified on the basis of days taken to basal floret opening as early, mid and late season.

3.2.1.8 Durability of basal floret (days)

Days taken from the basal floret opening till its withering were recorded for each cultivar

3.2.1.9 Number of florets per spike

The number of florets per spike from each treatment were counted and recorded.

The test cultivars were classified into four grades as per the standards followed by Wilfret (1980).

Florets spike⁻¹ (Minimum)	Grade
16	Fancy
14	Special
12	Standard
10	Utility

3.2.1.10 Number of florets open at a time

The number of florets (maximum) that remained open at a time were counted and recorded for each cultivar.

3.2.1.11 Durability of whole spike (days)

Days taken from the basal floret opening till the withering of the whole spike were recorded for each cultivar.

3.2.1.12 Size of the floret (cm)]

The size of the second floret from each representative spike was measured in centimeters when it was fully open.

3.2.2 Corm and cormel production characters

3.2.2.1 Number of corms per plant

The number of corms produced by the representative tagged plants for each treatment was counted and the average worked out. The corms included the ones that were well developed and would flower.

3.2.2.2 Weight of corm (g)

Weight of the corms in grams was recorded for all the tagged plants in a treatment per replication and average weight corm⁻¹ worked out..

3.2.2.3 Size of corm (cm)

In each cultivar size of corm was recorded in centimeters from the representative plants and average worked out.

3.2.2.4 Number of cormels per plant

The total number of cormels (pea size and above) produced per plant were counted and recorded for each cultivar.

3.2.2.5 Weight of 10-cormels (g)

Random samples of 10 cormels were taken from the pooled produce of five representative plants from each replication and weighed in grams.

3.3. Statistical and biometrical analysis

The data recorded during the present investigation was subjected to the following statistical and biometrical analyse.

- i) Analysis of variance and estimation of the components of variability,
- ii) Estimation of heritability and expected genetic gain,
- iii) Estimation of phenotypic and genotypic corelation coefficient,
- iv) Component contribution of different attributes to the number of florets per spike (Path analysis) ;
- v) Genetic divergence ; and
- vi) Stability analysis

3.3.1 Analysis of variance and estimation of the components of variance

3.3.1.1 Analysis of variance

Analysis of variance for all the characters in the individual environments (E_1 , E_2 and E_3) and for the data pooled over the environments was carried out for testing variation among the genotypes as per the procedure suggested by Verma *et al.* (1987).

3.3.1.1.1 Single environment data

The analysis was based on the following mathematical model:

$$Y_{ik} = \mu + g_i + r_k + (g)_{ik} + e_{ik}.$$

Where,

Y_{ik} = Observation of i^{th} genotype ($g = 1$ to i) in k^{th} replication
($r = 1$ to k),

μ = general mean,

- g_i = effect of the i^{th} genotype,
 r_k = effect of the k^{th} replication, and
 $(g)_{ik}$ = interaction effect of i^{th} genotype in k^{th} environment which gets confounded in e_{ik} ; and
 e_{ik} = residual random error associated with ik^{th} observation.

3.3.1.1.2 Expectations of mean square

Based on the model given above the expectations of various mean squares were derived as follows:

Source of variation	d.f.	M.S.	Expected mean squares
Replications	(r-1)	MSR	$\sigma_e^2 + g\sigma_r^2$
Genotypes	(g-1)	MSG	$\sigma_e^2 + r\sigma_g^2$
Error	(g-1)(r-1)	ME	σ_e^2

3.3.1.1.3 Pooled over environments

The analysis was based on the following mathematical model:

$$Y_{ijk} = \mu + g_i + E_j + r_{jk} + (G \times E)_{ij} + e_{ijk}$$

Where,

- Y_{ijk} = Mean of i^{th} genotype in k^{th} replicate of j^{th} environment,
 μ = overall mean,
 g_i = contribution of i^{th} genotype,
 E_j = contribution of j^{th} environment,
 r_{jk} = contribution of k^{th} replicate in j^{th} environment,
 $(G \times E)_{ij}$ = interaction between i^{th} genotype and j^{th} environment, and
 e_{ijk} = residual random error associated with ijk^{th} observation.

3.3.1.1.4 Expectations of mean square

Based on the model given above the expectations of various mean squares were derived as follows:

Source of variation	d.f.	M.S.	Expected mean squares
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Environments	(n-1)	MSE	$\sigma_e^2 + rg\sigma_{ng}^2 + rg\sigma_e^2$
Replications within Environments	r (n-1)	MSRE	$\sigma_e^2 + g\sigma_{nr}^2$
Genotypes	(g-1)	MSG	$\sigma_e^2 + r\sigma_{ng}^2 + rn\sigma_g^2$
Genotypes x Environments	(g-1) (n-1)	MSGE	$\sigma_e^2 + r\sigma_{ng}^2$
Error	(g-1) (r-1) n	ME	σ_e^2

3.3.1.2 Genotypic variance

Genotypic variance was calculated using the method suggested by Johnson *et al.* (1955) for the single environment and Al-Jibouri *et al.* (1958) for the data pooled over the environments.

3.3.1.2.1 Estimation of genotypic variance in a single environment

$$\sigma_g^2 = \frac{MSG - ME}{r}$$

Where,

σ_g^2 = genotypic variance,

MSG = mean sum of squares for the genotypes, and

ME = error mean sum of square.

r = number of replications

3.3.1.2.2 Estimation of genotypic variance from the data pooled over environments

$$\sigma_g^2 = \frac{MSG - MSGE}{r n}$$

Where,

- σ^2_g = genotypic variance among the genotypes,
MSG = mean sum of squares for the genotypes,
MSG_E = mean sum of squares for G x E interaction,
r = number of replications, and
n = number of environments.

3.3.1.3 Phenotypic variance

Phenotypic variance was also calculated by the formula devised by Johnson *et al.* (1955) for the single environment and Al-Jibouri *et al.* (1958) for the data pooled over environments.

3.3.1.3.1 Estimation of phenotypic variance in single environment

$$\sigma^2_p = \sigma^2_g + \sigma^2_{e/r}$$

Where,

- σ^2_p = Phenotypic variance,
 σ^2_g = genotypic variance among the genotypes,
 σ^2_e = error variance, and
r = number of replications

3.3.1.3.2 Estimation of phenotypic variance in data pooled over the environments

$$\sigma^2_p = \sigma^2_g + \sigma^2_{ge/n} + \sigma^2_{e/n}$$

Where,

- σ^2_p = phenotypic variance,
- σ^2_g = genotypic variance among the genotypes,
- σ^2_{gn} = genotypes x environment variance,
- σ^2_e = error variance,
- n = number of environments, and
- r = number of replications.

3.3.2 Heritability and genetic advance

3.3.2.1 Heritability (broad sense)

It was estimated in both single and data pooled over environments as per the procedure presented by Burton and Dewane (1953), Johnson *et al.* (1955) and Hanson *et al.* (1956).

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

where,

- h^2 = Estimate of heritability in broad sense,
- σ^2_g = genotypic variance, and
- σ^2_p = phenotypic variance

3.3.2.2 Genetic advance

Genetic advance at 5 per cent selection intensity was worked out using the formula given by Lush (1949) and Johnson *et al.* (1955).

$$G.A. = \frac{\sigma^2_g}{\sigma^2_p} \times (\sigma^2_p)^{0.5} \times K$$

$$\sigma_p^2$$

Where,

G.A = Genetic advance of the trait,

σ_g^2 = genotypic variance of the trait,

σ_p^2 = phenotypic variance of the trait, and

K = selection differential ; value of K at 5 per cent selection intensity being 2.06

3.3.2.3 Expected genetic gain (genetic advance as per cent of mean)

It was estimated as per the method suggested by Johnson *et al.* (1955).

$$\text{Genetic gain} = \frac{\text{GA}}{\bar{X}} \times 100$$

Where,

G.A. = Genetic advance of the trait, and

\bar{X} = mean of the trait.

3.3.3. Estimation of genotypic and phenotypic covariances and correlation coefficients

Covariance analysis followed the same pattern as that of the variance analysis. The genotypic and phenotypic covariances between two characters were obtained in the same fashion as the corresponding variances. Estimates of genotypic and phenotypic variances and covariances were substituted as per the formula suggested by Fisher (1954) and Al-Jibouri *et al.* (1958) so as to calculate correlation coefficient between any two traits.

3.3.3.1 Genotypic and phenotypic correlation co-efficients

$$r_{xy(g)} = \frac{\text{Cov.}xy(g)}{[V_x(g) \times V_y(g)]^{0.5}}$$

$$r_{xy(ph)} = \frac{\text{Cov.}xy(ph)}{[V_x(ph) \times V_y(ph)]^{0.5}}$$

Where,

$r_{xy(g)}$ = Genotypic correlation coefficient between a pair of characters viz. X and Y,

$r_{xy(p)}$ = Phenotypic correlation coefficient between a pair of characters viz. X and Y,

$\text{Cov.}xy_{(g)}$ = Genotypic covariance for a pair of characters viz., X and Y,

$\text{Cov.}xy_{(ph)}$ = Phenotypic covariance for a pair of characters viz., X and Y,

$V_{x(g)}$ = Genotypic variance for character X,

$V_{y(g)}$ = Genotypic variance for character Y,

$V_{x(ph)}$ = Phenotypic variance for character X, and

$V_{y(ph)}$ = Phenotypic variance for character Y.

The significance of correlation coefficient was tested by the formula:

$$t = \frac{r \cdot (n-2)^{0.5}}{(1-r^2)^{0.5}}$$

Where,

- n = Number of treatments, and
- r = Correlation coefficient.

3.3.4. Path co-efficient analysis:

The methodology suggested by Wright (1921) and Li (1956) was adopted while using the formula given by Dewey and Lu (1959).

Path diagram (Fig.-1) representing causes and effect relationship among various traits studied was constructed. In the diagram the double arrowed line indicated the inter-relationship between the characters as measured by correlation coefficients (r_{ij}) whereas, single arrowed lines indicated direct effects as measured by path coefficients (p_{ij}). The x variable represents residual factors.

The simultaneous equations given above are presented in matrix notation as:

$$\begin{array}{c}
 \left| \begin{array}{c} r_y \\ r_{2y} \\ \text{''} \\ \text{''} \\ r_{7y} \end{array} \right| = \left| \begin{array}{cccc} r_{1.1} & r_{1.2} & \dots & r_{1.7} \\ r_{2.1} & r_{2.2} & \dots & r_{2.7} \\ \text{''} & \text{''} & & \text{''} \\ \text{''} & \text{''} & & \text{''} \\ r_{7.1} & r_{7.2} & & r_{7.7} \end{array} \right| \times \left| \begin{array}{c} P_{1y} \\ P_{2y} \\ \text{''} \\ \text{''} \\ P_{7y} \end{array} \right|
 \end{array}$$

Or,

$$A = (B) \times C$$

Values of C vector were obtained as $C = B^{-1} \times A$ where,

B^{-1} is the inverse of mutual correlation matrix of characters. The inversion of this matrix was carried out by Pivotal Condensation Method (Singh and Choudhary, 1979).

Residual effect

$$P^2_{xy} = \{1 - (P^2_{1y} + 2 P_{1y} P_{2y} r_{12} + 2P_{1y} P_{3y} r_{13} + 2P_{1y} P_{4y} r_{14} + \dots + P^2_{2y} + 2P_{2y} P_{3y} r_{23} + 2P_{2y} P_{4y} r_{24} + 2P_{2y} P_{5y} r_{25} + \dots + P^2_{3y} + 2P_{3y} P_{4y} r_{34} + 2P_{3y} P_{5y} r_{35} + 2P_{3y} P_{6y} r_{36} + \dots + P^2_{ny})\}$$

Residual effects (R) = $(P^2_{xy})^{0.5}$

3.3.5 Estimates of genetic divergence

The genetic divergence was computed using the procedure as given by Rao (1952) and Singh and Choudhary (1979). The details of analysis are described under the following heads:

1. Test of Wilk’s criterion,
2. Transformation of correlated variables,
3. Computation of D^2 values,
4. Relative contribution of individual characters towards total divergence, and
5. Group constellation.

3.3.5.1 Test of Wilk’s criterion

Variances and covariances were obtained from analysis of variance and covariance tables and the following analysis of dispersion table was constructed.

Analysis of dispersion	
	Matrix due to
Dispersion	Sum of squares Sum of products

Due to	d.f	X^2_1	X^2_2	$X X_{1 2}$	$X X_{1 3}$	Replications
	r-1	a	b	c	d.....	
Between treatments(Q)	q	a'	b'	c'	d'.....	
Within treatments(W)	By subtraction	A-(a+a')	B-(b+b')	C-(c+c')	D-(d+d')....	
Total	n	A	B	C	D.....	

The determination of error and error + variety variance-covariance matrix were calculated by Pivotal Condensation Method and using 'V' statistics which, in turn, utilizes Wilk's criteria. A simultaneous test of differences between mean values of characters from all the genotypes (cultivars) in the present study was performed, as per the details given below:

The Wilk's test is:

$$V = -m \log eA$$

Where,

$$\lambda = \frac{W}{W + Q}$$

$$= \frac{\text{Determinant of error matrix}}{\text{Determinant of error + variety matrix}}$$

and,

$$m = n - \frac{q + k + 1}{2}$$

n = Total number of observations minus one,

q = number of variables minus one, and

k = number of characters under study.

'V' statistics so obtained was compared with the tabulated value of χ^2 for 2qk degrees of freedom.

3.3.5.2 Transformation of correlated variables

Plot means of the varieties corresponding to the characters studied were transformed to uncorrelated variables by Pivotal Condensation Method, which rendered the computation of D^2 values between any combination of two varieties to simple summation of squares of differences in transformed values for various characters. The skeleton procedure of obtaining transformed variables by Pivotal Condensation Method is described below:

Let dispersion matrix of original variables x_1, x_2, \dots, x_p be

$$\begin{array}{cccc}
 \lambda_{11} & \lambda_{12} & \dots & \lambda_{1p} \\
 \lambda_{21} & \lambda_{22} & \dots & \lambda_{2p} \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \lambda_{p1} & \lambda_{p2} & \dots & \lambda_{pp}
 \end{array}$$

and consider the extended matrix

$$\begin{array}{cccc}
 \lambda_{11} & \lambda_{12} & \dots & \lambda_{1p \times 1} \\
 \lambda_{21} & \lambda_{22} & \dots & \lambda_{2p \times 2} \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot \\
 \cdot & \cdot & \dots & \cdot
 \end{array}$$

$$\lambda_{p1} \quad \lambda_{p2} \quad \dots \quad \lambda_{pp}$$

taking λ_{11} as the first pivotal element, the first row is replaced by

$$1 \quad \lambda_{12} \quad \dots \quad \lambda_{1p} \quad x_1$$

$$\lambda_{11} \quad \lambda_{11}$$

Sweeping out first column and using the first pivotal row, following reduced matrix is obtained

$$\lambda_{22'} \quad \dots \quad \lambda_{2p'} \quad x_{2'}$$

$$\cdot \quad \cdot \quad \cdot$$

$$\cdot \quad \cdot \quad \cdot$$

$$\cdot \quad \cdot \quad \cdot$$

$$\lambda_{p2'} \quad \dots \quad \lambda_{pp'} \quad x_{p'}$$

Where,

$$\lambda_{ij} = - \frac{\lambda_{ij}}{\lambda_{11}} x_{2i}$$

$$x_i = - \frac{\lambda_{i1}}{\lambda_{11}} x_1$$

$$= V(x_i) - \frac{2\lambda_{i1}}{\lambda_{11}} \text{Cov.}(x_i x_1)$$

$$\text{Now, } V(x_i') = + \frac{\lambda_{i1}}{\lambda_{ii}} V(x_1)$$

Similarly, $\text{Cov.}(x_i' x_j) = \lambda_{ij}'$

$$= \lambda_{ii} - \frac{\lambda_{i12}}{\lambda_{11}} = \lambda_{1i}$$

$$\begin{aligned} \text{also, cov. } (x_1 x_1') &= \text{Cov. } (x_1 x_1') - \frac{\lambda_{i1}}{\lambda_{11}} v(x_i) \\ &= \lambda_{i1} - \lambda_{i1} = 0 \end{aligned}$$

So the new variables are uncorrelated.

Considering the second pivotal row

$$\begin{array}{ccc} \frac{\lambda_{23}}{\lambda_{22}'} & \frac{\lambda_{2p}'}{\lambda_{22}'} & \frac{x_2'}{22'} \end{array}$$

the further reduced matrix is

$$\left| \begin{array}{cc|c} \lambda_{33}'' & \dots & \lambda_{3p}'' \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \\ \lambda_{p3}'' & & \lambda_{pp}'' \end{array} \right| \quad \left| \begin{array}{c} \lambda x_3'' \\ \cdot \\ \cdot \\ \cdot \\ x_p'' \end{array} \right|$$

resulting into variables

$$x_1' \ x_2' \ x_3' \ \dots \ \text{with variance}$$

$$x_1^2 \ \lambda_{22}' \ \lambda_{33}'' \ \dots$$

They are all mutually uncorrelated as shown above and further x_2^2 ,

depends on x_1 and x_2 , and x_3 on x_1 , x_2 and x_3 only.

3.4.5.3 Computation of D^2 values

For each pair-wise combination of the varieties the differences in transformed values for various characters were computed and D^2 -values were calculated according to the following formula.

$$D^2 = \sum_{i=1}^P (Y_{ij} - Y_{ik})^2$$

Where,

p = Number of characters studied, and

Y_{ij} and Y_{ik} = are two transformed variables of the i th character for two genotypes

3.3.5.4 Relative contribution of individual characters towards total divergences

The ranking of differences in uncorrelated means between all the characters for all pair-wise combinations of varieties was carried out, with first rank being assigned to the highest difference. Finally relative contribution of a character towards total divergence was estimated by calculating the percentage of first rank in that character.

3.3.5.5 Group Constellation

Tocher's method was used for assigning various varieties to different clusters. The two varieties having smallest distance from each other were considered first to which a third variety having smallest average D^2 value from the first two varieties was added. Next came the nearest fourth variety and the process continued till the average D^2 value increased. The remaining varieties were then considered for the next cluster and the process was continued till all varieties were included in various clusters.

The spatial distances between clusters were arrived at by taking square root of average intra- and inter-cluster D^2 values.

3.3.6 Stability analysis

Based on the performance of the genotypes across the locations, ten elite genotypes on the basis of economic yield or (*per se* performance),

were selected and evaluated across 5 random environments comprising 5 locations (high altitude > 2000 m a.m.s.l.) and 2 locations valley basin with altitude from 1550 to 1640 m a.m.s.l.).

3.3.6.1 Analysis of variance for stability

The phenotypic stability of ten genotypes studied in five different environmental conditions was worked out following the linear model proposed by Eberhart and Russel (1966). The parameters are defined by the following model.

$$Y_{ij} = \mu_i + b_i I_j + s_{ij}$$

Where,

- Y_{ij} = mean performance of the i^{th} genotype ($I=1,2,\dots,g$) in the j^{th} environment ($j = 1,2,\dots,n$),
- μ_i = overall mean of the i^{th} genotype over all the environments,
- b_i = regression coefficient which measures the linear response of the i^{th} genotype to varying environments,
- I_j = environmental index obtained as the mean of all varieties at the j^{th} environment minus the grand mean, and
- S_{ij} = deviation from linear regression of the i^{th} genotype in the j^{th} environment.

The environmental index I_j for j^{th} environment was calculated as:

$$\left[\left(\sum_{j=1} \Sigma y_{ij} \right) \left(\Sigma \Sigma Y_{ij} \right) \right]$$

$$I_j = \frac{\sum_{i=1}^g y_{ij}^2}{g} - \frac{Y_{.j}^2}{gn}$$

Where,

$$\sum_{j=1}^n I_j = 0$$

Analysis of variance for phenotypic stability is presented below:

Source	d.f	SS
Genotypes	(g-1)	$\left[\frac{\sum y_{i.}^2}{n} - \frac{Y^2_{.}}{gn} \right]$
Environments	(n-1)	$\left[\frac{\sum Y^2_{.j}}{g} - \frac{Y^2_{..}}{gn} \right]$
Environments + (Genotypes x environment)	(n-1) + (g-1) (n-1) = g (n-1)	$\left[\sum_i \sum_j \frac{Y^2_{ij}}{n} = \frac{\sum_i Y^2_{i.}}{n} \right]$
Genotypes x Environments	(g-1) (n-1)	$\left[\sum_i \sum_j Y^2_{i,j} - \frac{\sum_i Y^2_{i.}}{n} - \frac{\sum_j Y^2_{.j}}{g} \right] + \frac{Y^2_{..}}{gn}$
Environment (Linear)	1	$\left[\frac{1}{g} \frac{(\sum_i Y_{.i} - \sum_j Y_{.j})^2}{\sum_j Y_{.j}^2} \right]$ or $\frac{1}{g} \frac{(SP)^2}{S.S. \text{ Env. Indexes}}$

(/)

Genotypes x environment (linear)	$(g-1)$	$\sum_i (\sum_j Y_{ij} - I_j)^2$	$\sum_{j1}^2 =$	-Env. (linear) S.S
Pooled deviation	$g(n-2)$	$\sum_i \sum_j \left[\sum_j Y_{ij}^2 - \frac{Y_{i.}^2}{n} \right]$	$- (\sum_j Y_{ij})^2 / (\sum_j I_j^2)$	
Genotype	1	$(n-2) \left[\sum_j Y_{1j}^2 - \frac{Y_{1.}^2}{n} \right]$	$(\sum_j Y_{1j} - \sum_{j1})^2 / \sum_{j1}^2$	
Genotype	g	$(n-2) \left[\sum_j Y_{gj}^2 - \frac{Y_{g.}^2}{n} \right]$	$(\sum_j \sum_{rgij}^2) / \sum_{j1}^2$	
Pooled error	$n(r-1)(g-1)$	Pooled replications x genotypes S.S. over environments = Me		
Total	$(gn-1)$	$\left(\sum_i \sum_j Y_{ij}^2 - \frac{Y_{..}^2}{gn} \right)$		

Where,

g = Number of genotypes,

n = number of environments,

r = number of replications,

I = environmental index,

Y_{ij} = basic observations (mean of the i^{th} genotype over replications in j^{th} environment), and

Me = pooled σ^2_e / r .

3.3.6.2 Estimation of stability parameters

i). Regression coefficient (b_i) = $\frac{\sum_j Y_{ij} - I_j}{\sum_{j=i} I_j^2}$

ii). Mean square deviation ($S^2 d_i$) from linear regression =

$$\sum_j S_{ij}^2 - S_e^2$$

$$\frac{\quad}{n-2} - \frac{\quad}{r}$$

Where,

$$\sum_j S_{ij}^2 = \left(\frac{\sum_j Y_{ij}^2 - \frac{Y_{..}^2}{n}}{n} \right) - \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

S^2_e = mean square for pooled error

3.3.6.3 Test of significance

i). Among the variety

$H_0 = g_1 = g_2 = g_3 \dots = g_n$, the appropriate test is defined as $F \approx MS_1 / MS_3$

ii). Among varieties for their regression on environmental index

$$H_0 = B_1 = B_2 = B_3 = \dots = B_g$$

$$F \approx MS_2 / MS_3$$

iii). The genetic differences among genotypes for their regression on environmental index was tested by 't' test.

$$t = \frac{b-0}{S.E. (b)}$$

where, $S.E. (b) = \left(\frac{\text{Pooled deviation MS}}{\sum_j I_j^2} \right)^{0.5}$

iv). The deviation of bi values from unity was tested as:

$$t = \frac{b \approx 1}{S.E.(b)} \quad \text{for } n-2 \text{ d.f.}$$

$$\left(\begin{array}{c} / / \\ / / \end{array} \right)$$

Where, $S.E. (b_i) = \frac{\sum_j S_{ij}^2}{n-2} \sum_j I_j^2$ ^{0.5}

For the deviation from regression of each genotype:

$$F = \left(\frac{\sum_j S_{ij}^2}{n-2} \right) / \text{M.S. pooled error}$$

CHAPTER-IV

EXPERIMENTAL FINDINGS

The results obtained in the present investigation entitled “Genetic divergence and stability performance for some economic traits in gladiolus” are presented in this chapter.

Sixty two gladiolus cultivars (Table 1) collected from different source were assessed for various vegetative, floral and corm production characters. The characters studied were days to sprout, plant height (cm), number of leaves plant⁻¹, number of shoots plant⁻¹, days to slipping (spike emergence), spike length (cm), days to basal floret opening, durability of basal floret (days), number of florets spike⁻¹, number of florets open at one time, durability of whole spike (days), size of the floret (cm), number of corm plant⁻¹, weight of corm (g), size of corm (cm), number of cormels plant⁻¹ and weight of 10 cormels (g).

Data were collected for the above mentioned metric characters and mean values of the five randomly selected plants in each of the three replications were subjected to statistical analyses. The results of the

statistical analyses and other genetic parameters for these characters are presented in the Tables 2 to 14.

Analysis of Variance

Perusal of the Table 2 revealed that the locations (environments) selected for evaluation of the materials were random and had significant effect on the expression of all the traits. The cultivars tested expressed significant variability for all the traits (both in the individual environments and in pooled analysis) and confirmed that the materials selected were diverse and possessed pool of genes for the traits. Interaction resulting from the behaviour of genotypes at different locations (G x E) was significant for all the traits except spike length revealing that the performance of a particular trait was not similar uniform for a cultivar over the test locations.

4.1 Estimates of mean, range, phenotypic and genotypic co-efficient of variations, heritability (broad sense) and expected genetic gain (per cent of mean)

The estimates were computed from the data over the environments.. Mean plant height of the cultivars was 113.91cm with a range of 89.84 to 135.28 cm (Table 3). Average days to sprout ranged from 22.05 to 29.50 with a mean of 26.17 days ; leaves plant⁻¹ ranged from 6.92 to 8.70 with a mean of 7.92; shoots plant⁻¹ ranged from 1.11 to 2.36 with a mean of 1.46; days to slipping ranged from 68.53 to 110.70 with a mean of 78.09 days ;

spike length ranged from 63.74 to 112.63 cm with a mean of 89.41 cm ; days to basal floret opening ranged from 3.92 to 5.22 with a mean of 4.49 days ; florets per spike⁻¹ ranged from 12.01 to 18.80 with a mean of 15.61; number of florets open at a time ranged from 2.91 to 4.64 with a range of 4.08; durability of whole spike ranged from 9.18 to 14.58 with a mean of 11.01 days ; size of the floret ranged from 7.87 to 11.05 cm with a mean of 9.61 cm ; corms per plant⁻¹ ranged from 1.24 to 1.96 with a mean of 1.52 ; weight of corm ranged from 17.79 to 38.80 g with a mean of 30.251 g ; size of corm ranged from 3.31 to 4.96 cm with a mean of 4.28 cm; number of cormels plant⁻¹ ranged from 12.53 to 145.73 with a mean of 46.69 and weight of 10 cormels ranged from 2.82 to 7.45 g with a mean of 5.14 g.

Magnitude of genotypic and phenotypic co-efficient of variation for days to sprout, plant height, leaves plant⁻¹, days to slipping, spike length, durability of basal floret, number of florets spike⁻¹, number of florets open at a time, durability of whole spike, size of the floret (cm), size of the corm was low (<10.0 per cent) in the materials; it was moderate (10.0-20.0 per cent) for number of shoots plant⁻¹, number of corms plant⁻¹, weight of corm and weight of 10 cormels, and high (>30.0 per cent) for number of cormels plant⁻¹ (Table 4).

Estimates of heritability (b.s) were high (>70.0 per cent) for most of the traits in all the environments and pooled analysis (Table 5) except days to sprout, number of leaves plant⁻¹, number of shoots plant⁻¹, and size of

corm (pooled analysis), and number of corms plant⁻¹ (E₁) where the estimates were moderate (≤ 40.0 to 69.9 per cent).

Genetic advance was estimated at 10 per cent of selection intensity (Table 5) and converted into expected genetic gain (per cent of mean). The estimates revealed that the expected genetic gain was high (≥ 30 per cent) for number of shoots plant⁻¹ (E₁ and E₃); days to slipping (E₃); days to basal floret opening (E₁); number of florets open at a time (E₁); number of corms plant⁻¹ (E₂ and E₃); weight of corm (E₁, E₂, and E₃ and pooled analysis); number of cormels plant⁻¹ (E₁, E₂, E₃ and pooled analysis); and weight of 10 cormels (E₁, E₂, E₃ and pooled analysis). It was moderate (10.0 to 30 per cent) for all other traits in the individual and pooled analysis except for number of leaves plant⁻¹ where it was low.

4.2 Association among traits

Correlation coefficients were estimated at both the phenotypic and genotypic levels among various vegetative, floral, corm, and cormel component traits in the individual environments and from the data pooled over the environments

(Table-6a, 6b, 6c and 6d). Genotypic correlation coefficients were, by and large, higher in magnitude, though similar in direction, than their corresponding correlation coefficients at the phenotypic level.

Character association studied in the Environment-1 (Table 6a) revealed that spike length exhibited positive and significant correlation with plant height, number of leaves plant⁻¹, number of florets spike⁻¹, size

of floret, weight of corm and size of corm at both the levels, but expressed a negative and significant correlation with days to basal floret opening and days to sprouting at both the levels. Days to basal floret opening exhibited positive and significant correlation with days to slipping at both the levels, but a negative and significant correlation with plant height, number of florets open at a time, number of florets spike⁻¹ and size of corm at both the genotypic and phenotypic levels.

