

Genetic studies of some gladiolus genotypes and standardization of *in-vitro* seed germination

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IN REVERENT DEDICATION

TO MY.....

FATHER

Acknowledgement

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Dated.....

Pundibari, Cooch Behar.

(Suresh Kr. Mahato)

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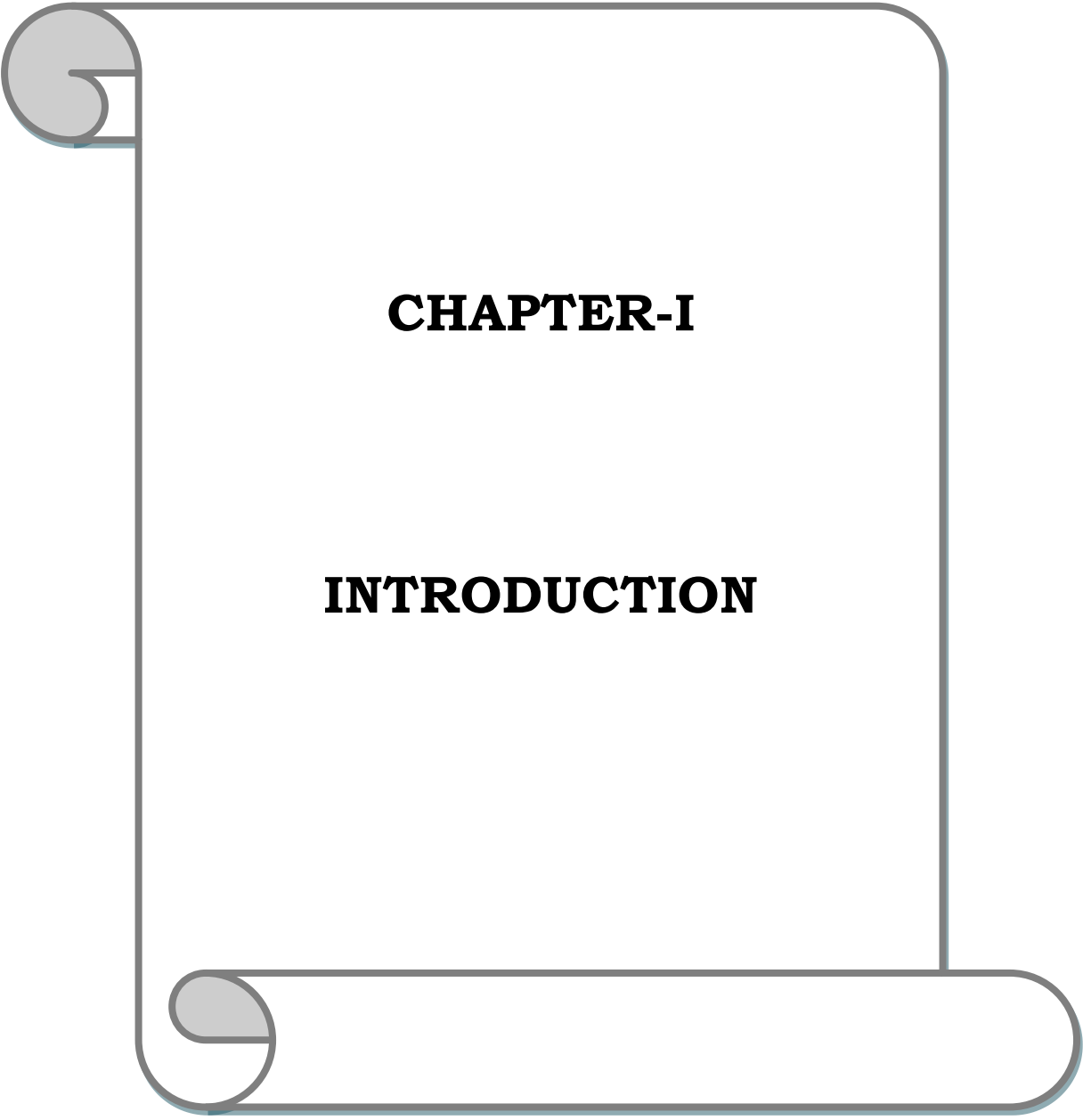
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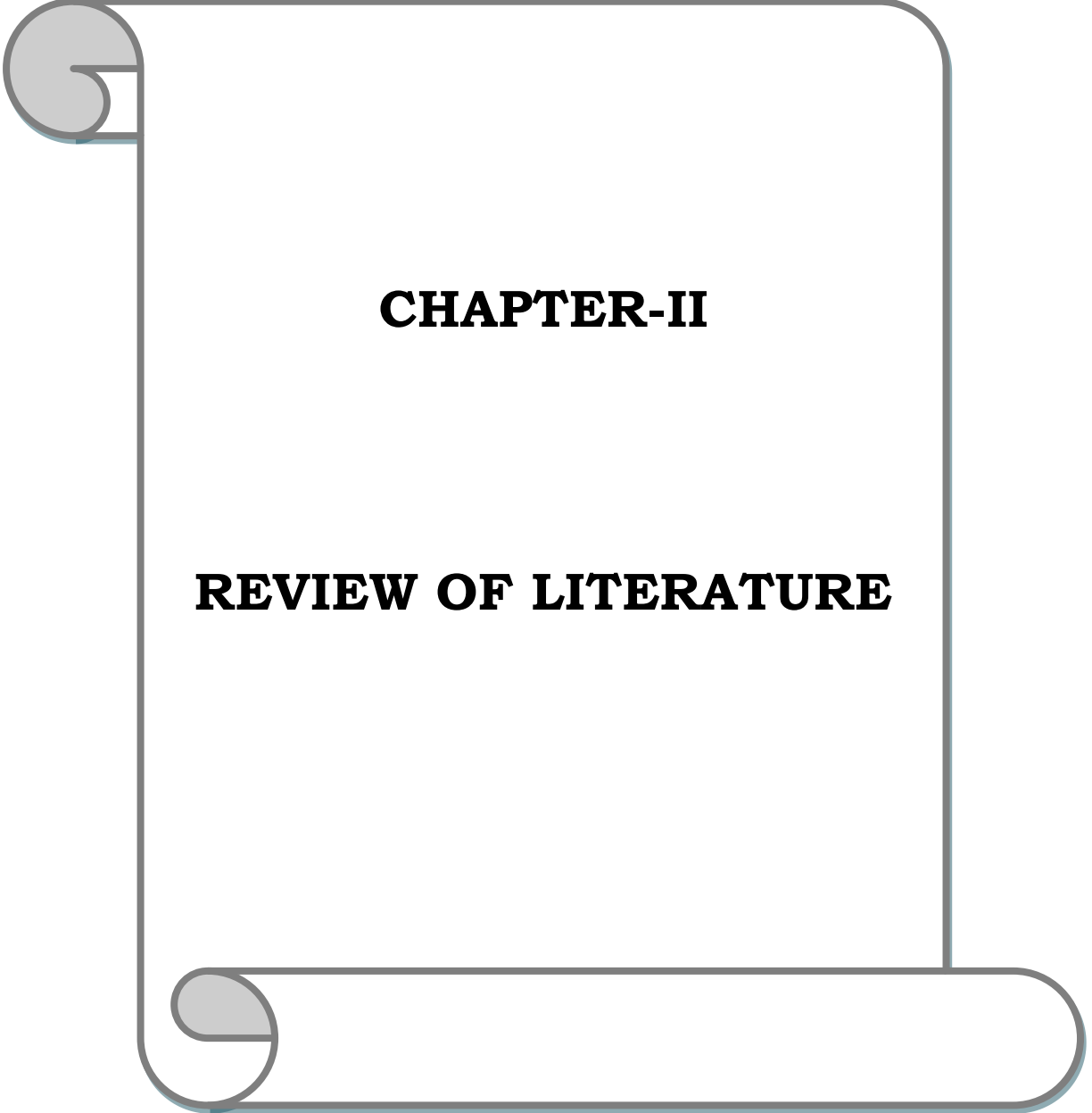
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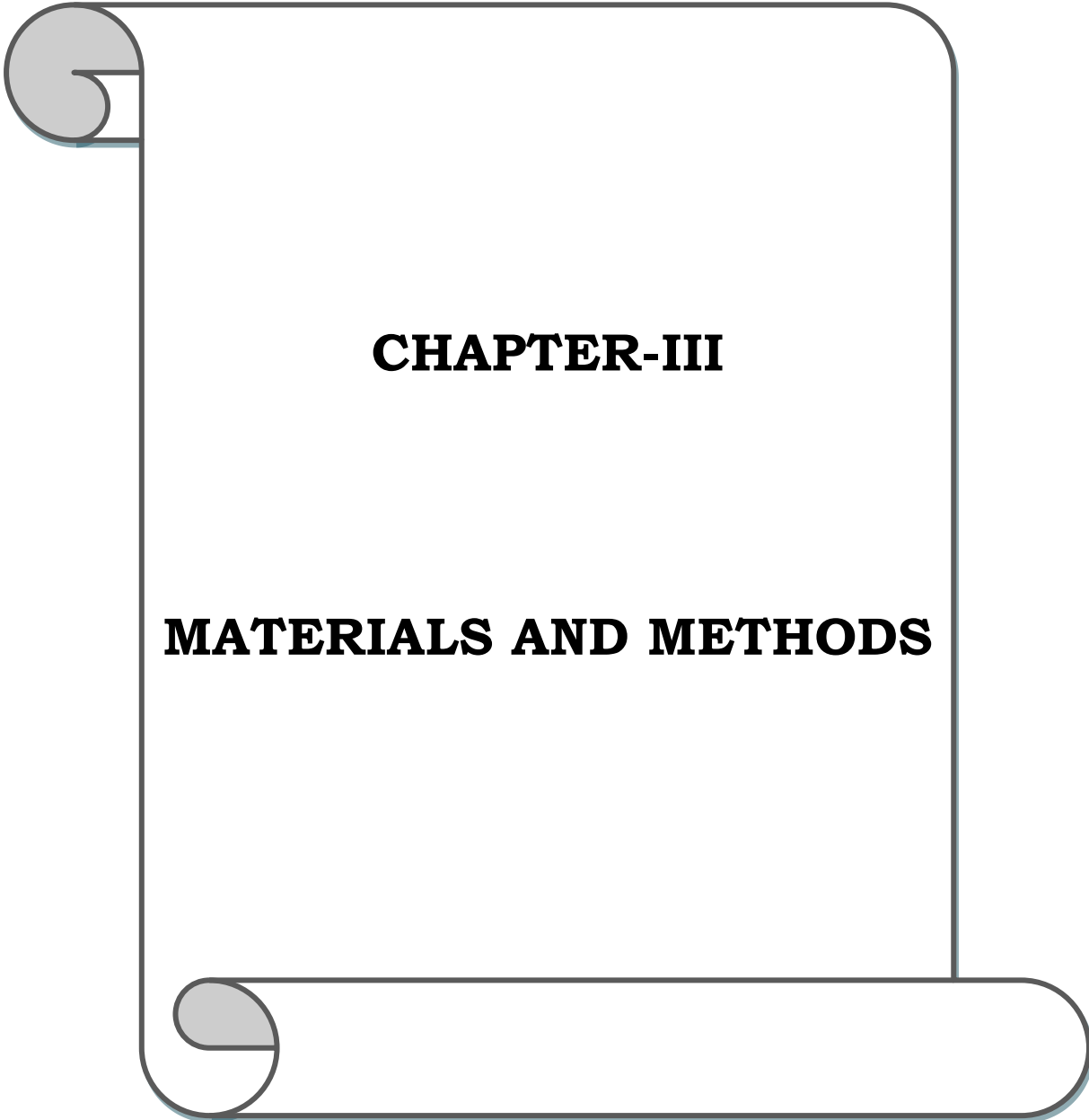
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INTRODUCTION



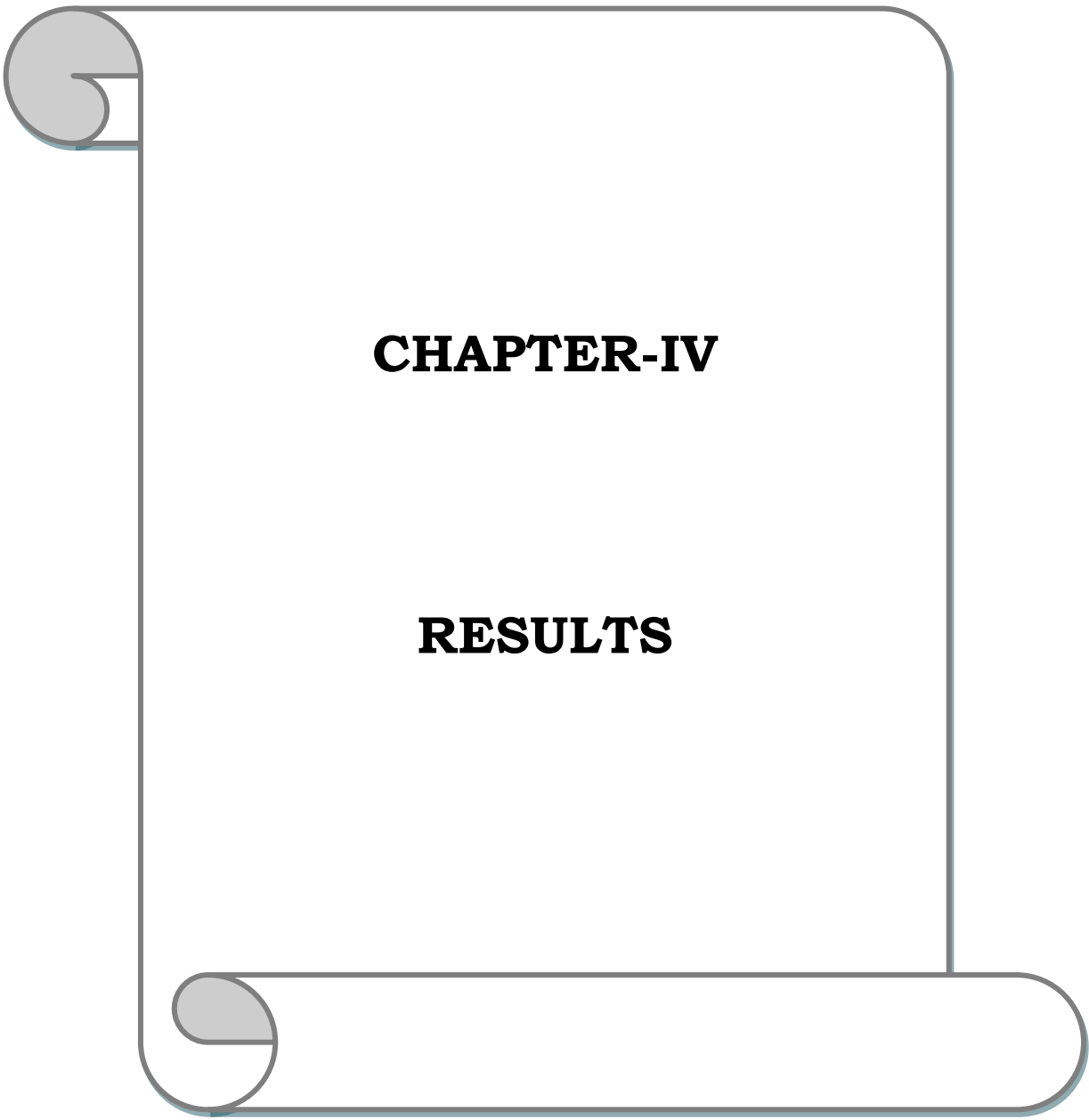
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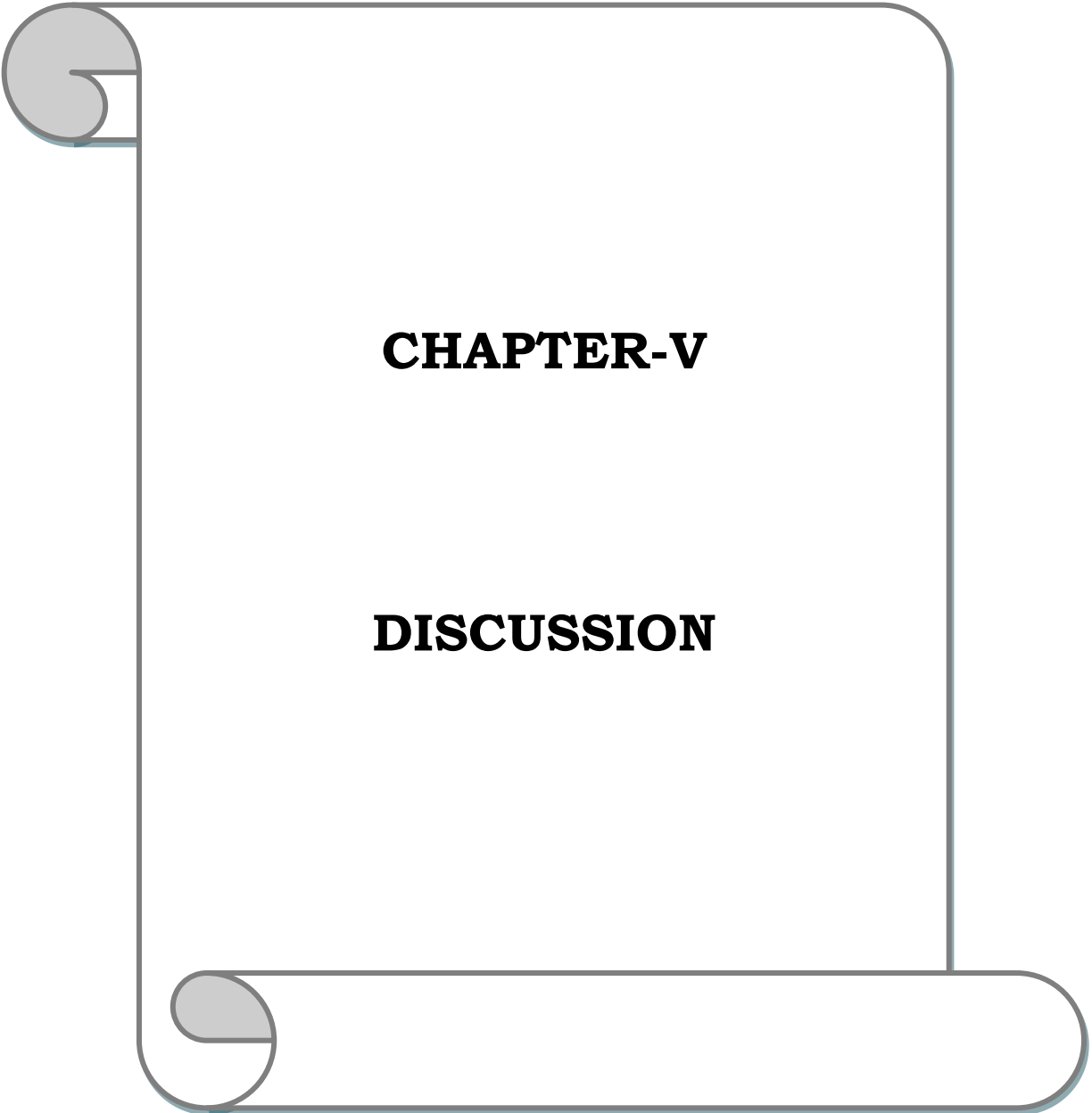
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MATERIALS AND METHODS