Durability of basal floret (days) revealed positive and significant correlation with number of florets open at a time at both the levels. Number of florets spike⁻¹ exhibited positive and significant correlation with number of florets open at time, durability of whole spike, plant height, size of floret, weight of corms and size of corms at both the levels. Number of florets open at a time exhibited positive and significant correlation with durability of whole spike, plant height, number of leaves plant⁻¹, size of floret, weight of corms and size of corms at both the levels, and a positive significant correlation with number of cormels plant⁻¹ at genotypic level only.

Durability of whole spike exhibited positive and significant correlation with days to slipping, size of floret, number of leaves plant⁻¹ and weight of corm at both the levels, but a negative and significant correlation with number of leaves plant⁻¹ and number of corms plant⁻¹ at the genotypic level and also with numbers of leaves plant⁻¹ at phenotypic level only.

Plant height revealed positive and significant correlation with number of leaves plant⁻¹, size of floret, weight of corm and size of corm at both the levels. It exhibited significant and negative correlation with days to slipping at both the levels. Number of leaves plant⁻¹ exhibited positive and significant correlation with number of corms plant⁻¹ at both the levels. It exhibited negative correlation with size of floret at both the levels and with days to slipping at the genotypic level only.

Size of flower exhibited a significant correlation with weight of corms at both the levels. Number of corm plant⁻¹ revealed positive and significant correlation with weight and size of corm at both the levels. Weight of corm exhibited positive and significant correlation with size of corm at both the levels. Similarly, size of corm exhibited negative and non-significant correlation with number of corms plant⁻¹ at both the levels. Similar trend was exhibited by number of corms plant⁻¹ with weight of 10 cormels.

In the Environment-2 (Table 6b) spike length revealed positive and significant correlation with plant height and number of florets spike⁻¹ at both the levels. Days to basal floret opening exhibited positive and significant correlation with number of leaves plant⁻¹, days to slipping and weight of 10 cormels at both the levels. It exhibited significant and negative correlation with number of shoots plant⁻¹ at both the levels, but with size of corm at genotypic level only. Durability of basal floret exhibited positive and significant correlation with size of floret and weight

of 10 cormel, at both the levels. It revealed significant and negative correlation with days to sprouting, plant height, number of leaves plant⁻¹ and number of cormels plant⁻¹ at both the levels.

Number of florets spike⁻¹ revealed positive and significant correlation with number of florets open at a time and plant height at both the levels. It exhibited significant correlation with number of shoots plant⁻¹ at both the levels.

Similarly, number of florets open at a time exhibited positive and significant correlation with plant height at both the levels, but with size of floret and number of corms plant⁻¹ at phenotypic level only.

Durability of whole spike revealed positive and significant correlation with days to sprouting and size of corm at genotypic level only, but it exhibited negative and significant correlation with number of leaves plant⁻¹ and days to slipping at both the levels.

Days to sprouting exhibited positive and significant correlation with plant height and number of cormels plant⁻¹ at both the levels.

Plant height exhibited positive and significant correlation with number of leaves plant⁻¹ at both the levels. Similarly, number of leaves plant⁻¹ revealed positive and significant correlation with weight of corms at both the levels. However, number of shoots plant⁻¹ revealed positive and significant correlation with number of cormels plant⁻¹ and weight of 10 cormels. Days to slipping revealed significant and positive correlation with

weight of 10 cormels at both the levels. Size of florets had significant and positive correlation with weight of corm at both the levels.

Number of corms plant⁻¹ exhibited significant positive correlation with weight of corm at both the levels. Significant positive correlation was observed between weight of corm and size of corm at both the levels. Similarly, size of corm exhibited positive and significant correlation with number of corms plant⁻¹ at the genotypic level only.

Character association studied in the Environment-3 (Table 6c) revealed that spike length had positive and significant correlation with number of florets spike⁻¹, number of florets open at a time, plant height, size of florets, weight of corms and size of corms at both the levels. However, it exhibited significant and negative correlation with days to sprouting and weight of 10 cormels at both the levels. Days to basal floret opening exhibited positive and significant correlation with durability of whole spike, days to sprouting and number of cormels plant⁻¹ at both the levels. However, it exhibited significant and negative correlation with number of florets open at a time. Durability of basal floret exhibited positive and significant correlation with size of corm and number of corms plant⁻¹ at both the levels, but a negative and significant correlation with days to sprouting at both the levels.

Number of florets spike⁻¹ revealed positive and significant correlation with number of florets open at time, durability of whole spike, plant height, weight and size of corm at both the levels. Number of florets open at a time

exhibited positive and significant correlation with plant height, size of floret and weight and size of corm at both the levels, but negative significant correlation with days to slipping at the both levels.

Durability of whole spike exhibited positive and significant correlation with days to slipping at both the levels. Days to sprouting revealed negative and significant correlation with plant height and size of corm at both the levels, however, it exhibited positive and significant correlation with days to slipping at both the levels.

Plant height revealed positive and significant correlation with size of floret and weight and size of corm at both phenotypic and genotypic levels.

Days to slipping exhibited positive and significant correlation with number of corms plant⁻¹ at both phenotypic and genotypic levels. Similarly, size of floret revealed positive and significant correlation with weight of corm.

Number of corms plant⁻¹ exhibited non-significant correlation with all the traits at both the levels. Weight of corm exhibited positive and significant correlation with size of corm at both the levels, however, size of corm exhibited positive and significant correlation with number of corms plant⁻¹ at both phenotypic and genotypic levels.

Estimation of the association among various traits on the data pooled over environments (Table 6d) revealed that spike length exhibited positive and significant correlation with plant height, number of florets spike⁻¹, number of florets open at a time, durability of whole spike, number of

leaves plant⁻¹, size of florets and weight and size of corm, but a negative and significant correlation with weight of 10 cormels at both the levels. Days to basal floret opening exhibited positive and significant correlation with days to slipping, number of corms plant⁻¹ and weight of 10 cormels at both the levels. It further exhibited negative and significant correlation with number of florets open at a time, size of florets and size of corms at both phenotypic and genotypic levels.

Durability of basal floret revealed positive and significant correlation with durability of whole spike and number of corms plant⁻¹ at both the levels but it exhibited negative and significant correlation with size of florets and number of corms plant⁻¹ at both the levels, and with days to sprouting at genotypic level only.

Number of florets spike⁻¹ revealed positive and significant correlation with number of florets open at one time, durability of whole spike, plant height, size of florets, number of corms plant⁻¹ and weight and size of corm at both the levels. Similarly, number of florets open at a time revealed positive and significant correlation with plant height, size of florets, and weight and size of corm at both the levels, However, it exhibited positive and significant correlation with number of shoots plant⁻¹ at the genotypic level only. Further, it exhibited negative and significant correlation with days to slipping at both the levels.

Durability of whole spike revealed positive and significant correlation with plant height, weight of corm and number of corms plant⁻¹ at both the

levels, but with days to slipping at genotypic level only. Negative and significant correlation was exhibited with number of shoots plant⁻¹ and number of corms plant⁻¹ at the genotypic level only.

Days to sprouting exhibited positive and significant correlation with size of florets and number of corms plant⁻¹ at both the levels, but with number of shoots plant⁻¹ at genotypic level only. Plant height exhibited positive and significant correlation with number of leaves plant⁻¹, size of florets and weight and size of corm at both the levels. Negative and significant correlation existed with days to slipping at both the levels.

Number of leaves plant⁻¹ revealed positive and significant correlation with weight of corm at both the levels, with size of floret and size of corm at the genotypic level only. Negative and significant correlation was exhibited with days to slipping at both the levels. Similarly, number of shoots plant⁻¹ exhibited negative and significant correlation with days to slipping at the genotypic level only.

Days to slipping exhibited negative and significant correlation with size of florets, and weight and size of corm at both the levels. It further exhibited positive and significant correlation with weight of 10 cormels at both the levels.

Size of florets exhibited positive and significant correlation with size of corm at both the levels, but with weight of corm at the genotypic level only. However, it exhibited negative and significant correlation with weight of 10 cormels at the genotypic level only.

Number of corms plant⁻¹ exhibited positive and significant correlation with size of corm and weight of 10 cormels at the genotypic level only. Weight of corm exhibited positive and significant correlation with size of corm and number of corms plant⁻¹ at both the levels. Similarly, size of corm exhibited positive and significant correlation with number of corms plant⁻¹ at the genotypic level only.

4.3 Cause and effect relationship

Cause and effect relationship among days to sprouting, plant height, days to slipping, days to basal floret opening, spike length, durability of whole spike, size of floret, durability of basal floret, number of corms plant⁻¹, size of corm and number of cormels plant⁻¹ was worked out in relation to their direct and indirect effects on the number of florets spike⁻¹ in the individual environments and from the data pooled over the environments at genotypic level only.

In the Environment-1 (Table 7a) maximum positive direct contribution (0.629) came from plant height which also exhibited highest genotypic correlation of 0.593 with number of florets spike⁻¹. Significant direct effects were also contributed by durability of whole spike (0.300), number of cormels plant⁻¹ (0.256) and number of corms plant⁻¹ (0.179); Spike length (-0.392) and days to slipping (-0.215) exhibited negative direct effect. The maximum positive indirect effect via plant height came from spike length, via durability of whole spike from spike length, via number of cormels from number of corms. The indirect effects from days to

slipping and days to basal floret opening were again found to be negative with higher magnitude. Overall, plant height exhibited highest direct and indirect effects on the number of florets plant⁻¹, followed by durability

of whole spike. The residual effect was 0.2516 revealing that some other traits, not included in the present study, were also contributing towards the number of florets plant⁻¹.

In the Environment-2 (Table 7b) maximum direct effect was contributed by plant height (6.728) followed by days to basal floret opening (1.032) and durability of whole spike (1.005). Spike length (-5.625), days to basal floret opening (-1.066), days to slipping (-0.969) and number of corms plant⁻¹ (-0.697) had high negative direct effect. The maximum positive indirect effect came from plant height via all the characters except days to basal floret, durability of whole spike and size of floret. The indirect effects from days to slipping, spike length ; durability of whole spike and number of corms plant⁻¹ were again found to be negative with higher magnitude. The residual effect was 0.1676.

In the Environment-3 (Table -7c) days to basal floret opening (1.914) followed plant height (0.662) and durability of whole spike (0.467) was observed to contribute maximum direct effect, whereas, days to slipping, spike length and number of cormels plant⁻¹ exhibited negative direct effect to the magnitude of -2.067, -0.3094 and -0.3852, respectively. The high

indirect positive effects were again from plant height via all the traits. Spike length, durability of whole spike, days to slipping and

size of floret by and large, produced negative indirect effects. The residual effect was 0.2378.

In the pooled analysis (Table 7d) the direct effect was again maximum from spike length (1.6102) followed by durability of whole spike (0.656) days to slipping (0.4992) and number of corms plant⁻¹ (0.2294). Plant height revealed maximum direct negative effect (-1.2984). The positive indirect effect came from plant height followed by spike length and durability of whole spike via all the characters. Indirect effects from days to slipping and days to basal floret opening were again found to be negative with higher magnitude. Thus, the most important traits contributing to number of florets⁻¹ were spike length, plant height, durability of whole spike, days to slipping and number of corms plant⁻¹. The residual effect of 0.2237 revealed that some other traits were also contributing to the number of florets spike⁻¹ which have not been estimated in the present study.

4.4 *Per se* performance of some elite genotypes

Mean performance of some top ranking genotypes in the individual and across the environments (Table-8) revealed that desirable spike length of ≥ 100 cm was expressed by Sunny Boy, White Giant, Sunset Jubilee and White Prosperity in E₁ ; Sanceree, Red Majesty, Moralla, Yellow Stone and

SKG -8 in E₂; Sunset Jubilee, Red Majesty, Sunny Boy and White Giant in E₃ ; and Yellow Stone, Sunset jubilee, Red Majesty, White Prosperity and Sunny Boy across the environments. Maximum number of florets spike⁻¹ (17.22 to 18.88) was expressed by Trader-horn, Pusa Suhagin, White Prosperity, Jester and Peter Pears in E₁; in E₂ by Tropic Sea's, Mayor, Sanceree, Moralla and Peter Pears (18.13 to 19.33) ; in E₃ by Peter Pears, Regency, Big Time Supreme, Pusa Suhagin and Oscar (18.19 to 19.84) ; and across the environments by Moralla, Friendship Pink, White Prosperity, Pusa Suhagin and Peter Pears, (17.15 to 18.80). Maximum size of floret (10.59 to 11.08 cm) in E₁ was expressed by White Prosperity, Peter Pears and Trader horn; in E₂ by Pink Jewel, Ratna's Butterfly and Mayur; (10.53 to 12.36 cm) ; in E₃ by Sunset Jubilee, Oscar and Red Majesty (11.27 to 12.46 cm); and across the environments by Oscar, Moralla and Punjab Selection (10.41 to 11.05 cm). Maximum durability of whole spike (12.47 to 13.11 days) in E₁ was observed in Jackson Villa Gold, Buff Beauty and Her Majesty ; in E₂ in SKG -10, Buff Beauty and Sunny Boy (13.78 to 15.83 days) ; in E₃ in Friendship Pink, Big Time Supreme and Nazrana (13.64 to 13.93 days) ; and in the pooled over environments in White Prosperity, Buff Beauty and Friendship Pink (12.21 to 14.58 days).

Maximum days to slipping in E₁ was recorded in Aarti (108 days), CPG -6 (107 days) and Sylvia (106 days) ; in E₂ in Aarti (107.66 days), Jester Gold (90 days) and Mayur (86.33 days); in E₃ in Aarti (116.44 days); CPG-6 (112.55) and Yellow Stone (109.55 days) and across the

environments in Aarti (110.70) ; Sylvia (92.71) and Top Brass (90.30 days).

Maximum days to basal floret opening in E₁ were observed in Aarti (113.33 days), Mayur (100.66 days) and Jester (97.33 days); in E₂ in Aarti (113.33 days), Moralla (100.66 days) and Tropic Sea's (98.66 days); in E₃ in Aarti (125.26 days) CPG -6 (119.44 days) and Yellow Stone (118.93 days) ; and across the environments in Aarti (118.52 days), Sylvia (116.96 days) and CPG -6 (105.80 days).

Maximum plant height of 122.50 to 136.49 cm was expressed by Trader-horn, White Giant, Sunset Jubilee and White Prosperity in E₁; 129.00 to 134.58 by Pusa Suhagin, Yellow Stone, Sunny Boy, SKG-8 and Red Majesty in E₂ ; 140.33 to 149.47cm by White Gaint, Sunset Jubilee, Oscar and White Prosperity in E₃, and 125.29 to 135.28 cm by Yellow Stone, White Prosperity and Sunny Boy across the environments.

Highest number of florets open at a time in E₁ was observed in Rose Delight (5.13), Apple Blossom (5.8) and Punjab Selection (4.89): in E₂ in Mayur (4.91), Punjab Selection (4.89) and Moralla (4.73); in E₃ in Peter Pears (5.84), Pusa Suhagin (5.26) and Powder Puff (5.24); and across the environments in Moralla (4.67), Oscar (4.55) and Jakson Villa Gold (4.51).

Maximum durability of basal floret in E₁ was recorded in Eurovision (6.12 days), Jester Gold (5.19 days) and Rose Supreme (5.01 days) ; in E₂ in Jester Gold (6.12 days), Jester (5.19 days) and Nazrana (5.11 days); in E₃ in White Prosperity (5.93 days), Friendship Pink (5.43 days) and Her

Majesty (5.27 days) and across the environments in Yellow Frills (5.65 days), Jester Gold (5.22 days) and Jester (5.20 days).

Highest days to sprouting in E_1 was observed in Trader horn (28.86 days), King Lear (29.98) and Water Melon Pink (30.13 days); in E_2 in Sylvia (86.33 days), Vink's Glory (87.66 days), Sapna (90.00 days) and Aarti; (107.66 days) ; in E_3 , CPG-6 (112.54 days), Aarti (116.44 days) and Sylvia (119.13 days) ; and across the environments in yellow stone 28.56) and Moralla (29.50).

Maximum number of leaves plant⁻¹ (9.78 to 10.33) in E_1 were observed in CPG-6, White Gaint and White Prosperity ; in E_2 in Mayur, Rose Delight and King Lear (8.22 to 9.33) ; in E_3 in R-N-96, Oscar and Red Majesty (8.44 to 8.86) ; and in pooled over environments in Nazrana, White Giant and White Prosperity (8.50 to 8.70).

Maximum number of shoots plant⁻¹ in E_1 was recorded in Purple King (3.44), Buff Beauty (2.77) and Pusa Suhagin (2.44); in E_2 in SKG⁻¹⁰ (2.33), Buff Beauty (2.15) and Bonus Memory (1.86); in E_3 in Bonus Memory (2.44), SKG-10 (2.10) and Apple Blossom (1.89) and in pooled analysis in Bonus Memory (2.36), Apple Bloosom (1.87) and Purple King (1.77).

Highest number of corms plant⁻¹ in E_1 was observed in Purple King (2.05), Mayur (2.03) and White Prosperity (1.99); in E_2 in Jackson Villa Gold (2.75), Vinks Glorry (2.47) and Powder puff (2.25) ; in E_3 in Sylvia (3.47), Regency (2.97) and Sunny Boy (2.76) and across the environments in Regency (2.43), Sunny Boy (1.96) and Priscilla (1.94). Highest number

of cormels plant⁻¹ in E₁ was recorded in Trader horn (11.08), Peter Pears (10.97) and Jester Gold (10.88); in E₂ in King Lear (167.98), Buff Beauty (121.44) and Wind Song (101.00) ; in E₃ in King Lear (197.77), Buff Beauty (124.11) and White Prosperity (121.12) ; and across the environments in King Lear (145.73), Buff Beauty (103.95) and Friendship Pink (88.96).

Maximum weight of corm in E₁ was recorded in Yellow Stone (39.26g), Sunset Jubilee (39.10g) and White Prosperity (38.53g); in E₂ in Buff Beauty (37.82g), Jester (37.67g) and Jester Gold (36.49g) ; in E₃ in Pusa Suhagin (38.80g), Oscar (38.80g) and White Prosperity (38.41g) ; and across the environments in Pusa Suhagin (38.80g), White Prosperity (38.41g) and Sunset Jubilee (38.12g).

Maximum size of corm in E₁ was observed in Suchitra (5.12cm), Trader-horn (5.07cm) and Purple King (5.01cm) ; in E₂ in White Prosperity (4.36cm), Pusa Suhagin (4.24cm) and Vink's Glory (4.31cm); in E₃ in Oscar (5.98cm), Princess Margret Rose (5.92cm) and White Prosperity (5.87cm) ; and across the environment from Spic and Span (4.90 cm), Wig's Sensation (4.96 cm) and Wind Song (4.79 cm).

Highest weight of 10 cormels in E₁ was recorded in Wig's Sensation (6.83g), Suchitra (6.60g) and Princess Margret Rose (6.50g); in E₂ in Aarti (9.08g), Sylvia (8.70g) and Buff Beauty (8.64g) ; in E₃ in Aarti (9.05g), Purple King (9.80g) and Poonam (8.64g) ; and across the environments in Aarti (7.45g), Buff Beauty (6.98g) and Poonam (6.99g).

4.5 Estimation of genetic divergence

Genetic divergence was estimated in the 60 gladiolus cultivars under the temperate agoroacclimate conditions of Kashmir valley along with two standard checks, i.e. Priscilla and Wig's Sensation. Analysis of variance for the vegetative, floral corm and cormel components in all the individual environments (E_1 , E_2 and E_3) and in the pooled analysis over the environments. The V-statistic, which is a measure of Wilk's criteria, was significantly higher than the corresponding chi-square value in the individual environments (-) and in the combined analysis (-) revealing thereby, that the genotypes possessed significant diversity and thus, could be studied for divergence studies.

Based on the performance of the cultivars in the Environment-1, the 62 genotypes (including checks) got grouped into five clusters (Table 9a) as per the Mahalanobis D^2 analysis employing Torcher's method (Rao, 1952). Cluster-1 comprised maximum cultivars (54) followed by cluster-II (5). The remaining three clusters had one cultivar each.

In the Environment-II, 59 cultivars got grouped into cluster-I (Table 9b), whereas, the remaining three clusters had only one cultivar each.

In the Environment-III (Table 9c) the maximum number of cultivars (50) got grouped in the cluster-I followed by the grouping of four different cultivars in each of the cluster II and III. Cluster-IV had 3 cultivars, whileas, cluster-V had only one cultivar.

Pooling the performance of the gladiolus cultivars across the location, the genetic divergence revealed a totally different picture so far as the grouping of cultivars was concerned (Table 9d). Twelve clusters were formed with cluster-1 comprising 50 cultivars whereas, the remaining clusters possessed only a single cultivar except the cluster-VIII that had 2 cultivars.

The mean intra -and inter cluster distance (D^2) values for the Environments-1 (Table 10a) revealed that cluster-II had the highest intra cluster distance (D^2) value of 23.009 followed by cluster-I (18.852). The inter-cluster distance (D^2) value was highest (52.303) between cluster-III and cluster-V followed by the distance between cluster-II and cluster-IV (43.639), cluster-IV and cluster-V (40.440) and cluster-II and cluster-IV (39.778). The minimum inter cluster distance was observed between cluster-II and cluster-III (31.62). Cluster-I was observed to express maximum inter cluster distance with other clusters followed by cluster-II. Interestingly the late blooming cultivars that also possessed high corm and cormel production potential in cluster-II again expressed high inter cluster distances with most of the other clusters.

Mean intra-and inter-cluster distance (D^2) values estimated in the Environment-II (Table 10b) revealed that cluster-I had maximum intra-cluster D^2 value (17.80) followed by cluster-II and cluster-III. The inter-cluster distance (D^2) value was maximum (59.69) between the cluster-IV and cluster-III followed by the distance between the cluster-III and cluster-

II (53.80), cluster-IV and cluster-III (47.48). the cluster-I expressed maximum intra-cluster distance with rest of the clusters.

Evaluation of the cultivars for divergence in the Environment-3 (Table10c) revealed that the cluster-III had highest intra cluster distance (D^2) value of 24.77 followed by a value of 23.89 in the cluster-I .The maximum inter-cluster distance (D^2) value of 70.50 was observed between the cluster-IV and cluster-V followed by the distance between the cluster-III and cluster-IV (56.75), cluster-I and cluster-V (51.49) and cluster-II and cluster-V (49.82). Cluster-I expressed maximum intra-cluster distances with most other clusters and this cluster included high grade flower spike producing exotic genotypes recommended for commercial cultivation and their introgression into the current local cultivars would result in maximum convergence of genetic variability.

Estimation of the mean inter- and intra-cluster distances among the cultivars falling into different clusters on the basis of pooled performance of the cultivars across the environments (Table 10 d) revealed a totally different picture. All the cultivars listed got grouped into twelve (XII) clusters, with cluster-I having 50 out of 62 cultivars. The intra-cluster distance (D^2) value of cluster-I was 8.92 followed by a value of 7.86 in the cluster-VIII. The maximum inter-cluster distance (D^2) value of 26.48 was observed between the cluster-II and cluster-VIII followed by the distance between the cluster-VII and cluster-VIII (22.98), cluster-II and cluster-IX (21.81), cluster-II and cluster-XII (20.87), and cluster-I and cluster-VIII

(19.84). Cluster-II was observed to express maximum inter-cluster distance with other clusters followed by cluster-VII and cluster-I. Interestingly the high grade producing cut flower spikes, corms plant⁻¹ and cormel plant⁻¹ cultivars falling in cluster-II again expressed high inter- cluster distances with most of the other clusters.

Cluster means for different traits in the Environment-1 (Table 11a) revealed that cluster-I that had maximum cultivars (54) expressed a mean plant height of 107.36cm, produced 1.44 shoots plant⁻¹, took 80-83 days to basal floret opening, possessed 15.20 florets spike⁻¹, average of 10.34 days durability of spike, spike length of 85.11 cm and produced 10 cormel weight of 4.66 g. The corm weight plant⁻¹, on an average was 29.59g and corms plant⁻¹ were 1.49. Cormels plant⁻¹ on an average, were 38.03g and the floret size was 9.82 cm. Cluster-II had five cultivars viz, Aarti, Jackson Villa Gold, Sylvia, Sunset Jubilee and Yellow Stone with the mean plant height was 105.77 cm. The spike length and number of florets per spike⁻¹ were nearly comparable to that of cluster-I, but number of florets open at a time and durability of whole spike was slightly better (3.72; 11.15 days) than the cluster-I. The cultivars were late in slipping stage as compared to rest of the clusters. The cluster-III, cluster-IV and cluster-V had only one cultivar each (namely CPG-6, Eurovision, Buff beauty respectively) and the mean plant height ranged from 81.18 cm to 87.51 cm, but the cultivars in cluster-V were late in slipping (107.86 days) and the cultivars in cluster-III and cluster-IV were earlier in slipping taking 76.73 and 72.73 days,

respectively as compared to the cultivars in the cluster-I and cluster-II. The cormels yield plant⁻¹ was maximum in the cluster-IV and cluster-V (136.69 g and 99.00 g, respectively). The spike length and the numbers of florets spike⁻¹ was less than that of the cluster-I and cluster-II. The number of florets open at a time and durability of whole spike was less as compared to the cluster-I and cluster-II. In the cluster-V durability of the whole spike was maximum (12.91 days).

In the Environment-2 (Table-11b), the mean of the traits in the cluster-1 (comprising 59 cultivars) was 113.71 cm (plant height), 90.77cm (spike length), 18.84 (number of florets spike⁻¹), 1.36 (shoots plant⁻¹), 72.14 (days taken to slipping) 83.89 (days taken to floret opening), 10.78 (durability of whole spike), 1.35 (corms plant⁻¹) and 43.34 (Cormels plant⁻¹) The average weight of corm and weight of 10 cormels was 28.29 and 5.09 g, respectively. The performance of the traits in rest of the clusters (each having only one genotype viz. Buff Beauty, Aarti and Eurovision) revealed that the maximum plant height of nearly 119.66 cm was recorded in the cluster-IV and maximum spike length plant⁻¹ (100.00 cm) was observed in the cluster-III. The cultivar Aarti (cluster-III) and Eurovision (cluster-IV) were late in days to basal floret opening among all the cultivars tested. Cultivar Buff Beauty (cluster-II) expressed a spike length of 80.00 cm and had 13.83 florets spike⁻¹ with durability of the whole spike as 14.00 days.

In the Environment -3, cluster-I contained 50 cultivars and cluster-II and cluster-III had three cultivars each while cluster-I had only one cultivar. Perusal of the data presented in the (Table 11c) revealed that the mean plant height in the cluster-I was 121.11 cm, shoots plant⁻¹, were 1.40, days taken to slipping and days taken to basal floret opening were 78.51 and 87.48, respectively. Spike length was 97.96 cm with average number of florets spike⁻¹ being 16.11 and durability of spike was 11.60 days. The corm and cormel yield plant⁻¹ was 1.69 and 45.25, respectively with a corm weight of 33.10 g.

Cluster-II comprised four cultivars, viz, Sunset Jubilee, Top Brass, Jackson Villa Gold and Yellow Stone. The mean plant height was 131.44 cm and took nearly 99.48 and 108.52 days to slipping and to basal floret opening, respectively. The spike length was 109.70 cm bearing nearly 16.52 florets spike⁻¹ with 12.56 days durability of the whole spike. The floret size and durability of basal floret was 10.56 cm and 4.81 days, respectively. The corm and cormel number plant⁻¹ was 1.72 and 71.35, respectively. Cluster-III had a mean plant height of 131.22 cm with a mean of 1.46 shoots plant⁻¹. The genotypes Buff Beauty, Purple King, Red Majesty and White Prosperity falling in the cluster-III took lesser days to slipping and basal floret opening (79.37 days and 88.65 days respectively). The genotypes in the cluster-III had a longer spike length (105.90 cm) with an average of 15.69 florets spike⁻¹ and a durability of 12.47 days of the whole spike. The corm and cormel number plant⁻¹ was 1.86 and 111.83, respectively. The average

weight of corm and weight of 10 cormels plant⁻¹ was 39.09 and 7.08 g, respectively. The performance of other clusters revealed that the maximum plant height (117.57) ; spike length (82.68 cm) ; shoots plant⁻¹ (1.77) and minimum days to slipping (75.79) and flowering (84.84) were expressed by the cultivar Eurovision falling in the cluster-V. In the cluster-IV the cultivars Aarti, CPG-6 and Sylvia had a mean of 101.32 cm, spike length (76.68 cm), florets spike⁻¹ (13.43), days taken to slipping (11.03), days taken to basal floret opening (124.25) and corm number plant⁻¹ (2.36).

Mean of the clusters as per the performance of the cultivars across the three random environments (Table-11d) revealed 50 cultivars falling in the cluster-I had a the mean plant height of 115.35 cm with shoots plant⁻¹ (1.46), florets spike⁻¹ (15.93), spike length, (90.82 cm), durability of whole spike (11.14 days), days taken to flowering (84.72), days to slipping (77.37), durability of basal floret (4.45 days), corm number plant⁻¹ (1.50) and cormel number plant⁻¹ (44.66). The cultivar White Prosperity falling in the cluster-II had a mean height of 133.23, shoots plant⁻¹ 1.31, possessed 105.35 cm spike length, had 17.55 florets spike⁻¹, durability of whole spike 12.21 days, days to slipping 77.35, and days to flowering 82.72. Corm and cormel number plant⁻¹ was 1.70 and 83.30 respectively. Weight of corm and weight of 10 cormels was 38.41 and 5.80, respectively. The days taken to slipping and days taken to basal floret opening were comparable to that in the cluster-I. The performance of the traits in rest of the clusters (each having only one except cluster-VIII having two genotypes) revealed that the

maximum plant height of nearly 123.79 cm and 112.76 cm was recorded in the cluster-VII and cluster-III respectively and maximum spike length (91.15cm) was observed in the cluster-VII that also had 17.02 florets spike⁻¹ and 9.45 days durability of the whole spike. The cultivar Regency (cluster-VII) and Punjab Selection (cluster-III) were late and early flowering respectively, among all the cultivars tested. Cultivar, Buff Beauty (cluster-VI) expressed a cormel yield plant⁻¹ of 103.95 g and had a corm weight of 31.05g. The genotype had a spike length of 86.19 cm and possessed 13.68 florets spike⁻¹ with a durability of 12.88 days. The late flowering cultivars were Aarti, CPG-6, Sylvia (cluster-VIII and cluster-XII) taking 112.16 and 116.96 days to basal floret opening, respectively. Maximum spike length (84.05cm) was found in the cultivar Sylvia (cluster-XII) which also had 15.53 florets spike⁻¹ and recorded 9.78 days durability of whole spike.

The per cent contribution of a trait towards the total genetic divergence (Table 12) revealed that number of cormels plant⁻¹ and days to basal floret opening were the factors contributing maximum to this divergence accounting for 28.77 to 49.87 and 16.55 to 34.32 per cent in the individual environments. Whereas, in the pooled analysis the contribution to the divergence from these two traits was 3.49 and 21.63 per cent, respectively. In the Environment-I, the maximum contribution of 29.24 per cent was from number of cormels plant⁻¹ followed by 27.39 per cent from days to basal floret opening, 24.11 per cent from days to slipping and 9.10 per cent from days to sprouting. The minimum contribution was from plant

height (0.05 per cent) and number of shoots plant⁻¹ (0.16 per cent). The contribution from rest of the traits ranged from 0.58 per cent (durability of basal floret) to 3.70 per cent (durability of the whole spike).

In the Environment-II the maximum contribution of 49.87 per cent came from number of cormels plant⁻¹ followed by days to basal floret opening (16.55 per cent) and weight of corm (7.35 per cent). The minimum contribution of 0.11 per cent was from number of florets opening at a time. Rest of the traits contributed between 0.32 per cent (number of leaves plant⁻¹) to 7.09 per cent (weight of 10 cormels).

In the Environment-III also the maximum contribution of 34.32 per cent came from days to basal floret opening followed by number of cormels plant⁻¹ (28.77%); days to sprouting (12.83%) and weight of corm (7.99%). The minimum contribution of 0.16 per cent was from number of leaves plant⁻¹ and number of corms plant⁻¹. Rest of the traits contributed between 0.21 per cent (number of florets open at a time) to 7.19 per cent (weight of 10 cormels).

Pooled analysis over the environments revealed that weight of corm contributed to a maximum of 28.71% towards the total divergence followed by days to basal floret opening (21.63%), number of florets spike⁻¹ (12.96%) and plant height (10.26%). The minimum contribution was from spike length (0.21%) followed by number of leaves plant⁻¹ (0.26%). For rest of the traits the per cent contribution ranged from 0.37% (days to slipping) to 6.08% (weight of 10 cormels).

4.6 Stability in performance of some promising gladiolus cultivars.

Based on the evaluation and performance of 62 cultivars of gladiolus across the 3 random locations for genetic variability and divergence, 10 top ranking cultivars were identified on the basis of the following parameters for studying their suitability in performance over 5 random environment:

The selected cultivars were evaluated over 5 random environments located all the different agro-ecological situations representing both macro and micro environmental differences viz., i) Rice Research and Regional Station, Khudwani, Anantnag, ii) Experimental field of the Floriculture Division, SKUAST Shalimar, iii) High Attitude Rice Research sub-station, Larnoo, Anantnag and iv) Vegetable Seed Multiplication Farm, Division of Olericulture, at Faculty of Veterinary Sciences and Animal Husbandary Shuhama SKUAST. The first four locations are the constituent units of SKUAST-K. The fifth location was a farmer's field at Harwan, Srinager Kashmir.

While the first two (i & ii) and the last two locations (iv & v) represented the main valley basin area (1550-1650 ma.m.s.l), the III location represented the high attitude agro-ecology (>1800 m. a.m.s.l) with short and comparatively cooler summer.

Analysis of variance for stability in the performance of different cultivars across the 5 random environments (Table 13) revealed that mean squares due to cultivars were highly significant for all the traits viz., leaves plant⁻¹, shoots plant⁻¹, days to slipping, spike length, days to basal floret opening, florets open at a time, size of floret, corms plant⁻¹, size of corm,

cormels plant⁻¹ and weight of 10 cormels. The materials selected were divergent and possessed significant genetic variation for all these traits, except days to sprout, plant height, durability of basal floret, florets spike⁻¹, durability of whole spike and number of corms plant⁻¹. Environments selected revealed significant differences for days to sprout, leaves plant⁻¹, shoots plant⁻¹, days to slipping, spike length, days to basal floret opening, durability of basal floret, florets spike⁻¹, florets open at a time, durability of the whole spike, size of floret, weight of corm, size of corm, cormels plant⁻¹, and weight of 10 cormels, confirming that the environment selected were variable and random and influenced the expression of most of the traits selected for stability studies.

Mean squares arising due to cultivars x environments (G x E interaction) revealed that except for days to sprout, plant height, days to slipping, spike length, days to basal floret opening, durability of basal floret, number of corms plant⁻¹ and weight of corm the variance ratio was non-significant. Significant influence was exercised by the changing environments on the performance of these important morpho-logical and time related traits. Component analysis of the environment + cultivars x environments [E +(G x E)] interaction revealed that except for spike length and size of corm the [E +(G x E)] was non- significant for all the traits. However, partitioning of this variation into linear and non linear components revealed that the mean squares due to environments {linear} were highly significant for days to sprout, leaves plant⁻¹, shoots plant⁻¹,

days of slipping, spike length, days to basal floret opening, durability of basal floret, florets spike⁻¹, florets open at a time, durability of the whole spike, size of floret, size of corm, cormels plant⁻¹, and weight of 10 cormels, whereas, for rest of the traits i.e plant height, corms plant⁻¹ and weight of corm this linear component of environments was non- significant. The significant mean squares confirmed that the environments were random and different and they exercised influence on the expression of a trait having significant mean squares and this variation could be attributed to have arisen do to linear response of the regression of the cultivars to the environments. The Mean squares due to G x E (linear) were significant for days to sprout, plant height, days to sprout, days to slipping, leaves plant⁻¹, days to basal floret opening, durability of basal floret, florets spike⁻¹, durability of the whole spike, corms plant⁻¹, weight of corm, cormels plant⁻¹, and weight of 10 cormels, revealing that behaviour of the genotypes could be predicted over environments more precisely, and the G x E interaction was the outcome of linear function of the environmental components. Non significant mean squares of G x E interaction for rest of the traits (i.e shoot plant⁻¹, spike length, floret opening at a time, size of floret and size of corm) indicated possible absence of genetic differences among the cultivars for their regression on environmental index making the prediction of the performance of these traits slightly more difficult.

The non-linear component arising due to heterogeneity measured as mean squares due to pooled deviation was significant for days to sprout,

plant height, leaves plant⁻¹, shoots plant⁻¹, days to slipping, spike length, days to basal floret opening, durability of basal floret, florets spike⁻¹, durability of whole spike, size of floret, corms plant⁻¹, weight of corm, size of corm, cormels plant⁻¹ and weight of 10 cormels. These significant mean squares revealed presence of non- linear response of the cultivars to the changing environments (stability performance). The significant mean squares for pooled deviation confirmed contribution of non- linear component to total G x E interaction. The cultivars differed with respect to stability of these traits making its prediction more difficult. However, comparing the magnitude of the linear component with that of non- linear component of mean squares it was observed that the linear component i.e environment (L) and cultivars x environment (L) was many times higher than the non- linear component (pooled deviation) for most of the traits except for florets open at a time, spike length, size of corm and weight of 10 cormels. Accordingly, for the traits having linear and non- linear components to be significant i.e days to sprout, plant height, leaves plant⁻¹, shoot plant⁻¹, days to slipping, days to basal floret opening, durability of basal floret, florets spike⁻¹, durability of the whole spike, weight of corm, cormels plant⁻¹, and weight of 10 cormels, The relative magnitude of the linear component was many times higher than that of the non- linear component revealing that predication of stability could be reliable, though it may get affected to some extent. In case of shoots plant⁻¹, spike length, floret open at a time and size of corm the non- linear components were non

significant revealing that G x E interaction for these traits was greatly influenced and there existed either no relationship or the relationship was complex between cultivars and environmental effects, making prediction difficult for these traits.

Comparison of GxE interaction with non-linear components revealed that the former was non significant for all the traits (except plant height, durability of basal floret and corms plant⁻¹) thereby revealing that the non-linear component of regression of genotypes on environments was, by and large, very small and in the present case prediction for stability performance for almost all the traits except (days to sprout, plant height, durability of basal floret and corms plant⁻¹) across environments would be comparatively precise.

Estimation of the stability parameters for different traits viz., vegetative (plant height, days to flowering, leaves and shoots plant⁻¹ and days to sprouting) ; floral parameters (spike length, durability of basal floret, florets spike⁻¹, durability of the whole spike and floret size,) and yield components (corms plant⁻¹, cormels plant⁻¹, weight and size of corm and weight of 10 cormels) across five random environments in the Kashmir valley are presented in the Table-14. The stability parameters estimated were mean of the trait (\bar{X}), linear regression (b_i) and mean square deviation from the regression (S^2d_i). While \bar{X} provides a measure of the performance of a variety as compared to other entries, the b_i and S^2d_i values are the measures of the G x E interaction. In general, if G x E interaction is non-

significant or where this G x E interaction is either linear or predominantly linear as compared to its non-linear component, the prediction of stability of a genotype over environments becomes more reliable. As per the Eberhart and Russell's Model of stability, the component S^2d_i measures predictability and b_i

the stability. Stability of a genotype could be predicted more precisely if GxE interaction and S^2d_i values are non-significant.

In the present study, the mean square due to GxE interaction were non-significant for all the traits except days to sprout, plant height, durability of basal floret and corms plant⁻¹. Therefore, predictability for the genotypes having non-significant S^2d_i values for a trait would be highly precise and reliable.

The stability parameters for the plant height revealed that the mean plant height ranged from 109.61 (Apple Blossom) to 136.73cm (White Prosperity). The differences in the mean performance were highly significant for all the cultivars. Estimation of the mean square deviation from the regression (S^2d_i) was non significant for all the cultivars indicating that the non-linear component (heterogeneity from regression) was equal to zero and thus, stability for other cultivars would be precise. The linear regression (b_i) ranged from 0.008 to 0.957. However, the regression coefficient was non significant in all the cultivars and b_i value could safely be presumed to be equal to unity and thus, were average in stability. These cultivars were either poorly or well adapted to all the environments,

depending on the mean of the cultivar as compared to the population mean. While White Prosperity, Peter Pears, Jackson Villa Gold and Yellow Stone were well adapted the Apple Blossom, Moralla, Sanceree, Big Time Supreme and Friendship Pink were poorly adapted to the average environment.

Estimates of stability for days to spout revealed that days taken to spouting ranged from 24.97 (White Prosperity) to 31.37 (Moralla). The mean square deviation from regression (S^2d_i) was significant for the cultivars viz. Apple Blossom, Big Time Supreme, Jackson Villa Gold, Peter Pears, Sanceree, White Prosperity and Yellow Stone, making it difficult to predict the stability for this trait over the environments. The linear regression (b_i) was non significant (equal to zero) for all the cultivars and it ranged from 0.06 to 1.78 indicating that the cultivars Friendship Pink, Moralla and Traderhorn were either poorly or well adapted to these environments. Friendship Pink, White Prosperity and Sanceree were slightly earlier in days to sprouting as compared to Big Time Supreme, Jackson Villa Gold, Moralla, Traderhorn and Yellow Stone.

Among the vegetative component traits, the leaves plant^{-1} revealed a mean value ranging from 7.54 to 8.97. The mean square deviation from regression (S^2d_i) was non-significant for all the cultivars and thus, prediction of stability of this trait across the environments would be precise and more reliable. The linear regression values (b_i) ranged from 0.20 to 1.92. White Prosperity and Big Time Supreme had b_i values significant and

more than unity. These cultivars were below average in stability and thus, adapted to unfavourable environments for this trait. On the other hand, Yellow Stone, Peter Pears, Traderhorn and Sanceree had significant and less than unity linear regression and were above in stability and thus, suitable for good environments. For rest of the cultivars viz, Peter Pears, Moralla, Jackson Villa Gold, Friendship Pink and Apple Blossom the linear regression did not deviate significantly from unity ($b_i=1$) and thus, had average stability and these cultivars were either poorly or well adapted to all the environments. Perusal of their mean value revealed that White Prosperity, Traderhorn, Peter Pears and Moralla were well adapted whereas, Apple Blossom, Big Time Supreme, Friendship Pink and Jackson Villa Gold were poorly adapted to all the environments.

Shoot plant⁻¹ revealed that the mean number of shoots ranged from 1.35 to 1.87. Mean square deviation from regression (S^2d_i) was non-significant for all the cultivars revealing that the values were equal to zero. The prediction of stability for this trait across the environments would thus, be precisely reliable. The linear regression values (b_i) ranged from 0.26 to 2.08, The cultivars Apple Blossom, Peter Pears and Traderhorn had b_i value significantly more than unity and thus, these two cultivars were below average in stability and specially adapted to poor environments. Jackson Villa Gold, Yellow Stone, Big Time Supreme, Friendship Pink, Moralla and Sanceree cultivars had linear regression coefficient significantly less than unity and thus, were above average in stability and specially adapted

unfavourable environments. For rest of the cultivar the linear regression coefficient was non-significant and equal to unity and these cultivars were average in stability and either poorly or well adapted to all the environments. Perusal of the mean value of these cultivars, revealed that, by and large, these cultivars though stable in performance, were mostly poorly adapted to all these environments.

Days to slipping revealed that the mean value ranged from 65.83 to 93.58 days across the environments. The non-linear component of regression (S^2d_i) was significant for the cultivars except Apple Blossom and Yellow Stone making it difficult to predict the stability for these two cultivars. The linear regression values (b_i) ranged from 0.35 to 3.44 with b_i value for Yellow Stone only being significant i.e, the value deviated from unity. This cultivar had significant S^2d_i as well. Rest of the cultivars had non-significant S^2d_i values and linear regression newly equal to unity. The stability was average and these cultivars were either poorly or well adapted to all the environments. While Big Time Supreme, Jackson Villa Gold, Moralla, Traderhorn and Yellow Stone were slightly late in slipping. The Friendship Pink, Apple Blossom, Peter pears, Sancerree were slightly earlier in slipping as compared to mean (78.44 days).

The stability parameters for the spike length revealed that the mean spike length ranged from 85.48 (Apple Blossom) to 109.29cm (White Prosperity). The difference in the mean performance was highly significant for all the cultivars. Estimation of the mean square deviation from the

regression (S^2d_i) was significant for all the cultivars except Friendship Pink and Peter Pears, indicating that the prediction for stability for these cultivars would be unrealistic. The linear regression (b_i) ranged from 0.51 to 1.56 and the values were non-significant. Thus, stability for the cultivars having non significant S^2d_i would be precise. Both the cultivars Friendship Pink and Peter Pears had less than average performance but had stability across the locations.

Estimates of stability for days to basal floret opening ranged from 76.80 (Apple Blossom) to 105.90 days (Yellow Stone). The mean square deviation from regression (S^2d_i) was significant for Apple Blossom, Big Time Supreme, Jackson Villa Gold, Peter Pears, Traderhorn, White Prosperity and Yellow Stone making it difficult to predict the stability for this trait over the environments. The linear regression (b_i) was non-significant (equal to unity) for all the cultivars except yellow stone and it ranged from 0.33 to 2.92 indicating that the cultivars Friendship Pink, Moralla and Sinceree were either poorly or well adapted to these environment. Apple Blossom, Friendship pink, Peter Pears and Sinceree were slightly earlier in days to flowering as compared to Big Time Supreme, Jackson Villa Gold, Moralla and Yellow Stone.

Stability for durability of basal floret revealed that the non-linear component (S^2d_i) was equal to zero for all the cultivars and hence prediction of stability for these cultivars could be precise and reliable. The linear regression coefficient (b_i) for all the cultivars was non-significant

and equal to unity except Friendship pink and White Prosperity. These cultivars were average in stability and either poorly or well adapted to all the environments depending on the cultivars mean value. Apple Blossom, White Prosperity and Yellow Stone had higher mean values as compared to population mean and were well adapted to all the environments. Whereas, Jackson Villa Gold, Moralla and Traderhorn had less than the population mean and were poorly adapted to all the environments.

The most important component (number of florets spike⁻¹) revealed that the mean number of florets spike⁻¹ of these cultivars across the environment ranged from 15.53 to 18.70. The mean square deviation from regression (S^2d_i) was non significant for all the cultivars except Apple Blossom, Moralla and Sancere and could be presumed to be equal to zero and thus, making it possible to predict the stability of all the cultivars across the environment. The linear regression coefficient (b_i) was non-significant for all the cultivars except Apple Blossom and Big Time Supreme and thus, equal to unity. All the cultivars having non-significant b_i values ($b=1$) were average in stability and were either poorly or well adapted to all the environments depending on their mean number of florets spike⁻¹. Taking into consideration the number of florets spike⁻¹ of these cultivars in comparison to over all population mean, the cultivars Friendship Pink, Moralla, Peter Pears and White prosperity were well adapted to all the environments, whereas, Apple Blossom, Big Time Supreme, Jackson Villa Gold, Traderhorn and Yellow Stone were poorly

adapted to all the environments. The cultivar Apple Blossom and Big Time Supreme had significantly higher b_i values and were below average in stability and specially adapted to the unfavourable environments.

For number of florets open at time the regression coefficient (b_i) and mean square deviation from the regression (S^2d_i) was equal to zero for all the cultivars and thus, making it possible to predict stability across the environments. The b_i values for all the cultivars were equal to unity, revealing that these cultivars were average in stability and were either poorly or well adapted to all these environments. Judging from the mean performance of these cultivars in comparison to the population mean it was observed that Friendship Pink, Jackson Villa Gold, Moralla and Peter Pears were well adapted; whereas, Apple Blossom, Big Time Supreme, Sanceree, Trader horn, White Prosperity and Yellow Stone were poorly adapted to all these environments.

Durability of whole spike (days) revealed that the mean square deviation from the regression (S^2d_i) was non significant and equal to zero for all the cultivars except Friendship Pink and Traderhorn, making prediction of stability possible. The b_i values for all the cultivars was equal to unity revealing that these cultivars were average in stability and were either poorly or well adapted to all these environment. Judging from the mean performance of these cultivars in comparison to the population mean it was observed that Big Time Supreme, Jackson Villa Gold, and White Prosperity were well adapted, whereas, Apple Blossom, Moralla, Peter

Pears, Sanceree and Yellow Stone were poorly adapted to all these environments.

Size of the floret revealed that the mean size of floret ranged from 9.48 to 11.27 cm. Mean square deviation from regression (S^2d_i) was non-significant for all the cultivars revealing that the values were equal to zero. The prediction of the stability for this trait across the environments would thus, be precise and reliable. The linear regression values (b_i) ranged from 0.18 to 1.80. The cultivars, White Prosperity and Yellow Stone had b_i value significantly more than unity and thus, these two cultivars were below average in stability and specially adapted to unfavorable environments. Peter pears, Friendship Pink and Big Time Supreme had linear regression coefficient significantly less than unity and thus, were above average in stability and specially adapted to favorable environments. For rest of the cultivars the linear regression coefficient was non-significant and equal to unity and these cultivars were average in stability and either poorly or well adapted to all the environments. Perusal of the mean values of these cultivars revealed that, by and large, these cultivars though stable in performance were mostly poorly adapted to all these environments.

Number of corms plant⁻¹ revealed that the non-linear component (S^2d_i) was equal to zero for all the cultivars and hence prediction of stability for all these cultivars could be precise and reliable. The linear regression coefficient (b_i) were non significant except in case of Friendship Pink, Moralla, Peter pears and Sanceree and thus, equal to unity. All the

cultivars having non significant b_i values ($b=1$) were average in stability and were either poorly or well adapted to all the environment depending on their mean number of corms plant⁻¹. Taking into consideration the number of corms plant⁻¹ of these cultivars in comparison to over all population mean, the cultivars Friendship Pink, Moralla, Peter Pears and White Prosperity were well adapted to all the environment, where as, Apple Blossom, Big Time Supreme, Sanceree, Traderhorn were poorly adapted to all the environments. The cultivars Friendship Pink and Peter Pears had significantly higher b_i value and were below average in stability and specially adapted to the unfavourable environment.

Weight of corm revealed that the non-linear component (S^2d_i) was equal to zero for Friendship Pink, Moralla, Sancere and White Prosperity and hence prediction of stability for these cultivars could be precise and reliable. The linear regression coefficient (b_i) for all the cultivars was non significant and equal to unity except for Sanceree and Traderhorn, thus these cultivars were average in stability and either poorly or well adapted to all the environments depending on the cultivars mean value. White Prosperity and Yellow Stone had higher mean values as compared to population mean and were well adapted to all the environments, whereas, Friendship Pink, Moralla, and Sanceree had less than the population mean and were poorly adapted to all the environment.

Stability for size of corn revealed that mean square deviation from regression (S^2d_i) was equal to zero for all the cultivars making possible to predict stability across the environments. The b_i value for all the cultivars

were equal to unity, revealing that these cultivars were average in stability and were either poorly or well adapted to all these environment. Judging from the mean performance of these cultivars in comparison to the population mean it was observed that Big Time Supreme, Peter Pears, Traderhorn, Yellow Stone and White Prosperity were well adapted; where as, Apple Blossom, Friendship Pink, Jackson Villa Gold, Moralla and Sanceree were poorly adapted to all these environments.

For number of cormels plant⁻¹ the mean square deviation from regression (S^2d_i) was equal to zero except in case of Jackson Villa Gold, Moralla, Traderhorn and White Prosperity, making it possible to predict stability across the environments. The b_i values for all the cultivars were equal to unity (except for White Prosperity), revealing that these cultivars were average in stability and were either poorly or well adapted to all these environments. Judging from the mean performance of these cultivars in comparison to the population mean it was observed that Apple Blossom and Friendship Pink were well adapted ; whereas, Big Time Supreme, Peter Pears, Sancere, and Yellow Stone were poorly adapted to all the environments.

Estimates of stability for weight of 10 cormels ranged from 3.72 (Apple Blossom) to 6.98 g (Peter Pears). The mean square deviation from regression (S^2d_i) was non-significant for all the cultivars revealing that the values were equal to zero. The prediction of stability for this trait across the environments would thus, be precise and reliable. The linear regression values (b_i) ranged from 0.05 to 2.86. The cultivar peter pears had b_i value

significantly more than unity and thus, the cultivars were below average in stability and specially adapted to unfavorable environment. For rest of the cultivars the linear regression of the coefficient was non-significant and equal to unity and these cultivars were average in stability and either poorly or well adapted to all the environments. Perusal of the mean values of these cultivars revealed that, by and large, these cultivars though stable in performance were well adapted to all these environments, except Apple Blossom, Jackson Villa Gold, Sanceree and Yellow Stone that were poorly adapted to all these environments.

CHAPTER-V

DISCUSSION

The success of any breeding programme depends on the presence of sufficient genetic variability to pursue effective selection. It is important to assess the relative magnitude of variability in order to use such information together with other selection parameters for the improvement of plant type through selection of effective breeding methods (Johnson *et al.*; 1955; Hanson *et al.*; 1956; Williams 1964; Briggs and Knowle's, 1967). Genetic variability (GCV) helps to choose a particular genotype, whereas, heritability (h^2) along with genetic advance (percent of mean) are more useful in predicting the resultant effect of selection of best genotypes.

Knowledge on the extent of genetic variation and diversity for colour, size, shape and flowering times, inflorescence component traits, durability and quality traits in traditional gladiolus cultivars and subsequent identification of land races as potential donors in gladiolus for improvement programmes is therefore, essential (Sakkeer Hussian. *et al.*, 2001 ; Misra *et al.*, 2001 ; Desh Raj *et al.*, 2001). These workers further emphasized the importance of such gene pools in the development of gladiolus cultivars possessing better economic traits like number of florets spike⁻¹, rachis length, floret diameter and other quality traits.

Gladiolus possesses a tremendous capacity to tolerate climatic stresses and has been subjected to rigorous human selection mostly for

numerous ornamental qualities and in such a process other components of economic traits also appear to have accumulated considerable variations through correlated response to selection. Robinson (1966) recommended that germplasm pools be created to provide a reservoir of gene complexes and to form the base for the profitable selection studies. Such germplasm resources offer an array of materials for incorporation in the breeding programmes, with the possibility of extending economic traits from a wider genetic base. Since most of the characters are quantitatively inherited and are subjected to different degrees of non-heritable variability therefore, good knowledge about the gene action is essential for making any improvement. The magnitude of genetic component of heritable variation is most important for the estimation of genetic constitution of breeding materials which subsequently leads to higher selection response.

In the Kashmir valley, the expansion of areas under a few genetically uniform and highly productive gladiolus cultivars has led to the risk of genetic erosion of land races/tested gladiolus cultivars growing over since half a century in the agro- and/or location specific regions. These current test germplasm resources have now been pushed into smaller areas and are likely to face the extinction. The current test cultivars/land races are best known for their high quality parameters, though they have an inherent low yielding capacity. Judging from the importance of bio-diversity for these gladiolus cultivars/land races, it is important to document them for use in the future breeding programmes involving exotic and current test cultivars.

The present study was accordingly chosen to estimate the genetic variation for economic traits, durability of spike and quality parameters present in these current test cultivars/ land races of Kashmir valley and to estimate the genetic divergence and their stability parameters.

Potent variability in genotypes is the result of prolonged natural and artificial selection, which is heritable, and accumulation of the significant magnitude of variability for economic traits leads to the genetic diversity, which is important for creation of new genetic variability through hybridization and re- organization of new gene constellation. An effective gladiolus varietal improvement programme must have sound objectives based on the needs of farmers and consumers (Negi *et al.*, 1982 ; Misra and Saini, 1990, 1988 ; Cohat, 1988 ; Chadha, 1993 ; Misra *et al.*, 2001 ; Nagaraja and Parthasarthy, 2001) and for a plant breeding programme to improve inflorescence with a good ornamental value, self colour, excellent stem strength and good disposition and attachment of the flowers (Desh Raj *et al.*, 1997 ; Misra *et al.*, 2001 ; Sirohi *et al.*, 2000 ; Sakkeer *et al.*, 2001). Information on genetic variability and inter-relationship is necessary in traditional cultivars and subsequent identification of land races as potential donors in gladiolus improvement programmes is therefore, essential. Misra and Saini (1990), Desh Raj *et al.* (1997), Sirohi *et al.* (2000), Sakkeer *et al.* (2001) and Misra *et al.* (2001) have emphasized the importance of such gene pools in the development of gladiolus cultivars possessing better economic and quality traits.

Genetic variability, heritability and expected genetic gain

In the present study 62 gladiolus cultivars were tested under different agro-climatic conditions of the Kashmir Valley, along with two standard check varieties, for the presence of genetic variability estimation of genetic parameters and genetic diversity.

The present study on the vegetative, floral and corm production traits revealed that significant genetic variability existed in these current test cultivars. Analysis of variance for the quantitative characters revealed presence of significant genetic variation for all the characters. Interaction resulting from the G x E interaction was also significant for all the traits except spike length.

Mean plant height ranged from 89.84 (CPG-6) to 135.28 (Sunny Boy) with a mean of 113.91 cm ; other traits like days to sprout ranged from 22.05 (Pusa Suhagin) to 29.90 (Moralla) with a mean of 26.17 ; number of leaves plant⁻¹ varied from 6.92 (Sapna) to 8.70 (White Prosperity) with a mean of 7.92 ; number of shoots plant⁻¹ ranged from 1.11 (Eurovision) to 2.36 (Bonos Memory) with a mean of 1.46 ; days to slipping ranged from 68.53 (Rose and Wine) to 110.70 (Aarti) with a mean of 78.09. Spike length in these cultivars ranged from 63.75 (CPG-6) to 112.63 cm (Sunny Boy) with a mean of 89.41 cm. Days to basal floret opening ranged from 74.87 (Trader horn) to 118.52 (Aarti) with a mean of 86.01 and durability of basal floret ranged from 3.92 (Purple King) to 5.65 (Yellow Frills) with a mean of 4.49 days.

The most important trait viz., florets spike⁻¹ ranged from 12.01 (R.N-96) to 18.80 (Peter Pears) with a mean of 15.61, whereas, number of florets open at a time ranged from 2.91 (Aarti) to 4.64 (Moralla) with a mean of 4.08.

Durability of whole spike (days) ranged from 9.18 (Bis Bis) to 14.58 (Friendship Pink) with a mean of 11.01 days, whereas, size of the floret ranged from 7.87 (King Lear) to 11.05 cm (Punjab Selection) with a mean of 9.61cm.

Number of corms plant⁻¹ ranged from 1.24 (Tropic Sea) to 2.43 (Regency) with a mean of 1.52; weight of corm ranged from 17.79 (Aarti) to 38.82 (Pusa Suhagin) with a mean of 30.25 g ; size of corm ranged from 3.31 (CPG-6) to 4.96 (Wig's Sensation) with a mean of 4.28 cm ; number of cormels plant⁻¹ ranged from 12.53 (Bindiya) to 145.73 (King Lear) with a mean of 46.09 and the weight of 10 cormels ranged from 2.82 (Bindiya) to 7.45 (Aarti) with a mean of 5.14g.