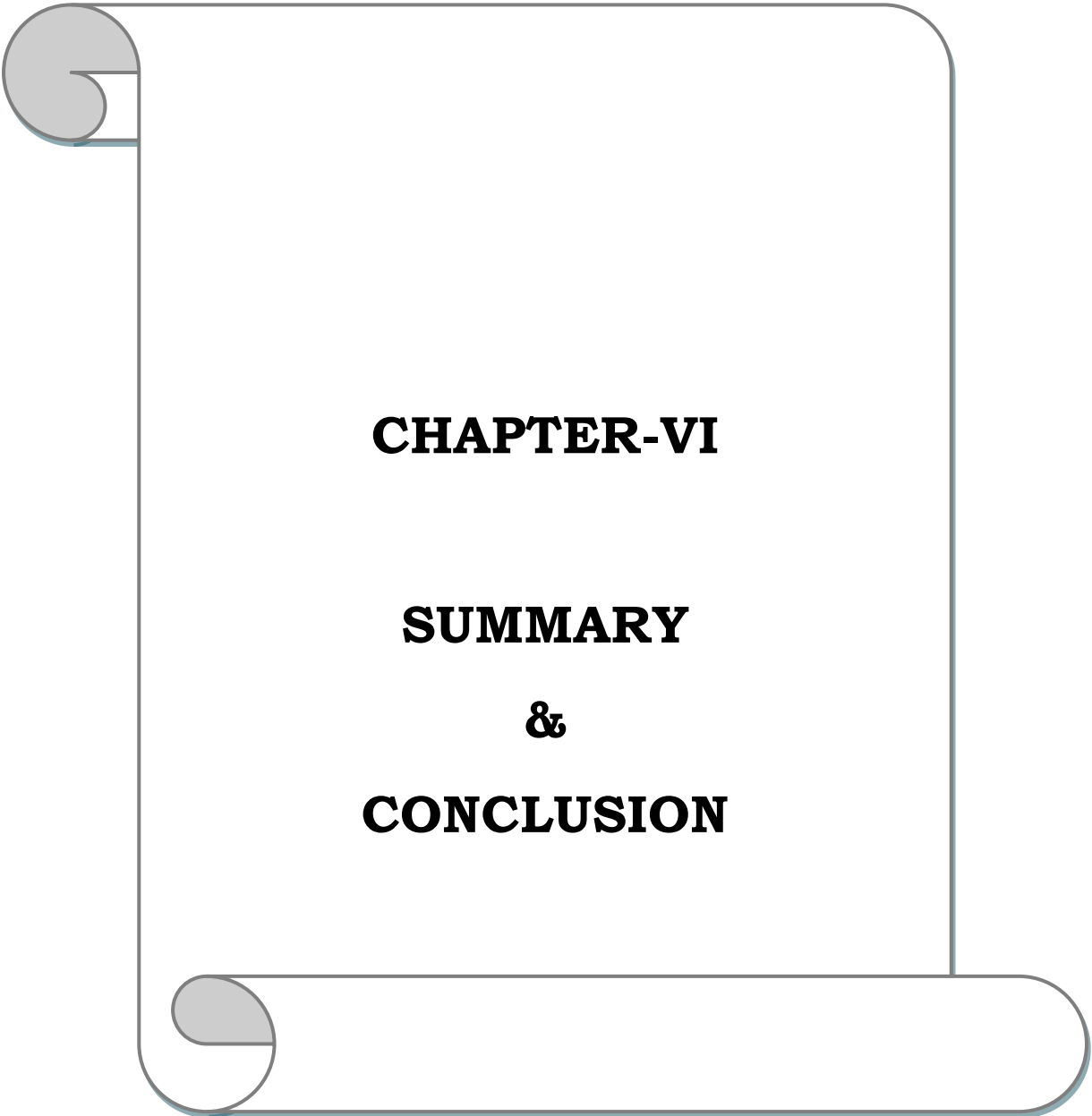
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RESULTS



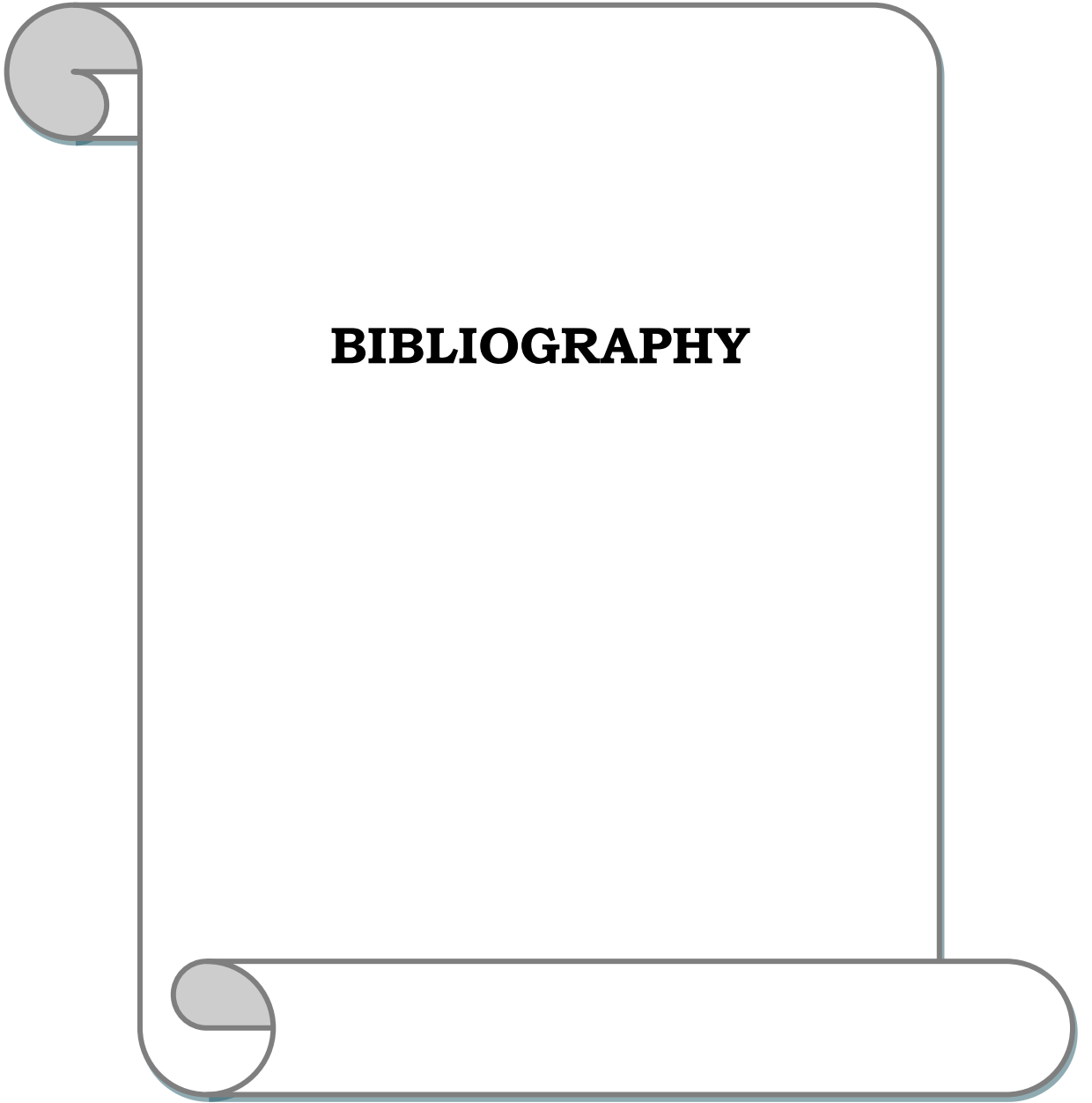
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LIST OF ABBREVIATION

DAP	=	Days after planting
VP	=	Phenotypic variance
VE	=	Environmental variance
VG	=	Genetic variance
VD	=	Dominance genetic variance
VI	=	Epistatic genetic variance
h^2_n	=	Broad sense heritability
h^2_b	=	Narrow sense heritability
GCV	=	Phenotypic coefficient of variance
PCV	=	Genotypic coefficient of variance
sca	=	specific combining ability
gca	=	general combining ability
Mr	=	Mean Square of replications
Mt	=	Mean Square of treatments
Me	=	Mean square of error
σ^2_g	=	Variance due to genotypes
σ^2_e	=	Variance due to error
CD	=	Critical Difference
SE	=	Standard Error
♂	=	Male Parents
♀	=	Female Parents
σ^2_g	=	Genotypic variance
σ^2_p	=	Phenotypic variance
h^2	=	Heritability
EGA	=	Expected genetic advance
σ_p	=	Phenotypic standard deviation
GAM	=	Genetic advance as per cent mean
r_g	=	Genotypic coefficient
r_p	=	Phenotypic coefficient
MP	=	Mid parent value
BP	=	Better parent value
MPH	=	Mid Parent Heterosis
HPH	=	High Parent Heterosis
RBD	=	Randomized Block Design
ANOVA	=	Analysis of variance
CRD	=	Completely Randomized Design
DTG	=	Days to germination
GP	=	Germination Percent
GS	=	Germination Speed
GV	=	Germination Value
SVI	=	Seedling Vigour Index
SL	=	Seedling Length
SW	=	Seedling Weight
SP	=	Survivability Percent
mm	=	Millimeter
ml	=	Milliliter
mg	=	Milligram
Kn	=	Knudson
VW	=	Vacin and Went
F ₁	=	First Generation
°C	=	Degree Celsius
%	=	Per cent
mg ⁻¹	=	Milligram per litre

g ⁻¹	=	Gram per litre
µg	=	Microgram
V/V	=	Volume/Volume
pH	=	Negative logarithm of hydrogen ion concentration
ppm	=	Parts per million
<i>In vivo</i>	=	In nature
<i>in vitro</i>	=	Under aseptic conditions
GA ₃	=	Gibberellic acid
2,4-D	=	2,4-Dichlorophenoxy acetic acid
Kn	=	Kinetin
EDTA	=	Ethylene diamine acetic acid
NaOH	=	Sodium hydroxide
HCl	=	Hydrochloric acid
HgCl ₂	=	Mercuric chloride
Kn	=	Kinetin
P ₂ O ₅	=	Phosphorus pent oxide
K ₂ O	=	Potassium oxide
KNO ₃	=	Potassium nitrate
Ca(NO ₃) ₂	=	Calcium nitrate
MgSO ₄	=	Magnesium sulphate
N	=	Nitrogen
NAA	=	Naphthalene acetic acid
BAP	=	6-benzylaminopurine
IAA	=	Indole acetic acid
IBA	=	Indole butyric acid

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The name gladiolus has been derived from the Latin word 'gladius', meaning a sword as it has sword shaped leaves (Lewis *et al.*, 1972). So, gladiolus popularly known as Sword lily or Corn Lily originated from South Africa (Poon *et al.*, 2012). *Gladiolus grandiflora* Hort., belong to family Iridaceae, sub-family Ixioideae, tribe Ixieae, sub-tribe Gladiolines is a prominent bulbous cut flower plant (Ranjan *et al.*, 2010). Various kind of Gladiolus flowers are produced in different parts of the country like India. Gladiolus "Queen of bulbous flower crops" grown in many parts of the world (Kaikal and Nauriyal, 1964) and has been rated as the second most important popular flower in the world. It is commercially cultivated in all parts of the world and it was introduced into cultivation towards the end of the 16 century (Innes, 1985). The major gladiolus producing countries are the United States, Holland, France, Poland, Italy, Bulgaria, Brazil, Australia, Israel and India. It occupies 8th position in the world cut flower trade and first in the domestic bulbous flower trade (Pragya *et al.*, 2010).

Gladiolus is the next most important cut flower crop after rose in India. It is being grown over an area of 1200 ha with a production of 1905.88 lakh spikes from states viz, West Bengal, Himachal Pradesh, Sikkim, Karnataka, Uttar Pradesh, Tamil Nadu, Punjab and Delhi. In the eastern states like Tripura, Assam, Manipur, Meghalaya and Nagaland, this flower has established itself as a commercial proposition. There is a sizeable area under glad in Jammu-Kashmir, Andhra Pradesh and Gujarat too (Rashmi, 2006). West Bengal possesses six different agro-climatic zones namely Hill Zone, Terai Zone, Old Alluvial zone, New Alluvial Zone, Red and Lateritic Zone and Coastal Saline zone and among them Hill zone (Kalimpong and adjoining areas in the Darjeeling Hills of West Bengal) is famous for gladiolus cultivation. Gladiolus is one of the principal flower crops of Terai region of West Bengal.

In gladiolus, new varieties are evolved through hybridization which is recognized as the most important sources of evolution and crop improvement. A plant breeding program can be divided into three stages, viz. building up a gene pool of variable germplasm, selection of individual from the gene pool and utilization of selected individual to evolved superior variety (Kempthorne, 1957). In ornamental plant breeding these phenomena go hand in hand and can be observed in the breeding history of many ornamental crops. Expert breeders have devoted more than a century of hybridization and selection to modify gladiolus plant to the colourful, blossom

laden varieties in demand today but evaluation is the first important step in any crop improvement programme. It is the basic tool for assessing the genetic variability present in any crop species, which could be exploited for its utilization. Selection of better plant type from the collected germplasm can be of immense value to the breeder for improvement of crop.

Gladiolus has 260 species, out of which 250 are native to sub-Saharan Africa and 10 belong to Eurasia (Manning and Goldblatt, 2008) with more than 30,000 varieties evolved in gladiolus so far through conventional breeding (Singh 2006) of which about 20 are grown for commercial purposes. Being a flowering plant, it exhibit great variability in respect of growth and their development which is the essence of any planned crop improvement programmed. It is well established that the greater the genetic diversity the higher the chance of getting better hybrid or recombinant. The study of existing varieties and genotypes performance in a particular region regarding their growth and flowering attributes and seed producing ability is the prerequisite for undertaking conventional breeding program so that suitable genotypes can be selected for further hybridization under given agro-climatic conditions.

Before taking crop improvement programmes in any crop species, a thorough knowledge on the amount of genetic variability for various characters existing in the crop is essential. Further, knowledge of relationship among yield and yield contributing characters is an effective basis for phenotypic selection in plant population (Anuradha and Gowdha, 1994). Information on nature and magnitude of variability in the existing plant material and association among characters is pre-requisites for improvement in the flower yield. The genetic potentialities of yield and yield contributing any type of characteristics and their relationships should be properly assessed for crop improvement. Information on genetic variability, correlation and seed setting studies in this crop is major.

Inheritance of a quantitative character is often influenced by variation in other characters which may be due to pleiotropy or genetic linkage. Hence, knowledge of association among economic characters and their attributes helps in determining the extent of improvement that could be brought about simultaneous selection of more than two characters. Such relationship can be known through precise estimation of genotypic and phenotypic correlation between yield and its components. Correlations between different characters helps in finding out the degree of inter relationship among various characters and in evolving selection criteria for improvement of the

available germplasm. Therefore, studies on genetic association are useful to ascertain the important component characters on which selection can be made (Choudhary *et al.*, 2011)

Among the three different methods of pollination of gladiolus cultivars viz natural self-pollination, artificial self-pollination and open pollination, artificial self-pollination generally gave the best results (Dhaduk *et al.*, 1987). Reduced natural cross pollination may have resulted from a lack of pollinating insects (Ohri and Khoshoo, 1981). Moreover, participation of inhibitory specificities of pollen cholinesterase in the pollen-stigma interaction failed to obtain matured seed from the crosses (Semenova and Roshchina, 1993). Presence of dry type of gladiolus stigma may be another reason for their incompatibility (Clarke *et al.*, 1977). Hossain *et al.* (2012) indicated the existence of wide variability among the genotypes considering crossing parameters and variations for length of capsule, breadth of capsule, number of seeds per capsule and weight of thousand seeds. Crosses produced more or less gladiolus true seed (F_1 seed). Therefore, studying the seed setting habit in gladiolus gives an idea on per cent seed setting in different cross combinations, nature and compatibility of crossing with desired parents.

Many commercial cultivars, besides their high agronomic performances, perform poorly in the F_1 generation, due to genetic hindrances in diverse cross combinations. Consequently, crossing in a diallel fashion is the only specific and effective technique for the measurement, identification and selection of superior genotypes (Mohammad, 2003). In diallel analysis, general combining ability is regarded as additive gene action and specific combining ability reflects non-additive gene actions (Sprague and Tatum, 1942). Estimates of additive and non-additive gene action are important in early stages of breeding procedures (Dudley and Moll, 1969). Selection would be successful during the early generations when additive gene action is predominant. Otherwise, the selection would be at later generations when these effects are fixed in the homozygous line. Gladiolus varieties are good general combiners for many traits and additive type of gene action has been noticed for many traits (Kumar *et al.*, 2008). Variances due to general combining ability (GCA) highly exceeded the variances due to specific combining ability (SCA), for most of the characters and significantly too. These high GCA and SCA values indicated that their inheritance was predominantly governed by additive and additive epistatic components of genetic variance (Pant *et al.*, 2000).

Heterosis in gladiolus has been studied and F_1 's have been commercially utilized in some countries (Kumar *et al.*, 2008). Heterosis is a genetic phenomenon resulting from heterozygosity, but the genetic basis of heterozygosity is still vague. Heterosis results from combined action and interaction of allelic and non-allelic factors and is commonly closely and positively correlated with heterozygosity (Burton, 1968). Flintham *et al.* (1997) explained that the heterozygosity is an essential component of heterosis and it can arise when the over dominance at a single locus is the major cause of heterosis. Heterosis is an important parameter of plant improvement, and efforts will be continued in many plant species. It has been utilized successfully even though its genetic basis has not been determined for the large part (Hallauer, 1999).

Gladiolus is largely propagated by corms and cormels whereas seeds propagation is followed to evolve new cultivars and for the recovery and maintenance of the threatened germplasm. Moreover, seed production is higher than cormel production in gladiolus (Gonzalez *et al.*, 2003). Dormancy of the cormels coupled with diseases in storage (*Fusarium* corm rot) as well as under field condition (*Botrytis* blight, bacterial leaf rot etc.) creates problem in multiplication of planting material and causes heavy losses. Hence shortage in availability of quality planting material and corm rot during storage have been the major bottleneck in the extensive cultivation of a number of commercial desirable varieties. Although, plants raised from seeds require four seasons to come to bloom under ordinary conditions but under best cultural treatments, it may be reduced to two seasons (Bose *et al.*, 2003) and plants produced from seeds can flower in the second year (Cohat, 1993).

From 1816, countries like France, Holland and Belgium started raising hybrids of gladiolus flower and all the modern and popular cultivars (cultivated varieties) of gladioli are raised from seeds. In recent years, a lot of work has been done on the invigoration of seeds to improve the germination rate and uniformity of growth and reduce the emergence time of some field crops (Basra *et al.*, 2003) and it is highly desirable in case of breeding programs with limited number of genotypes seeds obtained from controlled or manual pollination. To enhance the seed germination several treatments are needed to adopt better techniques on seeds after harvest, but prior to sowing (Taylor *et al.*, 1998). Moreover, poor crop stand is one of the major abiotic constraints encountered by resource-poor farmers (Harris *et al.*, 1999). Reasons for this include, low quality seed, inadequate seedbed preparation, untimely sowing, poor sowing technique, inadequate soil moisture, adverse soil properties and high temperatures. Effective amelioration of these physical constraints is often beyond the control of resource-poor farmers in rainfed farming systems. The

purpose of these treatments is to protect the seeds from biotic and abiotic factors during critical phase of seedling establishment so as to synchronize emergence, which will lead to uniform stand and improved yield.

Thus, tissue culture technique is useful in obtaining maximum germination percentage of gladiolus seeds within a short time, independent of the seasons and this offers a potential to establish a standard technique of *in-vitro* raising of gladiolus seeds. Although several reports on *in-vitro* propagation of gladiolus varieties (Misra and Singh, 1999 and Pathania *et al.*, 2001) are available, such reports generally underscore differential cultivar responses for different explants. Moreover, the response of culture medium differs even from species to species. However, the beneficial effects of *in-vitro* seed germination have been demonstrated in many other crops but *in-vitro* culture of gladiolus seeds for the germination attributes and seedling growth along with their mortality has not yet been reported and therefore optimization of medium for germination and its development is an important prerequisite.

Therefore, keeping in view the above points and with the motive of studying biometrical parameters of gladiolus the present study entitled “Genetic studies of some gladiolus genotypes and standardization of *in-vitro* seed germination” was undertaken with the following objectives:

- study on assessment of the *per se* performance of gladiolus genotypes
- study on seed setting in cross combinations and the combining ability of seed characters
- study on *in-vitro* seed germination and growth of gladiolus

2.1 Performance of gladiolus genotypes

The performance of gladiolus varieties varies to a great extent with respect to growth, flowering and quality of flowers. The literature pertaining to variations with respect to growth, flowering, flower yield and corm yield has been reviewed and presented.

2.1.1 Vegetative characters

Roy and Sharma (2000) reported a lot of variation in plant height and the cultivar 'Vedio' was dwarfest one (114 cm) and 'White Prosperity' was the much tallest (152 cm). Rai *et al.* (2000) reported the genotypes 'White Prosperity' (128.5 cm), 'White Goddess' (123.5 cm), 'Red Beauty' (123.3 cm), 'White Friendship' (121.4 cm) and 'First Lady' (135.8 cm) showed good plant height. Sanjai and Singh (2000) reported that significant variations in plant height ranging from 101.9 to 136.6 cm. 'Princess Margarat Rose' (136.6 cm) was the tallest followed by 'White Prosperity' (125.9 cm), 'Wings Sensation' (121.7 cm), 'Spic and Span' (120.7 cm) and 'Eurovision' (119.4 cm). Sidhu and Arora (2000) evaluated gladiolus varieties for summer flower production under Ludhiana conditions and reported that variety 'White Prosperity' produced significantly tall plants (130.85 cm) followed by 'Pole Position' (111.60 cm). In an evaluation of five gladiolus cultivars under Kerala conditions by Ravidas (1993) indicated that in both seasons, 'American Beauty' surpassed the other cultivars with regard to all the vegetative growth characteristics measured. Hegde (1994) who evaluated gladiolus and found that the number of leaves ranged from a minimum of 4.20 leaves plant⁻¹ in cultivar 'Green Wood Pecker' to a maximum of 7.6 in case of 'American Beauty'. The maximum number of leaves noticed under white prosperity and Wind Song (9.7) and minimum in 'Victor Borge' (8.7). 'American Beauty' produced more number of leaves (4.61) and plant height (41.94 cm) compare to that of 'Melody' at 30 DAP (days after planting) under Dharwad conditions (Kalasaraddi, 1996).

Arora and Uppar (1994) reported that cultivar 'Appalause' (9.8 days) was earliest to sprout, whereas 'Jester' (17.8 days) took maximum number of days to sprout. Swarup and Raghava (1972) evaluated many promising gladiolus cultivars for the North Indian plains. They assessed these genotypes on the basis of certain characteristics such as number of days taken for first floret opening, spike length and number of florets spike⁻¹. These 122 cultivars were grouped into early,

mid season and late flowering. The varieties which produced flower spikes within 60 days after planting (DAP) were grouped as early and those which flowered in 60 to 80 DAP as mid season and those which took more than 80 DAP as late flowering types. They found that 'Sylvia' flowers in 92 DAP. Misra and Choudhary (1976) studied the performance of 100 gladiolus cultivars under Simla conditions and 37 cultivars were found outstanding for various quantitative characters. The cultivars which flowered within 70 DAP were grouped as early and 70-100 days as midseason which include 'Friendship', 'Green Wood Pecker', 'Happy End', 'Oscar', 'Snow Princess' and 'Vinks Glory'. The group which took more than 100 days were categorised as late which include 'Sylvia'. Loeser (1981) investigated the earliness and quality of 44 gladiolus cultivars that were planted on three dates (14th April, 13th May and 13th June), corms planted in 3rd month (June) produced spikes early. Among the different studied genotypes viz., 'Arka Kesar', 'H.S.84-7-11' and 'Shobha' were early in respect of days to spike emergence, full spike emergence, the first bud showing colour, basal bud loosening and flowering. Duration of spike emergence to flowering was long in 'Psittacinus hybrid' (14.18 days), 'H.S.87-22-11' (13.17 days) and 'Dhiraj' (13.13 days). Duration of first floret bud loosening to complete opening of florets was short in 'Shobha' (21 hours 31 minutes), 'H.S.84-7-11' (21 hours 53 minutes) and 'Darshan' (21 hours 58 minutes) (Poon *et al.*, 2009). Arora and Sandhu (1987) reported that number of days taken to open basal floret in cultivar 'Teachoinn' was 87.9 days and in 'Peter Pears' it was 88.0 days. The cultivars 'Applause', 'Eurovision', 'Hunting Song', 'White Friendship' and 'Sancerre' took 100 days. The cultivars which showed opening of basal florets in 100 to 110 days were 'Bonaire', 'Nova Lux', 'Priscilla', 'Tender Horn' and 'White Prosperity'. Arora and Sharma (1991) in their varietal study under Ludhiana conditions with five cultivars found that 'Snow Princes' took least number of days for the basal floret to open and described 'Melody' as good performer.

2.1.2 Flowering attributes

Rai *et al.* (2000) reported that number of florets spike⁻¹ varied and it was 17.3 in 'White Prosperity' closely followed by 'Friendship' (17.00), 'First Lady' (17.00), 'Red Beauty' (16.70), while minimum (12.00) was found in 'Green Wood Pecker'. Sanjai and Singh (2000) reported on number of florets spike⁻¹ which was maximum 'White Prosperity' (21.1) followed by a 'Souvenir' (20.7), 'Friendship' (19.6), 'Novelty' (18.9), 'Princes Margaret Rose' (18.4). Pasannavar (1994) observed that the length of floret ranged from 8.47 cm to 11.19 cm. Further, he reported that florets

with maximum length (11.19 cm) were observed in 'American Beauty' and with minimum length (8.47 cm) were noticed in 'Sylvia' but diameter of florets (10.75 cm) were maximum in cultivar 'Copper King'. According to Kalasaraddi (1996), 'American Beauty' followed by 'Melody' was best with respect to diameter of flowers under Dharwad conditions. Sindhu and Verma (1995) recorded that the highest floret diameter was found in 'Sancera' (11.7 cm) and least in 'Arc' (6.0 cm). Sidhu and Arora (2000) reported that diameter of the floret was maximum in variety 'Rose Supreme' (8.92 cm) followed by 'Summer Line' (8.46 cm). Misra *et al.* (1987) in their two years experiment under Katrain conditions with 12 cultivars of gladiolus found that cultivar 'Salmon Queen' had maximum floret diameter. Singh *et al.* (1998) reported maximum spike length and number of florets spike⁻¹ were higher in 'Oscar' (77.61 cm and 18.16 respectively) than in 'Friendship' (69.15 cm and 12.66 respectively) under low hills of Nagaland.

Roy and Sharma (2000) reported that longest spike (98.2 cm) was produced by Jester followed by 'White Prosperity' (89.8 cm). Sidhu and Arora (2000) reported that for spike length variety 'White Prosperity' produce the longest spikes (102.27 cm). Arora and Uppar (1994) reported that spike length of 'Peter Pears' (90.3 cm) and 'White Prosperity' (86.5 cm) had significantly longer spikes than others. Rai *et al.* (2000) reported that spike length was variable between 81.9 cm to 84.4 cm. The maximum spike length was found in 'Friendship' (81.9 cm) followed by 'White Prosperity' (76.9 cm), 'First Lady' (75.5 cm) and 'White Friendship' (75.3 cm). Pasannavar (1994) observed that weight of floret ranged from 60.77 g to 128.3 g. The maximum spike weight was recorded in the cultivar 'Copper King' (128.3 g) and least was in cultivar 'Her Majesty' (60.77 g). Further the same author recorded maximum spike girth of 0.98 cm in cultivar 'Copper King' and minimum of 0.76 cm in cultivar 'Happy End'. He also recorded for the marketable spikes plant⁻¹; the range was from 1.13 in cultivar 'Wedding Bouquet' upto 3.13 in cultivar 'American Beauty'. Swarup and Raghava (1972) found that 'Sylvia' flowers in 92 days after planting and described 'Snow Princess' as promising cultivars having long spike and large florets at North Indian plains. Misra and Choudhary (1976) reported that cultivar 'Vinks Glory' performed well with respect to spike length (10 to 13 cm). In yellow, 'Vinks Glory' and in deep red, 'Oscar' was the best. 'Friendship', 'Happy End' and 'Vinks Glory' were good cultivars, which have attractive shape of the florets. According to Lal and Singh (1978), cultivars 'House of Orange' and 'Oscar' had the longest spikes (66.5 and 66.0 cm respectively) and the 'House of

Orange' was also first to flower (92.2 days) and the 'Oscar' produced the highest number (17) of florets spike⁻¹ under Chakrata conditions.

2.1.3 Quality and shelf life

Patil *et al.* (1994) in his trials indicated that among nine exotic gladiolus cultivars cv. 'Sancerre' corms followed by cultivars 'Yellow Stone' and 'Hunting Song' were rated high for colour, floret arrangement, shape and texture. Aswath and Parthasarathy (1996) evaluated 18 gladiolus varieties for their performance in terms of floral characters and reported the varieties like 'Blue Moon', 'Powder Puff', 'Friendship' and 'Red Majesty' were superior for spike characters. Seetharamu *et al.* (2003) reported 'American Beauty' was in uniform distribution of florets on the spike followed by 'Her Majesty' and 'Cheaper White' for hill zone. In an evaluation of five gladiolus cultivars under Kerala conditions by Ravidas (1993) indicated that 'American Beauty' and 'Friendship' produced better quality flowers, whereas 'Agnirekha' and 'Monsoon Red' lasted longer in the vase. In a field experiment was conducted by Riaz *et al.* (2010) to evaluate the agronomic performance of 23 gladiolus germplasm against corm rot disease, 'Glad Red' depicted highest field life of flowers (42.5 days), followed by 'Friendship' (42.5 days), 'Peter Pears' (38.7 days) and 'Chinon' (37.3 days).

2.1.4 Yield of corms and cormels

Arora and Sandhu (1987) studied the performance of 15 gladiolus cultivars for two dates of planting under Ludhiana conditions. They found that early planting resulted in better corm and cormel production than late planting. Corm production was highest in 'Melody' for the early and late plantings, respectively. Cormel production was highest in 'Suchitra' (113.0). Misra *et al.* (1987) in their two years of experience with 12 cultivars of gladiolus found that the miniature cultivars produce more number of corms than the late bloomers, which produce less number of corms. But, late bloomers produce bigger cormels as these get ample time for development. Singh and Singh (1987) studied the performance of 41 gladiolus cultivars in Delhi and reported that cultivar 'Friendship' and 'Melody' performed better for corm and cormel multiplication and found that the cultivar 'Sylvia' produced biggest cormels. Saini *et al.* (1991) studied the performance of six gladiolus cultivars under Hissar conditions and found that 'Melody' gave maximum number of corms and cormels. Arora and Khanna (1985) reported that size of the gladiolus corms was highest in cultivar 'Oscar' (6.29 cm), whereas cultivar 'Melody' produced smaller (4.04) sized corm.

Hegde (1994) also reported that cormels plant⁻¹ were more in case of ‘Melody’ (129.00), but it was least (10.10) in cultivar ‘Green Wood Pecker’. Further, he reported that weight of daughter corm in cultivar ‘Summer Pearl’ was highest (127.33 g) and also the highest size was in case of cultivar ‘Summer Pearl’ (8.5 cm). The daughter corm size was least in ‘Sylvia’ (5.86 cm). Sindhu and Verma (1995) reported that the maximum size of corms was in ‘Age Wonder’ followed by ‘Neelakanth’. The weight of the corms was highest in ‘Wind Song’ (88.00 g) followed by ‘Age Wonder’ 84.00 g). Rai *et al.* (2000) reported maximum corms plant⁻¹ was obtained in ‘First Lady’ (1.9) followed by ‘White Prosperity’ (1.6) and ‘Aldebrane’ (1.6) whereas least was in ‘Green Wood Pecker’ (1.00).

Roy and Sharma (2000) reported that corm diameter was highest in case of cultivar ‘Ice Gold’ (6.6 cm) and ‘Rose Supreme’ (6.6 cm) and smallest in ‘Priscilla’ and ‘Viedo’ (5.0 cm) and corm weight was also maximum in ‘Ice Gold’ (92.6 g) and lowest was in ‘Viedo’ (38.6 g). Further, they reported that maximum number of cormels (21.2) was produced by the cultivar ‘Vink’s Glory’ and least number of cormels in cultivar ‘Jester’ (3.0). Sanjai and Singh (2000) studied the number of cormels plant⁻¹ and found that the range was 18.7 to 55.5. The maximum number of cormels plant⁻¹ was observed in ‘Victor Borge’ (55.7) followed by ‘White Prosperity’ (50.2), ‘Eurovision’ (48.8), ‘Novelty’ (48.8) and ‘Souvenir’ (45.5), which were best varieties for cormel production. Sidhu and Arora (2000) reported that corm and cormel weight was significantly higher in the variety ‘Nova Lux’ i.e., 46.00 g. However, number of corms plant⁻¹ was highest in the variety ‘White Prosperity’ (1.28) and number of cormels plant⁻¹ was highest in the variety ‘Sunshine’ (12.90).

2.2 Study of genetic attributes

2.2.1 Variance components

Quantitative genetics is involved the variation expressed by quantitative traits. The variation is measured and expressed in terms of variance. The given trait’s total variance is its phenotypic variance (VP), or the variance of phenotypic values. It is the sum of environmental variance (VE) and genetic variance (VG) (Falconer and Mackay, 1996). Environmental variance is a source of error in genetic studies and includes all the variation of non-genetic origin. It reduces the efficiency of the selection procedure by the interaction between genotypes and phenotypes (Lynch and Walsh, 1998). To breeders, the genetic variance is more important, because it determine the

rates at which characters respond to selection. Dudley and Moll (1969) indicated the total genetic variance (VG) is composed of additive genetic variance (VA), dominance genetic variance (VD) and epistatic genetic variance (VI). The most important component is VA, which is the variance of selection values.

The genetic variability in a crop is of prime importance in its improvement. Knowledge of the existing variability in the crop help the plant breeder to make an efficient selection of genotypes from the available material which can be utilized for further crop improvement and enables the breeder for further crop improvement. The genetic potentialities of yield and yield contributing characteristics and their relationship should be properly assessed for crop improvement.

Genotypic coefficient of variation indicates the relative magnitude of genetic diversity present in the material and helps to compare the genetic variability present for different traits. Phenotype of any plant is influenced by the genotype, environmental and the interaction between the two. Further, the variation in a segregating population is attributed by both heritable and non heritable components and the variation in a pureline is only by environmental factors (Johansen, 1909).

2.2.2 Heritability

The effectiveness of selection for any character does not depend on the amount of phenotypic variability alone. It is necessary that breeder should determine how much of the phenotypic variability present in the character is heritable. Heritability estimates are useful methods in designing an effective hybrid program. They provide an indication of the expected response to selection in a segregating population (Burton and Devane, 1953). It determines the degree of resemblance between relatives and it expresses the proportion of the total variance that is attributable to differences of breeding values (Falconer and Mackay, 1996). Johnson *et al.* (1955) stated that heritability, assessed in conjunction with calculating expected genetic gains using h^2_n (Broad sense heritability) or h^2_b (Narrow sense heritability) estimates, are more effective and reliable in predicting the improvement through selection.

The term heritability has been further divided into two different concepts, broad sense and narrow sense heritability. The broad sense heritability is defined as the ratio of total genetic variance to phenotypic variance. The narrow sense heritability is the ratio of additive genetic variance to phenotypic variance (Dudley and Moll, 1969). Narrow sense heritability is more

reliable and it is important to breeding programs, because only additive genetic variability is inherited to the next generation (Chaudhary, 1982). Characters with high narrow sense heritability values can be selected more quickly with less intensive evaluation than those with low broad sense heritability values and therefore are useful in making selection progress estimates. Broad sense heritability includes non-additive effects and consequently overestimates the response of selection (Dudley and Moll, 1969).

2.2.3 Genetic advance

Genetic advance estimates the amount of improvement that can be achieved over the base population. The estimation of heritability along with genetic advance is usually more useful in predicting the resultant effect for selecting best individuals (Johnson *et al.*, 1955). This is due to the fact that, a character may have very high heritability but very less phenotypic variation, thus giving low values of genetic advance.

2.2.4 Variability, Heritability and Genetic Advance in gladiolus

Negi *et al.* (1982) reported that phenotypic and genotypic coefficient of variation, heritability in broad sense and genetic advance as per cent of means were all high for weight of cormels produced corm plant⁻¹, number of cormels for corm and weight of corm. Anuradha and Gowda (1990) studied the genetic variability in 25 genotypes of gladiolus for 24 characters and recorded high degree of variability for all the characters except number of side shots and number of side spikes. High phenotypic and genotypic coefficients of variation were observed for leaf area, rachis length, number of capsules and number of seeds capsule⁻¹, while these were low for number of side spike, floret diameter, floret length and number of leaves. Heritability was low for floret length, longevity of individual floret, days to spike emergence and spike length whereas, genetic advance was high for number of capsules and number of seed capsule⁻¹.

Sorianathasundaram and Nambisan (1991) studied the gladiolus cultivars for genetic variability and observed highest heritability value for spike weight and length. Estimated genetic advance as percentage of mean was highest for spike length (45.3), followed by spike weight (45.2), number of florets (35.5) and floret size (34.7), variability and genetic advance low for the characters like weight of daughter corm, number of sprouts plant⁻¹ and number of cormels plant⁻¹. Mahanta and Paswan (1995) reported maximum heritability (99.38) for weight of corm, followed by number of cormels plant⁻¹ (98.50) and diameter of cormel (94.27). Sheikh *et al.* (1995)

observed that plant height, days to flower, spike length, number of florets spike⁻¹ and floret size exhibited high heritability values which ranged from 58.75 to 99.00. Whereas, genetic advance was high in case of plant height (23.49), days to flower (19.07) and spike length (13.96) and heritability estimates were high for all the characters studied except for field life and vase life of flowers.

Balaram *et al.* (2000) reported that both the genotypic and phenotypic variance were highest for the characters plant height, spike length, spike weight, weight of daughter corm and number of cormels corm⁻¹. Genotypic variance was low for days for 50% sprouting (2.34), number of shoots plant⁻¹ (0.91), number of leaves shoot⁻¹ (1.25), floret diameter (2.49), floret length (2.09), number of florets open at one time (1.32), spike girth (0.04), number of spike corm⁻¹ (0.87), number of side shoots plant⁻¹ (0.18). Almost all the characters had higher heritability estimates. Deepti (2000) reported that heritability varied for different characters viz., diameter of leaf (47.2059), length of spike (93.9027), plant height at 30 DAP (93.9027), plant height at 60 DAP (89.7827) and length of flower (89.6375) and maximum heritability was length of spike (95.5745). Further, she reported that expected genetic advance ranged from 0.3107 and 0.2769. Balamurugan *et al.* (2002) noticed high genotypic coefficient of variance (GCV) in gladiolus for number of side shoots. Whereas, low for longevity of individual florets and duration of first floret. Further, they reported that there was a considerable difference in GCV and PCV (Phenotypic coefficient of variance) for number of side shoots plant⁻¹, duration of flowering, and longevity of individual florets. Bichoo *et al.* (2002) observed that high genotypic coefficient of variations for number of cormels plant⁻¹ and less cormel weight in gladiolus indicated the presence of sufficient genetic variability for selection and high heritability and high genetic advance for days taken for basal floret opening, plant height and number of florets spike⁻¹.

The genetic variability and association between different characters were undertaken in eleven genotypes of gladiolus. The maximum range of variation was observed for corm weight plant⁻¹ followed by plant height and length of spike. The PCV were higher than corresponding GCV indicating environmental influence on all the characters. High heritability was noted for number of spikes plant⁻¹ followed by plant height and length of spike. High heritability coupled with high genetic advance as a percentage of the mean was observed for number of spike plant⁻¹, number of corms plant⁻¹ and weight of corm plant⁻¹ indicating the influence of additive gene action.

Positive association with greater magnitude were observed between plant height with length of spike; duration of flowering and weight of corm plant⁻¹; number of spikes plant⁻¹ with number of corms plant⁻¹; length of spike with number of florets spike⁻¹; and duration of flowering and duration of flowering with weight of corms plant⁻¹ (Singh *et al.*, 2000).

2.2.5 Correlation and Path Co-efficient Analysis

The improvement of yield is one of the main objectives of any breeding programme. But yield being a complex character which is controlled by large number of characters. Hence, it becomes necessary to investigate how these characters contribute to yield, i.e. to find out how they are related, the magnitude and direction of association. Such knowledge of correlation will help the plant breeder in planning more efficient breeding programme.

The correlation coefficient analysis measures the mutual relationship between various characters and it determines the component traits on which selection can be relied upon to effect the improvement and path coefficient analysis, which involves the measurement of influence of one trait upon set of other traits through standardized partial regression coefficients to increase efficiency in selection.