Evaluation of the cultivars over three random environments revealed that the early flowering genotypes were Traderhorn, Apple Blossom, Punjab Selection, Suchitra, Buff Beauty, Peter Pears, Sapna, Her Majesty and White Goddess. The maximum days to slipping were observed in Aarti and Top Brass. Maximum spike length was found in Sunny Boy, Her Majesty and White Prosperity, while number of florets spike⁻¹ were more in Peter Pears, Pusa Suhagin and White Prosperity. Maximum size of the floret (cm) was observed in Punjab Selection, Purple King and Moralla.

Maximum days to basal floret opening were observed in Aarti, Sylvia and CPG-6. Maximum durability of basal floret was observed in Yellow Frills, Jester Gold and Jester, whileas in case of durability of the whole spike (days) the cultivars Friendship Pink, Buff Beauty and Jackson Ville Gold were top ranking.

Among the corm and cormel production characters King Lear, Buff Beauty and Friendship Pink were good for number of cormels plant⁻¹, whileas, in number of corms plant⁻¹ the cultivars like Regency, Sunny Boy, Priscilla and Moralla were top ranking. Maximum size of corm was observed in Wig's Sensation, Spic and Span, Wind Song and Oscar, but maximum weight per corm was observed in Pusa Suhagin, White Prosperity and Oscar. The weight of 10 cormels (g) were observed in Aarti, Poonam and Buff Beauty.

Coefficient of variation (both phenotypic and genotypic) was high for number of cormels plant⁻¹, moderate for number of shoots plant⁻¹, days to basal floret opening, number of corms plant⁻¹, weight per corm and weight of 10 cormels, while for other traits the parameters were low (Table-3).

Heritability estimates were high (≥ 70 per cent) for plant height, number of leaves plant⁻¹, days to slipping, spike length, durability of basal floret, days to basal floret opening, number of florets open at a time, durability of whole spike, weight of corm, number of cormels plant⁻¹ and weight of 10 cormels. It was moderate (≥ 40.0 to 69.9 per cent) for size of

the floret, size of corm, number of leaves plant, number of shoots plant⁻¹, days to slipping, spike length, durability of basal floret.

The expected genetic gain (per cent of mean) was high (>30%) for number of shoots plant⁻¹, number of corms plant⁻¹, weight of corm (g), number of cormels plant⁻¹ and weight of 10 cormels (g). It was moderate (10 to 30%) for days to sprout, plant height, number of leaves plant⁻¹, days to basal floret opening, durability of basal floret (days), spike length (cm), florets spike⁻¹, durability of whole spike (days), size of the floret (cm) and size of corm (cm).

Several workers have reported higher magnitude of genetic variability, genotypic and phenotypic coefficient of variation, heritability and genetic gain in gladiolus. Higher magnitude of genotypic variability and genotypic coefficient of variation have been reported for plant height (Lal and Singh 1978 ; Loeser, 1981 ; Lal *et al.*, 1984 ; Singh and Singh, 1987 ; Pant and Lal, 1991; Soorianathasundaram and Nambisan, 1991; Sheikh *et al.*, 1995 ; Desh Raj and Misra 1996 ; Katwate *et al.*, 2002), whereas, Misra and Saini, (1988) reported it moderate for this trait. Similarly, high genotypic coefficient of variation for shoots plant⁻¹ has been reported by Singh and Singh, (1987) and Misra and Saini, (1988). However, moderate to low genotypic coefficient of variation for days to slipping (spike emergence) has been reported by Khanna and Arora (1986). For spike length low estimates of genotypic coefficient of variation have been reported (Khanna and Arora, 1986 ; Arora and Khanna, 1986 ; Singh and

Singh, 1987 ; Misra and Saini, 1988 ; Pant and Lal, 1991 ; Sarangi *et al.*, 1994 ; and Sheikh *et al.*, 1995 and Patil *et al.*, 2002). Similarly lower estimates of genotypic coefficient of variation have been reported for days to basal floret opening (Arora and Khanna, 1986 ; Khanna and Arora, 1986 ; Singh and Singh, 1987 ; Misra and Saini, 1988 ; Pant and Lal, 1991 ; and Soorianathasundaram and Nambisan, 1991), whereas, Lal *et al.* (1985) reported it high for this trait. For number of corms plant⁻¹ a moderate genotypic coefficient of variation has been reported by Pant and Lal (1991) and Sheikh *et al.* (1995). High genotypic coefficient of variation for weight of corm has been reported by Pant and Lal. (1991). For number of cormels plant⁻¹ high genotypic coefficient of variation has been reported by Pant and Lal (1991), Khanna and Arora (1986), Singh and Singh (1987), De *et al.*, (1993), Sheikh *et al.*, (1995) and Desh Raj and Misra (1996), whereas, Misra and Saini (1988), Negi *et al.* (1982) and Ashwath and Parthasarathy (1994) reported moderate genotypic coefficient for this trait. Similarly, high genotypic coefficient of variation for weight of 10 cormels has been reported by Negi *et al.* (1982); Misra and Saini (1988), Pant and Lal (1991) ; Ashwath and Parthasarathy (1994) ; Sheikh *et al.* (1995) and Desh Raj and Misra (1996).

High heritability estimates for plant height, spike length, shoots plant⁻¹, days to slipping, days to basal floret opening, number of florets spike⁻¹ and size of floret have been reported by Negi *et al.* (1982), Arora and Khanna (1986), Misra and Saini (1988), Lal *et al.* (1985), Singh and

Singh (1987), Cohat (1988), Gowda (1989), Pant and Lal (1991), Soorianatha-sundaram and Nambisan (1991), De *et al.* (1993), Mahanta and Paswan (1993), Prasad *et al.* (1994), Sheikh *et al.* (1995) and Desh Raj and Misra (1996). For number of corms plant⁻¹, number of cormels plant⁻¹ and weight of 10 cormels high heritability has been reported by Arora and Khanna (1986), Anuradha and Gowda (1990), De *at al.* (1993), Negi *et al.* (1982), Singh and Singh (1987), Pant and Lal (1991), Misra and Saini (1988), Sheikh *et al.* (1995), and Desh Raj and Misra (1996).

Expected genetic gain was reported high for plant height by Singh and Singh (1987), Cohat (1988) and Pant and Lal (1991) ; moderate by Lal *et al.* (1985), Gowda (1989) and Soorianathasundaram and Nambisan (1991) ; and low by Misra and Saini (1988), and Sheikh *et al.* (1985) and Desh Raj and Misra (1996). For number of shoots plant⁻¹ high genetic gain has been reported by Misra and Saini (1988) and moderate by Singh and Singh (1987). Similarly, for days to basal floret opening high genetic gain has been reported by Misra and Saini (1988), Cohat (1988) and Desh Raj and Misra (1996), but Singh and Singh (1987), Gowda (1989) and Pant and Lal (1991) observed lowgenetic gain for this trait. For number of florets spike⁻¹ high expected genetic gain has been reported by Lal *et al.* (1985), Arora and Khanna (1986), Khanna and Arora (1986), Singh and Singh (1987), Cohat (1988), Gowda (1989) and Sooriana-thasunderam and Nambisan (1991). For number of corms plant⁻¹, a moderate expected genetic gain has been reported by Sheikh *et al.* (1995). Expected genetic gain was reported

high for weight of corm by Pant and Lal (1991), Arora and Khanna (1986), Singh and Singh (1987), Pant and Lal (1991) and Shiekh *et al.* (1995). Similarly, expected genetic gain was reported high for weight of 10 cormles by Pant and Lal (1991), Mahanta and Paswan (1993), Sarangi *et al.* (1994) and Sheikh *et al.* (1995). Number of cormels and 10 cormel weight showed high heritability along with high genetic advance, suggesting thereby the basis for selection for further breeding programme (Anuradha and Gowda, 1990).

Presence of high genotypic and phenotypic coefficient of variation is expected to help in the isolation of desirable genotypes. However, genotypic coefficient of variation alone is not sufficient for determination of magnitude of heritable variation. Burton (1952) suggested that genotypic coefficient of variation together with heritability estimates would give better picture of the expected genetic gain from selection. Higher heritability estimates along with high genetic gain are usually more useful than either of these parameters taken alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955). Falconer (1960) suggested that genotypic and phenotypic error variances are not helpful in determining heritable portion of the variation unless heritability is not estimated.

Low expected genetic advance results more from low genetic variance/genotypic coefficient of variation rather than due to moderate or low heritability estimates (Singh *et al.*, 1984). Panse (1957) reported that

high genetic advance and high heritability is the outcome of additive gene action and vice versa indicating the presence of more non-additive gene action (Dominance and/or epistasis). Paramasivan (1988) suggested that high heritability with moderate genetic advance arises from dominance and or/epistasis effects. Lal *et al.* (1985^a) observed that presence of high heritability along with lower genetic gain for a number of vegetative and floral characters indicated that non-additive gene effects were equally important in the inheritance of these traits.

However, the present studies does not support the findings of earlier workers in totality. This might have been due to a change in the physiological mechanism as one of the three sites of present study represented a much higher altitude (cool temperate) that helped in the growth of a better crop.

In the present set of materials the traits like number of corms plant⁻¹, weight of corm, number of cormels plant⁻¹ and weight of 10 cormels had high heritability and expected genetic gain and are expected to be governed by more additive gene effects. Improvement in these traits could be made through crossing and Subsequent selection in the existing germplasm materials as also suggested by earlier workers (Misra and Saini, 1998 ; Negi *et al.*, 1982 ; Anuradha and Gowda., 1990 ; De *et al.*, 1993). For other traits like vegetative and floral parameters hybridization with more divergent gene pools (exotic) followed by selection is expected to yield good recombinants.

Correlation and Path coefficient analysis

Correlation measured by a correlation coefficient is important in plant breeding because it measures the degree of association (genetic or non-genetic) between two or more traits. In most of the ornamental crops including gladiolus, the economic yield (spike length and number of florets spike⁻¹) is usually the trait of primary interest, though association of other traits like durability of spike, components of corm and cormel yield, quality and resistance to biotic and abiotic stresses are also important. Robinson *et al.* (1951) and Mode and Robinson (1959) have studied the implication of phenotypic and genotypic correlations in crop improvement programmes. Large number of research workers have studied the utility of correlation among economic traits in ornamental crops. The principal assumption underlying the correlation among traits has been the pleiotropic nature of genes. However, presence of linkages have also been observed to affect the correlation. Scientists have investigated the impact of indirect selection of a trait like economic character and they observed that this is effective only when heritability of the trait selected for indirect selection is very high and the additive genetic correlations between the target traits selected for indirect selection is also very high. Other workers are of the opinion that indirect selection for a complex trait like economic yield is an expression of fitness and any drastic change in any one of the component traits is accompanied by adjustment on other components; implying the existence of correlated changes of gene frequencies. Therefore, the most effective

method for economic improvement is direct selection for economic yield itself. There may be correlated changes among economic value characters and economic yield components, but these correlated changes will be in concert with development of most physiologically efficient genotypes for expression of genotype.

Dewey and Lu (1959) devised a method to analyze cause and effect relationship by breaking up the total genetic correlation existing between the most important traits, viz., grain yield with several other economic characters into components of direct and indirect effects, that helps in identifying the most important traits that contribute maximum towards target trait (economic yield). The traits having high direct and indirect contribution are normally showing correlated association. However, any component trait, that besides having high direct and/ or indirect effect reveals negative contribution with most other traits, is not considered for simultaneous selection while improving the target trait.

Presence of substantial additive genetic correlation will cause a change in the mean of a trait during selection through additive effects of genes in the selected genotypes and at the same time cause an indirect effect in the mean of the other traits. This will happen because of correlated response existing between the traits showing high direct and indirect effect towards the target trait.

The direct and indirect effect of characters and their relative contribution to the economic yield (number of florets spike⁻¹) are the key

factors for gladiolus improvement in a desirable direction (Desh Raj. *et al.*, 1997 ; Sirohi *et al.*, 2000 ; Neeraj *et al.*, 2001). Assessment of different characters of gladiolus including spike length, number of florets spike⁻¹, rachis length and their association with other components of characters are important in breeding for export market. Path coefficient analysis has proven useful in providing additional information that describe a prior cause and effect relationship between the component characters and their relative contribution towards the economic traits (Misra and Saini, 1990 ; De and Misra, 1994 ; Desh Raj and Misra, 1994 ; Desh Raj *et al.*, 1997 ; Desh Raj *et al.*, 1998 ; Sakkeer Hussain *et al.*, 2001 ; Neeraj *et al.*, 2001 ; Sirohi *et al.*, 2001). Path coefficient analysis results are useful while considering selection procedures for crop improvement (Desh Raj *et al.*, 1997 ; Neeraj *et al.*, 2001 ; Sirohi *et al.*, Sakkeer Hussain *et al.*, 2001).

Confounding of G x E interaction in the data recorded from single environments leads to biased estimates of genetic components of variances. It is therefore, necessary that the estimation of these genetic parameters be based on a set of random environments that can estimate precisely the extent of bias arising due to G x E interaction. Comstock (1951) and Comstock and Moll (1963) have argued that experiments conducted in single environments lead to biased estimates of components of variance. Robinson *et al.* (1955) have suggested that variance due to G x E interaction, if not estimated properly, leads to biased estimates of heritability, genetic gain and other genetic parameters.

In the present study significant G x E interaction was observed for all the traits and therefore, the estimates from the data pooled over environments are more appropriate and have been discussed. Analysis of cause and effect relationship revealed that number of florets spike⁻¹ exhibited positive and highly significant correlation with plant height, spike length, number of florets open at a time, size of floret, size of corm and number of corms plant⁻¹. The positive and highly significant direct effect came from spike length, days to slipping, number of cormels plant⁻¹, size of floret, number of florets open at a time and number of corms plant⁻¹, whileas, plant height and days to basal floret opening and durability of spike had maximum direct negative effect. In these cultivars the number of florets spike⁻¹ is not affected too much by the total biomass produced. Because of the requirements of number of florets spike⁻¹ and spike length these genotypes have been selected simultaneously for these two components. No concerted effort has been made to select the plant types having taller spikes and medium maturity with higher florets spike⁻¹. The traits that were observed to contribute more significantly towards the number of florets spike⁻¹ and at the same time had minimum negative contribution via other traits were days to slipping, spike length, days to basal floret opening, number of florets open at a time, size of floret, size and weight of corm and number of cormels plant⁻¹. These traits need to be considered while handling the population for improvement.

In gladiolus, ideotype breeding is believed to offer great opportunities to enhance economic yield viz. number of florets per spike and rachis length (Sandhu *et al.*, 1990 ; Misra & Saini. 1990 ; Desh Raj *et al.*, 1997 ; Desh Raj *et al.*, 1998 ; Sirohi *et al.*, 2000 ; Neeraj *et al.*, 2001 ; Sakkeer *et al.*, 2001; Misra, *et al.*, 2001 ; Anuradha *et al.*, 2000) and this objective could be achieved by estimating the relationship expressed by number of florets spike⁻¹ with other component characters (Desh Raj *et al.*, 1997, Sirohi *et al.*, 2000 ; Misra *et al.*, 2001). Path analysis has proved useful in providing additional information that describes cause and effect relationship (Sidwell *et al.*, 1976 ; Misra and Saini, 1990 ; Hedge *et al.*, 1997 Desh Raj *et al.*, 1997 ; Anuradha *et al.*, 2000 ; Sirohi *et al.*, 2000 Sakkeer *et al.*, 2001 ; Neeraj *et al.*, 2001 and Katwate *et al.*, 2002).

In the present study highly significant and positive associations exhibited between spike length and number of florets spike⁻¹ with number of florets open at a time, durability of whole spike, plant height, number of leaves plant⁻¹, weight of corm and size of corm. The plant height revealed positive and significant correlation with size of corm, weight of corm, size of floret and number of leaves plant⁻¹, but negative and significant correlation with days to sprout and weight of 10 cormels. Days to basal floret opening had positive and significant correlation with number of corms plant⁻¹, size of corm and weight of corm, but negative and significant correlation with number of florets open at a time. Durability of basal floret (days) revealed positive and significant correlation with durability of whole

spike and number of cormels plant⁻¹, whereas, number of florets open at a time expressed positive and significant correlation with plant height, leaves plant⁻¹, shoots plant⁻¹, size of the floret and size and weight of the corm. Durability of whole spike expressed positive and significant correlation with plant height, weight of corm and number of cormels plant⁻¹. Size of floret showed positive and significant correlation with size and weight of the corm. Number of corms plant⁻¹ had positive and significant correlation with size of corm and weight of 10 cormels, whereas, weight of corm had positive and significant correlation with size of corm and number of cormels plant⁻¹.

The correlations at the phenotypic level were similar in direction, though lower in magnitude, as compared to genotypic correlations. Variations in the magnitude of correlation coefficients was observed in the individual environments at both phenotypic and genotypic levels, whereas, the direction in majority of the trait associations was similar both at phenotypic and genotypic levels.

Positive and significant correlation has been reported between number of florets spike⁻¹ with plant height (Negi *et al.*, 1978, Anuradha and Gowda 1984 ; Lal *et al.*, 1985 ; Sandhu *et al.*, 1990 ; Misra and Saini, 1990 ; Desh Raj *et al.*, 1997 ; Neeraj *et al.*, 2001 ; Sakkeer Hussain *et al.*, 2001; Anuradha *et al.*, 2000 ; Katwate *et al.*, 2002) and between spike length and durability of whole spike (Anuradha and Gowda, 1984 ; Lal *et al.*, 1985 ; Sandhu *et al.*, 1990 Negi *et al.*, 1978 ; Pant and Lal. 1992 ; De

and Misra 1994 ; Desh Raj *et al.*, 1997 ; Desh Raj *et al.*,1998 ; Neeraj *et al.*, 2001 ; Sakkeer Hussain *et al.*, 2001; Katwate *et al.*, 2002). Further, significant positive correlation has been recorded between number of florets spike⁻¹ with size of floret (Neeraj *et al.*, 2001). However, negative correlation has been reported between number of florets spike⁻¹ with spike length (Misra and Saini 1990) and with number of corms plant⁻¹ and number of spikes plant⁻¹ (Neeraj *et al.*, 2001). Among vegetative traits, plant height has been reported to have significant correlation with the diameter of the corm and average weight of a corm (Gil *et al.*, 1978 ; Anuradha and Gowda, 1994 ; Neeraj *et al.*, 2001).

Spike length has been observed to possess positive and significant correlation with plant height, number of florets spike⁻¹, number of florets remaining open at a time, durability of whole spike and size of corm (Singh & Singh 1983 ; Sandhan *et al.*, 1990 ; Anuradha & Gowda, 1994 ; Gowda 1989 ; ; Katwate *et al.*, 2002. Neeraj *et al.*, 2001 ; Sirohi *et al.*, 2000). Similarly, positive and significant correlation has been reported between days to 50 per cent sprouting with days to 50 per cent heading and between days to first floret opening and days to last floret opening (Misra and Saini 1990 ; Desh Raj *et al.*, 1997 ; Sakkeer Hussain *et al.*, 2001).

Among the floret traits, first floret diameter expressed positive and significant correlation with plant height, rachis length, spike length, number

of leaves plant⁻¹, average corm weight, corm diameter and number of florets remaining open at a time (Misra and Saini, 1990 ; Desh Raj *et al.*, 1997; Sirohi *et al.*, 2000 ; Sakkeer Hussain *et al.*, 2001). Similarly, rachis length was positively and significantly correlated with plant height (Misra and Saini 1990 ; Desh Raj *et al.*, 1997 ; Sirohi *et al.*, 2000 ; Anuradh *et al.*, 2000 ; Neeraj *et al.*, 2001 ; and Katware *et al.*, 2002). However, durability of whole spike (days) expressed negative and significant correlation with days to first floret colour showing and days to first floret opening (Sirohi *et al.*, 2000).

Among yield component traits number of corms plant⁻¹ was found to have positive and significant correlation with propagation coefficient (De *et al.*, 1993 ; Desh Raj *et al.*, 1997). Similarly, diameter of corm had positive and significant correlation with average weight of corm (Misra and Saini, 1990 ; Desh Raj *et al.*, 1997).

Johnson *et al.* (1955) proposed that besides genotypic and phenotypic variances, estimation of genotypic and phenotypic correlations are also important for the improvement of a trait. Newell and Eberhart (1961) observed that when two characters are showing negative association at both phenotypic and genotypic levels, simultaneous selection for the improvement of these characters becomes difficult and accordingly a judicious breeding programme needs to be drawn up. Adams (1967) reported that negative association between developing traits may arise from the development of one character at the cost of the suppression of the other

resulting from competition for common resources for development of a plant and its component traits.

Highest direct effect on number of florets spike⁻¹ from days to first floret opening has been reported by Misra and Saini (1990) ; Desh Raj *et al.* (1997) Desh Raj *et al.* (1998). Hedge *et al.* (1997) and Neeraj *et al.* (2001). The other component characters contributing significantly and directly towards number of florets spike⁻¹ have been reported as durability of whole spike, length of rachis, length of spike, plant height, diameter of first floret, number of florets open at first, diameter of a daughter corm and propagation coefficient. Hedge *et al.*, 1997 ; Desh Raj *et al.*, 2000 ; Anuradha *et al.*, 2000 ; Sakkeer Hussain *et al.*, 2000 and Katwate *et al.*, 2002. High indirect effects towards number of florets spike⁻¹ from days to first floret opening, average weight of a corm, number of cormels plant⁻¹ have been reported by Desh Raj *et al.*, (1997) Hedge *et al.*, (1997) and Neeraj *et al.* (2001) ; Sakkeer Hussain *et al.* (2000). High and positive indirect effects were contributed by spike length and days to first floret showing colour via plant height, days to spike initiation, durability of whole spike. Desh Raj *et al.* (1997) also observed strong indirect relationship in number of florets spike⁻¹ with rachis length and days to first floret opening. Correlation simply measures the association without due regard to causation, whereas, the path coefficient analysis specifies the causes and measures their relative importance. Dewey and Lu (1959) observed that apparent conflict between correlation analysis and path coefficient analysis arise largely from the fact

that the two methods measure entirely different things. Jangale *et al.* (1987) observed that correlation between dependant and independent characters and the direct effect of the independent characters are completely different things. Sometimes the correlation between two characters might be highly positive but the direct effect of the independent character may be negative or very small.

Genetic Diversity

Cultivation of high economic yielding gladiolus cultivars is now occupying large proportion of the area under gladiolus cultivation in both developed and developing countries. In the State of J & K also the area under high economic yielding gladiolus cultivars is nearly 80 to 85 per cent of the total area under its cultivation. In the Kashmir valley, gladiolus cultivation is the major flower for cut flower production and has the highest production as compared to other cut flower crops, but only a few high economic yielding cultivars like, White Prosperity, Suchitra, Sanceree, Wig's Sensation, Princess Margret Rose, Jackson Villa Gold, Oscar, Mayur, Friendship Pink, Peter Pears, Her Majesty and Priscilla are presently being cultivated. This has led to more uniformity in the high economic yielding genotypes at the cost of genetic erosion of the current test cultivars/land races. These current test germplasm resources have been pushed to smaller pockets of cultivation and in the areas where the growers do not have resources to go for high input management required for high economic

yielding gladiolus cultivars. All these high economic yielding gladiolus cultivars have exotic allelic resources.

The importance of conservation of the local test cultivars/land races of gladiolus in the Kashmir valley has now become imperative from the point of view of conservation of plant biodiversity and utilization of the allelic resources that these cultivars possess.

For scientific utilization of the allelic resources present in this tested local gene pool of gladiolus through hybridization with high economic yielding exotic cultivars and subsequent selection of recombinants possessing high economic yield potential together with tolerance to cold and assembly of genes for good quality parameters, it is imperative to characterize these cultivars/land races on scientific basis. Genetic diversity is an important parameter to identify the genotypes for hybridization.

Genetic diversity in the current local tested germplasm arises from several factors and one of the main contributions to this diversity has resulted from regressive human selection for productivity and quality parameters. Correlated response has also generated considerable variation in other vegetative and economic component traits. Diverse agro-ecological conditions in the areas of the adaptation might also result in a substantial genetic divergence. Clausen and Hiesey (1958) demonstrated that even a single component of environment, such as temperature, could cause differences between and within land races. Disturbance of habitat by man also accelerates the evolutionary process in the crop species (Anderson and

Stebbins, 1954). Murty and Arunachalam (1966) have studied that genetic drift and selection in different environments could cause greater diversity than the geographical distance. Inbreeding changes the genetic architecture of a population and also modifies its adaptive value. Therefore, it is likely that adaptability of gladiolus over wide range of conditions is due to its genetic heterogeneity as well as physiological homeostasis Cohat. (1988).

Several workers (Moll *et al.*, 1962 ; Avishai and Zohary, 1980) have reported that geographic distance contributed to the genetic diversity, but several other workers (Timothy, 1963; Murty *et al.*, 1965 ; Murty and Arunachalam, 1979; Desh Raj and Misra, 2000 ; Nimbalkar *et al.*, 2002) observed that geographic diversity need not be related to genetic diversity. Maurya and Singh (1979) have reported that in the areas where geographically distant locations do not differ sufficiently in the elements of climate, like biotype, soil and management, the accumulation of substantial genetic variability may not be possible. In these areas the main source of diversity results from the prolonged selection for some specific traits.

Bhatt (1970) suggested that genetic drift and human selection could cause greater diversity than the geographical distance. Several research workers observed no parallelism between geographical distance and genetic diversity (Mohanty and Pristi, 2002 ; Desh Raj and Misra. 2002 ; Nimbalkar *et al.*, 2002). Precise information about the extent of genetic divergence and characters used for discrimination among populations is thus, crucial in any crop improvement programme.

In the past, attempts have been made by several workers to classify gladiolus and to understand the probable factors responsible for sub-specific differentiation by studying, for example, geographical distribution, taxonomic, sexual affinity and differences (Anderton and Park, 1989; Ohri and Khoshoo, 1985b). It is now possible to effectively classify biological populations on the basis of genetic divergence measured by Mahalanobis D^2 statistic and also to identify factors influencing the genetic divergence (Rao, 1952; Murty and Arunachalam, 1966). The utility of multivariate analysis in quantifying the degree of divergence between populations so as to understand the trend of their evolutionary pattern, assess the relative contribution of different components to the total divergence and determine the nature of forces operating at inter- and intra- cluster levels has greatly been emphasized. (Murty and Qadri, 1966 ; Anand and Murty, 1968; Desh Raj and Misra, 2000 ; Nimbalkar *et al.*,2002).

The method of classifying genetic stocks on the basis of genetic divergence measured by D^2 -statistic is now well established in plant breeding (Murty *et al.*, 1973 ; Vairavan *et al.*, 1973).

In the present study, 62 current tested gladiolus cultivars/landraces were evaluated in three random environments to estimate the genetic diversity as per Mahalanobis D^2 -statistic. The data of three individual environments was also used to estimate the genetic divergence on the pooled over environment basis. Two of the locations viz., Rice Research and Regional Station Khudwani (E_2) and the Experimental Fields of the

Division of Floriculture, Medicinal and Aromatic Plants, SKUAST Kashmir (E_1) represented two different locations in the main growing areas of Kashmir valley basin (1550-1650 m a.m.s.l. The third location viz., High Altitude Rice Research Sub-station, Larnoo (E_3) represented the cold high altitude location (2250 m amsl). Priscilla and Wig's Sensation were used as checks for E_1 , E_2 , and E_3 .

Analysis of variance for divergence revealed that the values of V-statistic (measuring Wilk's criteria) were high and significant, indicating presence of substantial genetic diversity in the materials as expressed in the individual environments and pooled over the environments.

Classification of the cultivars led to formation of 5 clusters in E_1 . Cluster-I contained 54 cultivars/land races and cluster-II had 5 cultivars, whileas the remaining 3 clusters contained one cultivar each. Similarly, in E_2 the cluster-I contained 59 cultivars ; whileas, the remaining three clusters contained one cultivar each. However, in E_3 the cluster-I had 50 cultivars; cluster-II and cluster-III had 4 cultivars each, cluster IV had 3 cultivars and cluster-V had one cultivar. The picture changed altogether when the data was pooled over the environments. A total of 12 clusters were formed with cluster-I containing 50 clusters, while the remaining 11 clusters contained one cultivar each except cluster-VIII that had 2 cultivars.

Considering the grouping of cultivars into different clusters in the present study, both in the individual environ-ments and from the data pooled over the environments, it was observed that cultivars originally

collected from a particular region or presently grouping in different pockets had no tendency to group together in a cluster, revealing that there was no parallelism in the geographical genetic diversity.

According to Rao (1952), no formal rules can be laid down for forming a cluster, but any two groups belonging to the same cluster should at least, on an average, show a smaller D^2 value as compared to those belonging to two different clusters. Singh and Chaudhary (1977) on the other hand, proposed a different method for classifying the materials into different clusters by adopting two methods, however, the method proposed by scientist has been found to be defective since it ignores the pattern of D^2 – variation and basic definition of a group (Arunachalam and Bandyopadhyay. 1989).