The idea of correlation was presented by Galton (1889) and later elaborated by Fisher (1918) and Wright (1921). The direct observation of phenotypic correlations does not indicate the magnitude or direction of genetic correlation, which presents a true genetic picture of relationship between the genes controlling the characters.

The correlation of characters may be due to either genetic linkage or pleiotropy (Harland, 1939). Probably the main cause of genetic correlation is due to pleiotropic effects of genes, i.e. some of genes which affect one trait also affect the other. If the correlation is high, then probably pleiotropy is important and if the correlation is low then we might say that the two traits are inherited independently as they are under the control of different sets of genes (Jain, 1982).

The technique of path coefficient analysis was developed by Wright (1921), as a means of separating direct and indirect contribution of various factors; path coefficient analysis is a standardized partial regression coefficient analysis and as such measures the direct influence of one variable upon the other and permits the separation of correlation coefficients into components

of direct and indirect effects. Use of this technique requires a cause and effect situation among the variables.

2.2.6 Correlation and Path Co-efficient Analysis in gladiolus

Deshraj and Mishra (1998) reported that correlation is in fact one of the important aspects in selection programme as the breeder can make an effective selection based on the correlated and uncorrelated response to understand the association between the component character and their relative contribution to economic yield or essential to bring out important in the desirable selection.

Gowda (1989) studying 20 cultivars of gladiolus reported positive correlation between plant height and spike length and between spike weight and number of leaves. Anuradha and Gowda (1990) in her study with 25 gladiolus genotypes for 24 character reported that among the intercomponental correlations, all characters exhibited high positive correlations among themselves. Sandhu *et al.* (1990) studied 15 genotypes of gladiolus and observed that number of florets spike⁻¹ exhibited moderate to low correlation with most of the characters, whereas spike length had significant correlations with number of florets spike⁻¹. Misra and Saini (1990) reported positively significant correlations of number of florets spike⁻¹ with height of the plant, number of leaves shoot⁻¹, number of florets remaining open at a time, durability of spike, number of florets spike⁻¹, weight of daughter corm and cormels. There were negative correlations of number of shoots corm⁻¹ with days to flowering. The strongest positive correlation was observed between number of cormels produced and number of shoots plant⁻¹, diameter and weight of the daughter corm. Deshraj and Mishra (1998) in their character association studies were conducted on 25 genotypes of gladiolus grown at three locations. A significant association of number of florets spike⁻¹ with durability of whole spike, rachis length and plant height indicated that single plant selections would be more effective for gladiolus improvement.

Lal *et al.*, (1985) reported from their study with gladiolus that plant height was correlated significantly with spike length and leaf number exhibited a positive correlation with the spike weight. Misra and Saini (1990) reported positively significant correlation of number of florets spike⁻¹ with height of the plant, number of leaves shoot⁻¹, number of florets remaining open at a time, durability of spike, number of capsule spike⁻¹, weight of the daughter corm and cormels and negative correlation of number of shoots corm⁻¹ with days to flowering. The strongest positive

correlation was observed between number of cormels produced and number of shoots plant⁻¹ and equatorial diameter and weight of daughter corm. A study on the association of various morphological traits through correlation analysis in gladiolus (*Gladiolus x hybridus* Hort.) by Choudhary *et al.* (2011) showed that spike length had significant positive correlation with plant height, rachis length, duration of flowering and number of florets spike⁻¹, whereas it had negative correlation with number of shoots plant⁻¹, size of the floret and number of corms plant⁻¹ at both phenotypic and genotypic levels. Number of florets spike⁻¹ was positively and significantly correlated with number of leaves plant⁻¹, rachis length, leaf area, spike length and number and weight of cormels produced plant⁻¹ at both phenotypic and genotypic levels. The results revealed that spike length, number of florets spike⁻¹ and floret size is important spike quality characters. Hence, these characters may be considered as selection indices in gladiolus breeding programme. Sandhu *et al.* (1990) studied 15 genotypes of gladiolus and reported that number of florets spike⁻¹ exhibited moderate to low correlation with most of the characters, whereas spike length had significant correlation with the number of florets spike⁻¹ and duration of flowering had significant correlation with spike length and number of florets spike⁻¹. Lone *et al.* (1999) indicated that number of florets spike⁻¹ and spike length exhibited significant and positive phenotypic and genotypic correlation with flowering duration, number of florets open at one time, floret size, distance between two florets, plant height, spike weight, vase life, size and weight of corm. Significant and positive correlation was observed between corm weight and number of cormels plant⁻¹. However, significant negative association existed between number and weight of corms plant⁻¹.

At both phenotypic and genotypic levels, spike length was positively associated with plant height, number of florets spike⁻¹, number of florets open at one time, floret size, corm weight and corm size. Significant positive correlation of spike length was observed with durability of basal floret and number of cormels plant⁻¹ at genotypic level. Plant height was positively and significantly correlated with of florets open at one time, floret size, corm weight and corm size both at phenotypic and genotypic levels. Number of leaves plant⁻¹ had positively significant correlations with days to slipping, days to basal floret opening, and durability of whole spike at both genotypic and phenotypic levels. The number of shoots plant⁻¹ had significant positive association with number of corms plant⁻¹. For early flowering, the importance of reduced number of shoots corm⁻¹ was indicated by negative correlation of days to slipping and days to basal floret

opening with number of shoots plant⁻¹. Corm size was positively and significantly correlated with plant height, spike length, florets spike⁻¹ floret size and corm weight at both genotypic and phenotypic levels. The yield in terms of cormels per plant increased with the increase in plant height, number of shoots plant⁻¹, spike length, durability of basal floret, number of florets open at one time, durability of whole spike, floret size, number of corms plant⁻¹, corm weight and corm size since these characters was positively correlated with cormels plant⁻¹ at both phenotypic and genotypic levels (Jhon *et al.*, 2002).

Further path analysis revealed that spike length has a positive direct effect on number of florets spike⁻¹, whereas it has indirect effect through duration of flowering and vase life. Vase life has positive indirect effect through size of the floret and negative indirect effect through number of florets spike⁻¹ (Sandhu *et al.* 1990). Anuradha and Gowda (2000) studied the path coefficient analysis in 25 genotypes of gladiolus which revealed high magnitude of positive direct effect of plant height, rachis length and floret length on spike length. Number of florets spike⁻¹ and weight of daughter corm showed positive direct effects. The indirect effects of plant height, rachis length were positive through all the characters. Floret length and plant height exhibited a high magnitude of direct effect on floret diameter. Spike length, rachis length, durability of spike and days to emergence showed positive direct effects on number of florets spike⁻¹ whereas Katwate *et al.* (2002) studied path analysis in gladiolus hybrids and revealed that character rachis length exhibited the highest direct effect (1.487) followed by weight of cormels plant⁻¹ (0.571), length of spike (0.46) and number of leaves plant⁻¹ (0.425) on the number of florets spike⁻¹. Results of pooled analysis for both years by Nazir *et al.* (2005) revealed that days to first floret colour showing and average weight of cormels plant⁻¹ showed positive direct effects. These characters also showed positive significant correlation with number of florets spike⁻¹, so it is suggested that a single plant selection for these traits would be useful for the improvement in the number of florets spike⁻¹.

Path coefficient analyses conducted by Balaram and Janakiram (2005) on 35 Gladiolus genotypes (11 indigenous, 23 exotic and one wild species for number of leaves shoot⁻¹, floret diameter, floret length, number of floret open at one time, plant height, rachis length, spike girth, spike weight, number of florets spike⁻¹, polar corm diameter, equatorial corm diameter and weight

of daughter corm concluded that the spike length as a dependent variable were effected directly by plant height followed by rachis length and floret length.

Findings of Anuradha *et al.* (2002) confirmed that among the characters studied, plant height (0.6155) showed the highest positive direct effect on spike length, followed by rachis length (0.3129), floret length (0.2626), number of florets spike⁻¹ (0.1332) and weight of daughter corm (0.0440). Leaf area, floret diameter and number of leaves showed negative direct effects towards spike length. Among indirect effects, plant height through rachis length (0.1473) was relatively high than the low indirect effects of floret length, number of florets spike⁻¹ and weight of daughter corm. The indirect contribution of rachis length through plant height and floret length was positive and high. Floret length showed positive indirect effects through plant height and rachis length, followed by number of florets spike⁻¹ and weight of daughter corm. Number of florets spike⁻¹ exhibited positive indirect effect via plant height, rachis length and floret length, followed by weight of daughter corm on spike length. Weight of daughter corm exhibited high indirect positive effect on spike length through plant height and low positive indirect effect via number of florets, rachis length and floret length. The direct contribution of floret diameter through plant height, floret length and rachis length was positive and high. Number of leaves and leaf area exhibited high indirect effect through plant height and rachis length. Their indirect effects via other characters were low on spike length. Floret length (0.7042) was the foremost character directly affecting floret diameter. Among indirect effects, plant height recorded positive influence via floret length only. Number of florets per spike recorded low positive direct effect and its association with floret diameter was mainly due to indirect effect through floret length (0.2841) and plant height (0.1598). Spike length and rachis length exhibited high indirect effects via floret length and plant height. Floret length had the highest direct effect (0.7042) on floret diameter.

2.3 Seed setting in cross combinations and combining ability

2.3.1 Seed setting in gladiolus

The structure and placement of stamens and stigma suggest that Gladiolus is essentially out crossing. In India, anthesis occurs between 8.15 to 10.15 hours and anther dehiscence takes place soon after. Stigma becomes receptive nearly 11/2 hours after anther dehiscence (Ohri and Khoshoo, 1981). Duration of initiation and completion of anther dehiscence is long from 5 hours 7 minutes to 5 hours 19 minutes and duration of initiation to completion of stigma receptivity is long

from 3 days 22 hours 59 minutes to 4 days 1 hour 37 minutes (Poon *et al.*, 2009). The pollination of female parent of gladiolus at one day before just at bud opening using anthers that had just dehisced are considered best for obtaining good results (Mahawer and Misra, 1993). It has been found that pollen of *G. tristis* can be stored at -20°C for 1 year and low air temperatures (15 to 20°C) is best for pollen tube growth, fertility, and fruit set in the cross between *G. x grandiflora* and *G. tristis* (Takatsu *et al.*, 2001). But maximum pod development are observed only in hand-pollinated flowers, where as natural cross-pollinated and bagged flowers showed considerable reduction in pod formation of gladiolus (Ohri and Khoshoo, 1981). Artificial self-pollination generally gave the best results, with the cultivars ‘Melody’ and ‘Patricia’ performing well under all methods of pollination; the cultivars ‘Sylvia’ and ‘Psittacinus Hybrid’ gave poor results (Dhaduk *et al.*, 1987). Reduced natural cross-pollination may have resulted from a lack of pollinating insects. Workers (*Apis cerana indica*) foraging for nectar did not contact anthers or stigma, but those collecting pollen may affected self or cross pollination (Ohri and Khoshoo, 1981).

Even in an interspecific hybridization carried out by Takatsu *et al.* (2005) failed to obtained matured seed from the crosses using *Gladiolus orchidiflorus* as a female parent. This may be due to possible participation of inhibitory specificities of pollen cholinesterase in the pollen-stigma interaction (Semenova and Roshchina, 1993). Presence of dry type of Gladiolus stigma may be another reason for their incompatibility because compatible pollen grains alighted and germinated on the receptive surface of the papillae, penetrated the cuticle and grew towards the style through a sub-cuticular pollen-tube guide or mucilage. This is secreted from epidermal cells of the stylodium and style canal. The cuticle, which covered the pollen tube guide mucilage, is continuous through the style canal to the ovary (Clarke *et al.*, 1977).

In order to study the cross ability relationship in two species of Glorisa, Anandhi *et al.* (2013) crossed five genotypes of *G. superba* with *G. rothschildiana* in both directions and observed varying percentage of pod set within 25 days of pollination which were shrunked thereafter and died irrespective of the cross combination. None of the pod reached the harvestable stage. Post fertilization barrier was observed in both direct and reciprocal crosses. This may be due to embryos abortion and degeneration during embryogenesis. Selvakumar (2006) reported that seed attain physiological maturity at 40 days after anthesis and can be harvested during such time to obtain seeds of higher quality in China aster cv. ‘Poornima’. Vaerbak and Andersen (1999)

concluded that selection of high seed setting single plants during early generations of inbreeding is efficient for improvement of seed set in future inbred in *Primula*.

Wide hybridization enables the interspecific gene transfer, which may lead to the additional source of variation for the desirable characters (Anandhi *et al.*, 2013) and Takatsu *et al.*, (2001) made interspecific hybridization between a modern cultivar of *Gladiolus x grandiflora* Hort. ($2n = 60$) and the wild species *G. tristis* L. ($2n = 30$) to introduce characteristics of the wild species into the cultivated one and reported best pollen tube growth, fertility, and fruit set in their cross at low air temperatures for F_1 hybrid plants production (15 to 20°C) (Takatsu *et al.*, 2001). Ethylene also stimulated pollen germination and pollen tube growth in several species of bulbous plant but Piskornik (1986) reported that ethylene evolution induced by pollination did not cause any significant changes in the permeability of cell membranes in the style; however, a second increase in ethylene production, prior to decay of the style, caused a rapid rise in permeability. These observations indicate that ethylene plays at least a dual role in flower life; it controls pollen germination and pollen tube growth, and it also stimulates the disintegration of membranes and accelerates the onset of senescence in certain parts of the flower, excluding the ovary.

Timchenko (1990) studied pollen viability and seed set from selfing and open pollination in 24 promising varieties and reported ‘Appliance’, ‘Bibi, Buckeroo’, ‘Garnet Ruffles’, ‘Morocco’, ‘Priscilla’, ‘Sabre’, ‘Shell Pink’, ‘Swiss Chocolate’, ‘Gimn Kosmonavtam’ and ‘Soyuz 20’ as best pollinators. Those considered best as maternal parents were ‘Appliance’, ‘Ivan Franko’, ‘Morocco’, ‘Shokoladnitsa’, ‘Soyuz 20’ and ‘Swiss Chocolate’, which gave a high capsule and seed set from open pollination. However, ‘Bazaar’, ‘Bibi’, ‘Buckeroo’, ‘Color Parade’, ‘Cordula’, ‘Ivan Franko’, ‘Lucina’, ‘Priscilla’ and ‘Sabre’ were found self sterile, while ‘Cameltone’, ‘Garnet Ruffles’, ‘Morocco’, ‘Plum Tart’ and ‘Shell Pink’ gave a high capsule and seed set when selfed (Timchenko,1990). Hossain *et al.* (2012) indicate the existence of wide variability among the gladiolus genotypes considering crossing parameters and variations were observed for length of capsule (cm), breadth of capsule, number of seed capsule⁻¹ and weight of thousand seed (g). Crosses produced more or less gladiolus true seed (F_1 seed) and number of seed capsule⁻¹ ranged from 15.08 to 38.40. The highest number of seed capsule⁻¹ was produced by the cross ‘Yellow×Red’ (38.40) while the lowest number of seed per capsule was produced by the cross ‘Violet×Red’ (15.08). Grabowska (1983) reported that among 50 inter varietal hybrids,

‘Eurovision’ showed better crossing ability than ‘Pres. de Gaulle’ (46.4 and 28.9%, respectively) when crossed with red cultivars having similar pollen parents. Hybrid seeds of ‘Bird of Dawning’ gave more seedlings and corms (55.8%) than seeds of ‘West Point’ (13%); the figures for hybrid seeds of ‘Eurovision’ and ‘Pres. de Gaulle’ were 38.3 and 22.9%, respectively.

2.3.2 Diallel analysis

Diallel analysis is the first step in most plant breeding programs aimed at improving yield and other related parameters. Danish animal breeder, Schmidt, first introduced the diallel-crossing concept in 1919 (Pirchner, 1979). Then it was quickly introduced in plant breeding. The diallel is defined as making all possible crosses in a group of genotypes. It is the most popular method used by breeders to obtain information on value of varieties as parents, and to assess the gene action in various characters (Pickett, 1993; Griffing, 1956). Griffing (1956) developed a range of diallel analytical procedures. This should help breeders to develop appropriate selection strategies and compare heterotic patterns at the early period of hybridization breeding (Le Gouis *et al.*, 2002). Four methods can be used 1) Parents, F_1 's and reciprocals, 2) Parents and F_1 , 3) F_1 and reciprocals and 4) F_1 only. The linear analysis model can be for either fixed or random effects. If the genotypes are highly selected and inbred, then a fixed model for analysis is usually done for applied breeding programs (Agrobases, 2000). In this case the sampling error becomes the residual for testing combining ability mean squares, and estimating variance components and standard errors. When additive and dominance variances are estimated, certain limitations apply: normal diploid segregation, no epistasis, no reciprocal differences, no multiple alleles, homozygous parents, independent gene distribution, no linkage, and an inbreeding coefficient of zero (Griffing, 1956), but these assumptions are rarely fulfilled in practice (Baker, 1978).

2.3.3 Combining ability

The concept of combining ability is becoming increasingly important in plant and animal breeding. It is especially useful in connection with "testing" procedures, in which it is desired to study and compare the performances of lines in hybrid combination. Combining ability is defined as the ability of a parent line in hybrid combinations (Kambal and Webster, 1965). It plays an important role in selecting superior parents for hybrid combinations and in studying the nature of genetic variation (Duvick, 1999). It is a powerful method to measure the nature of gene action involved in quantitative traits (Baker, 1978).

Here, it is concerned with the definitions of general and specific combining ability when the testing procedure utilizes a diallel crossing system. Sprague and Tatum (1942) introduced the concept of general combining ability (GCA) and specific combining ability (SCA). It was with such a system that the tested by the masking of deleterious recessive alleles in one cultivar by dominant or specific dominant alleles in the second cultivar. Some authors explain the heterosis with these hypotheses: (a) partial dominance of a large amount of loci, (b) over dominance of several loci, (c) several types of epistasis. Sinha and Khanna (1975) reported that, based on parents used, there are two major types of estimates of heterosis: 1) Mid-parent or average heterosis (MPH), which is the increased vigour of the F_1 over the mean of two parents; 2) High-parent or better parent heterosis (HPH), which is the increased vigour of the better parent.

Heterosis is a genetic phenomenon resulting from heterozygosity, but the genetic basis of heterozygosity is still vague. Heterosis results from combined action and interaction of allelic and non-allelic factors and is commonly closely and positively correlated with heterozygosity (Burton, 1968). Flintham *et al.* (1997) explained that the heterozygosity is an essential component of heterosis and it can arise when the over dominance at a single locus is the major cause of heterosis. Heterosis is an important parameter of plant improvement, and efforts will be continued in many plant species. It has been utilized successfully even though its genetic basis has not been determined for the large part (Hallauer, 1999).

2.3.4 Combining ability and heterosis in different plants

Kumar *et al.* (2008) carried out combining ability and heterobeltiosis analysis in gladiolus based on 7x7 half diallel for growth traits utilizing seven varieties viz. ‘American Beauty’, ‘Sylvia’, ‘Melody’, ‘Summer Sunshine’, ‘Vedanapoli’, ‘Magic’ and ‘Priscilla’. He reported the varieties ‘American Beauty’, ‘Summer Sunshine’ and ‘Priscilla’ as good general combiners for many traits. The important hybrid exhibiting significant heterobeltiosis and sca effect were ‘Sylvia’x‘Priscilla’ and ‘Sylvia’x‘Melody’. The range of heterobeltiosis for plant height varied from -20.54 to 14.72% whereas it ranges between -13.86 to 17.31% for number of leaves. Additive type of gene action was noticed for many traits.

Combining ability analysis was carried out in gladiolus based on 8x8 full diallel, for five important traits, viz., number of florets spike⁻¹, spike length, number of corms plant⁻¹, weight of corms plant⁻¹ and spike weight. Variances due to general combining ability (GCA) highly exceeded

the variances due to specific combining ability (SCA), for all the characters and were also significant. These high GCA and SCA values indicated that their inheritance was predominantly governed by additive and additive epistatic components of genetic variance. The varieties 'Oscar' and 'Friendship' were good general combiners for most characters, while, 'Meria Geretti' and 'Tropic Sea' were good general combiners for the number of corms plant⁻¹ (Pant *et al.*, 2000).

A 10x10 full diallel was made in a native population of stone pine (*Pinus cembra* L.) from high elevation, to provide information on the genetic variation and inheritance of important breeding traits. The families, including self-pollinated parents were arranged in a RBD (Randomized Block Design) with four replications and 12 seedlings plot⁻¹. Fifteen traits were measured during nursery testing. In addition, weight of 100 seeds and cotyledon number were assessed. The most important result was that significant ($p < 0.05$) and highly significant differences occurred in all 17 traits for general and specific combining abilities as well for reciprocal effects. Maternal effects were significant in 13 traits, including diameter and total height. This suggests that the traits are controlled by nuclear (additive and non-additive) and extra nuclear genes, and by nuclear x extra nuclear gene interactions. Additive and non-additive genetic variances accounted for 25% and 27% of the total for height at age six and 14% and 22% for root collar diameter at the same age, respectively. These figures indicate that both variances were important for growth traits within the tested population. Parents were found with significant general combining effects for growth and other traits. Narrow-sense heritability estimates at family level ranged between 0.150 to 0.675 for cotyledon number and lamma shoots, respectively with 0.453 for total height at age six (H.6). By selecting the best 10 to 40 families, a genetic gain in H.6 of 10.6% to 5.5% could be achieved. An extra genetic gain could also be achieved by individual within family selection. Improvement of growth using both additive and non-additive gene effects should be possible (Blada, 1999).

Six morphological and agronomic traits of Snap bean (*Phaseolus vulgaris* L.) were studied to investigate their gene action, and to estimate the general combining abilities (GCA) and specific combining abilities (SCA) of parents and crosses. Three snap bean varieties 'Amy', 'Monel' and 'Morlane' and two dry bean varieties 'GLP 20' and 'GLPX 92' were used as parents in a complete diallel cross. Significant ($p < 0.01$) additive and dominance effects were observed for days to flowering, plant height at flowering, number of pods plant⁻¹, pod weight plant⁻¹, pod length and

pod diameter. Additive gene effects were predominant for all traits apart from pod weight. Significant ($p < 0.01$) maternal and non-maternal reciprocal effects were detected on plant height and days to flowering. Estimates of GCA, SCA and reciprocal effects suggested that 'Amy', 'Morlane' and 'GLP 20' were generally the best combiners for incorporation into Snap bean breeding programmes. This basic information is valuable for Snap bean breeding programmes (Arunga *et al.*, 2010).

A nine parent diallel excluding reciprocals was formed for the inbreds that derived from material from temperate, subtropical and tropical ecologies and their combining ability effects were estimated for 11 biometric traits. Genotypic combining ability (GCA) effects were highly significant for all the traits under study, but specific combining ability (SCA) effects were less significant in certain cases suggesting predominance of additive genes. High GCA effects for grain yield were observed in the temperate material i.e. 'QPM-1 (0.168)', 'QPM-3 (0.169)' and 'QPM-5 (0.485)', while SCA effects were remarkable for hybrids 'QPM-3×NCML-1078' (0.890), 'NCML-1071×NCML-1084' (0.878) and 'NCML-1082×NCML-1083' (0.831). Temperate material also gave high GCA effects for striking characters contributing towards high grain yield i.e. plant and ear heights, leaf area, ears plant⁻¹, ear weight and kernels row⁻¹. Tropical inbreds gave eminent GCA effects for days to pollen shedding, ear weight and grain moisture at harvest. Considering its negative GCA and SCA effects for days to pollen shedding, subtropical material was marked as a valuable source for inducing earliness (Malik *et al.*, 2004).

Breeding of Crape myrtle (*Lager stroeinia*) in the United States carried out with objective to study the general and specific combining ability of several horticultural important traits in crosses between pest-resistant parents and those with saturated flower colours. Ten Crape myrtle parents were tested in a factorial mating design including 25 of the 29 possible families. Analysis of variance revealed significant differences for all traits for the general combining ability of parents. The cross between 'Arapaho' and 'Whit-IV' displayed the best specific combining ability for a desirable combination of height, leaf-out time, bloom time, and flower colour based on current breeding objectives. Overall, this study revealed the importance of both additive and non additive genetic variability in Crape myrtle, suggesting that an integrated breeding strategy to capture both additive and dominance variance would be appropriate for producing new, improved Crape myrtle clones for the four traits evaluated (Pounders *et al.*, 2007).

Heterosis was studied over mid-parents and better-parents for 11 hybrids combination of gladiolus for 16 characters, including number of florets spike⁻¹ and rachis length. Maximum percentage of heterosis was observed in individual hybrids up to 83.81% over mid-parent and 62.64% over better-parents for weight of cormels plant⁻¹ and number of cormels produced plant⁻¹, respectively, and lowest up to -85.05% (mid-parent) and -79.30% (better-parent) for number of cormels produced plant⁻¹. The best crosses identified on the basis of heterosis percentage for different characters were 'Ave'x'Mayur' for days to 50% sprouting, 'Mayur'x'Heady Wine' for number of leaves shoot⁻¹ and plant height, 'Pfitzer's Sensation'x'Christian Jane' for leaf area, weight of cormels plant⁻¹ and number of seeds capsule⁻¹, 'Gambier Pearl'x'Regency' for diameter of first floret and number of seeds capsule⁻¹, 'White Oak'x'Christian Jane' for days to last floret opening, 'White Oak'x'Smoky Lady' for propagation coefficient, and 'Green Lilac'x'Heady Wine' for plant height and number of capsules spike⁻¹. It was concluded that manifold increase in component characters would lead to marginal increase in number of florets spike⁻¹ and rachis length because market value of gladiolus depends upon these characters (Misra *et al*, 2001).

2.4 In-vitro seed germination and survivability of gladiolus

2.4.1 Germination of seeds under *in vitro* conditions

Seed germination is a complex process various physical and biochemical cues such as water, light and phytohormone (Sen, 2010). Recently, various seed priming techniques have been developed, including hydro priming (soaking in water), halo priming (soaking in inorganic salt solutions), osmo priming (soaking in solutions of different organic osmotic), thermo priming (treatment of seed with low or high temperature) bio priming (hydration using biological compounds). Each treatments has advantages and disadvantages and may have varying effects depending upon plant species, stage of plant development, concentration of priming agent and incubation period. Seed germination and seedling growth are known to be regulated by exogenous hormones. Growth regulators used in presowing seed treatment with growth regulator play an important role in regulating germination and vigour (Raghav and Kasera, 2012).

The germination of three species of genus Gladiolus, *G. illyricus*, *G. italicus* and *G. tristis* (var. *tristis* and *concolor*) was studied. The seeds used had different origins: *G. illyricus* seeds originated from wild plants and *G. tristis* seeds originated from plants cultivated in an unheated greenhouse. Seeds were germinated on petri dishes in different germination chambers. The *G.*

italicus germination percentage was almost zero in all the treatments except in seeds from greenhouse cultivated plants germinated at 13°C in darkness (6%). The percentage of *G. tristis* var. *concolor* germination was good, except in the 20/15°C for 12 hours photoperiod treatment, when it was 29%. Similar results were obtained with *G. tristis* var. *tristis*, although with higher percentages of germination. In *G. illyricus* the highest percentages of germination were obtained at 13 and 15°C from seeds gathered from plants cultivated in an unheated greenhouse and from wild plants (Fernandez *et al.*, 2005).

Gladiolus (*G. grandiflorus*) seed germination was light-independent, but temperature influenced the germination rate. Constant 20°C promoted higher total germination (97%), fewer days (4.3) to 50% of final germination, and shorter span of days (4.8) between 10% and 90% germination than other constant temperatures, although similar results were achieved by alternating 12 hours cycles of 20 to 25°C. Total germination was unchanged after seed treatment for 7 days at 10 to -20°C, but longer germination periods were required after treatments below -10°C. Reducing seed moisture contents from 11.8 to 4.2% caused no reduction in total germination, but moisture contents below 6.6% delayed achieving 50% of final germination and extended the periods from 10 to 90% of germination. Smallest declines in total germination during 12 months of storage occurred at 11% and 33% Relative humidity at 15°C. The statistical analysis estimated the optimum seed storage at 14°C and 26% Relative humidity (Carpenter *et al.*, 1991).

The effects of Hilden (35% Endosulfan) and Rogor (30% Dimethoate) on pollen germination, tube elongation and time of emergence of the 1st pollen tube was studied in *Gladiolus psitticinus* by adding these insecticides at 25, 50, 75 and 100 ppm to the basal medium (an optimum concentration of sucrose). Germination averaged 22.5-37.9%, as compared with 45.2-57.2% in the untreated basal medium; germination was inversely related to insecticide concentrations. Treatment also delayed first emergence and slowed growth of the pollen tubes (Bharadwaj *et al.*, 1988).

Fresh pollen of 16 promising genotypes of gladiolus was tested for their pollen viability. Modified cellophane method was employed to assess the pollen viability. Pollen germination media consisted of 15% sucrose supplemented with 300 ppm calcium nitrate, 200 ppm magnesium sulphate, 100 ppm potassium nitrate and 100 ppm boric acid. Highly significant variations were observed for percentage of pollen germination, non-germinated pollen and sterile pollen. The

highest pollen germination (76.41%) was in genotype 'Hybrid selection 88-10-22', and did not differ significantly from *Gladiolus callianthus* (75.41%), 'Sapna' (75.10%), 'Hybrid selection 86-32-11', (73.28%), 'Kum Kum' (69.41%), 'Poonam' (69.22%), 'Hybrid selection 87-22-1' (67.87%), 'Hybrid selection 87-1-1' (67.61%), 'Psittacinus hybrid' (64.64%) and 'Darshan' (63.97%). The lowest non-germinated pollen (10.47%) was in genotype *Gladiolus callianthus*, and insignificantly followed by 'Hybrid selection 88-10-22' with 18.77% and 'Hybrid selection 87-22-1' with 18.95%. The lowest percentage of sterile pollen was noticed in genotype 'Sapna' (2.82%) followed by 'Poonam' with 4.00%, 'Hybrid selection 88-10-22' with 4.82% and 'Hybrid selection 82-11-27' with 5.22% (Poon *et al.*, 2010).

In-vitro seed germination and seedling development of *Phaius tancarvilleae* (L'Her.) Blume. was carried out on 0.8% (w/v) agar solidified MS Medium (Murashige and Skoog, 1962) without hormones or supplemented with different concentration and combination of Naphthalene acetic acid (NAA) and 6-benzylaminopurine (BAP). MS medium supplemented with 0.5 mg l⁻¹ of BAP was the most ideal condition for early seed germination, protocorm formation and development of seedlings. Germination started after 7 weeks of culture and complete seedlings were obtained after 24 weeks of culture. This protocol might be helpful for mass propagation of orchids by asymbiotic seed germination (Pant *et al.*, 2011).

Esmeralda clarkei Rchb. f. (Orchidaceae), an epiphytic orchid native to Nepal with high ornamental value grows from cool to intermediate climatic conditions with medium amount of light. In an attempt to preserve this important orchid by establishing an efficient *in-vitro* regeneration protocol using seed culture was conducted. MS with BAP and NAA alone or in combination were used. In MS protocorms developed within 16 weeks followed by seedling development in 25 weeks of seed culture. Presence of BAP (0.5 mg l⁻¹) in MS improved seed germination by protocorm formation and seedling development in 17 and 26 weeks of seed culture, respectively. In 0.5 mg l⁻¹ NAA supplemented media, development of protocorms was observed in 18 weeks and seedling growth was observed in 26 weeks of seed culture. Protocorm and seedling development was delayed in other media (Paudel *et al.*, 2012).

Gibberellins are a family of 136 tetracyclic diterpenes, a small subset of which are active as plant hormones and known to stimulate seed germination in a wide range of plant species; the predominant active GA depends on the species (Thomas *et al.*, 2005). Gibberellins stimulate

germination by inducing hydrolytic enzymes that weaken the barrier tissues such as the endosperm or seed coat, inducing mobilization of seed storage reserves and stimulating expansion of the embryo. GA₃ is known to obviate the requirement of seeds for various environmental clues as it promotes germination and counteracts the inhibitory effect of ABA (Bewley & Black, 1994). Gibberellins appear to play a role in two different stages of germination. One occurs at the initial enzyme induction in their transcription from the chromosomes. The second is in the activation of reserve food mobilizing system (Hartman *et al.*, 1990). It was found that GA₃ has a significant effect on germination rate as compared to IAA, IBA and NAA during light and dark period. It indicates that GA₃ at 50 ppm gave best response but as the concentration increased above 60 ppm the germination decreased rapidly and vigour index also decreased during light and dark period (Dhoran and Gudadhe, 2012).

The basal media devoid of GA₃ showed poor response and inclusion of GA₃ increased the germination percentage. On increasing the concentration of GA₃ the germination percentage was reduced. GA₃ has been found to induce and enhance the germination which is in consonance with earlier findings in *Silybum marianum* and *Lipidium sativum* (Saba, 1998). Among the different hormone, GA₃ performed better than IAA, and IBA. IBA favoured maximum length of both root and shoot of the plant at 50 ppm concentration. NAA and GA₃ also favoured the increase in plant height over control. GA₃ and IAA suppress the inhibitory action of ethylene when they act as a promoter. An interaction between endogenous and exogenous levels of hormones also might have play important role in plant growth. Pre-sowing seed treatments with growth substances such as gibberellic acid have been found to improve the seedling growth of many species. In present study it was found that GA₃ was better than IAA, IBA, NAA inducing germination and root growth (Raghav and Kasera, 2012).

A pot culture experiment conducted by Dutt *et al.* (2001) to determine the effects of gibberellic acid (GA₃) soaking treatment on the seed germination of 10 gladiolus hybrids, i.e. 'Apsara'x'Priscilla', 'Sel 3'x'Sel 1', 'Sel 3'x'Apsara', 'Apsara'x'Yellowstone', 'Priscilla'x'Sel 3', 'Priscilla'x'Apsara', 'Good White'x'Priscilla', 'Sel 3'x'Priscilla', 'Summer Sunshine'x'Priscilla' and 'Summer Sunshine'x'Sel 3' reported that all GA₃ treatments significantly increased the percentage of seed germination and reduced the number of days required for germination compared with the water and control treatments. Seed germination values of 66.5, 62.8 and 64.4%

were obtained with GA₃ at 100, 150 and 200 ppm, respectively. Seeds soaked in GA₃ at 100, 150 and 150 ppm germinated in 10.1, 9.2 and 9.8 days, respectively. Among the different hybrids, 'Priscilla'x'Apsara' and 'Summer Sunshine'x'Priscilla' recorded the highest values for seed germination (70.9 and 70.4%, respectively). The earliest germination (10.8 days) was recorded in 'Sel 3'x'Sel 1' seeds.

Laboratory experiments were conducted to evaluate the pollen germination of Gladiolus cultivars viz. 'Summer Pearl', 'Mother Fisher' and 'Friendship' under the local conditions of Chaubattia, Uttaranchal, India. Pollen grains were collected at appropriate times and placed on cavity slides. Culture media, comprising distilled water, sucrose solution (6, 8, 10, 12, 14, 15, 18 and 20%), sucrose (6, 8, 10, 12 and 14%)+boric acid (75 ppm), sucrose (4, 6, 8, 10 and 12%)+boric acid (100 ppm)+Ca(NO₃)₂ (300 ppm)+KNO₃ (100 ppm)+MgSO₄ (200 ppm) were added and the slides were subjected to incubation at 23±1.0 °C for 24 hours using the hanging drop technique. Significant differences in pollen germination, pollen tube length and pollen tube diameter were observed for the different cultivars cultured in different solutions. In general, sucrose with boric acid, KNO₃, MgSO₄ and Ca(NO₃)₂ proved less effective in pollen germination than sucrose alone (Shah *et al.*, 2002).

The effects of 0.1, 0.2, 0.3, 0.4 and 0.5% pendimethalin on the germination and growth of gladiolus cv. 'Mayur' were determined in a field experiment. Treatment with 0.1% pendimethalin resulted in the highest seed germination (28.7%) and number of leaves plant⁻¹ (3.56). Differences in the number of days before seed germination, plant height, number of cormels plant⁻¹ and corm diameter were not significant (Dhiman, 2003).

Effects of four asymbiotic media; Murashige and Skoog (MS), Phytamax (Sigma, USA; PM), Mitra *et al.* (M) and Knudson 'C' (KC) were evaluated for seed germination and early protocorm development in *Epidendrum ibaguense* Kunth. Besides, effects of peptone, activated charcoal and plant growth regulators (6-benzylaminopurine) and 2,4-dichlorophenoxyacetic acid (2,4-D) were also studied. Maximum seed germination was achieved on M and PM (90%) fortified with 2 gl⁻¹ peptone. Medium supplemented with 1.0 mg l⁻¹ BAP improved seed germination in contrast to basal media whereas 2,4-D either singly or in combination with BAP remarkably reduced the germination rate. Activated charcoal in the medium enhanced germination of seed, induced significantly large size protocorms (1.63±18) and early rooting in protocorms. Within two

weeks of culture, spherules emerged out due to cracking of the seed coat. The spherules developed into protocorms with a leaf primordium at apical portion after 3 to 4 weeks and gradually produced complete seedlings. Strong and stout root system was induced in *in-vitro* seedlings on transferring in half strength PM and M media fortified with 0.5-1.0 mg l⁻¹ indole acetic acid (IAA). Well-rooted seedlings were transferred to green house with 90 % survival (Hossain, 2008).

Propagation of the medicinal and pesticidal tree, *Bobgunnia madagascarensis* in pre-sowing seed treatments involved soaking seeds in cold and hot water for 12 and 24 hours and soaking in different concentrations (0, 100, 200, 400 and 800 mg l⁻¹) of gibberellic acid for 24 hours. Soaking of seeds in cold or hot water for up to 24 hours did not achieve more than 45% germination, while seeds treated with gibberellic acid achieved less than 20% germination rates.

Coelogyne nervosa is an epiphytic orchid endemic to Western Ghats, South India. The mature seeds of *C. nervosa* were cultured on ½ MS (Murashige and Skoog), MS, Kn (Knudson) and VW (Vacin and Went) media to evaluate the seed germination response. Of the four basal media used, MS medium supported maximum seed germination (Abraham *et al.*, 2012).

Germination of seed and seedling development of *Phaius tancarvilleae* (L'Her.) Blume. was carried out on 0.8% (w/v) agar solidified MS Medium (Murashige and Skoog, 1962) without hormones or supplemented with different concentration and combination of Naphthalene acetic acid (NAA) and 6-benzylaminopurine (BAP). MS medium supplemented with 0.5 mg l⁻¹ of BAP was the most ideal condition for early seed germination, protocorm formation and development of seedlings. Germination started after 7 weeks of culture and complete seedlings were obtained after 24 weeks of culture. This protocol might be helpful for mass propagation of orchids by asymbiotic seed germination (Pant *et al.*, 2011).

Chitosan was studied to see the effect of chitosan on *in vitro* growth of *Dendrobium* 'Queen Pink' protocorms. Protocorms at the approximate size of about 0.3-0.5 cm were cultured on modified Vacin and Went (VW) medium supplemented with chitosan at the concentrations of 10, 20, 40, 60 mg l⁻¹ or without chitosan (control). The growths were recorded after being cultured for 1 year. The results showed that seedlings grown on VW supplemented with chitosan at all concentrations had a higher fresh weight and dry weight when compared to the control. Chitosan at the concentration 60 mg l⁻¹ had the highest plant height, root length and leaf area compared to other treatments including the control. However, there was no statistical difference on the number of

leaves, roots and new shoots. The effect of chitosan on the number of stoma showed that chitosan at all concentrations increased the number of stomata in comparison to the control but the number and size of the chloroplasts was not different (Obsuwan *et al.*, 2013).

2.4.2 Hardening and establishments of *in vitro* regenerated plantlets

Hardening of shoots prior to transfer in the soil increases the survival rate of transferred plants. So, gradually to withstand the harsh natural environment, misting, spraying or covering the pots may serve to fulfil the above objective. Various types of substrates have been used during acclimatization such as peat and perlite mixture (Bekheet, 1999) soil, soilrite, garden soil and composed soil (Sunaina and Goyal, 2000), soil, sand and vermiculite (Chukwujekwu *et al.*, 2002), sand and vermiculite (Yang *et al.*, 2002) and soil, sand, farmyard compost, vermiculite and soil (Chakradhar and Pullaiah, 2006), garden soil, farmyard soil and sand (2:1:1) (Baskaran and Jayabalan, 2005).