Nimbalkar *et al.*, (2002) evaluated one hundred one genotypes of gladiolus to assess the genetic diversity and obtained 12 clusters. Similarly, Desh Raj and Misra (2000) studied 20 quantitative characters in 25 gladiolus cultivars for genetic divergence and obtained 5 clusters, which revealed that number of genotypes included in a cluster varied from one environment to another. They further suggested that the extent of genetic divergence between populations should comparatively be stable over the environments to be of practical importance. In their study they found that the grouping pattern of genotypes was not constant across the environments; a finding also observed in the present study. It has been observed that various genotypes shift their position from one cluster to another cluster

across the environments. Changes in the environments alter the clustering pattern due to G x E interaction (De and Misra, 1993 ; Desh Raj and Misra, 2000 ; Arya *et al.*, 1999 ; Nimbalkar *et al.*, 2002).

Formation of more clusters in one environment indicates that more diversity by genotypes is expressed in a particular environment and this happens because of genetic drift and selection in a different environment (Murty and Arunachalam, 1966). In the present study also the grouping of the current test cultivars into different clusters was not uniform in the three individual environments, whereas, in the pooled analysis the grouping into clusters was altogether different. The cultivars were grouped into 12 clusters. Cluster-I was largest with 50 genotypes followed by cluster VIII with two genotypes and remaining 10 were clusters with solitary cultivar.

This diversity observed in a particular environment might have arisen more from modifying factors than change in the major genes responsible for economic yield component traits. Which is a common principle in the polygenic inherited traits. While pooling the performance of these genotypes across locations the effect of modifying factors might have been reduced to a greater extent due to balancing of the effects either way around the mean, resulting in the more uniform performance of the genotypes on pooled analysis basis. However, these current test cultivars still continue to show great diversity when evaluated in a particular but different environment. Mean intra- and inter- cluster distances revealed that in E₁ the intra-cluster distance was maximum (23.009) in cluster II followed by

cluster I (18.85). The inter cluster distance was maximum (52.303) between cluster III and cluster V; however, cluster V had high inter-cluster D^2 values with all other clusters. Similarly, in E_2 the maximum intra-cluster distance (24.77) was observed in the cluster-III followed by cluster-I (23.89) and cluster-IV (21.72). The inter-cluster distance was again observed to be maximum (70.50) cluster-IV and cluster-V followed by the distance between the cluster-III and cluster-IV (56.75). The inter cluster D^2 values were again high between cluster-IV and all other clusters. In E_3 the highest intra-cluster distance was observed in cluster III (24.77) followed by cluster -I (23.89) cluster-IV (21.72) and cluster II (20.72). The maximum inter-cluster distance (70.50) was observed between cluster V and cluster IV. This cluster had again high inter-cluster D^2 values with all other clusters. While pooling the data over the environments the intra-cluster distance (D^2) in cluster-I (representing 50 of the 62 cultivars) was maximum 8.92 followed by cluster VIII (7.86). Rest of the clusters had only one cultivar. Maximum inter clusters distance (26.48) was observed between cluster-II and cluster-III followed by the distance between the cluster VII and VIII (22.98), and cluster-II and IX (21.81).

From the above it is clear that tremendous potential existed for introgressing the allelic resources present in these current test cultivars from exotic high yielding genotypes through a systemic breeding and selection approach so as to recover high economic yielding (spike length and number of florets spike⁻¹) and floral quality recombinants.

Cluster means for different agro morphological traits of these current test gladiolus cultivars revealed that substantial genetic variability existed for all the traits. In E_1 the highest cluster means were for plant height (107.36 cm) in cluster-I ; days to basal floret opening (116.97) in cluster-III ; days to slipping (29.98) in cluster-IV ; number of leaves plant⁻¹ (9.78) in cluster-V ; number of shoots plant⁻¹ in cluster-IV ; days to slipping (107.86) in cluster-V ; spike length (85.11 cm) in cluster-I ; number of florets spike⁻¹ (15.99) in cluster-IV ; durability of whole spike (12.91 days) in cluster-I ; number of corms plant⁻¹ (1.49) in cluster-I ; weight of corms per plant⁻¹ (34.14 g) in cluster-IV ; size of corm (4.15cm) in cluster-II ; number of cormels plant⁻¹ (136.67) in cluster-IV and weight of 10 cormels (4.96 g) in cluster-V. Similarly, in E_2 the highest cluster means of different traits were as follows plant height (199.66 cm) in cluster-IV ; days to slipping (107.66) in cluster-III, ; days to basal floret opening (113.33) in cluster-III ; number of floret spike⁻¹ (17.16) in cluster-IV ; durability of whole spike (14.20 days) in cluster-II ; number of corms plant⁻¹ (1.55) in cluster-II ; weight of corm (37.82) in cluster-II ; number of cormels plant⁻¹ (167.98) in cluster-IV and weight of 10 cormels, (9.08 g) in cluster-III. In E_3 the highest cluster means of the different traits were for plant height (131.44 cm) in cluster-II, days to slipping (116.03) in cluster-IV ; number of florets spike⁻¹ (16.52) in cluster-II ; days to basal floret opening (109.70) in cluster-II ; durability of whole spike (12.56 days) in cluster-II ; number of corms plant⁻¹ (2.36) ;

cluster-IV ; weight of corm (44.91) in cluster-II, number of cormels plant⁻¹ (197.77) in cluster-V and weight of 10 cormels (8.48 g) in cluster-IV.

Cluster means of different clusters identify the characters to be chosen for hybridization (Desh Raj and Saini ; Desh Raj & Misra, 2000 ; Nimbalkar *et al.*, 2002). Characters contributing to divergence are reported to vary from crop to crop (Murty and Tiwari, 1967 ; Murty and Arunachalam, 1967 and Jawahar, 1967 ; Murty and Arunachalam, 1979 ; Desh Raj and Misra, 2000 ; Nimbalkar *et al.*,2002). In general, the traits contributing maximum to genetic divergence in gladiolus crop have been identified as days to 50 per cent heading, first floret colour showing, first floret opening and last floret opening (Desh Raj and Misra, 2000). However, other traits which also contribute towards divergence were number of florets spike⁻¹, plant height, average weight of corm, propagation coefficient, and number and weight of corm and cormels plant⁻¹ (De and Misra, 1993 ; Desh Raj and Misra, 2000 ; Nimbalkar *et al.*, 2002).

In the present study, the traits contributing maximum towards the total divergence in current test gladiolus cultivars studied under temperate climate conditions of Kashmir were observed to be number of cormels plant⁻¹ followed by days to basal floret opening, days to slipping, days to sprout in E₁. Number of cormels plant⁻¹ followed by days to basal floret opening and weight of corm in E₂. Similarly, in E₃ the traits were days to basal floret opening, number of cormels plant⁻¹, days to sprouting and weight of corm. On the basis of data pooled over the environments, the traits viz.,

days to basal floret opening, number of florets spike⁻¹ and plant height were observed to contribute maximum towards the total divergence in these current test cultivars. Improvement over existing cultivars is a continuous process in plant breeding. Any successful hybridization programme for genotype improvement depends mainly on the selection of parents with high genetic variability so that desirable character combinations could be selected for the target trait to be improved upon (Cohen and Barzilay, 1991 ; Wilfret. 1986 ; Desh Raj and Misra, 1996; Desh Raj and Misra, 2000 ; De and Misra, 1993 and Numbalkar *et al.*, 2002).

Selection of parents based on the extent of genetic divergence has been successfully utilized in different crop species by Moll *et al.* (1962), Murthy and Anand (1966) and Bhatt (1970). Desh Raj and Misra (2000) and Nimbalkar *et al.* (2002) suggested that while selecting parents for hybridization on the basis of genetic diversity, it is also advisable to take into consideration the *per se* performance of the traits to be improved. Selection of parents for hybridization should be done from different clusters having wider inter cluster distance and the parents to be selected from the clusters should also have the high *per se* performance of the traits that are contributing maximum towards the divergence

Stability analysis

On the basis of evaluation of the 62 current test cultivars across three random environments (E₁, E₂ and E₃) during *Kharif*, 2002 for the estimation of genetic divergence and other genetic parameters, ten genotypes were

identified on the basis of their superior performance across these random environments for the different traits.

All these ten elite cultivars were evaluated for stability performance for seventeen characters in five random environments representing three valley basin locations (Shalimar, Khudwani and Alustang) one high altitude environment (Larnoo) and a test location in the farmers field. The cultivars were selected their superior/good characteristics across the random environments on pooled data performance basis.

Analysis of variance revealed that the cultivars possessed highly significant genetic variability for all the traits., viz., days to sprout, plant height, days to slipping, days to first floret opening, spike length, size of floret, durability of basal floret, durability of whole spike, number of leaves and shoots plant⁻¹, number of corms plant⁻¹, number of cormels plant⁻¹, weight and size of corm, and weight of 10 cormels. The influence of the environment was also significant for all the traits except plant height revealing that environments selected were random and different in Agroclimatic conditions.

The cultivar x environment interaction component was significant for days to sprout, plant height, days to slipping, spike length, days to basal floret opening, durability of basal floret, number of corms plant⁻¹ and weight of corm, revealing that these traits were not stable over the environments and did not behave similarly across the environments. However, the mean squares due to environments + (cultivar x

environments) was significant only for size of corm, revealing variable response of genotypes for this trait in the changing environments. Further component analysis of this environment + cultivar x environments) mean squares revealed that the mean squares due to environments (Linear) were highly significant for all the traits except for plant height and number of corms plant⁻¹ which confirmed that differences between the environments existed and the environments had considerable influence on the traits showing significant mean squares, and major portion of this variation could be attributed to linear regression. Similarly, the component cultivar x environment (linear) interaction was significant for days to sprout, plant height, days to slipping, spike length, days to basal florets opening, number of corms plant⁻¹, weight of corm, number of cormels plant⁻¹ and weight of 10 cormels revealing that the behaviour of the cultivars for these traits was predictable over the environment and this had resulted from the linear function of the environmental component.

The mean squares due to pooled deviation (non-linear) were significant for all the traits except number of florets open at a time, size of floret and size of corm, revealing thereby that the non-linear component was important for these traits which contributed towards the total G x E interaction and the genotypes differed considerably for stability of their traits over the environments.

Significant mean squares have also been reported for most of the traits in gladiolus over the environments by Arora and Sharma, (1991)

Desh Raj and Misra (1998), Jhon *et al.* (1999) and Sun Yanzhi and Yi (2002). Similarly, for environments + (cultivars x environments) significant mean squares were reported by Arora and Sharma (1991), Desh Raj and Misra (1998a), Desh Raj and Misra (1998b) and Jhon *et al.* (1999). In case of environments (linear) significant mean squares were reported by Desh Raj and Misra (1991), Arora and Sharma (1991) and Jhon *et al.* (1999). Significant mean squares have been reported for cultivars x environments (Linear) by Arora and Sharma, 1991 and Jhon *et al.*, (1999); Desh Raj and Misra (1998a) ; Desh Raj and Misra (1998b). Significant mean squares of pooled deviation (non-linear) for various characters have been reported by Desh Raj and Misra (1998) and Jhon *et al.* (1999).

The value of phenotype is the resultant of both genotype and environment and their interaction. When G x E interaction is about the average difference between genotypes estimated through phenotypic stability in different environments is constant. Significant G x E interaction results from changes in the magnitude of the differences among genotypes (Allard and Bradshaw, 1964). The G x E interaction reduces the correlation between phenotypes and genotypes and decreases selection progress (Comstock and Moll, 1963). Success of new cultivars is based on the performance of economic yield and other essential agronomic traits over a wide range of random environmental conditions (Becker, 1981). Plant breeders generally agree on the importance of good “Phenotypic stability” but there is much less accord on the most appropriate definition of

“stability” and on statistical measures of stability in economic yield traits. The basic concepts of phenotypic stability have been defined as; (i) a stable genotype having a minimal variance under different environmental conditions (biological concept), or (ii) a stable genotype showing minimal interaction with environments as measured by the covalence (agronomic concept).

A genotype showing a constant performance in most of the environments does not respond to improved growing conditions with regard to increase in economic yield. Therefore, most agronomists no longer regard this type of stability as desirable, their objective is a cultivar which could always show the economic yield expected at a level in productivity of the respective environments as measured by the average economic yield of all treatments in that environment i.e., a genotype that shows no G x E interaction. As an appropriate measure of phenotypic stability, Wricke (1962) proposed to calculate the covalence i.e., the contribution of the genotype to the total G x E interaction sum of squares.

Yates and Cochran (1938) proposed a method of partitioning the genotype x environment interaction by calculating regression of yield of a given genotype in the different environments on the respective means of all the genotypes. This procedure, as elaborated by Eberhart and Russell (1966) has been widely used to estimate phenotypic stability and provides two statistical measures to characterize an entry (i) the coefficient of regression (b) which measures whether the genotype is better adapted to good

environments ($b < 1$), to most of the environments ($b = 1$) or to poor environments ($b > 1$); and (ii) the mean square deviation from regression (S^2d_i) which measures the reliability of the linear responses.

Genotype x environment (G x E) interactions are of major concern to plant breeders for developing improved cultivars. For a cultivar to be commercially successful, it must perform well across the range of environments in which the cultivar may be grown. The presence of G x E interaction reduces the correlation between phenotype and genotype, and makes it difficult to judge the genetic potential of a genotype. Plant breeders grow performance tests at different sites (locations) in different years in the target area and data obtained from these tests are used to determine the magnitude of G x E interactions. Stability of a cultivar refers to its consistency in performance across environments and is less affected by the presence of G x E interaction. In the presence of significant G x E interaction the stability parameters are estimated to determine the superiority of individual genotypes across the range of environments (Sharma *et al.*, 1985). Methods available for estimating the magnitude of G x E interactions involve an analysis of variance approach (Sprague and Federer, 1951; Hanson *et al.*, 1956; Comstock and Moll, 1963). A significant G x E interaction can be partitioned into components using regression analysis. This method was proposed by Yates and Cochran (1938) and later modified by Finlay and Wilkinson (1963); Eberhart and Russell (1966) and Perkins and Jinks (1968). It involves the regression of

each genotype on an environmental index that is determined by the mean performance of all genotypes grown in each environment. Stability parameters are estimated from this regression analysis.

Finlay and Wilkinson (1963) used mean yield of a genotype and the slope of its regression line to determine the stability of genotype over the environments. This method was modified by Eberhart and Russell (1966) who added an extra parameter that measures the deviation from linear regression. The choice of a genotype depends on its performance at different locations in different years and seasons. Presence of large amount of genotype x environment interaction nullifies the selection of lines based on mean performance under a particular environment. Comstock and Moll (1963) suggested that selection would not be effective due to presence of significant genotype x environment interaction. Therefore, breeders should give emphasis on stable performance of a line over a wide range of environments. The parameters of stability and adaptability were applied in gladiolus by several workers like Arora and Sharma. (1991); Desh Raj and Misra (1998a,b) ; Jhon *et al.* (1999) and Sun-Yanzhi, (2002) for comparing different cultivars to ascertain their usefulness over a wide range of environments.

Lin *et al.* (1986) investigated the statistical relationships among nine stability parameters and classified them into three types; the Type 1 stability is where a stable genotype is characterized by a small variance across all environments. Francis and Kannenberg's (1978) coefficient of

variability belongs to Type-1. Type-2 stability is where stable genotypes fit a linear regression model and have a much slope. Finlay and Wilkinson's (1963) regression coefficient (b_i) belongs to Type-2 stability. Since the regression analysis uses the mean of all cultivars included in the test as environmental index, it is a stability measure relative to the other cultivars. Eberhart and Russell's (1966) residual mean square of deviation from regression (Sd_i) belongs to Type-3 stability. Although it has been extensively used as a stability measure, its statistical validity has been questioned because S^2d_i is an indication of how well the data fit on the regression line and is not an estimation of stability (Lin *et al.*, 1986). However, in the actual experiments carried out by Eberhart and Russell (1966) the inbred lines of maize differed in their average response to varying environments and the genotype x environment (linear) sum of squares was not a large proportion of the variety x environmental interaction. Hence the parameter S^2d_i appeared to be very important. Since the variance of S^2d_i is a function of number of environments so several environments with minimum replications per environment were advocated to be necessary to obtain reliable estimates of S^2d_i . Identification of the stable genotypes having adaptability over a wide range of agroclimatic conditions is of major significance in crop improvement with the statistical techniques developed to estimate stability parameters (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966) and it has become possible to detect genotypic differences for wide adaptability in crop improvement.

Different stability parameters such as phenotypic stability (S^2b_i), residual mean variance (S^2d_i) and phenotypic index (P_i) are available to test the stability of genotypes. A new parameter of stability designated as “adaptability index (A_i)” has been introduced and estimated for genotypes. A large value of A_i indicated degree of adaptability, whereas, its sign indicates the performance of genotype. The estimates of A_i help to study critically the performance of genotype across the environments. Besides, this value reveals the latent potentialities of a strain in its yielding capacity over other genotypes, which have got the same P_i values. Therefore, “adaptability index” is such a parameter which is dependent on both the phenotype and environment, and is sensitive enough to sort out stable cultivars both across and within environments.

Partitioning of variance components associated with interaction of genotypes with locations and years (Hanason, 1964) can assist in determining whether more emphasis should be laid on the sampling sites or years within the limitations of resources available Sprague and Federer (1951) discussed the determination of optimum number of years and replications for obtaining the maximum gain in performance through selection based on the genetic variability present in the populations. In most breeding programmes early field screening of a large number of lines is done over a small number of sites than would be required for the selected lines selected for more intensive testing (Shorter *et al.*, 1977).

Large shifts in rank order are regarded as indicative of instability. The superiority of some genotypes in a particular environment lies in part due to their ability to exploit particular ecological site to their own particular advantage and, in part, with the elimination of poor yielding genotypes by natural selection during propagation. Locations need to be classified into homogenous groups based on G x E interactions so that there is no significant cross over G x E interaction in each group.

The estimation of stability parameters of 10 different current test cultivars under random agro-climatic sites of Kashmir valley for seventeen different traits in the present study revealed that for days to slipping the mean square deviation from regression (S^2d_i) was significant for Apple Blossom and Yellow Stone; for spike length in all the cultivars except Friendship Pink and Peter Pears; for days to basal floret opening in all the cultivars except Friendship Pink, Moralla and Sanceree ; for number of florets spike⁻¹ in Apple Blossom, Moralla and Sanceree; for durability of whole spike in Friendship Pink and in Traderhorn; for days to sprout in all the cultivars except Friendship Pink, Moralla and Traderhorn; for weight of corm in all the cultivars except Moralla, Sanceree and White Prosperity and for number of cormels plant⁻¹ in Jackson Villa Gold, Moralla, Traderhorn and White Prosperity. Contrarily, mean square deviation from regression was non-significant for plant height, number of leaves plant⁻¹, durability of basal floret, size of floret, number of florets open at a time, number of shoots plant⁻¹, size of corm, number of corms plant⁻¹ and weight of 10

cormels for all the ten cultivars. The cultivars showing non-significant mean square deviation (S^2d_i) from the regression indicated that non-linear component (heterogeneity from regression) was equal to zero.

The linear regression deviated from unity for days to slipping and days to basal floret opening in Yellow Stone; for durability of basal floret in Friendship Pink and White Prosperity; for number of florets spike⁻¹ in Apple Blossom and Big Time Supreme; for number of shoots plant⁻¹ in Peter Pears; for weight of corm in Sanceree and Traderhorn; for number of cormels plant⁻¹ in White Prosperity and for number of corms plant⁻¹ in Friendship Pink, Moralla, Peter Pears and Sanceree. The cultivars not deviating significantly from unit regression for a particular trait revealed that these were average in performance and were either favourably or poorly adapted to all the environments. In case of plant height the cultivars that showed average stability and high mean performance and were well adapted to the environments were Jackson Villa Gold, Peter Pears, White Prosperity and Yellow Stone; for days to slipping the cultivars showing average stability and high mean performance were Big Time Supreme, Jackson Villa Gold, Moralla and Traderhorn; for days to basal floret opening the cultivar showing average stability and high mean performance was Moralla; for durability of basal floret the cultivars with average stability and high mean performance were Apple Blossom, Peter Pears, White Prosperity and Yellow Stone; for number of florets spike⁻¹ the cultivars were Friendship Pink, Peter Pears and White Prosperity; for

number of florets open a time the cultivars with average stability and high mean performance were Friendship Pink, Jackson Villa Gold, Moralla, and Peter Pears; for durability of whole spike the cultivars were Big Time Supreme, Jackson Villa Gold, and White Prosperity; for days to sprout the cultivars were Moralla and Traderhorn; for number of shoots plant⁻¹ the cultivars were Apple Blossom, Moralla, Sanceree and White Prosperity; for weight of corm the cultivar was White Prosperity; for size of corm the cultivars were Big Time Supreme, Jackson Villa Gold, Peter Pears, Traderhorn, White Prosperity and Yellow Stone; for number of cormels plant⁻¹ the cultivars were Apple Blossom, Friendship Pink and Jackson Villa Gold; for weight of 10 cormels (g) the cultivars were Moralla, Peter Pears, Traderhorn and White Prosperity; for number of corms plant⁻¹ the cultivars was White Prosperity and for size of floret the cultivars were Jackson Villa Gold, Moralla, Peter Pears and Traderhorn.

The cultivars showing below average stability (b_i value significant and > 1) were Yellow Stone for days to slipping; Yellow Stone for days to basal floret opening; White Prosperity for durability of basal floret (days); Apple Blossom and Big Time Supreme for number of shoots plant⁻¹; Sanceree and Traderhorn for weight of corm; White Prosperity for number of cormels plant⁻¹; Friendship Pink, Moralla, Peter Pears and Sanceree for number of corms plant⁻¹. Contrarily, the cultivars having significantly lower b_i values than unity ($b < 1$) revealed that they were above average in stability and well perform better under the poor environments.

The cultivars showing significant mean square deviation from regression (pooled deviation) for any trait were not considered, since prediction of stability would not be precise and reliable for these traits. The stability analysis for most important trait i.e. number of florets spike⁻¹ in the present study revealed that mean square deviation from the regression were not significant for all cultivars except Apple Blossom, Moralla and Sanceree and thus, could be assumed to be equal to zero. The prediction for stability for this trait for most of the cultivars would be precise and reliable. The linear regression coefficients (b_i) were also non-significant for all the cultivars except Apple Blossom and Big Time Supreme. Thus, it could be presumed that non-significant b_i values were equal to unity and these cultivars were average in stability and were either poorly or well adapted to all the environments. Considering the mean performance and the average stability of the cultivars it could be derived that the cultivars Jackson Villa Gold, Traderhorn and White Prosperity were well adapted to all the environments; whereas Peter Pears, and Yellow Stone were poorly adapted to all the environments. The cultivar Friendship Pink had significantly higher b_i value than unity ($b_i > 1$) and was below average in stability and, thus, specially adapted to the unfavourable environments. Desh Raj and Misra (1998b) estimated stability performance of gladiolus under different environments and observed that the stability parameters appeared to be governed by different gene and gene combinations.

Jhon *et al.* (1999) assessed phenotypic stability for thirteen promising cultivars of gladiolus for some floral and corm traits and observed that the

mean performance (\bar{X}), deviation of regression from unity (b_i) and mean square deviation from regression (S^2d_i) were more adequate in assessing the stability of the genotypes. Four of the genotypes were found to be highly stable for different floral and corm traits.

Freeman and Dowker (1973) suggested that if genotypes respond similarly to all the environments tested, their relative performance in other environments could be predicted with confidence. More often, however, there are differences in the relative performance and an analysis of pattern between and within genotypes is necessary to determine as to which particular genotype would respond differentially from others.

The stability based on linear regression coefficient and deviation from linearity has been criticized on physiological grounds by Knight (1970), but nevertheless, the biometrical model given by Eberhart and Russell (1966) has been highly successful in predicting genotypic performance over a wide range of environments. Jinks and Mather (1955) observed that above average performance of a genotype is indicative of the fact that the capitalization of additive type of gene action and residual genetic heterozygosity coupled with critical structural variability could confer wider adaptability to the genotypes. Harrison *et al.* (1959) observed that some factors other than heterozygosity, such as genetic make up of the organism are also equally important in their development regressions.

One of the objectives of the stability for number of florets spike⁻¹ and spike length across five random environments during *Khariief*, 2003 in the present study was to estimate the economic feasibility of cultivation of

some of the high value current tested commercial gladiolus cultivars over an expanded period during lean time in the sub-tropical part of the country and earn more profits. Some of the high valued current tested gladiolus cultivars suited to agro-climatic conditions of Kashmir valley were identified as White Prosperity, Big Time Supreme, Traderhorn, and Jackson Villa Gold. The economic yield performance of White Prosperity, Big Time Supreme, Traderhorn and Jackson Villa Gold was estimated from the average performance of these four cultivars across the locations comprising high altitude and valley basis climatic conditions during *Kharief*, 2002-2003.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation was carried out to characterize the current tested gladiolus cultivars of Kashmir valley with regard to magnitude of their genetic variability, divergence and stability of some of the elite cultivars across the random environments in the Kashmir valley. Sixty-two current tested gladiolus cultivars/land races were selected for the present study and evaluated for magnitude of variability, association of traits, path coefficient analysis and magnitude of genetic divergence at three different locations representing random environments during the *Kharif*, 2002. The three random environments were, Experimental Farm of Division of Floriculture, Medicinal and Aromatic plants, SKUAST-K, Shalimar (E₁), Rice Research and Regional Station, SKUAST-K, Khudwani (E₂), and High Altitude Rice Research Sub-station, SKUAST-K, Larnoo (E₃). While E₁ and E₂ represented the valley basin agro-climatic conditions, the E₃ represented high altitude agro-climatic conditions. The checks used in E₁, E₂ and E₃ were Priscilla and Wig's Sensation.

For quantitative analysis the data was recorded on days to sprout, plant height, leaves plant⁻¹, shoots plant⁻¹, days to slipping (spike emergence), spike length, days to basal floret opening, florets spike⁻¹, florets open at a time, floret size, durability of basal floret, durability of whole spike, corm production plant⁻¹, corm weight, corm size, number of

cormels plant⁻¹ and weight of 10 cormels for the estimation of different genetic parameters and divergence.

Coefficient of variation (genotypic and phenotypic) was high for cormels plant⁻¹, moderate for weight of 10 cormels, weight of corm, corms plant⁻¹, shoots plant⁻¹ and days to sprout and low for rest of the traits. Heritability (broad sense) was high for plant height, days to basal floret opening, florets spike⁻¹, number of florets open at a time, durability of whole spike, corms plant⁻¹, weight of corm, cormels plant⁻¹ and weight of 10 cormels. It was moderate for days to slipping, spike length, durability of basal floret, size of the floret and size of corm, and low for days to sprout, leaves plant⁻¹ and shoots plant⁻¹. The expected genetic gain (per cent of mean) was high for number of cormels plant⁻¹, weight of corm and weight of 10 cormels and corms plant⁻¹ moderate for days to sprout, plant height, shoots plant⁻¹, days to slipping, spike length, florets spike⁻¹, number of florets open at a time and durability of whole spike, and low for leaves plant⁻¹, durability of basal floret, size of the floret and size of corm.

Association among traits, measured by a correlation coefficient, revealed a significant and positive association of number of florets spike⁻¹ with spike length, number of florets open at a time, durability of whole spike, plant height, size of the floret, number of corms plant⁻¹, weight of corm and size of corm. Spike length had positive and significant correlation with number of florets spike⁻¹, number of florets open at a time, durability of whole spike, plant height, leaves plant⁻¹, corms plant⁻¹, weight of corm

and size of corm, but had a significant negative correlation with size of the floret and weight of 10 cormels. Days to basal floret had positive and significant correlation with days to sprout, number of corms plant⁻¹, and weight of 10 cormels but a significant negative correlation with number of florets open at a time, size of the floret and size of corm. Durability of whole spike showed positive and significant correlation with spike length, durability of basal floret, number of florets spike⁻¹, plant height, days to sprout, weight of corm and number of cormels plant⁻¹. Size of the floret revealed positive and significant correlation with weight and size of corm, but a significant negative correlation with number of cormels plant⁻¹ and weight of 10 cormels. Days to sprout expressed positive and significant correlation with weight of 10 cormels, but negative and significant correlation with size of the floret, weight of corm and size of corm. Number of corms plant⁻¹ had positive and significant correlation with size of corms and weight of 10 cormels. Weight of corm expressed positive and significant correlation with size of corm and number of cormels plant⁻¹. Size of corm had significant positive correlation with number of cormels plant⁻¹.

The correlations at the phenotypic level were mostly similar in direction, though lower in magnitude, as compared to genotypic correlations, revealing that the association at both the phenotypic and genotypic levels were reliable and mostly outcome of the genotypic component.

Significant G x E interaction was observed for all the traits and therefore, the estimates from the single environment were slightly biased. Data pooled over environments eliminated most of the G x E interaction and the conclusions drawn from the pooled analysis over environments were more appropriate and are thus, presented in the summary. Analysis of cause and effect relationship revealed that number of florets spike⁻¹ exhibited positive and highly significant correlation with plant height, spike length, number of florets open at a time, size of floret, size of corm, number of cormels plant⁻¹ and durability of whole spike. The positive and highly significant direct effects were contributed by spike length, days to slipping, number of florets open at a time, size of floret, number of cormels plant⁻¹, number of corms plant⁻¹ and weight of corm. The negative high direct effects were revealed by plant height, days to basal floret opening, durability of whole spike and shoots plant⁻¹. The traits contributing indirectly towards number of florets spike⁻¹ were spike length, number of florets open at a time, durability of whole spike, size of floret, size of corm and plant height.