Hegde and Kuruvinashetty (1998) achieved the maximum survival rates of 95% and 100% of micropropagated plants of gladiolus cv. 'American Beauty' and 'Souvenir', respectively, when planted out in sterilized vermiculite as compared to sterilized soil, soil with biogas slurry (1:1), and sand with biogas slurry (1:1). However, Jager *et al.* (1998) successfully hardened-off the rooted plantlets of *Gladiolus corneus* in sand and soil mixture (2:1) in mist house for 4 weeks and then transferred to greenhouse.

Ziv *et al.* (1998) recorded 95 to 100% survival of shoots of gladiolus with corms at their base on transfer to acclimatization greenhouse. Misra and Singh (1999) obtained 60% survival of micropropagated rooted plantlets of gladiolus cv. 'America Beauty' on transfer to sterilized potting mixture composed of FYM, sand and loam (2:1:1, v/v). Priyakumari and Sheela (2005) recorded that the rooted plantlets transferred to plastic pots containing sand and soil (2:1) provided cent percent survival at 15 days after planting.

The present experiment was carried out at the Horticultural Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during 2011-2014 to investigate the growth and yield characteristics of gladiolus genotypes and to find out the *in-vitro* response of gladiolus seeds. The details of the experimental materials used, methods followed and the statistical techniques adopted during the course of investigations have been discussed in this chapter.

3.1 Geographical location of experimental site

The area lies under the terai agro climatic zone of West Bengal. Geographically the farm is situated at 26°19'86" N latitude and 89°23'53" E longitude, at an elevation of 43 m above mean sea level.

3.2. Agro-climatic conditions

The climatic condition of terai zone is characterized by high rainfall (above 3000 mm annually), high humidity, moderate temperature, prolonged winter with high residual soil moisture. The meteorological data pertaining to the study period are presented in Table 2.

3.3 Soil of the experimental site

The soil of the experimental field was sandy loam in nature and coarse in texture having poor water holding capacity with low pH are given in Table 1.

Table 1. Chemical properties of experimental soil

Particulars	Years		
	2011-12	2012-13	2013-14
pH	5.23	5.11	5.36
Organic Carbon (%)	0.91	0.85	0.93
Available N (kg ha ⁻¹)	219.27	211.50	217.21
Available P (kg ha ⁻¹)	20.41	19.22	18.24
Available K (kg ha ⁻¹)	114.74	112.93	111.89

Table 2. Metrological data pertaining to the study period from 2011 to 2014

Months	Temperature (⁰ C)						Relative Humidity (%)					
	2011-12		2012-13		2013-14		2011-12		2012-13		2013-14	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
September	32.68	25.24	30.89	24.68	31.81	24.61	98.87	66.90	99.00	76.17	99.00	75.00
October	31.30	21.77	30.38	20.22	29.09	21.08	99.00	60.52	99.00	60.48	99.00	72.58
November	27.25	15.17	27.74	13.96	27.88	14.22	98.93	51.90	99.00	45.70	99.00	48.97
December	23.80	11.82	23.13	11.68	23.56	11.71	98.84	56.19	99.00	60.58	99.00	57.77
January	21.15	9.60	22.11	7.96	22.06	10.68	98.87	57.45	99.00	51.55	66.52	51.81
February	25.02	10.86	26.69	12.34	22.18	11.13	99.00	46.48	99.00	45.29	62.36	50.64
March	29.14	15.20	30.27	16.72	28.48	15.33	93.61	37.10	98.87	41.87	68.00	54.84
April	29.63	20.30	30.33	20.15	31.38	18.40	97.57	60.07	96.03	53.57	71.00	57.50
	Rainfall (mm)			Wind Speed (Km hr ⁻¹)			Sunshine (hr:mm)					
	2011-12	2012-13	2013-14	2011-12	2012-13	2013-14	2011-12	2012-13	2013-14			
September	11.75	23.62	13.47	4.49	4.55	3.72	8.63	7.84	8.26			
October	0.47	0.71	5.45	2.77	2.90	3.51	8.69	8.10	7.62			
November	0.03	0.00	0.07	3.00	2.47	5.08	7.66	7.83	8.08			
December	0.13	0.00	0.00	3.26	2.55	7.53	7.14	6.10	6.75			
January	0.08	0.00	0.00	2.94	3.11	3.16	6.31	7.01	6.32			
February	0.31	0.64	0.70	3.05	3.15	3.61	7.86	7.63	6.86			
March	0.23	0.00	0.47	4.84	4.96	4.15	8.53	8.73	8.64			
April	5.48	4.08	0.00	6.24	6.23	6.55	8.67	8.90	9.54			

Source: Department of Agronomy, AAS (Agro-met Advisory Services), UBKV, Pundibari

Experiment-I

3.4 Studies on assessment of the *per se* performance of gladiolus genotypes

New varieties are being developed in different parts of the world, which need to be tested under different set of agro-climatic conditions as the genotypes vary in their size of the plant, colour, range, flower size, growing period etc. Therefore, there is a need for evaluation of genotypes and new hybrids before they are recommended for the particular agro-climatic region. For this reason, many workers have done the work of evaluating different genotypes and new hybrids for studying their performance under different regions.

3.4.1 Experimental details

3.4.1.1 Selection of germplasm

The planting materials for the present experiment comprising of 20 Gladiolus genotypes were taken from Horticulture Experimental Farm of UBKV, Pundibari are given in Table 3.

3.4.1.2 Site preparation

The land was brought to a fine tilth by ploughing and harrowing. A spacing of 100 cm between two replications was provided for laying out irrigation channels and working space.

3. 4.1.3 Planting of corms

The corms of gladiolus having almost 5 cm diameter and about to sprout were taken and cleaned by removing the dried husk present on them. Then, they were dipped in Carbendazim (0.2%) solution for 30 minutes as a preventive measure for *Fusarium* wilt disease. These corms were then planted along the lines of the raised bed at a depth of 5 to 6 cm by keeping the row-to row distance of 45 cm and the plant to plant distance of 15 cm. Light irrigation was given immediately after planting.

3.4.1.4 Manures and fertilizers

Well decomposed farm yard manure at the rate of 5 kg per m² was applied at the time of land preparation. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. Recommended dose of 30:20:20 g per m² of NPK was applied. At the time of planting half the dose of N, full dose of P₂O₅ and K₂O were applied. The crop was top dressed with remaining half dose of N at 45 days after planting (DAP).

Table 3. Gladiolus germplasm used in present investigation

Genotype's Accession No.	Flower colour grouping and RHS (5th Edition) Number	Spike and floret characters
ACC-01	Red group (43-B)	All florets faced one side of the spike having light white coloured throat
ACC-02	Red group (45-B)	Florets are loosely arranged side by side and all florets faced at one side of the spike
ACC-03	Red group (45-B)	All florets faced one side of the spike
ACC-04	Violet group (83-B)	All florets faced one side of the spike and sparsely arranged without any throat
ACC-05	Red-purple group (N57-A)	Each floret on the spike face alternatively and loosely having creamy yellow coloured at mid portion
ACC-06	White group (NN155B)	Florets compactly arranged one above the other facing one side of the spike along with red coloured throat
ACC-07	Red group (45-B)	All florets arranged loosely in zig-zag fashion
ACC-08	Red-purple group (N57-A)	Florets arranged compactly one above the other and faced one side of the spike and throat colour is creamy colour
ACC-09	White group (NN155-B)	Each floret on the spike face alternatively one above the other having light greenish throat
ACC-10	Red-purple group (N57-B)	Florets faced in appositive manner one above other and loosely arranged having dark red coloured throat and outside creamy yellow at lower tip portion
ACC-11	Red group (40-C)	Florets faced one side and compactly arranged one above the other without any throat
ACC-12	Violet group (N88-C)	Each floret on the spike face alternatively in loose manner along with white shade at centre
ACC-13	Yellow group (8-C)	Florets are compactly arranged and faced at one side of the spike and fringed
ACC-14	Yellow group (12-C)	Florets are arranged in zig-zag fashion and sparsely having outside orange shade at tip portion
ACC-15	Orange red group (13-B)	Florets are faced side by side and arranged compactly with white shade at centre
ACC-16	Purple group (N20-C)	Arranged in zig-zag fashion and compact manner along with creamy coloured throat at lower two petals
ACC-17	Red-purple group (N57-C)	Florets arranged compactly and faced one above the other and petals become smaller at lower portion
ACC-18	White group (NN155-A)	Florets faced one side and loosely arranged one above the other even petals are big as well as loosely attached
ACC-19	White group (NN155-D)	Florets faced one side and arranged compactly one above the other without ant throat
ACC-20	Red-purple group (N57-C)	Arranged in zig-zag fashion but faced one side having violet coloured throat

Plates 1. Different activities that practices during field preparation



Plates 1.1 Sprouting of corms



Plates 1.2 Irrigation of plants



Plates 1.3 Staking of plants



Plates 1.3 Observations collection

3.4.1.5 Cultural operation

The experimental site was kept free of weeds by periodic hand weeding. Protective irrigations were given at an interval of 7 to 8 days regularly during crop growth period. Totally, about 26 irrigations were given, 20 days prior to lifting the corms, irrigation was withheld.

3.4.1.6 Plant protections

Fusarium wilt was seen during the crop growth period. To control, Captan at the rate of 0.2% was used to drench the soil alternating with Carbendazim (0.2%).

3.4.1.7 Harvesting

The harvested spikes were used for recording the different parameters. The corms and cormels were lifted from the ground when the foliage turned to yellow colour. Thus, harvested corms and cormels were further used for recording different parameters.

3.4.2 Biometrical observations

Five representative plants were selected at random and tagged in each treatment and replication for the convenience of observing the characters include in the study of germplasm performance. The pooled value of the two years data observed was taken to represent a particular germplasm with respect to a character. The observations on growth and productions parameters were recorded from 60 days of planting to post harvest stages. During the two years experiment (2011-12 and 2012-13), the growth characteristics, flowering attributes, flower characters and yield attributes were studied.

3.4.2.1 Growth parameters

i. Height of plant (cm)

Height of the plant was recorded from the ground to the tip of the youngest leaf at 60 DAP (Days of planting).

ii. Number of leaves per plant

The number of leaves from each plant was counted at 60 DAP and the mean was worked out.

iii. Length of leaves (cm)

The width of all the leaves was recorded from the tagged plants by using scale and average was worked out.

3.4.2.2 Flowering attributes

i. Number of days taken for the initiation of flower spikes

Number of days taken from planting of corm to flower spike initiation was recorded.

ii. Number of days taken for the full emergence of spike

Number of days taken from planting of corm to full emergence of the spike from leaves was recorded.

iii. Number of days taken for bud separation

Number of days taken from planting of corm to bud separation of the spike was recorded.

iv. Number of days taken for first floret to show colour

Number of days taken from planting of corm to the opening of first floret in each spike was taken and average was worked out.

v. Number of days taken for first floret to open

Number of days taken from planting of corm to the opening of first floret in each spike average was worked out.

vi. Number of days taken for flowering

Number of days taken from planting of corm to the flowering of each spike average was worked out.

3.4.2.3 Floret characters

i. Length of floret (cm)

Length of the florets in each spike was measured from the point of its attachment to the tip of the longest petal.

ii. Diameter of floret (cm)

Diameter of the florets in each spike was measured from the two opposite end point of its petal.

3.4.2.4 Yield and yield components

i. Number of florets per spike

Total number of florets per spike was counted and recorded.

ii. Rachis girth (cm)

The girth of the spike was measured with the help of the Vernier calliper below the first floret.

iii. Length of the rachis (cm)

Length of the rachis was measured from the point of emergence of first floret to the last floret.

iv. Length of the spike (cm)

Length of the spike was measured from the internode next to 4th leaf upto the tip of the spike.

v. Weight of the spike (g)

The weight of the individual spike was taken.

vi. Field life

Number of days taken from flowering to the wilting of each spike average was worked out.

vii. Number of corms per plant

Total number of the cormels produced per plant was recorded as cormel yield per plant.

viii. Size of the daughter corm (cm)

Equatorial diameter of the harvested corm was recorded with Vernier callipers.

ix. Weight of the daughter corm (g)

Weight of the harvested corm was recorded using digital balance.

x. Number of cormels per plant

Total number of the cormels produced plant⁻¹ was recorded as cormels yield per plant.

xi. Size of the daughter cormels (cm)

Equatorial diameter of the harvested corm was recorded with Vernier Callipers.

xii. Weight of the daughter cormels (g)

Weight of the harvested corm was recorded using digital balance.

3.4.3 Experimental design

The field experiments of 2011-2012 and 2012-2013 was laid out in RBD (Randomized Complete Block Design) with different gladiolus genotypes replicated three times.

3.4.3.1 Statistical analyses

Fisher's method of analysis of variance was applied for analysis and interpretation of the data. All the parameters were statistically analysed on pooled basis taking data for the whole period and interpretation about the respective parameters were done mainly on their performance on pooled basis.

3.4.3.2 Analysis of variance

Variance is the measure of variability and is defined as the average of the square deviation from the mean. It helps in working out the variance due to different source and also provides the basis for test of significant (Singh and Choudhary, 1979).

Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1967) using the mean values of random plant in each replication from all treatments to find out the significance of treatment effect.

The model of analysis of variance is given as below

Source	Df	SS	MSS	'F' ratio	Expected MSS
Replication	(r-1)	SSr	Mr	$\frac{Mr}{Me}$	
Treatment	(t-1)	SSt	Mt	$\frac{Mt}{Me}$	$\sigma^2_e + r \sigma^2_g$
Error	(t-1) (r-1)	SSe	Me		σ^2_e
Total	(rt-1)				

Where,

df = Degrees of freedom; SS = Sum of squares; MSS = Mean sum of squares; r = Number of replications; t = Number of treatments; SSr = Sum of squares of replications; SSt = Sum of squares of treatments; SSe = Sum of squares of error; Mr = Mean Square of replications; Mt = Mean Square of treatments; Me = Mean square of error; σ^2_g = Variance due to genotypes and σ^2_e = Variance due to error

Variation due to genotype was tested by comparing calculated values to Table 'F' value at five per cent.

3.4.3.3 Critical Difference

In order to compare the means of entries, Critical Difference (CD) was calculated by using the following formula.

CD = SE x 't' value at error degrees of freedom.

$$\text{Where SE} = \sqrt{\frac{2 \times \text{Error MSS}}{r}}$$

t = Tabulated 't' value at 5 per cent or 1 per cent probability level.

3.4.4 Estimation of genetic parameters

3.4.4.1 Genotypic and phenotypic variances

$$\text{Genotypic variance } (\sigma^2_g) = \frac{\text{Treatment MSS} - \text{Error MSS}}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma^2_p) = \sigma^2_g + \sigma^2_e$$

3.4.4.2 Coefficient of Variation (%)

The coefficient of variation (CV) being a standardized form of variance is useful for comparing the extent of variation between different characters with different scales (Singh and Choudhary, 1979). Genotypic and phenotypic coefficients of variation were estimated according to Burton and Devane (1953) based on estimate of genotypic and phenotypic variance.

$$\text{Genotypic coefficient of variation} = \frac{\sigma^2_g}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variation} = \frac{\sigma^2_p}{\bar{X}} \times 100$$

Where,

$\bar{X}$ = General mean of the character; σ^2_g = Genotypic variance and σ^2_p = Phenotypic variance

PCV and GCV were classified as suggested by Shivasubramanian and Menon (1973) as follows.

0 – 10% - Low;

10-20 % – Moderate and

20% and above- High

3.4.4.3 Heritability (h^2)

The broad sense heritability (h^2) was estimated by following the procedure suggested by Weber and Moorthy (1952) as indicated here below.

Heritability (h^2)

$$= \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

σ^2_g = Genotypic variance; σ^2_p = Phenotypic variance

Heritability estimates in cultivated plants could be placed in the following categories as suggested by Robinson *et al.* (1966).

Low: 0-30%; Moderate: 30-60% and High: >60%

3.4.4.4 Expected genetic advance (EGA)

This was calculated using formula given by Robinson *et al.* (1949)

$$EGA = i \times h^2 \times \sigma_p$$

Where,

i = Selection differential ($i=2.06$) at 5 per cent selection intensity; h^2 = Heritability in broad sense and σ_p = Phenotypic standard deviation

3.4.4.5 Genetic advance as per cent mean (GAM)

Genetic advance as per cent as per cent mean was worked out as suggested by Johnson *et al.* (1955).

$$GAM = \frac{EGA}{X} \times 100$$

Where,

EGA = Expected genetic advance; X = General mean of the character

The genetic advance as per cent mean was categorized as suggested by Johnson *et al.* (1955).

0 – 10% - Low; 10-20% - Moderate and >20% - High

3.4.4.6 Correlation

Genotypic (r_g) and Phenotypic (r_p) coefficient of correlation were estimated as suggested by Al-Jibouri *et al.* (1958).

$$\text{Genotypic correlation} = r_{xy}(g) = \frac{\text{Co V}_{xy}(G)}{\sqrt{V_x(G) \times V_y(G)}}$$

$$\text{Phenotypic correlation} = r_{xy}(p) = \frac{\text{Co V}_{xy}(P)}{\sqrt{V_x(P) \times V_y(P)}}$$

Where,

CoV_{xy} (G) = Genotypic covariance between x and y; CoV_{xy} (P) = Phenotypic covariance between x and y; V_x (G) = Genotypic variance of character x; V_x (P) = Phenotypic variance of

character x; $V_y (G)$ = Genotypic variance of character y; $V_y (P)$ = Phenotypic variance of character y

Test of significance of correlation was tested by comparing the 'r' value with obtained value.

3.4.4.7 Path coefficient analysis

The concept of path coefficient analysis developed by Wright (1921) and illustrated by Dewey and Lu (1959) was carried out separately to know the direct and indirect effects of the important components, which are the standardized partial regression. Coefficients were obtained by solving the following set of 'p' simultaneous equations through the use of 'Doo-little techniques' as given by Goulden (1959).

$$P_{01} + P_{02}r_{12} + \dots + P_{0p}r_{1p} = r_{01}$$

$$P_{01}r_{12} + P_{02} + \dots + P_{0p}r_{2p} = r_{02}$$

$$P_{01}r_{1p} + P_{02}r_{2p} + \dots + P_{0p} = r_{0p}$$

Where $P_{01}, P_{02}, \dots, P_{0p}$ are the direct path effects of 1, 2, ..., p variables between dependent variable and independent variable and $r_{01}, r_{02}, \dots, r_{0p}$ are the correlation coefficients between dependent variable and independent variable. The indirect effect of 'i' th variable through 'j' th variable was worked out as $P_{0j} \times r_{ij}$.

The contribution of the remaining unknown factors is measured as the residual factor and calculated as

$$P_{0x}^2 = 1 (P_{01}^2 + 2P_{01} P_{02}r_{12} + 2P_{01}P_{03}r_{13} + \dots + P_{02}^2 + 2P_{02} P_{03}r_{23} + \dots + P_{0p}^2)$$

$$\text{Residual factor} = \sqrt{P_{0x}^2}$$

The direct and indirect effects were classified based on the scale given by Lenka and Misra (1973).

More than 1.0 – Very high; 0.30 to 0.99 – High; 0.20 to 0.29 – Moderate; 0.10 to 0.19 – Low and 0.00 to 0.009 – Negligible

Experiment -II

3.5 Studies on seed setting in cross combinations and the combining ability of seed characters

The present experiment was carried out at the Horticultural Farm of Uttar Banga Krishi Viswavidyalaya, to investigate cross combinations and the combining ability of seed characters. A separate crossing block was maintained during 2011-2013 for crossing and open pollination was carried out among the 20 genotypes of gladiolus to study their cross combinations and characteristics viz capsule set percent, capsule harvest percent and number of seeds capsule⁻¹ were recorded. On the basis of result found during 2011-2012, five superior gladiolus genotypes from 20 evaluated gladiolus germplasm were selected and an experiment was carried out during 2012-2014 to investigate cross combinations and the combining ability of seed characters through full diallele analysis. The details of the experimental materials used, methods followed and the statistical techniques adopted during the course of investigations have been discussed in this chapter.

3.5.1 Experimental details

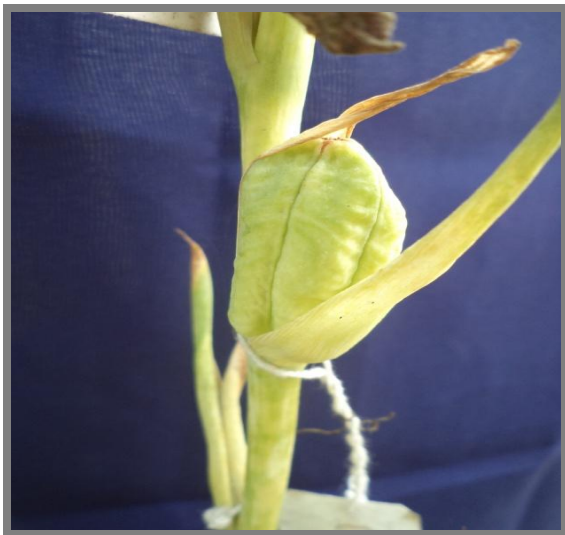
3.5.1.1 Planting materials

Out of total 20 gladiolus genotypes, five genotypes i.e. ACC-15(1), ACC-13(2), ACC-11(3), ACC-14 (4) and ACC-04 (5) were used for the experiment.

3.5.1.2 Parental lines and crossing scheme

Five superior plants were selected based on spike size and seed yield for a full diallel cross from 20 gladiolus genotypes after evaluation in the farm. The superior plants were crossed in a full-diallel mating design (5×5) as in Table 5.

Plates 2. Different activities that practices during seedbed preparation and seedling raising



Plates 2.1 Pod Setting



Plates 2.2 Sowing of crossed seeds



Plates 2.3 Tagging of seed lines



Plates 2.4 Raised seedlings

3.5.1.3 Hybridization

The following full-diallel crosses were made to study the seed setting in parents and their cross combinations.

Table 4. 5x5 complete diallele hybridization diagram

♂	♀				
	1	2	3	4	5
1	1x1*	2x1#	3x1#	4x1#	5x1#
2	1x2+	2x2*	3x2#	4x2#	5x2#
3	1x3+	2x3+	3x3*	4x3#	5x3#
4	1x4+	2x4+	3x4+	4x4*	5x4#
5	1x5+	2x5+	3x5+	4x5+	5x5*

#, + and * -represents direct crosses, reciprocal crosses and parents respectively

3.5.1.4 Generation of F₁ seeds from open and diallel cross

A crossing block was maintained for the production of F₁ true seeds in 2012-2014 taking five genotypes. Time of sowing was manipulated as per their days to spike emergence for confirmation of simultaneous spike emergence among the seven genotypes. After spike emergence of gladiolus genotypes, a full diallele crossing was carried out among the five genotypes to study seed setting studies in cross combinations and the combining ability of seed characters. Two inflorescences with five female flowers each was employed for making cross. According to the formula designed by Griffing (1956) method 1, 20 crosses were made from the five parents (P). Number of crosses = P (P-1). The total entries were therefore 25 (parents, crosses and reciprocals). In the female parent, flowers at pre-anthesis stage were selected for emasculation. Emasculation was carried out between 4:00 to 5:00 pm and bagged with butter paper cover. Similarly, in the male parents, a few selected flower buds at pre-anthesis stage were bagged without emasculation to avoid contamination by foreign pollen for collection of pollen grains. Pollen from bagged flowers of pollen parents were collected between 8.00 to 10.00 am in the next day morning and dusted on the stigma of emasculated flowers of the respective female parents. The flowers were bagged with butter paper and then labelled. The covers were removed after ensuring proper pod

set. The F₁ pods were harvested at full physiological maturity, when the capsules start to burst. Each individual cross was threshed by hand.

3.5.1.5 Seedbed preparation and sowing

All seeds of parental genotypes and hybrids (Fifteen seeds from each parental genotypes and hybrids) were planted on well prepared and raised seedbeds to produce seedlings. Before sowing, the seedbed was prepared carefully and a small amount of cowdung and vermicompost were applied in the soil and at the same time the seeds are rubbed between two layers of cloth to remove the waxy covering. It has been reported that the waxy covering contains some substances that retard the germination process. Seeds are sown in 2 cm deep furrows with individual seed not closer than 2.5 cm to allow development of large cormels. The seedbeds are watered with a water can having a fine rose for ensuring the germination of seeds.

3.5.2 Observations recorded

3.5.2.1 Seed setting in cross combinations

i. Number of days taken for capsule setting

Number of days taken form pollination to setting of capsule was recorded.

ii. Number of days taken for maturity of capsule

Number of days taken form pollination to maturity of capsule was recorded.

iii. Length of capsule (cm)

Length of the capsule was measured from their two end points.

iv. Weight of dried capsule (g)

Weight of the one harvested capsule was recorded.

v. Capsule set percent (%)

Setting number of capsule out of total crossing carried out and expressed in percentage.

vi. Capsule harvest percent (%)

Total number of the harvestable capsule produced out of total set capsules and expressed in percentage.

vii. Number of seeds per capsule

Total number of the seeds produced per capsule was recorded as seed yield per capsule.

viii. Weight of 100 seeds (g)

Weight of the one hundred harvested seeds was recorded.

3.5.2.2 Combining ability of seed characters

For morphological traits, data from germination to corm development was collected at different intervals after sowing.

i. Days to germination

The number of days taken for complete germination from the date of first emergence of radical of seeds was recorded and was expressed as mean number of days.

ii. Germination percentage (%)

The germination percentage was calculated using appendix equations as described by Sharma (2013).

iii. Germination speed (GS)

Germination speed was calculated using the formula as described by Aldhous (1972).

iv. Seedling vigour index (SVI)

It reflects the health of the seedling produced. It was calculated on the basis of the following formula (Abdual-baki and Anderson, 1973).

v. Seedling length (cm)

Length of the seedling was taken after two weeks of complete germination of seeds and measured from their two end points (from root ends to shoot tip).

vi. Weight of plant (g)

The weight of the individual seedling was taken along with corm when the foliage of seedlings start to turn brown.

vii. Size of corm (diameter in cm)

Equatorial diameter of the harvested corm was recorded with vernier callipers.

3.5.3 Field experimental design and layout

Experimental design : Randomized Complete Block Design

Number of replications : Three

Number of genotypes : Five

3.5.4 Estimation of genetic parameters

3.5.4.1 Combining Ability

Diallel analysis was performed to calculate general combining ability (GCA) and specific combining ability (SCA) according to the Griffing's (1956).

Griffing (1956) designed two main models and four methods for the analysis of diallel data. In this study, analysis of the combining ability for each experiment was done following Griffing's Method 1, where parents, F_1 's and reciprocals are included. The data was analyzed with Agrobases (2000) using a fixed model. If the fixed effects model is used, the sampling error becomes the effective residual for testing combining ability mean squares and estimating variance components and standard errors.

The below model was considered for statistical analysis in this experiment:

$$Y_{ijk} = \mu + G_i + G_j + S_{ij} + R_k + E_{ijk}$$

Where: Y_{ijk} = the observed value for a hybrid between the i^{th} and j^{th} parents in the k^{th} replication

μ = population mean

G_i and G_j = GCA effect of the i^{th} and j^{th} parents

S_{ij} = SCA effect for the hybrid between the i^{th} and the j^{th} parents

R_k = effect of the k^{th} replication

E_{ijk} = the error associated with the ijk^{th} hybrid (the residual) (Johnson and King, 1998).

3.5.4.2 GCA : SCA ratio

The GCA : SCA ratio was estimated to study the performance of the effects and to measure the relative importance of additive gene or non-additive gene effects. This parameter indicates whether a character is mainly determined by additive or non-additive gene action (Singh and Chaudhary, 1979).

3.5.4.3 Heterosis

These were computed as the percentage of superiority of the hybrid over its mid parent value (MP %) or better parent value (BP %), respectively.

Two types of the heterosis were analyzed based on the mean values of the genotypes in this study; mid-parent heterosis (MPH) and high parent heterosis (HPH).

I. MPH is calculated from the formula (Falconer and Mackay, 1996):

$$HF1 = (F1 - MP) / MP \times 100\%$$

Where: HF1 is the heterosis for F1 cross
F1 is the mean value of F1 cross
MP is the mean mid-parent value

II. HPH is calculated from the formula:

$$HF1 = (F1 - HP) / HP \times 100\%$$

Where: HF1 is the heterosis for F1 cross
F1 is the mean value of F1 cross
HP is the mean high parent value

Experiment -III

3.6 Studies on *in-vitro* seed germination and growth of gladiolus

The technique of *in vitro* regeneration of plant tissue and organs is primarily devoted to keep the explant free from microbes and to ensure the desired development in the cells and organs by providing suitable nutrient media and other environmental conditions. From the literature, it is evident that gladiolus is highly amenable to *in-vitro* studies, as its explants were found to favourably respond to different culture media with different types and concentrations of growth regulators.

The present study on *in-vitro* seed germination in gladiolus as affected by plant growth regulators was conducted in the Tissue Culture Laboratory of Department of Floriculture Medicinal and Aromatic Plants, Faculty of Horticulture.

The materials used and the methods adopted to record the observations during the course of this study are presented below.

3.6.1 Plant materials

The mature and healthy seeds of gladiolus collected from the plant grown in Floriculture farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar.

3.6.2 Chemicals

All the organic reagents used were of high purity, analytical grade and obtained from BDH, Glaxo, E. Merck, Sisco Research Laboratory (SRL), Hi-Media and Qualigens Fine Chemicals. Fine chemicals, such as, growth hormones, vitamins, myo-inositol, glycine, etc., were obtained from Sigma Chemical Company, St. Louis (USA).

3.6.3 Glasswares/Plasticwares

Borosilicate quality glass wares and Tarsons plastic wares were used throughout the experiments. These were obtained from Borosil India Limited, Corning Glass Company and Tarsons Products Pvt. Limited. Conical flasks of volume 50, 100, 150, 250, 500 and 1000 ml, culture tubes of size 25x150 mm, 25x200 mm, 50x200 mm and Jam bottles (500 ml) were used for culturing the explants and media preparation.

3.6.3.1 Sterilization of glassware and other equipment

Glasswares (pipettes, beakers, flasks and test tubes, etc.) were thoroughly washed with liquid soap solution (Teepol) followed by sufficient washing with running tap water. These were then rinsed with distilled water. After that glassware were heat sterilized in an oven for three hours at 180°C. Scalpels, needle and forceps were sterilized in an incinerator till they turned red hot. The laminar air-flow was always switched on 30 minutes before use and the platform was surface sterilized by thorough wiping with spirit or 95% ethyl alcohol.

3.6.4 Nutrient media

Murashige and Skoog basal medium was used for all the experiments. MS media were prepared from stocks solution (Appendix-I). Modification to the medium was done by adding growth regulators only.

3.6.4.1 Preparation and storage of stock solutions (Appendix-I)

For preparing the nutrient medium, five different stocks were prepared along with the stocks of growth regulators.

Stock A: Macro salts

Stock B: Micro salts

Stock C: Calcium chloride

Stock D: Ferrous sulphate with EDTA

Stock E: Vitamins

During the preparation of individual stock solution, all ingredients listed in Appendix-I were measured and required quantity of each was added one at a time to distilled water. Each ingredient was dissolved completely before adding the next ingredient. The volume was made up by adding distilled water. Stock solutions of major and minor salts, chelating agent (Fe EDTA), vitamins, growth regulators were prepared (mg/ml) according to their solubility separately and stored in refrigerator at 4°C. Amber coloured bottles were used for storage of individual stock solutions to eliminate the light effect. All the stock solutions were used within one month of their preparation.

3.6.4.2 Preparation of growth regulator stocks

Stock solutions of Gibberllic acid (GA₃), Kinetin, were prepared by dissolving them first in few drops of 1N NaOH and the volume was made upto the required concentration with double distilled water.

3.6.4.3 Preparation of culture media

Murashige and Skoog's (1962) (MS) medium was used as basal medium with 3% sucrose, myo-inositol (100 mg w/v) and 0.8% agar during the course of present investigation. Growth regulators like Gibberllic acid (GA₃) and Kinetin (Kn) were used with basal media.

While preparing individual medium using stocks, required quantity of stock solutions were added along with sucrose and the volume was made up by adding distilled water. The pH was adjusted between 5.6 and 5.8 with the help of 0.1N NaOH or 0.1N HCl. The volume was finally made up and required quantity of agar was added into the medium. Agar in the medium was completely melted by in a microware. After melting the agar, medium was dispensed into culture flasks/tubes/bottles. These were plugged with non-absorbent cotton or closed with lids. These flasks/tubes/bottles were then autoclaved.

3.6.4.4 Sterilization and storage of culture media

The test tubes with nutrient media were autoclaved at a pressure of 1.06 kg cm⁻² (121⁰C) for 20 minutes. The tubes were then removed from the autoclave and allowed to cool. After autoclaving the flasks/tubes/bottles were kept in the culture room at temperature of 25±2⁰C. The inoculation was done after 4 to 5 days ensuring that the tubes were free from contaminations.

3.6.5 Experimental conditions

The experiments were conducted under well defined conditions of the culture room maintained at temperature of 25±2⁰C. Uniform light was provided by using fluorescent tubes (7200 Lux) over a light/dark photoperiodic cycle of 16 hours light/8 hours' dark.

3.6.6 Explants and their preparation

3.6.6.1 Explants Source

The seeds of different genotypes viz, ACC-15, ACC-13, ACC-11, ACC-14 and ACC-04 were utilized for the germination study. They were cultured such a way that the basal portion of the seeds was in contact with the medium. All procedures were performed under aseptic conditions.

3.6.6.2 Surface sterilization of the explants

All the seeds were carefully washed under running tap water followed by washings in tap water containing Teepol and again by running tap water for 30-40 min and thereafter rinsed with distilled water. These were then surface sterilized with 70% absolute alcohol (1-2 minute) followed by 0.1% sodium hypochlorite solution for 10 minutes. Finally they were rinsed 3-5 times with sterile water. These seed explants were then ready for use.

3.6.7 Transfer area and maintenance of aseptic conditions

All the aseptic manipulations such as surface disinfection of the explants, preparation and inoculation of explants and subsequent sub-culturing were carried out in the laminar air flow cabinet. The working table of laminar air flow cabinet and spirit lamp were sterilized by swabbing with absolute alcohol. All the required material like media, spirit lamp, lighter, glassware, etc. were transferred on to the clean laminar air flow. The ultra violet light was switched on for half an hour to achieve aseptic environment inside the cabinet before working in the lamina air flow cabinet.

3.6.8 Germination

Seeds of five selected genotypes were transferred on MS basal medium containing different concentrations of GA₃ along with Kinetin. Visual attributes like germination response and seedling growth were studied during investigation and used to select best germination medium.

3.6.9 Experiments conducted during research work

In vitro germination of Gladiolus was investigated through five genotypes of gladiolus. Various media compositions were designed for each set.

Plates 3. Different activities that practices *in-vitro* raising of seedling



Plates 3.1 Culture of seeds in germ bottle



Plates 3.2 Tagging of germ bottle



Plates 3.3 Germination of seeds



Plates 3.4 Seed cultured room

3.6.9.1 Experiment on seed germination

Seeds obtained from gladiolus after selfing were cultured in different treatment combinations with three replicates. For germination GA₃ in different concentration (0, 1, 2, 3, 4, 5 or 5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) were used in these experiments. The seed explants were incubated in growth room for a month. Subsequent seed germination and shoot development were achieved with few root initiation in all the cultures. The effects of increased GA₃ level (1-5 mg l⁻¹) were investigated to increase germination percent and to induce seedling development. MS medium including all vitamins was supplemented with five levels of GA₃. Throughout the study, the *in vitro* seed germination and raising capacity of gladiolus seedlings is observed and recorded.

3.6.10 Experimental details

3.6.10.1 Effect of different concentration of GA₃ in combination of Kinetin on germination and growth of gladiolus

Table 5. Different concentration of GA₃ along with Kinetin

Sl. No.	Medium code	Treatments
1.	MGK ₁	MS
2.	MGK ₂	MS + 1 mg l ⁻¹ GA ₃ + 0.5 mg l ⁻¹ Kn
3.	MGK ₃	MS + 2 mg l ⁻¹ GA ₃ + 0.5 mg l ⁻¹ Kn
4.	MGK ₄	MS + 3 mg l ⁻¹ GA ₃ + 0.5 mg l ⁻¹ Kn
5.	MGK ₅	MS + 4 mg l ⁻¹ GA ₃ + 0.5 mg l ⁻¹ Kn
6.	MGK ₆	MS + 5 mg l ⁻¹ GA ₃ + 0.5 mg l ⁻¹ Kn

3.6.10.2 Effect of different composition of hardening medium on survivability of gladiolus

Table 6. Different combination of hardening media

Sl. No.	Medium code	Hardening medium composition (V/V)
1.	VSM	Vermiculite + sand (1:1)
2.	GSM	Garden soil + sand (1:1)
3.	VVM	Vermiculite + vermicompost (1:1)
4.	GSV	Garden soil + sand + vermicompost (1:1:1)

3.6.11 Observation recorded

3.6.11.1 Observation recorded at seed germination and seedling growth stage

i. Days to germination

The number of days taken for complete germination from the date of first emergence of radical of seeds was recorded and was expressed as mean number of days.

ii. Germination percentage

The germination percentage was calculated using appendix equations as described by Sharma (2013).

iii. Germination speed (GS)

Germination speed was calculated using the formula as described by Aldhous (1972).

iv. Germination value (GV)

Germination values were calculated using the formula as described by Djavanshir and Pourbeik (1976).

v. Seedling vigour index (SVI)

It reflects the health of the seedling produced. It was calculated on the basis of the following formula (Abdual-baki and Anderson, 1973).

vi. Length of seedling (cm)

The length of seedling was measured from base of root to the top of the shoot with scale.

vii. Weight of seedling (mg)

The fresh weight of the seedling was recorded with electronic balance.

viii. Survival of seedlings (%)

The number of plantlet survived out of total seedlings subjected to hardening was counted at different intervals.

3.6.12 Statistical analysis of data

For proper interpretation of the results, appropriate statistical test was selected depending upon the nature of the treatment and objectives of the research. The experiment was laid out under factorial experiment in CRD (Completely Randomized Design). The data were analyzed by Fisher's analysis of variance (ANOVA) technique and then results were interpreted.

Experiment - I**4.1 Studies on assessment of the *per se* performance of gladiolus genotypes**

The present investigation was carried out involving twenty genotypes of gladiolus to find the nature and extent of genetic variability. Further, the genetic components like genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (broad sense), genetic advance (GA), correlation and path analysis studies were also conducted for growth, flowering and yield attributes. The results are presented in this chapter.

4.1.1 Variability, heritability and genetic advance**4.1.1.1 Vegetative characteristics**

The growth parameters considered were the plant height, number of leaves plant⁻¹ and leaves length at 60 days after planting (DAP). The data concerned to these growth parameters are presented in Table 7.

4.1.1.1.1 Height of plant

Significant differences were recorded among the genotypes under the trial for the plant height. The range was from 43.98 to 91.58 cm with the maximum height (91.58 cm) was recorded by the ACC-13 which was followed by the genotypes ACC-15 (85.58 cm), ACC-19 (85.05 cm) and so on. The least height recorded in ACC-05 (43.98 cm) which was followed by ACC-07 (46.82 cm), ACC-02 (48.25 cm) and so on.

Moderate genotypic and high phenotypic co-efficient of variation was recorded i.e. 19.10% and 20.20%, respectively, and High heritability (89.40%) with high genetic advance as per cent mean (37.19%) was observed.