Estimation of the divergence studies revealed that the significant divergence existed among the currently tested cultivars. The grouping of the cultivars in individual environments revealed that in E₁ five clusters were formed with cluster-I containing 54 cultivars followed by cluster-II (5 cultivars) and rest of the clusters had one cultivar each. In E₂ four clusters were formed with cluster-I containing-59 cultivars and the remaining 3

clusters had one cultivars each. In E_3 , five clusters were formed with cluster-I having 50 cultivars followed by cluster-II (4 cultivars) and remaining clusters had one cultivar each. The picture in the pooled analysis changed where the 62 cultivars got grouped into 12 clusters, with cluster I comprising 50 cultivars and cluster VIII only two cultivars, while rest of the clusters had only one cultivar each.

Maximum inter-cluster distances were observed in the individual environments and in pooled analysis between the cluster(s), revealing ample possibility for developing superior genotypes through hybridization. Maximum inter-cluster distances were observed between cluster II and VIII ; cluster VII and VIII ; cluster II and IX ; cluster II and cluster XII and cluster I and VIII in pooled analysis.

Cluster means help in identifying the characters to be chosen for hybridization. The cluster means for different vegetative, floral, and corm and cormel production traits revealed substantial genetic variability for all the traits in the individual environments and their mean values were maximum mostly in the clusters containing high economic yielding commercial cultivars as compared to other clusters. The traits contributing maximum to the divergence were days to basal floret opening, number of florets spike⁻¹, spike length, durability of whole spike, size of the floret, corms plant⁻¹, number of cormels plant⁻¹, weight of corm and weight of 10 cormels. These traits need to be given due weightage while selecting parents for hybridization programme. The divergent genotypes from the

clusters identified for developing transgressive segregants with high economic yield were White Prosperity, Regency, Aarti, CPG-6, Sapna, Amsterdam, Jester Gold, Red Majesty, Sunny Boy, Sunset Jubilee, Jackson Villa Gold and Yellow Stone.

Stability performance was estimated for ten elite gladiolus cultivars selected on the basis of floral component and quality traits from the experiment on divergence. These ten elite local cultivars were evaluated across five random locations (environments) in the valley. Analysis of variance revealed presence of significant genetic variability for all the traits studied viz., plant height, days to slipping, leaves plant⁻¹, shoots plant⁻¹, days to sprouting, days to slipping, spike length, days to basal floret opening, durability of basal floret, florets spike⁻¹, number of florets open at a time, durability of whole spike, size of the floret, number of corms plant⁻¹, weight of corm, size of corm, number of cormels plant⁻¹ and weight of 10 cormels.

Mean squares due to environments were significant for days to basal floret opening, durability of basal floret, florets spike⁻¹, number of florets open at a time, durability of whole spike, size of floret, corms plant⁻¹, weight of corm, size of corm, cormels plant⁻¹ and weight of 10 cormels. The G x E interaction was significant for days to sprouting, plant height, days to slipping, spike length, days to basal floret opening, durability of basal floret, number of corms plant⁻¹ and weight of corm. Mean squares due to environment + (cultivars x environments) was significant for size of corm

revealing variable response of genotypes for this traits in the changing environments. Mean squares due to environments (linear) were highly significant for most of the traits revealing that the environments were random and different. The cultivars x environments (Linear) interaction was significant for days to sprouting, plant height, days to slipping, spike length, days to basal floret opening, number of corms plant⁻¹, weight of corm, number of cormels plant⁻¹ and weight of 10 cormels. Mean square deviation from linear regression was significant for days to slipping in Apple Blossom and Yellow Stone; for spike length (all the cultivars except Friendship Pink and Peter Pears); for days to basal floret opening (all the cultivars except Friendship Pink, Moralla and Sanceree); for florets spike⁻¹ (Apple Blossom, Moralla and Sanceree); for durability of whole spike (Friendship Pink and Traderhorn) ; for days to sprout (all the cultivars except Friendship Pink, Moralla and Traderhorn); for weight of corm (all the cultivars except Friendship Pink, Moralla and Traderhorn) and for number of cormels plant⁻¹ in Jackson Villa Gold, Moralla, Traderhorn and White Prosperity.

The mean square deviation from regression was non-significant for plant height, leaves plant⁻¹, durability of basal floret, size of floret, number of florets open at a time, shoots plant⁻¹, corms plant⁻¹, size of corm and weight of 10 cormels indicating that stability would be more reliable and predictable when mean square deviation from regression is non-significant i.e. equal to zero within the limit of standard error.

Stability analysis for most important trait i.e. number of florets spike⁻¹ revealed that the mean square deviation from regression was non-significant for all the cultivars except, Apple Blossom, Moralla and Sanceree and the prediction for stability of number of florets spike⁻¹, across the environments would be precise and reliable. The linear regression was also non-significant for all the cultivars except Apple Blossom and Big Time Supreme, indicating that the cultivars showing non-significant b_i and S^2d_i values were having average stability and were either poorly or well adapted to these environments, Considering the mean performance of the cultivars for number of florets spike⁻¹ it could be derived that the cultivars Friendship Pink, Jackson Villa Gold, Peter Pears, Traderhorn and White Prosperity were well adapted to all the environments.

Based on these findings the following broad line conclusion could be drawn:

- i) Significant genetic variability was present for all the vegetative, floral, and corm and cormel traits among the current test gladiolus cultivars.
- ii) Higher magnitude of genotypic coefficient of variability was observed for number of cormels plant⁻¹, which also revealed high heritability and expected genetic gain.
- iii) Significant G x E interaction was observed for all the traits indicating their differential behaviour across the environments.
- iv) Positive and significant correlation existed for number of florets spike⁻¹ with spike length, number of florets open at a time, durability of whole

spike, plant height, size of the floret, number of corms plant⁻¹ and weight and size of corm.

- v) Maximum direct contribution towards the number of florets spike⁻¹ came from spike length, days to slipping, number of florets open at a time, size of floret, corms plant⁻¹, cormels plant⁻¹ and weight of corm, whereas, indirect positive and significant contribution also came from spike length.
- vi) Estimation of genetic divergence on the basis of data pooled over environments revealed that maximum cultivars got grouped into single cluster and in the remaining clusters the cultivars were generally one or in a few not more than 4. Thus indicated that the lines were probably from the same source and over centuries the accumulation of variation has resulted from directional selection by the florists.
- vii) Plant height was observed to contribute maximum towards the genetic divergence followed by number of florets spike⁻¹, days to basal floret opening, durability of whole spike, number of cormels plant⁻¹ and weight of 10 cormels.
- viii) Stability of number of florets spike⁻¹ across the environments revealed that the mean square deviation from regression (S^2d_i) was non-significant for most of the cultivars and thus, predictability was reliable and precise. Most of the cultivars were average in stability.
- ix) Comparing the performance of some of the elite test cultivars with the high economic yielding exotic cultivars, there exists ample scope to

improve some of the elite current test cultivars through hybridization with the high economic yielding exotic cultivars. Selection of recombinants possessing good quality of current test cultivars and high economic potential of high yielding exotic cultivars could increase the income of the florists still cultivating some of these elite current test cultivars.

Table : 2. Analysis of variance for different characters of gladiolus cultivars under temperate climatic conditions of

Kashmir

Source of variation	d.f	Mean Squares											
		Days to sprout				Plant height (cm)				Number of leaves plant ⁻¹			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	4258.87**	---	---	---	10863.75**	---	---	---	43.25**
Replications	2	16.43**	24.39**	0.02	40.75**	41.43	19.47	22.80*	65.75	0.18	0.36	0.18	0.60
Environments x Replications	4	---	---	---	12.37	---	---	---	8.25	---	---	---	0.06
Genotypes	61	34.57**	18.99**	30.92**	591.65**	414.91**	412.47**	504.89**	711.83**	1.80*	1.24*	1.00*	2.03*
Genotypes x Environments	122	---	---	---	174.31**	---	---	---	310.20**	---	---	---	1.00*
Error	122	0.68	2.73	0.286	---	22.92	43.30	9.09	---	0.16	0.14	0.07	---
Pooled error	366	---	---	---	2.21	---	---	---	25.11	---	---	---	0.12

Continued.....

Table : 2 (Contd.)

Source of variation	d.f	Mean Squares											
		Number of shoots plant ⁻¹				Days to slipping				Spike length (cm)			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	5.61**	---	---	---	524.03**	---	---	---	14405.25**
Replications	2	0.06	0.00	0.06	0.11	2.14	59.09	4.53	127.01	20.60	28.18	17.13	567.50
Environments x Replications	4	---	---	---	0.11	---	---	---	65.99**	---	---	---	1023.37**
Genotypes	61	0.59*	0.22*	0.29*	0.50*	291.10**	209.40**	439.77**	39.45**	303.96**	358.95**	462.53**	1460.43**
Genotypes x Environments	122	---	---	---	0.30*	---	---	---	22.52**	---	---	---	1104.04
Error	122	0.09	0.06	0.07	---	1.27	3.67	1.68	---	14.02	32.43	9.12	---
Pooled error	366	---	---	---	0.07	---	---	---	1.23	---	---	---	941.71

Continued....

Table : 2 (Contd.)

Source of variation	d.f	Mean Squares											
		Days to basal floret opening				Durability of basal floret				Number of florets spike ⁻¹			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	2635.25**	---	---	---	19.24**	---	---	---	32.90**
Replications	2	18.50*	37.58*	1.28	45.37*	0.11	0.14	0.00	0.19	0.21	0.15	1.75	1.28
Environments x Replications	4	---	---	---	5.50	---	---	---	0.03	---	---	---	0.41
Genotypes	61	459.22**	186.41**	429.66**	772.52**	1.27*	1.26*	0.43*	0.97**	9.76**	9.42**	10.84**	15.05**
Genotypes x Environments	122	---	---	---	151.37**	---	---	---	1.00**	---	---	---	7.48**
Error	122	1.89	2.61	1.15	---	0.09	0.10	0.04	---	0.60	1.08	0.33	---
Pooled error	366	---	---	---	1.89	---	---	---	0.08	---	---	---	0.67

Continued....

Table : 2 (Contd.).

Source of variation	d.f	Mean Squares											
		Durability of whole spike (days)				Number of florets open at a time				Size of the floret (cm)			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	83.27**	---	---	---	12.51**	---	---	---	27.43**
Replications	2	0.52	0.18	0.39	0.44	0.94	0.14	0.03	0.40	1.00	0.00	0.41*	0.78
Environments x Replications	4	---	---	---	0.32	---	---	---	0.35	---	---	---	0.32
Genotypes	61	4.93*	7.77*	6.39*	7.15*	1.25*	0.54*	0.84*	1.20*	2.44*	4.49*	3.20*	5.01*
Genotypes x Environments	122	---	---	---	0.59*	---	---	---	0.72*	---	---	---	2.56*
Error	122	0.19	0.96	0.23	---	0.08	0.10	0.06	---	0.32	0.16	0.15	---
Pooled error	366	---	---	---	0.46	---	---	---	0.08	---	---	---	0.21

Continued....

Table : 2 (Contd.)

Source of variation	d.f	Mean squares											
		Number of corms plant ⁻¹				Weight of corm (g)				Size of corm (cm)			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	7.11**	---	---	---	1331.50**	---	---	---	66.97**
Replications	2	0.25	0.04	0.26*	0.23	10.10	38.05*	26.58*	5.93	0.24	0.57*	0.18*	0.11
Environments x Replications	4	---	---	---	0.16	---	---	---	34.34	---	---	---	0.44
Genotypes	61	0.22*	0.35*	0.85*	0.56*	125.31**	101.88**	265.19**	288.04**	0.92*	0.50*	1.18*	1.07*
Genotypes x Environments	122	---	---	---	0.43*	---	---	---	102.18**	---	---	---	0.76*
Error	122	0.15	0.03	0.05	---	7.85	3.41	3.14	---	0.16	0.06	0.02	---
Pooled error	366	---	---	---	0.07	---	---	---	4.80	---	---	---	0.08

Continued....

Table : 2 (Contd.).

Source of variation	d.f	Mean Squares							
		Number of cormels plant ⁻¹				Weight of 10 cormels (g)			
		E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Environments	2	---	---	---	6875.75**	---	---	---	52.79**
Replications	2	4.17	136.95*	49.01*	132.37**	1.68**	0.50*	0.64*	0.46**
Environments x Replications	4	---	---	---	28.71	---	---	---	1.18**
Genotypes	61	1797.45**	2359.40**	3098.03**	6982.12**	3.59*	7.56**	8.46**	12.07**
Genotypes x Environments	122	---	---	---	136.38**	---	---	---	3.77**
Error	122	10.52	9.26	11.53	---	0.62	0.20	0.12	---
Pooled error	366	---	---	---	104.40	---	---	---	0.31

*,** Significant at 5 and 1 per cent level, respectively

Table : 1 List of Cultivars used in the present study

S,No	Cultivar	S,No	Cultivar
1.	Aarti	32.	Pink Jewel
2.	Amsterdam	33.	Rose Supreme
3.	Apple Blossom	34.	Regency
4.	CPG-6	35.	Ratna's Butterfly
5.	American Beauty	36.	R N-96
6.	Big Time Supreme	37.	Rose Delight
7.	Bindiya	38.	Red Majesty
8.	Bis Bis	39.	Rose and Wine
9.	Bonos Memory	40.	Suchitra
10.	Buff Beauty	41.	Sylvia
11.	King Lear	42.	Sapna
12.	Eurovision	43.	SKG-8
13.	Fidelo	44.	Spic and Span
14.	Friendship Pink	45.	Sunny Boy
15.	Mescagani	46.	Sunset Jubilee
16.	Her Majesty	47.	Sancere
17.	Jester	48.	SKG-10
18.	Jester Gold	49.	Traderhorn
19.	Jackson Ville Gold	50.	Tropic Sea
20.	Morallo	51.	Top Brass
21.	Mayur	52.	Vink's Glory
22.	Nazrana	53.	Wind Song
23.	Oscar	54.	White Giant
24.	Purple King	55.	White Prosperity
25.	Punjab Selection	56.	Wig's Sensation (Check)
26.	Pusa Suhagin	57.	Watermelon Pink
27.	Power Puff	58.	White Goddess
28.	Priscilla (Check)	59.	Yellow Stone

29. Peter Pears	60. Melody
30. Poonam	61. Pisitachinus Hybrid
31. Princes Margret Rose	62. Yellow Frills

Table : 3. Magnitude of variability for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir.

Traits	Range	Mean*
Days to sprout	22 .05 - 29.50	26.1 7
Plant height (cm)	89.84 - 135.28	113.91
Number of leaves plant⁻¹	6.92 - 8.70	7.92
Number of shoots plant⁻¹	1.11 - 2.36	1.46
Days to slipping	68.53 - 110.70	78.09
Spike length (cm)	63.74 - 112.63	89.41
Days to basal floret opening	74.87 - 118.52	86.01
Durability of basal floret (days)	3.92 - 5.65	4.49
Florets spike⁻¹	12.01 - 18.80	15.61
Number of florets open at a time	2.91 - 4.64	4.08
Durability of whole spike	9.18 – 14.58	11.0 1

(days)

Size of the floret (cm)	7.87 - 11.05	9.61
Number of corms plant⁻¹	1.24 – 2.43	1.52
Weight of corm (g)	17.79 - 38.82	30.25
Size of corm (cm)	3.31 - 4.96	4.28
Number of cormels plant⁻¹	12.53 - 145.73	46.69
Weight of 10 cormels (g)	2.82 - 7.45	5.14

* Mean values are based on the performance across the three locations (environments)

Table : 4. Estimates of coefficient of variation (phenotypic and genotypic) for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir.

Traits	Phenotypic coefficient of variation (PCV)				Genotypic coefficient of variation (GCV)			
	E ₁	E ₂	E ₃	Pooled over environment	E ₁	E ₂	E ₃	Pooled over environment
Days to sprout	13.87	9.90	11.57	13.82	13.73	9.16	11.52	9.77
Plant height (cm)	11.08	10.30	10.68	7.83	10.77	9.75	10.58	7.61
Number of leaves plant⁻¹	9.16	8.55	7.36	5.04	8.74	8.03	7.07	4.09
Number of shoots plant⁻¹	26.38	20.13	22.29	13.45	24.27	17.00	19.04	10.87
Days to slipping	12.33	11.50	14.82	8.62	12.30	11.39	14.79	7.60
Spike length (cm)	11.91	12.06	12.67	9.93	11.63	11.50	12.55	8.39
Days to basal floret opening	14.73	9.34	13.20	10.83	14.70	9.27	13.18	10.66
Durability of basal floret (days)	15.26	15.69	7.96	7.22	14.69	15.05	7.96	6.09
Florets spike⁻¹	11.92	11.20	11.95	8.21	11.54	10.54	11.76	8.00
Number of florets open at a time	16.73	10.52	12.12	8.61	16.17	9.46	11.66	7.99
Durability of whole spike (days)	12.30	14.92	12.45	8.88	12.05	13.96	12.22	8.22
Size of the floret (cm)	9.20	13.27	10.40	6.87	8.56	13.03	10.15	6.10
Number of corms plant⁻¹	18.34	25.49	30.66	16.14	12.68	24.10	29.59	14.81
Weight of corm (g)	22.07	20.56	28.17	18.68	21.37	20.21	28.00	18.33
Size of corm (cm)	13.02	11.08	12.88	7.15	11.80	10.29	12.72	5.92
Number of cormels plant⁻¹	59.39	60.55	60.26	46.87	59.21	60.43	60.15	42.02

Weight of 10 cormels (g)	23.84	30.60	29.71	19.33	21.67	30.17	29.40	18.18
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Table 5 : Estimates of heritability, genetic advance and expected genetic (per cent of mean) gain for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir.

Traits	Heritability (Broad sense)				Genetic advance				Expected genetic gain (per cent of mean)			
	E ₁	E ₂	E ₃	Pooled	E ₁	E ₂	E ₃	Pooled	E ₁	E ₂	E ₃	Pooled
Days to sprout	0.98	0.85	0.90	0.50	6.85	4.43	6.55	3.72	28.00	17.47	23.63	14.23
Plant height (cm)	0.94	0.89	0.98	0.94	22.88	21.61	26.24	17.35	21.56	19.00	21.61	15.23
Number of leaves plant⁻¹	0.90	0.88	0.92	0.65	1.45	1.16	1.09	0.54	17.17	15.54	13.98	6.84
Number of shoots plant⁻¹	0.84	0.71	0.72	0.65	0.77	0.40	0.47	0.26	45.99	29.57	33.50	18.11
Days to slipping	0.99	0.98	0.99	0.77	20.20	16.90	24.84	10.79	25.29	23.27	30.41	13.82
Spike length (cm)	0.95	0.90	0.98	0.71	19.77	20.49	25.07	13.08	23.41	22.49	25.59	14.63
Days to basal floret opening	0.99	0.98	0.99	0.96	25.38	16.01	24.58	18.60	30.23	18.98	27.12	21.63
Durability of basal floret (days)	0.92	0.92	0.88	0.71	1.24	1.23	0.69	0.47	29.12	29.77	14.57	10.58
Florets spike⁻¹	0.93	0.88	0.96	0.94	3.48	3.22	3.79	2.50	23.03	20.42	23.86	16.04
Number of florets open at a time	0.93	0.80	0.92	0.86	1.24	0.70	1.01	0.62	32.20	17.51	23.12	15.29
Durability of whole spike (days)	0.76	0.87	0.96	0.85	2.53	2.90	2.89	1.72	24.34	26.93	24.71	15.69
Size of the floret (cm)	0.86	0.96	0.95	0.78	1.61	2.43	2.02	1.07	16.41	26.36	20.39	11.15

Number of corms plant⁻¹	0.47	0.89	0.93	0.84	0.26	0.63	1.02	0.42	18.07	46.96	58.83	27.99
Weight of corm (g)	0.93	0.96	0.98	0.96	12.48	11.60	19.13	11.21	42.62	40.93	57.34	37.07
Size of corm (cm)	0.82	0.86	0.97	0.68	0.94	0.72	1.26	0.43	22.04	19.70	25.87	10.11
Number of cormels plant⁻¹	0.99	0.99	0.99	0.80	50.12	50.54	57.54	36.24	121.63	124.25	123.68	77.60
Weight of 10 cormels (g)	0.82	0.97	0.98	0.85	1.86	3.18	3.40	1.81	40.58	61.30	60.29	35.22

Table : 6 (a) Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir. (Environment-I)

Traits	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)	Number of Florets spike ⁻¹	Number of florets open at a time	Durability of whole spike (days)	Days to slipping	Plant height (cm)	Number of leaves plant ⁻¹
Spike length (cm)	----	-0.225*	0.154	0.312**	0.178	0.050	-0.248*	0.765**	0.346**
Days to basal floret opening	-0.220*	----	0.149	-0.238**	-0.299**	0.045	0.121	-0.340**	-0.085
Durability of basal floret (days)	0.145	0.145	----	0.087	0.268*	0.158	0.017	0.010	-0.148
Number of florets spike ⁻¹	0.310**	-0.229*	0.084	----	0.362**	0.364*	-0.070	0.593**	0.209
Number of florets open at a time	0.174	-0.291*	0.257*	0.343**	----	0.379*	0.055	0.351**	0.258*
Durability of whole spike (days)	0.046	0.045	0.147	0.339**	0.365**	----	-0.015	0.190	0.241*
Days to slipping	-0.239*	0.119	0.013	-0.070	0.055	-0.016	----	-0.151	-0.065
Plant height (cm)	0.757**	-0.331**	0.011	0.572**	0.392**	0.184	-0.149	----	0.381**
Number of leaves plant ⁻¹	0.315**	-0.079	-0.140	0.185	0.237*	0.223*	-0.059	0.354*	----
Number of shoots plant⁻¹	-0.091	-0.036	-0.023	-0.230*	-0.035	-0.216*	-0.025	-0.167	-0.095
Days to sprout	-0.148	0.690**	0.028	-0.115	-0.174	0.286**	0.158	-0.214*	0.151
Size of the floret (cm)	0.340**	-0.104	0.054	0.340**	0.406**	0.383*	-0.019	0.398**	0.230*
Number of corms plant⁻¹	0.125	-0.007	-0.058	0.084	0.174	-0.211	0.096	-0.124	0.139
Weight of corm (g)	0.305**	-0.174	0.193	0.434**	0.519**	0.228*	-0.031	0.444**	0.090

Size of corm (cm)	0.228*	-0.219*	0.107	0.338**	0.372**	-0.011	0.005	0.331**	0.060
Number of cormels plant⁻¹	0.154	-0.000	0.096	0.173	0.141	0.162	0.060	0.026	0.158
Weight of 10 cormels (g)	0.136	-0.148	-0.135	0.144	-0.031	-0.197	-0.036	0.121	-0.081

Continued.....

Table : 6 (a) (Contd.)

Traits	(Environment-I)								
	Number of shoots plant ⁻¹	Days to sprout	Size of the floret (cm)	Number of corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of cormels plant ⁻¹	Weight of 10 cormels (g)	
Spike length (cm)	-0.093	-0.151	0.356**	0.180	0.319**	0.247*	0.157	0.160	
Days to basal floret opening	-0.035	0.693*	-0.112	-0.000	-0.181	-0.242*	-0.004	-0.166	
Durability of basal floret (days)	-0.021	0.030	0.055	-0.094	0.210*	0.145	0.102	-0.147	
Number of florets spike ⁻¹	-0.250*	-0.118	0.353**	0.107	0.471**	0.383**	0.177	0.234	
Number of florets open at a time	-0.043	-0.179	0.453**	0.260*	0.556**	0.432**	0.145	-0.037	
Durability of whole spike (days)	-0.240*	0.292**	0.422**	-0.291*	0.239*	-0.004	0.167	-0.219	
Days to slipping	-0.032	0.161	-0.020	0.140	-0.028	0.004	0.060	-0.035	
Plant height (cm)	-0.182	-0.220*	0.422**	0.187	0.479**	0.372**	0.027	0.142	
Number of leaves plant ⁻¹	-0.120	0.159	0.253*	0.221	0.094	0.095	0.167	-0.097	
Number of shoots plant⁻¹	----	-0.216*	-0.307**	0.427**	0.127	0.193	0.128	-0.019	
Days to sprout	-0.198	----	0.133	-0.002	-0.155	-0.113	0.080	-0.106	
Size of the floret (cm)	-0.277*	0.120	----	0.038	0.283**	0.210	0.097	-0.088	
Number of corms plant⁻¹	0.271*	-0.005	0.029	----	0.427**	0.575**	0.032	-0.101	
Weight of corm (g)	0.111	-0.149	0.261*	0.277*	----	0.527**	0.137	-0.049	

Size of corm (cm)	0.155	-0.098	0.198	0.338**	0.487**	----	0.069	0.189
Number of cormels plant⁻¹	0.117	0.079	0.090	0.025	0.132	-0.063	----	-0.087
Weight of 10 cormels (g)	0.007	-0.097	0.052	0.064	0.041	0.127	-0.079	----

*, ** significant at 5 and 1% level, respectively

Table : 6 (b) Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir.

(Environment-II)									
Traits	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)	Number of Florets spike ⁻¹	Number of florets open at a time	Durability of whole spike (days)	Days to slipping	Plant height (cm)	Number of leaves plant ⁻¹
Spike length (cm)	---	0.180	-0.172	0.307*	0.183	0.077	0.245*	0.952**	0.185
Days to basal floret opening	0.172	---	-0.038	-0.022	-0.094	-0.301	-0.077	0.137	0.261*
Durability of basal floret (days)	-0.163	-0.035	----	-0.139	-0.101	0.085	-0.277*	-0.274**	-0.359
Number of florets spike ⁻¹	0.275*	-0.023	-0.126	---	0.282*	0.219*	0.175	0.445**	0.224*
Number of florets open at a time	0.140	-0.076	-0.079	0.247*	---	-0.147	-0.049	0.243*	-0.048
Durability of whole spike (days)	0.063	-0.287*	0.081	0.191	-0.130	---	0.251*	-0.010	-0.255*
Days to slipping	0.187	-0.063	-0.249*	0.134	-0.046	0.205	----	0.377*	0.028
Plant height (cm)	0.934**	0.130	-0.253*	0.386**	0.182	-0.006	0.295*	----	0.283*
Number of leaves plant ⁻¹	0.160	0.245**	-0.325**	0.202	-0.045	-0.216*	0.025	0.245*	---
Number of shoots plant⁻¹	0.085	-0.221*	-0.038	-0.244*	0.040	-0.011	0.106	0.126	0.105
Days to sprout	0.155	0.853**	0.088	0.029	-0.168	-0.227*	-0.028	0.132	0.037
Size of the floret (cm)	0.159	0.078	0.262*	0.045	0.212*	-0.043	-0.132	0.145	0.098

Number of corms plant⁻¹	0.044	-0.023	-0.173	0.050	0.266**	0.039	0.096	0.043	-0.032
Weight of corm (g)	0.045	-0.023	0.062	0.098	-0.034	0.163	0.046	0.078	0.325**
Size of corm (cm)	-0.134	-0.202	0.141	0.046	-0.002	0.261**	0.160	-0.079	-0.026
Number of cormels plant⁻¹	-0.076	-0.090	-0.245**	0.153	-0.092	0.215	0.230*	0.058	-0.003
Weight of 10 cormels (g)	-0.181	0.230*	0.268*	-0.111	0.027	-0.299**	-0.224*	-0.158	-0.137

Continued

Table : 6 (b) (Contd.)

Traits	(Environment-II)								
	Number of shoots plant ⁻¹	Days to sprout	Size of the floret (cm)	Number of corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of cormels plant ⁻¹	Weight of 10 cormels (g)	
Spike length (cm)	0.102	0.164	0.162	0.057	0.048	-0.148	-0.076	-0.194	
Days to basal floret opening	-0.270*	0.864**	0.082	-0.025	-0.025	-0.219*	-0.092	0.237*	
Durability of basal floret (days)	-0.050	0.090	0.277*	-0.191	0.069	0.159	-0.256*	0.279*	
Number of florets spike ⁻¹	-0.306**	0.038	0.050	0.065	0.096	0.034	0.158	-0.118	
Number of florets open at a time	0.093	-0.202	0.241*	0.305**	-0.032	-0.021	-0.103	0.028	
Durability of whole spike (days)	-0.016	-0.239*	-0.043	0.055	0.181	0.298*	0.232**	-0.325	
Days to slipping	0.136	-0.036	-0.142	0.091	0.052	0.200	0.245*	-0.231	
Plant height (cm)	0.139	0.147	0.143	0.053	0.083	-0.093	0.065	-0.170	
Number of leaves plant ⁻¹	0.127	0.037	0.109	-0.042	0.343**	-0.069	-0.004	-0.149	
Number of shoots plant⁻¹	----	-0.204	0.013	0.311**	0.446**	0.236*	0.122	0.085	
Days to sprout	-0.176	----	0.063	-0.009	-1.021	-0.206	-0.030	0.252*	
Size of the floret (cm)	0.012	0.057	----	0.415**	0.243*	-0.064	-0.128	-0.114	
Number of corms plant⁻¹	0.249*	-0.005	0.040	----	0.255*	0.180	0.162	0.000	

Weight of corm (g)	0.371**	-0.021	0.229*	0.225*	----	0.423**	0.223	-0.193
Size of corm (cm)	0.146	-0.191	-0.067	0.156	0.401**	---	0.216*	0.176
Number of cormels plant⁻¹	0.107	-0.030	-0.126	0.149	-0.219*	0.202	----	-0.105
Weight of 10 cormels (g)	0.081	0.246*	-0.111	-0.001	0.183	0.163	-0.105	----

*, ** significant at 5 and 1% level, respectively

Table: 6 (c) Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir. (Environment-III)

Trait	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)	Number of Florets spike ⁻¹	Number of florets open at a time	Durability of whole spike (days)	Days to slipping	Plant height (cm)	Number of leaves Plant ⁻¹
Spike length (cm)	---	-0.750**	0.140	0.501**	0.342**	0.168	-0.218*	0.879**	0.101
Days to basal floret opening	-0.074	---	-0.151	-0.010	-0.240*	0.250*	0.317**	-0.059	-0.125
Durability of basal floret (days)	0.130	-0.142	---	0.050	0.035	0.197	-0.317**	0.180	-0.079
Number of florets spike ⁻¹	0.486**	-0.008	0.051	---	0.475**	0.414**	-0.153	0.584**	0.122
Number of florets open at a time	0.326**	-0.234*	0.040	0.447**	----	0.032	-0.085	0.434**	0.112
Durability of whole spike (days)	0.163	-0.245*	0.191	0.400**	0.034	----	-0.067	0.180	0.013
Days to slipping	-0.214*	0.314**	-0.295*	-0.150	-0.083	0.067	---	-0.270*	-0.006
Plant height (cm)	0.874**	-0.058	0.168	0.566**	0.410**	0.175	-0.265*	----	0.157
Number of leaves plant ⁻¹	0.099	-0.009	-0.053	0.113	0.095	0.005	-0.008	0.152	----
Number of shoots plant⁻¹	-0.009	0.099	-0.148	0.050	-0.138	-0.051	0.041	-0.068	-0.001
Days to sprout	-0.082	0.996**	-0.148	-0.020	-0.244*	0.262*	0.311**	-0.072	-0.022
Size of the floret (cm)	0.321**	-0.068	-0.136	0.215*	0.334**	0.087	-0.136	0.451**	0.161

Number of corms plant⁻¹	0.023	0.318**	-0.053	0.154	0.091	-0.016	0.101	0.063	0.021
Weight of corm (g)	0.590**	0.009	0.035	0.395**	0.230*	0.140	-0.174	0.552**	0.003
Size of corm (cm)	0.461**	-0.101	0.252**	0.324**	0.194	0.161	-0.252*	0.443**	-0.023
Number of cormels plant⁻¹	0.109	-0.066	0.357**	-0.123	0.109	0.094	-0.075	0.195	-0.019
Weight of 10 cormels (g)	-0.312*	0.191	-0.066	-0.086	-0.064	0.084	0.177	-0.198	0.088

Continued

Table : 6 (c) (Contd.)

Trait	(Environment-III)								
	Number of shoots plant ⁻¹	Days to sprout	Size of the floret (cm)	Number of corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of cormels plant ⁻¹	Weight of 10 cormels (g)	
Spike length (cm)	-0.004	-0.084	0.333**	0.025	0.598**	0.472**	0.112	-0.318**	
Days to basal floret opening	0.119	0.997**	-0.069	0.328**	0.009	-0.102	-0.066	0.022	
Durability of basal floret (days)	-0.180	-0.159	-0.146	-0.058	0.031	0.270*	0.379**	-0.069	
Number of florets spike ⁻¹	0.054	-0.022	0.220*	0.164	0.405**	0.338**	-0.123	-0.089	
Number of florets open at a time	-0.1600	-0.252*	0.355**	0.093	0.236*	0.209*	0.114	-0.067	
Durability of whole spike (days)	-0.078	0.268*	0.085	-0.017	0.142	0.171	0.096	0.087	
Days to slipping	0.044	0.313**	-0.143	0.104	-0.175	-0.257**	-0.075	0.180	
Plant height (cm)	-0.815**	-0.073	0.470**	0.066	0.560**	0.453**	0.199	-0.202	
Number of leaves plant ⁻¹	0.167	-0.024	0.177	0.031	0.006	-0.034	-0.020	0.088	
Number of shoots plant⁻¹	---	0.122	0.097	-0.015	0.097	0.078	0.166	-0.099	
Days to sprout	0.098	---	-0.078	0.309**	-0.009	-0.116	-0.075	0.189	
Size of the floret (cm)	0.074	-0.077	---	-0.081	0.225*	-0.034	0.271	-0.164	
Number corms plant⁻¹	-0.006	0.299*	-0.073	---	-0.148	-0.107	0.050	0.108	

Weight of corm (g)	0.084	-0.009	0.216*	-0.143	----	0.634**	0.124	-0.052
Size of corm (cm)	0.068	-0.114	-0.037	-0.108	0.622**	----	0.281**	0.056
Number of cormels plant⁻¹	0.140	-0.075	0.263*	0.047	0.123	0.278*	----	-0.026
Weight of 10 cormels (g)	-0.081	0.188	-0.155	0.106	-0.052	0.056	0.026	----

*, ** significant at 5 and 1% level, respectively

Table : 6 (d) Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for different characters of gladiolus cultivars under temperate climatic conditions of Kashmir.

(Pooled over environments)									
Trait	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)	Number of Florets spike ⁻¹	Number of florets open at a time	Durability of whole spike (days)	Days to slipping	Plant height (cm)	Number of leaves plant ⁻¹
Spike length (cm)	---	-0.139	0.134	0.535**	0.447**	0.407**	0.113	0.953**	0.356**
Days to basal floret opening	-0.114	----	0.057	-0.173	-0.380**	-0.054	0.117	-0.203	-0.100
Durability of basal floret (days)	0.070	0.043	---	0.033	0.102	0.252**	-0.309**	-0.0248	-0.003
Number of florets spike ⁻¹	0.439**	-0.167	0.032	----	0.534**	0.387**	0.006	0.576**	0.115
Number of florets open at a time	0.369**	-0.356**	0.102	0.492**	----	0.047	0.204	0.421**	0.228*
Durability of whole spike (days)	0.317**	-0.044	0.233*	0.339**	0.038	----	-0.144	0.235*	-0.082
Days to slipping	0.057	0.083	-0.181	-0.001	0.157	-0.081	----	0.005	0.043
Plant height (cm)	0.775**	-0.199	-0.015	0.537**	0.362**	0.210*	-0.009	---	0.518*
Number of leaves plant ⁻¹	0.291*	-0.079	0.008	0.106	0.190	-0.044	0.047	0.404**	----
Number of shoots plant⁻¹	-0.033	-0.157	-0.102	-0.093	0.189	-0.189	0.192	-0.056	0.070
Days to sprout	-0.095	0.732**	0.150	-0.113	-0.334*	0.173	0.091	-0.246*	-0.243*

Size of the floret (cm)	0.320**	-0.243*	-0.250*	0.438*	0.438**	0.089	0.217*	0.327**	0.159
Number of corms plant⁻¹	0.118	0.226*	-0.217*	0.221*	0.221*	-0.184	0.238*	0.114	0.037
Weight of corm (g)	0.471**	-0.158	0.131	0.456*	0.378**	0.274**	-0.085	0.553**	0.454**
Size of corm (cm)	0.235*	-0.298**	-0.166	0.410*	0.298**	0.038	0.064	0.273**	0.195
Number of cormels plant⁻¹	0.051	-0.055	0.244*	0.055	0.120	0.253**	0.063	0.107	0.058
Weight of 10 cormels (g)	-0.280**	0.232*	-0.171	-0.151	-0.217*	-0.070	-0.024	-0.301	-0.076

Continued

Table 6 : (d) (Contd.)

Trait	(Pooled over environments)							
	Number of shoots plant ⁻¹	Days to sprout	Size of the floret (cm)	Number of corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of cormels plant⁻¹	Weight of 10 cormels (g)
Spike length (cm)	-0.055	-0.151	-0.289**	0.386**	0.563**	0.303**	0.054	-0.363**
Days to basal floret opening	-0.203	0.832**	-0.283**	0.248*	-0.166	-0.354**	-0.067	0.249*
Durability of basal floret (days)	-0.131	0.204	-0.301**	-0.300**	0.169	-0.166	0.303**	-0.071
Number of florets spike ⁻¹	-0.131	-0.158	0.507**	0.257*	0.488**	0.509**	0.051	-0.164
Number of florets open at a time	0.286*	-0.392**	0.607**	0.140	0.407**	0.409**	0.171	-0.250*
Durability of whole spike (days)	-0.285*	0.217*	0.113	-0.210*	0.302**	0.044	0.293**	-0.069
Days to slipping	0.319**	0.166	0.289*	0.386**	-0.114	0.057	0.043	-0.015
Plant height (cm)	-0.080	-0.291**	0.369**	0.115	0.582**	0.335*	0.133	-0.333**
Number of leaves plant ⁻¹	0.148	-0.324**	0.226*	0.073	0.564**	0.299*	0.105	-0.126
Number of shoots plant⁻¹	---	-0.218*	-0.027	0.074	0.145	0.066	0.102	-0.038
Days to sprout	-0.170	---	-0.292*	0.143	-0.264**	-0.345**	-0.060	0.314*
Size of the floret (cm)	0.037	-0.230*	---	0.035	0.241*	0.325**	-0.273*	-0.251*

Number of corms plant ⁻¹	0.043	0.104	0.180	----	0.127	0.289*	-0.172	0.228*
Weight of corm (g)	0.118	-0.232*	0.209	0.109	----	0.509**	0.273*	-0.172
Size of corm (cm)	0.084	-0.221*	0.246*	0.192	0.425**	----	0.260*	-0.183
Number of cormels plant ⁻¹	0.083	-0.035	-0.213*	-0.121	0.234*	0.191	----	-0.117
Weight of 10 cormels (g)	-0.023	0.237*	-0.205	0.188	-0.163	-0.146	-0.102	----

*, ** significant at 5 and 1% level, respectively

Table : 7 (a) Direct and indirect effects (Genotypic level) of some important traits on number of florets spike⁻¹ in gladiolus cultivars under temperate climatic conditions of Kashmir.

Traits	Environment-I						
	Plant height (cm)	Days to sprout	Number of shoots plant ⁻¹	Spike length (cm)	Days to basal floret opening	Number of florets open at a time	Durability of whole spike (days)
Plant height (cm)	0.629	-0.138	-0.114	0.481	-0.214	0.221	0.119
Days to sprout	0.047	-0.215	0.046	0.032	-0.149	0.038	-0.062
Number of spikes plant ⁻¹	0.058	0.069	-0.319	0.030	0.011	0.014	0.076
Spike length (cm)	-0.300	0.059	0.036	-0.392	0.088	-0.070	-0.190
Days to basal floret opening	-0.007	0.015	-0.000	-0.004	0.021	-0.006	0.001
Number of florets open at a time	-0.070	0.036	0.008	-0.035	0.060	-0.201	-0.076

Durability of whole spike (days)	0.057	0.087	-0.072	0.015	0.013	0.114	0.300
Size of the floret (cm)	0.008	0.002	-0.006	0.006	-0.002	0.008	0.008
Size of corm (cm)	0.086	-0.026	0.045	0.057	-0.056	0.100	-0.001
Weight of 10 cormels (g)	0.042	-0.013	0.011	0.028	-0.016	0.049	0.214
Number of corms plant⁻¹	0.033	-0.000	0.076	0.032	-0.000	0.046	-0.052
Number of cormels plant⁻¹	0.007	0.020	0.032	0.040	-0.000	0.037	0.043

Residual effect = 0.251

Continued.....

Table : 7 (a) (Contd.)

Traits	Size of the floret (cm)	Size of corm (cm)	Weight of corm	Number of corms plant⁻¹	Number of cormels plant ⁻¹	Genotypic correlation
Plant height (cm)	0.266	0.234	0.301	0.118	0.017	0.593
Days to sprout	-0.287	0.024	0.033	0.000	0.005	-0.118
Number of spikes plant ⁻¹	0.098	-0.061	-0.040	-0.136	-0.041	-0.250
Spike length (cm)	-0.139	-0.097	-0.012	-0.070	-0.061	0.312
Days to basal floret opening	-0.002	-0.005	-0.003	-0.000	-0.000	-0.238
Number of florets open at a time	-0.091	-0.086	-0.119	-0.029	-0.052	0.362

Durability of whole spike (days)	0.126	-0.001	0.071	-0.087	0.050	0.364
Size of the floret (cm)	0.019	0.004	0.005	0.000	0.001	0.353
Size of corm (cm)	0.048	0.232	0.122	0.133	-0.016	0.383
Weight of 10 cormels (g)	0.025	0.047	0.089	-0.038	0.012	0.472
Number of corms plant⁻¹	0.007	0.103	0.076	0.179	0.005	0.107
Number of cormels plant⁻¹	0.025	-0.017	0.122	0.256	0.008	0.177

Residual effect = 0.251

Table : 7 (b) Direct and indirect effects (Genotypic level) of some important traits on number of florets spike⁻¹ in gladiolus cultivars under temperate climatic conditions of Kashmir.

Traits	Environment-II						
	Plant height (cm)	Days to sprout	Number of shoots plant ⁻¹	Spike length (cm)	Days to basal floret opening	Number of florets open at a time	Durability of whole spike (days)
Plant height (cm)	0.728	0.991	0.941	0.410	0.923	1.635	-0.009
Days to sprout	-0.121	-0.826	0.168	-0.135	-0.715	0.167	0.197
Number of spikes plant ⁻¹	-0.040	0.065	-0.320	-0.032	0.086	-0.030	1.005

Spike length (cm)	-5.625	-0.969	-0.606	-0.903	-1.066	-1.082	-0.457
Days to basal floret opening	0.141	0.893	-0.279	0.186	1.032	-0.097	-0.310
Number of florets open at a time	-0.089	0.074	-0.034	-0.067	-0.067	-0.367	0.054
Durability of whole spike (days)	-0.010	-0.240	-0.016	0.078	-0.302	-0.148	1.005
Size of the floret (cm)	-0.027	-0.012	-0.002	-0.030	-0.015	-0.045	0.008
Size of corm (cm)	0.023	0.051	-0.059	0.037	0.054	0.005	-0.074
Weight of 10 cormels (g)	0.009	-0.002	0.049	0.005	-0.002	-0.003	0.020
Number of corms plant⁻¹	0.025	-0.004	0.148	0.027	-0.011	0.145	0.026
Number of cormels plant⁻¹	-0.045	0.021	-0.085	0.053	0.064	0.072	-0.162

Continued.....

Table : 7 (b) (Contd.)

Traits	Size of the floret (cm)	Size of corm (cm)	Weight of corm	Number of corms plant⁻¹	Number of cormels plant ⁻¹	Genotypic correlation
Plant height (cm)	0.968	-0.631	0.562	0.358	0.443	0.445
Days to sprout	-0.008	0.170	0.017	0.008	0.024	0.038
Number of spikes plant ⁻¹	-0.004	-0.075	-0.143	-0.099	-0.075	-0.306
Spike length (cm)	-0.957	0.876	-0.283	-0.338	0.452	0.307

Days to basal floret opening	0.084	-0.226	-0.025	-0.025	-0.095	-0.022
Number of florets open at a time	-0.088	0.007	0.011	-0.112	0.039	0.282
Durability of whole spike (days)	-0.043	0.300	0.181	0.055	0.234	0.219
Size of the floret (cm)	-0.187	0.012	-0.045	-0.007	0.024	0.065
Size of corm (cm)	0.160	-0.250	-0.106	-0.045	-0.054	0.034
Weight of 10 cormels (g)	0.027	0.047	0.110	0.028	0.024	0.096
Number of corms plant⁻¹	0.019	0.086	0.122	0.477	0.077	0.065
Number of cormels plant⁻¹	0.089	-0.151	-0.156	-0.697	0.113	0.158

Residual effect = 0.167

Table : 7 (c) Direct and indirect effects (Genotypic level) of some important traits on number of florets spike⁻¹ in gladiolus cultivars under temperate climatic conditions of Kashmir.

Environment-III							
Traits	Plant height (cm)	Days to sprout	Number of shoots plant ⁻¹	Spike length (cm)	Days to basal floret opening	Number of florets open at a time	Durability of whole spike (days)
Plant height (cm)	0.662	-0.048	-0.054	0.583	0.039	0.287	0.119

Days to sprout	0.152	-2.067	-0.253	0.173	-2.061	0.522	-0.555
Number of spikes plant ⁻¹	-0.022	0.033	0.271	-0.001	0.032	-0.045	-0.021
Spike length (cm)	-0.272	0.026	0.001	-0.309	0.023	-0.105	-0.052
Days to basal floret opening	-0.114	1.909	0.228	-0.143	1.914	-0.461	0.479
Number of florets open at a time	0.125	-0.073	-0.046	0.098	-0.069	0.288	0.009
Durability of whole spike (days)	0.084	0.125	-0.036	0.078	0.117	0.015	0.467
Size of the floret (cm)	-0.041	0.006	-0.008	-0.029	0.006	-0.031	-0.007
Size of corm (cm)	0.270	-0.006	0.004	0.028	-0.006	0.012	0.010
Weight of 10 cormels (g)	0.042	-0.000	0.007	0.045	0.000	0.018	0.010
Number of corms plant⁻¹	0.010	0.049	-0.002	0.004	0.052	0.014	-0.002
Number of cormels plant⁻¹	-0.767	0.029	-0.064	-0.043	0.025	-0.044	-0.037

Continued.....

Table : 7 (c) (Contd.)

Traits	Size of the floret (cm)	Size of corm (cm)	Weight of corm	Number of corms plant⁻¹	Number of cormels plant ⁻¹	Genotypic correlation
Plant height (cm)	0.311	0.300	0.371	0.043	0.131	0.584
Days to sprout	0.162	0.240	0.193	-0.639	0.155	-0.022

Number of spikes plant ⁻¹	0.024	0.021	0.016	-0.004	0.021	0.054
Spike length (cm)	-0.103	-0.146	-0.185	-0.007	-0.034	0.501
Days to basal floret opening	-0.133	-0.195	0.018	0.629	-0.127	-0.010
Number of florets open at a time	0.102	0.060	0.068	0.027	0.032	0.475
Durability of whole spike (days)	0.040	0.080	0.066	-0.008	0.045	0.414
Size of the floret (cm)	-0.088	0.003	-0.019	0.007	-0.024	0.220
Size of corm (cm)	-0.002	0.059	0.037	-0.006	0.016	0.338
Weight of 10 cormels (g)	0.017	0.048	0.076	-0.011	0.009	
Number of corms plant⁻¹	-0.012	-0.017	-0.023	0.008	0.159	0.164
Number of cormels plant⁻¹	-0.104	-0.108	-0.048	-0.385	-0.019	-0.123

Residual effect = 0.237

Table : 7 (d) Direct and indirect effects (Genotypic level) of some important traits on number of florets spike⁻¹ in gladiolus cultivars under temperate climatic conditions of Kashmir.

Environment-III

Traits	Plant height (cm)	Days to sprout	Number of shoots plant ⁻¹	Spike length (cm)	Days to basal floret opening	Number of florets open at a time	Durability of whole spike (days)
Plant height (cm)	-1.298	0.378	0.104	-1.238	0.264	-0.547	-0.305
Days to sprout	-0.145	0.499	-0.109	-0.075	0.415	-0.195	0.108
Number of spikes plant ⁻¹	0.021	0.059	-0.270	0.014	0.055	-0.077	0.077
Spike length (cm)	1.535	-0.243	-0.088	1.610	-0.224	0.721	0.065
Days to basal floret opening	0.088	-0.362	0.088	0.060	-0.435	0.165	0.023
Number of florets open at a time	0.108	0.101	0.073	0.115	-0.098	0.257	0.012
Durability of whole spike (days)	-0.076	-0.070	0.093	-0.132	0.017	-0.015	-0.325
Size of the floret (cm)	0.125	-0.099	-0.009	0.137	-0.096	0.207	0.038
Size of corm (cm)	-0.018	0.019	-0.003	-0.016	0.019	-0.022	-0.002
Weight of 10 cormels (g)	0.115	-0.052	0.028	0.111	-0.033	0.080	0.060
Number of corms plant⁻¹	0.026	0.032	0.017	0.034	0.056	0.032	-0.048
Number of cormels plant⁻¹	0.061	-0.028	0.047	0.025	-0.031	0.079	0.136

Continued.....

Table : 7 (d) (Contd.)

Traits	Size of the floret (cm)	Size of corm (cm)	Weight of corm	Number of corms plant⁻¹	Number of cormels plant ⁻¹	Genotypic correlation
Plant height (cm)	-0.047	-0.436	-0.755	-0.150	-0.172	0.576
Days to sprout	-0.146	0.172	-0.132	0.071	-0.030	-0.158
Number of spikes plant ⁻¹	0.007	0.017	-0.039	-0.020	-0.027	-0.131
Spike length (cm)	0.646	0.488	0.906	0.244	0.088	0.535
Days to basal floret opening	0.123	0.154	0.072	-0.108	0.029	-0.173
Number of florets open at a time	0.156	0.105	0.105	0.036	-0.135	0.534
Durability of whole spike (days)	-0.037	-0.014	-0.098	0.068	0.044	0.387
Size of the floret (cm)	0.341	0.110	0.082	0.012	-0.095	0.507
Size of corm (cm)	-0.180	-0.055	-0.028	-0.016	-0.014	0.509
Weight of 10 cormels (g)	0.047	0.101	0.198	0.025	0.054	0.051
Number of corms plant⁻¹	0.008	0.066	0.029	0.229	-0.039	0.257
Number of cormels plant⁻¹	-0.127	0.121	0.127	-0.080	0.465	0.051
Residual effect	= 0.227					

Table : 8. *Per se* performance of some top ranking gladiolus cultivars for different vegetative, floral, corm and cormel component traits under temperate climatic conditions of Kashmir.

Environments	Spike length (cm)	Number of florets spike ⁻¹	Size of floret (cm)	Durability of whole spike (days)
Environment-1 (E ₁)	White Prosperity = 107.18	Peter Pears = 18.88	Jester Gold = 10.88	Her Majesty = 13.11
	Sunset Jubilee = 106.63	Jester = 18.55	Peter Pears = 10.97	Buff Beauty = 12.91
	White Giant = 105.11	White Prosperity = 18.22	SKG-10 = 10.88	Pink Jewel = 12.59
	Sunny Boy = 102.50	Pusa Suhagin = 17.29	Traderhorn = 11.08	Jackson Villa Gold = 12.47
	Traderhorn = 97.76	Traderhorn = 17.22	White Prosperity = 10.59	Yellow Stone = 12.55
Environment-2 (E ₂)	SKG-8 = 115.82	Peter Pears = 19.33	Mayur = 12.36	Sunny Boy = 15.33
	Yellow Stone = 109.48	Moralla = 18.66	Ratna's Butterfly = 11.28	Big Time Supreme = 14.11
	Moralla = 107.00	Sancere = 18.16	Jester Gold = 10.66	Buff Beauty = 14.00
	Red Majesty = 103.66	Mayur = 18.13	Pink Jewel = 10.53	Mescagami = 14.00
	Sanceree = 102..25	Tropic Sea's = 18.16	Punjab Selection = 10.76	SKG-10 = 13.78
Environment-3 (E ₃)	White Giant = 124.47	Oscar = 19.84	Red Majesty = 12.46	Nazrana = 13.93
	Sunny Boy = 122.89	Pusa Suhagin = 19.70	Powder Puff = 12.13	CPG -6 = 13.91
	White Prosperity = 121.53	Big Time Supreme = 18.04	Oscar = 12.08	Aarti = 13.89
	Red Majesty = 121.48	Regency = 18.28	Jackson Villa Gold = 11.38	Big Time Supreme = 13.90
	Sunset Jubilee = 119.78	Peter Pears = 18.19	Sunset Jubilee = 11.27	Friendship Pink = 13.64
Pooled over environments	Sunny Boy = 112.63	Friendship Pink = 17.45	Punjab Selection = 11.05	Friendship Pink = 14.58
	White Prosperity = 105.55	Pusa Suhagin = 17.88	Purple King = 10.86	Buff Beauty = 12.88
	Red Majesty = 106.36	Peter Pears = 18.80	Moralla = 10.84	Traderhorn = 12.39
	Sunset Jubilee = 103.80	White Prosperity = 17.55	Peter Pears = 10.56	Jackson Villa Gold = 12.57
	Yellow Stone = 100.29	Moralla = 17.15	Oscar = 10.41	White Prosperity = 12.21

Continued....

Table : 8. (Contd.)

Environments	Days to slipping	Days to basal floret opening	No. of corms plant ⁻¹	No of cormels plant ⁻¹
Environment-1 (E ₁)	Aarti = 108.00	Aarti = 113.33	Mayur = 2.03	Her Majesty = 10.85
	CPG-6 = 107.00	Big Time Supreme = 96.66	Purple King = 2.05	Jester Gold = 10.88
	Sylvia = 106.00	Mayur = 100.66	White Prosperity = 1.99	Peter Pears = 10.97
	Yellow Stone = 102.50	Jester = 97.33	Traderhorn = 1.89	White Prosperity = 10.59
	Sunset Jubilee = 96.20	SKG-10 = 96.66	Regency = 1.94	Traderhorn = 11.08
Environment-2 (E ₂)	Aarti = 107.66	Aarti = 113.33	Jackson Villa = 2.75	King Lear = 167.98
	Jester Gold = 90.00	Moralla = 100.66	Gold = 2.47	Buff Beauty = 121.44
	Mayur = 86.33	Jester Gold = 98.33	Vink's Glory = 2.25	Wind Song = 101.00
	Sapna = 90.00	Tropic Sea's = 98.66	Powder Puff = 2.24	Friendship Pink = 90.00
	Sylvia = 86.66	King Lear = 94.66	Rose Supreme = 2.03	Jester = 87.00
Environment-3 (E ₃)	Aarti = 16.44	Aarti = 125.26	Sylvia = 3.47	Buff Beauty = 124.11
	CPG-6 = 112.54	CPG-6 = 119.44	Regency = 2.97	King Lear = 197.77
	Yellow Stone = 109.55	Yellow Stone = 118.93	Sunny Boy = 2.76	White Prosperity = 121.12
	Top Brass = 99.47	Top Brass = 108.33	Water Melon Pink = 2.72	Purple King = 103.51
	Mayur = 96.66	Mayur = 105.88	Friendship Pink = 2.65	Jackson Villa Gold = 102.55
Pooled over environments	Aarti = 110.70	Aarti = 118.52	Regency = 2.43	King Lear = 145.73
	Top Brass = 90.30	CPG-6 = 105.80	Priscilla = 1.94	Buff Beauty = 103.95
	White Goddess = 86.16	Mayur = 100.41	Moralla = 1.94	Friendship Pink = 88.96
	Sylvia = 92.71	Sylvia = 116.96	Sunny Boy = 1.96	White Prosperity = 83.30
	Jester Gold = 86.25	Yellow Stone = 101.01	Sylvia = 1.94	White Giant = 80.89

Continued....

Table : 8. (Contd.)

Environments	Plant height (cm)		Number of florets open at a time		Durability of basal floret (days)	
Environment-1 (E ₁)	Sunset Jubilee	= 133.73	Rose Delight	= 5.13	Eurovision	= 6.12
	White Prosperity	= 136.49	Big Time Supreme	= 4.92	Jester Gold	= 5.19
	White Giant	= 127.57	Friendship Pink	= 4.79	Rose Supreme	= 5.01
	Sunny Boy	= 123.65	Jester	= 4.46	Yellow Stone	= 4.99
	Traderhorn	= 122.50	Apple Blossom	= 508	White Prosperity	= 4.62
Environment-2 (E ₂)	Red Majesty	= 134.50	Mayur	= 4.91	Jester	= 5.19
	SKG-8	= 134.50	Punjab Selection	= 4.89	Jester Gold	= 6.12
	Sunny Boy	= 134.58	Moralla,	= 4.73	Nazrana	= 5.11
	Yellow Stone	= 131.76	Peter Pears	= 4.42	Apple Blossom	= 4.97
	Pusa Suhagin	= 129.00	Princes Margret Rose	= 4.80	Sylvia	= 5.01
Environment-3 (E ₃)	White Prosperity	= 149.47	Fidelo	= 4.80	Friendship Pink	= 5.43
	Sunny Boy	= 147.61	Friendship Pink	= 5.02	Her Majesty	= 5.27
	Oscar	= 145.53	Pusa Suhagin	= 5.26	Rose and Wine	= 5.26
	Sunset Jubilee	= 143.82	Powder Puff	= 5.24	Tropic Sea's	= 5.31
	White Giant	= 140.33	Peter Pears	= 5.84	White Prosperity	= 5.93
Pooled over environments	Sunny Boy	= 135.28	Moralla	= 4.67	Jester	= 5.20
	Red Majesty	= 134.49	Oscar	= 4.55	Yellow Frills	= 5.65
	White Prosperity	= 133.23	Jackson Villa Gold	= 4.51	Jester Gold	= 5.22
	White Giant	= 130.13	Peter Pears	= 4.51	Apple Blossom	= 4.96
	Yellow Stone	= 125.29	Rose Delight	= 4.44	White Prosperity	= 4.94

Continued....

Table : 8. (Contd.)

Environments	Weight of corm (g)		Size of corm (cm)		Weight of 10 cormels plant ⁻¹	
Environment-1 (E ₁)	Sunset Jubilee	= 39.10	Friendship Pink	= 5.01	Wig's Sensation	= 6.83
	Yellow Stone	= 39.26	R-N-96	= 5.01	Melody	= 6.36
	White Prosperity	= 38.53	Suchitra	= 5.12	Suchitra	= 6.60
	Ratna's Butter Fly	= 37.46	Traderhorn	= 5.07	Princes Margret Rose	= 6.50
	Jester Gold	= 37.73	Purple King	= 5.01	Rose Supreme	= 6.23
Environment-2 (E ₂)	Buff Beauty	= 37.82	White Prosperity	= 4.36	Aarti	= 9.08
	Jester	= 37.67	Oscar	= 4.36	Buff Beauty	= 8.64
	Jester Gold	= 36.49	Pusa Suhagin	= 4.24	Sylvia	= 8.70
	Red Majesty	= 35.32	Vink's Glory	= 4.31	Pusa Suhagin	= 7.66
	White Prosperity	= 34.49	Big Time Supreme	= 4.24	Peter Pears	= 7.60
Environment-3 (E ₃)	Traderhorn	= 55.34	Oscar	= 5.98	Aarti	= 9.05
	Sunset Jubilee	= 53.77	Princes Margret Rose	= 5.92	Purple King	= 9.80
	Vink's Glory	= 52.91	Eurovision	= 5.87	Sylvia	= 9.33
	Oscar	= 49.24	White Prosperity	= 5.87	Poonam	= 8.64
	Rose Supreme	= 46.70	Buff Beauty	= 5.84	Princess Margret Rose	= 8.40
Pooled over environments	Oscar	= 38.12	Jackson Villa Gold	= 4.68	Aarti	= 7.45
	Pusa Suhagin	= 38.82	Spic and Span	= 4.90	Buff Beauty	= 6.98
	Rose Supreme	= 37.51	Wig's Sensation	= 4.96	Oscar	= 6.68
	Sunset Jubilee	= 38.12	Wind Song	= 4.79	Poonam	= 6.99
	White Prosperity	= 38.41	Oscar	= 4.68	Princess Margret Rose	= 6.73

Table : 11(a) Cluster means for different traits in gladiolus cultivars under temperate climatic conditions of Kashmir.

[Environment-I]

Cluster No.	No. of cultivars	Days to sprouting	Plant height (cm)	Number of leaves plant ⁻¹	Number of shoots plant ⁻¹	Days to slipping	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)
I	54	24.18	107.36	8.51	1.68	77.57	85.11	80.83	4.25
II	5	26.92	105.77	8.26	1.59	101.07	83.34	111.50	4.33
III	1	20.80	81.18	7.11	2.10	76.73	69.36	116.97	4.82
IV	1	29.98	87.51	7.55	2.22	72.73	71.89	86.84	6.12
V	1	25.55	84.30	9.78	1.44	107.86	82.23	78.41	3.11

Continued....

Table : 11(a) (Contd.)

Cluster No.	No. of cultivars	Number of Florets spike ⁻¹	Number of florets open at one time	Durability of whole spike (days)	Size of the floret (cm)	Number corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of corms plant⁻¹	Weight of 10 corms (g)
I	54	15.20	3.93	10.34	9.82	1.49	29.59	4.32	38.03	4.66
II	5	15.06	3.72	11.15	10.18	1.45	28.41	4.15	44.91	4.02
III	1	12.44	2.33	9.34	8.03	1.24	23.23	3.63	41.27	4.13
IV	1	15.99	4.28	9.59	9.37	1.55	34.14	3.57	136.67	3.66
V	1	13.65	2.56	12.91	9.51	1.11	17.64	2.71	99.00	4.96

Table : 11(b) Cluster means for different traits in gladiolus cultivars under temperate climatic conditions of Kashmir. [Environment-II]

Cluster No.	No. of cultivars	Days to slipping	Plant height (cm)	Number of leaves plant ⁻¹	Number of shoots plant ⁻¹	Days to slipping	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)
I	59	25.27	113.71	7.52	1.36	72.14	90.77	83.89	4.15
II	1	29.33	106.00	6.11	2.15	67.33	80.00	71.66	4.82
III	1	24.83	116.66	7.44	1.10	107.66	100.00	113.33	4.48
IV	1	29.35	119.66	9.33	1.23	72.66	86.00	94.66	2.58

Continued....

Table : 11(b) (Contd.)

Cluster No.	No. of cultivars	Number of Florets spike ⁻¹	Number of florets open at one time	Durability of whole spike (days)	Size of the floret (cm)	Number corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of corms plant⁻¹	Weight of 10 corms (g)
I	59	15.84	4.04	10.78	9.27	1.35	28.29	3.67	43.34	5.09
II	1	13.83	4.33	14.00	7.31	1.55	37.82	5.27	121.44	8.64
III	1	14.50	2.89	8.97	8.88	1.25	17.50	3.06	24.66	9.08
IV	1	17.16	4.20	9.33	7.83	1.51	32.26	3.53	167.98	3.66

Table:11(c) Cluster means for different traits in gladiolus cultivars under temperate climatic conditions of Kashmir.**[Environment-III]**

Cluster No.	No. of cultivars	Days to sprout	Plant height (cm)	Number of leaves plant ⁻¹	Number of shoots plant ⁻¹	Days to slipping	Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)
I	50	27.47	121.11	7.85	1.40	78.51	97.96	87.48	4.71
II	4	30.06	131.44	7.41	1.44	99.48	109.70	108.52	4.81
III	4	26.99	131.12	8.05	1.46	79.37	105.90	88.65	5.00
IV	3	31.14	101.32	7.86	1.18	116.03	76.68	124.25	4.73
V	1	23.77	117.57	7.88	1.77	75.79	82.68	84.86	5.36

Continued....

Table : 11(c) (Contd.)

Cluster No.	No. of cultivars	Number of Florets spike ⁻¹	Number of florets open at one time	Durability of whole spike (days)	Size of the floret (cm)	Number corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of corms plant⁻¹	Weight of 10 corms (g)
I	50	16.11	4.41	11.60	9.88	1.69	33.10	4.86	45.25	5.25
II	4	16.52	4.48	12.56	10.56	1.72	44.91	5.33	71.35	3.98
III	4	15.59	4.34	12.47	10.49	1.86	39.09	5.64	111.83	7.08
IV	3	13.43	3.83	12.43	8.82	2.36	16.66	3.62	37.64	8.48
V	1	11.28	3.89	9.19	11.00	1.67	27.88	4.92	197.77	4.33

Table : 11(d) Cluster means for different traits in gladiolus cultivars under temperate climatic conditions of Kashmir.

[Pooled over

Cluster No.	No. of cultivars	Days to sprouting	Plant height (cm)	Number of leaves plant ⁻¹	Number of shoots plant ⁻¹	Days to slipping	Environment]		
							Spike length (cm)	Days to basal floret opening	Durability of basal floret (days)
I	50	25.99	115.35	7.93	1.46	77.37	90.82	84.72	4.48
II	1	24.04	133.23	8.70	1.31	77.35	105.55	82.72	4.94
III	1	26.09	112.76	7.44	1.33	71.63	84.40	75.33	4.28
IV	1	25.91	100.01	7.51	1.11	80.86	75.96	94.20	4.01
V	1	27.37	109.14	7.40	2.36	77.38	85.92	84.38	4.21
VI	1	27.64	102.53	7.40	1.44	83.47	86.19	78.26	4.58
VII	1	28.04	123.79	8.25	1.44	77.49	91.15	92.57	3.94
VIII	2	25.28	91.84	7.68	1.38	97.45	68.31	112.16	4.64
VIV	1	28.02	104.89	8.58	1.40	72.46	84.48	81.10	4.29
X	1	28.30	106.81	8.55	1.55	69.73	86.29	77.78	4.47
XI	1	27.70	109.28	8.14	1.65	75.21	81.63	88.78	4.92
XII	1	29.27	108.50	7.39	1.22	92.71	84.05	116.96	4.50

Continued....

Table : 11(d) (Contd.)

Cluster No.	No. of cultivars	Number of Florets spike ⁻¹	Number of florets open at one time	Durability of whole spike (days)	Size of the floret (cm)	Number corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of corms plant⁻¹	Weight of 10 corms (g)
I	50	15.93	4.12	11.14	9.76	1.50	31.31	4.33	44.66	5.00
II	1	17.55	4.04	12.21	9.42	1.70	38.41	4.41	83.30	5.80
III	1	15.22	4.49	9.98	11.05	1.27	17.79	4.27	33.29	5.06
IV	1	13.64	3.79	10.84	8.60	1.60	25.01	3.78	57.70	4.94
V	1	14.02	3.96	9.86	8.06	1.91	23.79	4.23	44.07	6.35
VI	1	13.68	3.59	12.88	8.66	1.41	31.05	4.60	103.95	6.98
VII	1	17.02	4.32	9.45	9.44	2.43	35.05	4.41	21.15	5.37
VIII	2	12.88	2.96	10.88	8.45	1.46	17.83	3.43	35.28	6.96
VIV	1	12.54	3.96	9.88	9.28	1.39	18.67	4.18	27.16	6.29
X	1	2.01	4.26	9.65	9.46	1.30	31.79	4.35	30.97	3.78
XI	1	14.81	4.12	9.37	7.87	1.27	32.62	4.28	145.73	3.73
XII	1	15.53	4.13	9.78	9.35	1.94	19.59	4.01	44.37	6.60

Table : 12 Per cent contribution of different character component traits towards total divergence among gladiolus cultivars under temperate climatic conditions of Kashmir

Traits	Number of times appearing first in the rank				Per cent contribution towards total divergence among the material studied			
	E ₁	E ₂	E ₃	Pooled over environments	E ₁	E ₂	E ₃	Pooled over environments
Days to sprout	172	126	243	41	9.10	6.66	12.85	2.17
Plant height (cm)	1	0	40	194	0.05	4.00	2.12	10.26
Number of leaves plant⁻¹	4	6	3	5	0.21	0.32	0.16	0.26
Number of shoots plant⁻¹	3	0	0	15	0.16	1.74	0.00	0.79
Days to slipping	56	13	7	7	1.11	0.09	0.37	0.37
Spike length (cm)	22	21	20	4	1.16	1.11	1.06	0.21
Days to basal floret opening	518	313	649	409	28.39	26.55	33.32	21.63
Durability of basal floret (days)	11	15	0	35	0.55	0.79	1.00	1.85
Florets spike⁻¹	30	7	17	245	1.59	0.37	0.90	12.96
Number of florets open at a time	7	2	4	45	0.37	0.11	0.21	2.38
Durability of whole spike (days)	70	8	10	79	3.70	0.42	0.53	4.18
Size of the floret (cm)	5	127	12	10	0.26	6.72	0.63	0.53
Number corms plant⁻¹	0	32	3	58	2.00	1.69	0.16	3.07
Weight of corm (g)	34	139	151	543	5.80	7.35	7.99	3.49
Size of corm (cm)	0	5	52	20	1.00	0.26	2.75	1.06
Number of cormels plant⁻¹	553	943	544	66	37.24	35.67	28.77	28.71
Weight of 10 cormels (g)	59	134	136	115	7.26	7.09	7.19	6.08

Table : 13 Analysis of variance for stability of different vegetative, floral, corm and cormel component traits in some gladiolus cultivars evaluated across 5 random environments in the Kashmir valley.

Source of variation	Mean Squares							
	d.f	Days to sprouting	Plant height (cm)	Number of leaves plant ⁻¹	Number of shoots plant ⁻¹	Days to slipping	Spike length (cm)	Days to basal floret opening
Genotypes	9	20.49**	2259.44**	0.73*	0.12**	367.59**	236.32**	465.79**
Environments	4	54.42**	1624.07	1.74*	0.20**	288.47**	586.17**	270.96**
Genotypes x Environments	36	5.06*	2339.34**	0.18	0.03	51.31**	51.08**	34.67**
Pooled error	49	11.93	2266.28	0.40	0.06	128.76	128.78	133.15
Environments + Genotypes x Environments	40	10.00**	2267.82	0.33	0.05	75.03	104.58	58.30
Environments (L)	1	217.69**	6496.31	6.97**	0.80**	1153.90**	2344.65**	1083.86**
Genotypes x Environments (L)	9	9.88**	6568.02**	0.28	0.03	110.53**	39.95**	60.31**
Pooled deviation	30	3.11*	836.80**	0.12*	0.03**	28.41**	49.30**	23.51**
Pooled error for testing pooled deviation	100	0.70	2218.88	0.03	0.02	11.60	6.40	2.74

Continued.....

Table : 13 (Contd.)

Source of variation	Mean Squares					
	d.f	Durability of basal floret (days)	Number of Florets spike ⁻¹	Number of florets open at a time	Durability of whole spike (days)	Size of Floret (cm)
Genotypes	9	0.22*	3.51	0.487*	2.84**	1.55*
Environments	4	1.78*	2.89*	1.351*	3.80*	2.45*
Genotypes x Environments	36	0.19*	0.92	0.150	0.85	0.24
Pooled error	49	0.33	1.56*	0.310	1.46	0.66
Environments + Genotypes x Environments	40	0.35	1.22	0.270	1.15	0.46
Environments (L)	1	7.15**	11.58**	5.406	15.22**	9.81**
Genotypes x Environments (L)	9	0.42	1.49	0.162	1.48	0.40
Pooled deviation	30	0.10**	0.66**	0.132	0.58**	0.17*
Pooled error for testing pooled deviation	100	0.02	0.15	0.033	0.27	0.06

Continued.....

Table : 13 (Contd.)

Source of variation	Mean Squares					
	d.f	Number of corms plant ⁻¹	Weight of corm (g)	Size of corm (cm)	Number of cormels plant ⁻¹	Weight of 10 cormels (cm)
Genotypes	9	0.17	91.42**	0.27**	3986.97**	4.18**
Environments	4	0.33*	51.96**	2.99**	451.61**	1.98**
Genotypes x Environments	36	0.16*	33.76**	0.08	42..24	0.34
Pooled error	49	0.18	45.84	0.35	800.20	1.18
Environments + Genotypes x Environments	40	0.18	35.58	0.37*	83.17	0.50
Environments (L)	1	1.33	207.86**	11.98**	1806.46**	7.94**
Genotypes x Environments (L)	9	0.40*	104.21**	0.08	75.07**	0.55*
Pooled deviation	30	0.08*	9.25**	0.07	28.16**	0.24*
Pooled error for testing pooled deviation	100	0.02	0.98	0.02	24.84	0.08

*,** significant at 5 and 1 per cent level, respectively

Table : 14. Stability parameters for different vegetative, floral, corm and cormel component traits in the gladiolus cultivars evaluated across 5 random environments in the Kashmir valley.

Cultivar	Size of floret (cm)			Plant height (cm)			Number of leaves plant ⁻¹			Number of corms plant ⁻¹		
	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i
Apple Blossom	9.48	0.59	0.02	109.61	0.72	-1916.27	7.91	0.79	-0.03	1.36	0.34	-0.02
Big Time Supreme	9.75	0.21*	-0.02	120.20	-0.06	-1958.75	7.74	1.57	0.07	1.53	1.65	-0.00
Friendship Pink	9.93	0.23*	0.89	121.51	-0.00	-2130.11	7.97	1.44	0.23	1.97	3.09**	0.20
Jackson Villa Gold	11.27	1.46	0.06	122.09	-0.17	-2199.06	7.54	1.46	0.15	1.58	0.78	-0.01
Moralla	10.30	1.35	0.08	119.03	-0.35	-2194.02	8.20	1.47	0.20	1.74	-2.40**	0.22
Peter Pears	10.44	0.18*	0.08	126.75	0.95	-2044.63	8.24	0.20	0.20	1.83	3.07**	0.04
Sanceree	9.63	1.30	0.02	115.77	-0.44	-2167.01	8.14	0.42	0.02	1.53	2.60**	-0.01
Traderhorn	10.29	1.10	-0.00	121.57	0.42	-2137.16	8.28	0.48	0.09	1.44	-0.67	0.08
White Prosperity	9.66	1.74*	-0.04	136.73	0.60	-1997.56	8.97	1.92*	0.02	1.72	0.21	0.01
Yellow Stone	9.51	1.80*	-0.03	122.92	-0.06	-2165.43	8.16	0.20	-0.03	1.56	1.31	0.01
Mean	10.02	---	---	121.67	---	---	8.12	---	---	1.63	---	---
SE (m)	0.20	---	---	14.46	---	---	0.18	---	---	0.14	---	---
SE (b)	----	0.41	---	----	1.13	---	---	0.43	---	----	0.77	---

Continued....

Table : 14. (Contd.)

Cultivar	Days to slipping			Spike length (cm)			Days to basal floret opening			Durability of basal floret (days)		
	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i
Apple Blossom	65.83	0.06	111.28**	85.48	1.37	113.52**	76.80	0.76	15.69**	4.95	0.43	0.19
Big Time Supreme	85.13	0.66	-6.23	93.17	1.44	9.40**	95.16	0.33	8.50**	4.57	0.60	-0.00
Friendship Pink	73.17	0.42	0.17	96.11	1.23	-5.95	78.91	0.86	0.45	4.67	2.11*	0.66
Jackson Villa Gold	87.07	1.54	0.29	99.63	0.57	6.31**	96.22	1.11	42.52**	4.37	0.42	0.22
Moralla	81.61	0.35	-3.10	94.84	0.47	31.76**	87.05	0.47	0.51	4.43	0.15	0.19
Peter Pears	70.29	0.42	-8.68	88.31	0.51	-4.88	77.39	0.60	5.10**	4.63	1.61	0.02
Sanceree	71.80	0.86	-8.45	94.87	0.64	66.57**	79.56	0.60	-2.05	4.56	1.41	-0.02
Traderhorn	79.58	1.43	-8.74	99.32	1.06	33.38**	85.21	1.42	24.69**	4.41	0.78	-0.01
White Prosperity	76.35	0.78	-5.72	109.29	1.56	84.95**	83.78	0.87	8.69**	4.91	2.22*	0.12
Yellow Stone	93.58	3.44**	97.32**	102.73	1.13	93.96**	105.90	2.92*	103.59**	4.88	0.22	-0.00
Mean	78.44	---	---	96.38	---	---	86.60	---	---	4.65	---	---
SE (m)	2.66	---	---	3.51	---	---	2.42	---	---	0.16	---	---
SE (b)	----	0.49	---	---	0.46	---	----	0.47	---	---	0.38	---

Continued.....

Table : 14. (Contd.)

Cultivar	Number of florets spike ⁻¹			Number of florets open at a time			Durability of whole spike (days)		
	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i
Apple Blossom	15.33	2.45*	1.71*	4.37	1.50	0.25	10.98	-1.50	0.25
Big Time Supreme	16.37	2.96*	-0.05	3.89	1.61	0.44	12.78	1.01	-0.06
Friendship Pink	17.38	0.99	-0.03	4.64	1.03	0.00	13.08	1.54	0.83*
Jackson villa Gold	16.49	0.64	-0.06	4.61	1.27	-0.00	12.73	0.76	-0.14
Moralla	17.23	0.70	2.01**	4.76	0.39	0.02	11.22	1.58	-0.60
Peter Pears	18.70	-0.77	-0.10	4.86	1.53	0.36	11.23	1.62	-0.23
Sanceree	17.11	0.70	1.17*	4.27	0.98	-0.01	11.71	1.83	-0.08
Traderhorn	16.97	1.81	0.52	4.13	-0.15	-0.02	12.54	1.29	1.10*
White Prosperity	17.56	-0.20	0.05	4.20	0.98	-0.02	12.45	1.45	0.20
Yellow Stone	16.70	0.68	-0.15	4.18	0.83	-0.02	11.93	0.38	0.62
Mean	17.00	---	---	4.39	1.00	---	12.07	---	---
SE (m)	0.40	---	---	0.18	---	---	0.39	---	---
SE (b)	----	0.75	---	----	0.49	---	----	0.62	---

Continued...

Table : 14. (Contd.)

Cultivar	Days to sprout			Number of shoots Plant ⁻¹			Weight of corm (g)		
	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i
Apple Blossom	28.66	1.74	2.35**	1.87	1.92	0.03	31.24	-1.55	6.17**
Big Time Supreme	29.51	0.30	1.75**	1.45	0.56	0.01	30.36	-0.71	13.12**
Friendship Pink	26.46	0.18	0.17	1.35	0.49	0.00	30.81	-0.25	0.77
Jackson Villa Gold	29.67	1.78	2.33**	1.49	-0.26	-0.01	33.63	0.87	15.87**
Moralla	31.37	1.09	-0.16	1.6	0.95	0.02	27.82	0.53	-0.62
Peter Pears	28.47	1.77	1.65*	1.43	2.08*	0.03	30.91	-0.97	6.79**
Sanceree	25.80	0.06	9.67**	1.63	0.85	-0.01	30.65	2.75*	0.47
Traderhorn	29.49	0.71	-0.28	1.36	1.39	-0.01	40.31	6.11**	37.37**
White Prosperity	24.97	0.89	3.34**	1.53	1.29	0.03	39.74	1.76	-0.79
Yellow Stone	29.69	1.43	3.29**	1.39	0.70	0.00	36.78	1.45	3.57**
Mean	28.41	---	---	1.51	---	---	33.23	1.00	---
SE (m)	0.88	---	---	0.09	---	---	1.52	---	---
SE (b)	---	0.37	---	---	0.64	---	----	0.66	---

Continued...

Table : 14. (Contd.)

Cultivar	Size of corm (cm)			Number of cormels plant ⁻¹			Weight of 10 cormels (g)		
	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i	Mean (\bar{X})	b_i	S^2d_i
Apple Blossom	4.45	1.06	0.02	63.52	0.77	-2.30	3.72	0.16	0.17
Big Time Supreme	4.67	0.54	-0.00	47.19	1.04	-22.48	5.05	1.57	0.05
Friendship Pink	4.34	1.17	0.04	92.52	1.49	-14.31	4.77	1.23	-0.02
Jackson Villa Gold	4.56	0.67	0.02	91.84	1.74	3.65*	4.22	0.84	0.22
Moralla	4.41	0.91	0.07	63.60	1.12	7.24**	5.58	1.38	0.29
Peter Pears	4.84	1.14	-0.00	28.82	0.74	-21.13	6.98	2.84**	0.26
Sanceree	4.30	0.81	0.08	36.06	0.46	-20.09	4.29	0.57	0.20
Traderhorn	4.85	0.93	0.08	34.52	0.08	40.13**	5.02	-0.05	0.11
White Prosperity	5.00	1.37	0.01	106.88	2.14*	81.28**	5.47	1.00	0.04
Yellow Stone	4.63	1.33	0.18	37.11	0.38	-18.74	4.50	0.42	0.27
Mean	4.60	---	0.03	60.21	---	---	4.96	---	---
SE (m)	0.13	---	---	2.65	---	---	52.46	---	---
SE (b)	---	0.24	---	---	0.39	---	---	0.55	---

Table : 10 (a) Mean intra- and inter-cluster distance (D^2) among 62 gladiolus cultivars under temperate climatic conditions of Kashmir [Environment-I]

Cluster No.	CLUSTERS				
	I	II	III	IV	V
I	18.852	36.812	32.670	35.939	41.254
II		23.009	31.622	43.639	38.971
III			0.000	39.978	52.303
IV				0.000	40.440
V					0.000

Table : 10 (b) Mean intra- and inter-cluster distance (D^2) among 62 gladiolus cultivars under temperate climatic conditions of Kashmir. [Environment-II]

Cluster No.	CLUSTERS			
	I	II	III	IV
I	17.87	35.77	33.89	47.48
II		0.000	53.80	28.73
III			0.000	59.09
IV				0.000

Table : 10 (c) Mean intra- and inter-cluster distance (D^2) among 62 gladiolus cultivars under temperate climatic conditions of Kashmir. [Environment-III]

Cluster No.	CLUSTERS				
	I	II	III	IV	V

I	23.89	34.57	32.66	49.14	51.49	²
II		20.72	33.63	41.39	49.82	
III			24.77	56.75	34.86	
IV				21.72	70.50	
V					0.000	

Table : 9(a) Classification of the gladiolus cultivars into different clusters on the basis of divergence.

Cluster	Cultivars included in the cluster	Number of cultivars in the cluster	Environment-I
I	2,3,5,6,7,8,9,11,13,14,15,16,17,18,20,21,22 23,24,25,26,27,28,29,30,31,32,33,34,35,36, 37,38,39,40,42,43,44,45,47,48,49,50,51,52, 53,54,55,56,57,58,60,61,62	54	
II	1,19,41,46,59	5	
III	4	1	
IV	12	1	
V	10	1	

Serial number of the cultivars given in the Table 9(a) is as per the Table 1.

Table : 9(b) Classification of gladiolus cultivars into different clusters on ³ the basis of divergence.

Cluster	Cultivars included in the cluster	Number of cultivars in the cluster
I	2,3,4,5,6,7,8,9,11,13,14,15,16,17,18,19, 20, 21, 22,23,24,25,26,27,28,29,30,31,32,33,34,35,36, 37,38,39,40,41,42,43,44,45,46,47,48,49,50,51, 52,53,54,55,56,57,58,59,60,61,62	59
II	10	1
III	1	1
IV	12	1

Serial number of the cultivars given in the Table 9(b) is as per the Table 1.

Table : 9(c) Classification of the gladiolus cultivars into different clusters on the basis of divergence.

Environment-III		
Cluster	Cultivars included in the cluster	Number of cultivars in the cluster
I	2,3,5,6,7,8,9,11,13,14,15,16,17,18,20,21,22,23, 25,26,27,28,29,30,31,32,33,34,35,36,37,39,40, 42,43,44,45,47,48,49,50,52,53,54,56,57,58,60, 61,62	50
II	19, 46,51,59	4
III	10,24,38,55	4
IV	1,4,41	3
V	12	1

Serial number of the cultivars given in the Table 9(c) is as per the Table 1.

Table : 9(d) Classification of the gladiolus cultivars into different clusters on ⁵ the basis of divergence.
(Pooled over environments)

Cluster	Cultivars included in the cluster	Number of cultivars in the cluster
I	2,3,5,6,7,8,13,14,15,16,17,18,19, 20, 21, 22, 23,24,26,27,28,29,30,31,32,33,35,37,38,39, 40,42,43,44,45,46,47,48,49,50,51,52,53,54, 56, 57, 58, 59,60,62	50
II	55	1
III	25	1
IV	11	1
V	9	1
VI	10	1
VII	34	1
VIII	1,4	2
VIV	61	1
X	36	1
XI	12	1

- The checks being same for individual environments have been included in D² analysis.
- Serial number of the cultivars given in the Table 9(d) is as per the Table 1.

Annexure-I : Selection of elite cultivars for stability studies

S,No	Cultivar	Specific features for selection	
1.	Apple Blossom	i) Spike length	90.00 – 95.00
		ii) No. of Florets spike ⁻¹	17 – 18
		iii) Floret size (cm)	10.50 – 11.00
2.	Big Time Supreme	i) Spike length (cm)	85.00 – 90.00
		ii) No. of florets spike ⁻¹	16 – 17
		iii) Floret size (cm)	9.50 – 10.00
3.	Friendship Pink	i) Spike length (cm)	80.00 – 85.00
		ii) No. of florets spike ⁻¹	15 – 16
		iii) Floret size (cm)	9.00 – 10.00
4.	Jackson Villa Gold	i) Spike length (cm)	90.00 – 95.00
		ii) No. of florets spike ⁻¹	16 – 17
		iii) Floret size (cm)	10.00 – 11.00
5.	Moralla	i) Spike length (cm)	85.00 – 90.00
		ii) No. of florets spike ⁻¹	16 – 17

		iii) Floret size (cm)	9.00 – 10.00 ⁷
6.	Peter Pears	i) Spike length (cm)	80.00 – 85.00
		ii) No. of florets spike ⁻¹	15 – 16
		iii) Floret size (cm)	9.00 – 9.50
7.	Sanceree	i) Spike length	80.00 – 90.00
		ii) No. of florets spike ⁻¹	17 – 19
		iii) Floret size (cm)	9.00 – 10.00
8.	Traderhorn	i) Spike length	85.00 – 90.00
		ii) No. of florets spike ⁻¹	15 - 17
		iii) Floret size (cm)	10.50 – 11.00
9.	White Prosperity	i) Spike length	100.00 – 110.00
		ii) No. of florets spike ⁻¹	17.00 – 19.00
		iii) Floret size (cm)	9.50 – 10.50
10.	Yellow Stone	i) Spike length	90.00 – 100.00
		ii) No. of florets spike ⁻¹	17.00 – 19.00
		iii) Floret size (cm)	9.00 – 10.00

Annexure II : Meteorological data during growing period of gladiolus ⁸ (*Gladiolus hybrida* L.)

Months	Temperature (°C)			Relative humidity	Total Precipitation	Total sunshine
	Maximum	Minimum	Mean			
2002						
March	16.5	5.3	10.9	64.4	175.4	180.5
April	19.7	6.7	13.2	68.6	150.6	192.0
May	24.2	10.8	17.5	66.3	63.5	233.0
June	27.2	13.3	20.2	64.9	38.2	255.6
July	30.5	17.5	24.2	69.5	46.4	260.0
August	30.0	17.	23.5	72.1	90.1	208.9
September	26.8	12.9	19.8	71.6	18.6	198.5
October	23.1	6.3	14.7	70.3	16.4	208.1
2003						
March	15.7	4.3	10.00	50.3	157.3	180.2
April	20.4	6.5	13.55	52.1	90.5	191.5
May	24.0	7.9	15.95	63.7	57.4	229.8
June	29.7	13.1	21.4	56.8	32.5	244.8
July	30.4	17.0	23.7	61.2	30.9	304.1
August	29.6	16.2	22.9	72.6	64.7	260.8
September	27.1	13.5	20.3	69.2	24.4	235.1
October	22.5	4.3	13.4	67.2	0.0	247.1

Source : Agro-meteorological Observatory

Division of Agronomy, SKUAST-K< Shalimar, Srinagar



Field view of Gladiolus germplasm



Traderhorn



Regency



Spic & Span



Yellow Stone



Moralla



Tropic Seas



White Giant



JackSon Villa Gold



Eurovision



Pusa Suhagin



White Prosperity



Amsterdam



Punjab Selection



Oscar



American Beauty



Powder Puff



Red Majesty



Princess Margaret Rose



Sunny Boy



Purple King



Her Majesty

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* **Original not seen**