Table 7. Mean performance of twenty genotypes of gladiolus for growth characters

Accession No.	Plant height (cm)			Leaf number plant ⁻¹			Leaf length (cm)			Days to spike initiation		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	66.46	68.78	67.62	5.88	6.78	6.33	35.93	40.09	38.01	65.39	67.29	66.34
ACC-02	46.25	50.25	48.25	5.34	5.99	5.67	32.66	35.16	33.91	72.66	74.89	73.78
ACC-03	74.89	70.13	72.51	5.96	6.69	6.33	31.98	35.03	33.51	73.26	69.39	71.33
ACC-04	66.44	72.86	69.65	5.78	6.87	6.33	32.15	34.91	33.53	71.55	73.12	72.34
ACC-05	41.55	46.41	43.98	3.95	4.71	4.33	30.96	33.25	32.11	78.91	80.43	79.67
ACC-06	55.76	62.28	59.02	5.69	6.98	6.34	34.91	36.76	35.84	63.44	65.22	64.33
ACC-07	43.32	50.31	46.82	5.71	6.95	6.33	31.22	33.21	32.22	67.58	69.32	68.45
ACC-08	78.54	82.15	80.35	6.88	7.77	7.33	40.65	42.05	41.35	64.01	63.33	63.67
ACC-09	77.46	81.44	79.45	6.43	6.91	6.67	39.76	41.25	40.51	61.74	63.16	62.45
ACC-10	64.68	66.81	65.75	5.85	6.15	6.00	36.45	38.55	37.50	63.78	61.56	62.67
ACC-11	78.79	83.36	81.08	6.88	7.77	7.33	40.94	43.07	42.01	56.43	58.23	57.33
ACC-12	61.36	65.34	63.35	5.37	5.96	5.67	35.98	38.15	37.07	67.28	69.59	68.44
ACC-13	89.65	93.51	91.58	8.39	8.95	8.67	51.98	54.15	53.07	66.54	64.79	65.67
ACC-14	77.87	83.68	80.78	7.44	7.88	7.66	40.74	42.14	41.44	60.39	62.27	61.33
ACC-15	82.17	88.98	85.58	8.51	8.83	8.67	50.22	51.88	51.05	73.81	71.95	72.88
ACC-16	66.76	70.87	68.82	5.98	6.67	6.33	37.89	39.88	38.89	63.77	65.79	64.78
ACC-17	60.77	64.62	62.70	6.44	6.88	6.66	36.88	39.10	37.99	64.88	66.45	65.67
ACC-18	80.32	84.63	82.48	7.11	7.55	7.33	42.68	44.91	43.80	58.66	60.67	59.67
ACC-19	82.48	87.62	85.05	7.99	8.66	8.33	47.57	50.24	48.91	67.72	69.62	68.67
ACC-20	80.41	85.88	83.15	7.79	8.21	8.00	45.15	47.11	46.13	61.89	62.77	62.33
CD at 5%	7.311	6.375	6.843	0.969	0.930	0.950	7.000	8.943	7.972	6.375	6.979	6.677
SE(d)	3.119	3.024	3.072	0.552	0.615	0.584	3.316	3.295	3.306	3.715	3.088	3.402
SE(m) ±	2.445	2.132	2.289	0.324	0.311	0.318	2.341	2.991	2.666	2.132	2.334	2.233
CV	6.781	5.998	6.390	10.328	11.143	10.736	10.112	10.316	10.214	5.324	4.998	5.161

(Year-1: 2011-12; Year-2: 2012-13)

4.1.1.1.2 Number of leaves per plant

The genotypes showed significant differences with respect to the number of leaves plant⁻¹. The range obtained was from 4.33 to 8.67 cm. The maximum number of leaves (8.67) was produced by the ACC-13 and ACC-15, which was followed by the genotypes ACC-19 (8.33), ACC-20 (8.00) and so on. The least number of leaves (4.33) was recorded in the ACC-05.

Genotypic and phenotypic co-efficient of variation was 7.66% and 31.85%, respectively. Low heritability (5.71%) and low genetic advance as per cent mean (3.80%) was noticed.

4.1.1.1.3 Length of leaves

The genotypes showed significant differences with respect to the leaves length. The range obtained was from 32.11 to 53.07 cm. The maximum leaf length (53.07 cm) was recorded in the ACC-13. The least (32.11 cm) was recorded in the ACC-05.

Genotypic co-efficient of variation (14.20%) and phenotypic co-efficient of variation (17.51%) were obtained for length of leaves. This trait had a high heritability of (65.77%) with high genetic advance as per cent mean (23.72%).

4.1.1.1.4 Number of days taken for spike initiation

Significant differences were noticed for the number of days taken for spike initiation among the genotypes. The range was from 57.33 to 79.67 days. The maximum numbers of days (79.67 days) was recorded by the genotype ACC-05 which was followed by the genotype ACC-02 (73.78 days), ACC-15 (72.88) and so on. The minimum number of days (57.33) was taken by ACC-11 which was followed by the genotype ACC-18 (59.67 days), ACC-14 (61.33 days) and so on.

Low genotypic co-efficient variation (7.46%) and low phenotypic co-efficient of variation (9.38%) were obtained for number of days taken for spike initiation. This trait had high heritability (63.22 %) with moderate genetic advance as per cent mean (12.22 %).

4.1.1.2 Flowering attributes

The different flowering attributes taken for the study were from number of days taken for spike initiation to flowering. The data pertaining to these characters are presented in Table 8.

Table 8. Mean performance of twenty genotypes of gladiolus for flowering characters

Accession No.	Days to spike emergence			Days to bud separation			Days to show colour			Days to open floret			Days to flowering		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	68.14	70.32	69.23	73.33	76.77	73.33	73.48	75.17	74.33	74.41	76.25	75.33	78.77	76.55	77.67
ACC-02	75.37	77.34	76.36	79.28	77.24	79.28	82.81	83.85	83.33	86.12	87.31	86.72	87.22	89.22	88.22
ACC-03	73.27	75.39	74.33	76.68	77.97	77.33	81.46	79.87	80.67	81.68	83.66	82.67	84.79	86.54	85.67
ACC-04	73.69	75.36	74.53	79.14	77.41	78.27	79.65	80.79	80.22	83.14	81.47	82.31	83.88	85.54	84.71
ACC-05	81.68	83.65	82.67	87.64	89.70	88.67	91.59	92.40	92.00	92.76	93.89	93.33	96.73	97.93	97.33
ACC-06	68.43	66.23	67.33	69.51	70.49	70.00	71.75	72.25	72.00	72.41	74.24	73.33	75.13	76.21	75.67
ACC-07	70.28	72.18	71.23	75.87	76.81	76.34	80.32	78.97	79.65	80.57	81.66	81.12	82.16	84.28	83.22
ACC-08	66.69	67.97	67.33	68.62	70.21	69.33	73.58	71.76	72.67	73.75	74.25	74.00	76.21	77.79	77.00
ACC-09	67.57	65.93	66.75	67.87	69.61	68.74	73.05	71.44	72.25	73.21	74.63	73.92	74.26	76.83	75.55
ACC-10	64.89	66.45	65.67	69.51	67.82	68.67	71.21	70.13	70.67	72.33	77.35	72.33	74.45	76.21	75.33
ACC-11	59.38	61.27	60.33	62.48	64.18	63.33	67.87	66.78	67.33	70.00	73.15	70.00	72.55	73.45	73.00
ACC-12	71.70	72.98	72.34	76.81	78.52	77.67	80.94	79.54	80.24	84.54	83.11	83.83	85.21	87.45	86.33
ACC-13	68.41	70.49	69.45	71.77	70.78	71.28	74.48	72.47	73.48	74.67	76.28	75.48	76.45	77.78	77.12
ACC-14	63.85	62.87	63.36	64.31	67.02	65.67	67.87	68.79	67.33	68.32	70.33	69.33	72.15	71.19	71.67
ACC-15	76.92	78.41	77.67	80.37	78.11	79.24	80.76	82.58	81.67	81.89	83.70	82.80	84.82	86.96	85.89
ACC-16	66.41	67.59	67.00	68.98	70.35	69.67	71.31	72.68	72.00	72.65	74.69	73.67	75.47	77.87	76.67
ACC-17	69.64	68.81	69.23	70.43	71.57	71.00	72.68	74.66	73.67	73.66	74.83	74.25	78.43	79.57	79.00
ACC-18	59.21	60.79	60.00	66.21	65.32	65.77	66.81	68.52	67.67	70.13	69.50	69.85	70.54	72.11	71.33
ACC-19	70.21	71.79	71.00	76.39	74.27	75.33	79.29	77.36	78.33	79.67	81.66	80.67	82.55	84.79	83.67
ACC-20	64.77	65.88	65.33	68.05	66.61	67.33	71.45	73.21	72.33	74.25	72.41	73.33	76.33	74.32	75.33
CD at 5%	6.372	6.222	6.297	9.024	6.697	7.861	8.323	7.281	7.802	5.520	4.638	5.079	6.685	7.064	6.875
SE(d)	3.250	3.712	3.481	3.005	3.128	3.067	3.451	3.653	3.552	2.557	2.634	2.596	3.211	3.121	3.166
SE(m) ±	2.117	2.067	2.092	2.998	2.225	2.612	2.765	2.419	2.592	1.834	1.541	1.688	2.221	2.347	2.284
CV	6.000	5.870	5.935	5.241	5.221	5.231	5.498	5.576	5.537	4.110	4.000	4.055	2.321	2.256	2.289

(Year-1: 2011-12; Year-2: 2012-13)

4.1.1.2.1 Number of days taken for spike emergence

The data showed highly significant differences for the number of days taken for the full emergence of spike among the genotypes. The range was between 60.33 to 82.67 days. The maximum number of days (82.67 days) was taken by the ACC-05 while minimum number of days was taken by ACC-11 (60.33 days).

Genotypic and phenotypic co-efficient of variation were recorded as 7.37% and 9.62%, respectively with medium heritability (58.72%) and moderate genetic advance as per cent mean (11.64%).

4.1.1.2.2 Days of days taken for bud separation

Significant differences were recorded among the genotypes under the trial for the days to bud separation. The range was from 63.33 to 88.67 days again the maximum number of days (88.67 days) was recorded by the genotype ACC-05. The least days for bud separation recorded in genotype ACC-11 (63.33 days) and this were followed by the ACC-14 (65.67 days), ACC-18 (65.77 days) and so on.

Genotypic and phenotypic co-efficient of variation 7.90% and 9.43%, respectively with high heritability (70.23%) and moderate genetic advance as per cent mean (13.64%) was obtained.

4.1.1.2.3 Number of days taken for first floret show colour

Genotypes differed significantly with respect to days taken for the first floret to show colour. The range recorded was from 67.33 to 92.00 days. Maximum number of days for the first floret to show colour was required by the ACC-05 (92.00 days). The minimum number of days (67.33) was recorded by the ACC-11 and ACC-14 which was followed by the genotype ACC-18 (67.67 days) and so on.

Low genotypic and phenotypic co-efficient of variation was recorded i.e. 7.65% and 9.47%, respectively, and high heritability (65.26%) with moderate genetic advance as per cent mean (12.73%) was observed.

4.1.1.2.4 Number of days taken for first floret to open

There were significant differences among the genotypes with respect to first floret to open. The range recorded was from 69.33 to 93.33 days. The maximum number of days was recorded in the ACC-05 (93.33 days), which was followed by the genotypes ACC-02 (86.72 days), ACC-12 (83.33 days). The minimum number of days (69.33) was recorded by ACC-14 which was followed by ACC-18 (69.67 days), ACC-10 and ACC-12 (72.33 days) and so on.

Low genotypic and phenotypic co-efficient of variation was recorded i.e. 8.84% and 9.71%, respectively, and high heritability (82.91%) with medium genetic advance as per cent mean (16.59%) was observed.

4.1.1.2.5 Number of days taken for flowering

Significant differences were recorded among the genotypes under the trial for the days to flowering. The range was from 71.33 to 97.33 days and the maximum days for flowering (97.33 days) were recorded by the ACC-05 which was followed by ACC-02 (88.22 days), ACC-12 (86.33 days) and so on. The least duration for flowering recorded in ACC-18 (71.33 days).

Low genotypic and phenotypic co-efficient of variation was recorded i.e. 7.13% and 8.60%, respectively, and high heritability (68.71%) with moderate genetic advance as per cent mean (12.17%) was observed.

4.1.1.3 Flower characters

The different spike characters considered in the present study were length of floret, diameter of floret, number of florets spike⁻¹, rachis length, length of spike, average weight of spike, and field life. The data pertaining to these characters are presented in Table 9.

4.1.1.3.1 Length of floret

The significant differences were noticed with respect to length of the floret. The range was from 7.54 to 11.20 cm. The maximum floret length was recorded in ACC-06 (11.20 cm) which was followed by ACC-18 (11.19 cm), ACC-07 (11.10 cm) and so on. The lowest floret length was recorded in ACC-02 (7.54 cm).

Table 9. Mean performance of twenty genotypes of gladiolus for flowering characters

Accession No.	Floret length (cm)			Floret diameter (cm)			Florets spike ⁻¹			Rachis girth (mm)		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	9.94	9.86	9.90	9.21	9.90	9.56	15.00	15.80	15.40	21.78	22.34	22.06
ACC-02	7.20	7.88	7.54	5.78	4.78	5.28	9.20	11.20	10.20	20.55	18.59	19.57
ACC-03	9.50	9.50	9.50	9.15	9.59	9.37	14.05	14.82	14.44	23.11	21.91	22.51
ACC-04	9.21	8.81	9.10	7.98	8.52	8.25	13.98	12.90	13.40	27.98	28.87	28.43
ACC-05	7.76	8.90	8.33	4.88	5.32	5.10	10.74	11.25	11.00	18.11	18.56	18.34
ACC-06	10.87	11.53	11.20	11.57	10.86	11.22	13.95	12.81	14.38	37.21	38.27	37.74
ACC-07	10.76	11.44	11.10	10.52	9.73	10.13	12.05	13.17	12.61	21.96	22.99	22.48
ACC-08	9.98	10.21	10.10	9.94	10.27	10.11	14.85	14.27	14.56	21.15	22.12	21.64
ACC-09	9.93	10.27	10.10	9.90	10.59	10.25	14.03	13.39	13.70	31.35	30.89	31.12
ACC-10	9.54	9.72	9.63	11.12	11.49	11.31	11.80	12.68	12.24	24.65	26.17	25.41
ACC-11	8.04	8.36	8.20	6.84	7.59	7.22	15.02	16.32	15.67	25.98	27.13	26.56
ACC-12	8.57	9.24	8.91	7.05	7.37	7.21	10.54	11.34	10.94	17.88	18.96	18.42
ACC-13	7.25	7.89	7.57	6.80	7.47	7.14	16.87	17.41	17.14	26.56	27.44	27.00
ACC-14	8.12	8.30	8.21	7.32	7.98	7.65	14.95	15.85	15.40	20.11	20.34	20.23
ACC-15	9.15	9.29	9.22	9.09	9.63	9.36	14.21	14.84	14.53	32.13	33.01	32.57
ACC-16	8.39	8.93	8.66	9.81	10.49	10.15	9.65	10.43	10.04	22.82	23.61	23.22
ACC-17	7.54	7.66	7.60	7.13	7.75	7.44	11.95	12.64	12.30	18.89	19.87	19.38
ACC-18	10.76	11.61	11.19	14.62	15.38	15.00	8.67	9.63	9.15	25.11	25.95	25.53
ACC-19	7.88	8.12	8.00	10.52	11.77	11.15	12.75	13.25	13.00	26.89	27.98	27.44
ACC-20	9.65	10.34	10.00	8.50	9.15	8.83	10.22	10.88	10.55	43.79	44.89	44.34
CD at 5%	1.044	1.329	1.187	4.074	4.014	4.044	3.345	3.399	3.372	4.974	5.676	5.325
SE(d)	0.512	0.235	0.374	1.871	1.889	1.880	1.591	1.781	1.686	2.600	2.581	2.591
SE(m) ±	0.348	0.443	0.396	1.358	1.338	1.348	1.115	1.133	1.124	1.658	1.892	1.775
CV	8.345	9.324	8.835	24.553	25.622	25.088	15.283	14.761	15.022	11.769	12.771	12.270

(Year-1: 2011-12; Year-2: 2012-13)

Low genotypic and high phenotypic co-efficient of variation was recorded i.e. 4.50% and 24.03%, respectively, and low heritability (3.56%) with low genetic advance as per cent mean (1.74%) was observed.

4.1.1.3.2 Diameter of floret

Genotypes differed significantly with respect to the diameter of the floret. The range recorded was from 5.10 cm to 15.00 cm. The maximum diameter of the floret was recorded in ACC-18 (15.00 cm), which was followed by ACC-10 (11.31 cm), ACC-06 (11.22 cm) and so on. The lowest diameter was recorded in ACC-05 (5.10 cm).

Genotypic and phenotypic co-efficient of variation 20.38% and 33.52%, respectively with medium heritability of (36.97%) and high genetic advance as per cent mean 25.53% were obtained with respect to flower diameter.

4.1.1.4 Spike and yield attributing characters

4.1.1.4.1 Number of florets per spike

The genotypes showed significant differences with respect to the number of florets spike⁻¹. The range recorded was between 9.15 to 17.14 florets spike⁻¹. The maximum number of 17.14 florets spike⁻¹ was recorded in ACC-13 which was followed by ACC-11 (15.67), ACC-14 (15.40) and so on. The lowest (9.15) number of florets spike⁻¹ was recorded in ACC-18.

Medium genotypic and high phenotypic co-efficient of variation for number of florets spike⁻¹ i.e. 14.40% and 21.01% with a medium heritability of (46.93%) and high genetic advance as per cent mean (20.34%) were obtained.

4.1.1.4.2 Girth of rachis

There were significant differences among the genotypes with respect to the girth of rachis. The range was between were 18.42 to 44.34 mm. The maximum (44.34 mm) girth of the rachis was recorded in ACC-20, which was followed by ACC-06 (37.74 mm), ACC-15 (32.57 mm) and so on. The minimum girth (18.42 mm) was recorded in ACC-12.

High genotypic and phenotypic co-efficient of variation was recorded i.e. 25.01 % and 28.06 %, respectively, and high heritability (79.43 %) with high genetic advance as per cent mean (45.93 %) was observed.

4.1.1.4.3 Length of rachis

For the rachis length, the genotype showed significant variations with a range of 34.22 to 51.30 cm. The maximum rachis length (51.30 cm) was observed in ACC-13, which was followed by ACC-15 (49.50 cm), ACC-01 (48.82 cm) and so on. The lowest rachis length (34.22 cm) was recorded in ACC-05.

Medium genotypic and phenotypic co-efficient of variation was recorded i.e. 12.20% and 14.17%, respectively, and high heritability (74.06%) with high genetic advance as per cent mean (21.62%) was observed.

4.1.1.4.4 Length of spike

The genotypes under study were varying significantly with respect to the spike length. The range of the spike length recorded was from 57.60 to 89.07 cm. The maximum spike length (89.07 cm) was recorded in ACC-19, which was followed by ACC-13 (86.94 cm), ACC-15 (84.13 cm) and so on. The minimum (57.60 cm) length of the spike was recorded in ACC-05.

Medium genotypic and phenotypic co-efficient of variation was recorded i.e. 12.43% and 13.24%, respectively, and high heritability (88.01%) with high genetic advance as per cent mean (24.01%) was observed.

4.1.1.4.5 Average weight of spike

Significant differences were found among the genotypes with respect to the weight of spike. The data revealed a range of 70.63 to 138.45 g of the spike weight. The maximum spike weight (138.45 g) was recorded in ACC-13, which was followed by ACC-11 (132.68 g), ACC-15 (132.63 g) and so on. The lowest weight of the spike was 70.63 g recorded by ACC-05.

Medium genotypic and phenotypic co-efficient of variation was recorded i.e. 18.84% and 19.08%, respectively, and high heritability (97.46%) with high genetic advance as per cent mean (38.31%) was observed.

Table 10. Mean performance of twenty genotypes of gladiolus for yield characters

Accession No.	Rachis length (cm)			Spike length (cm)			Spike weight (g)			Field life (days)		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	48.84	48.80	48.82	69.46	71.26	70.36	102.00	100.93	101.47	6.30	6.70	6.50
ACC-02	41.12	41.27	41.20	58.20	61.25	59.72	82.55	83.17	82.86	6.05	7.20	6.63
ACC-03	39.43	41.06	40.25	73.85	75.05	74.45	99.05	106.27	102.66	5.95	6.34	6.15
ACC-04	39.54	41.36	40.45	65.75	66.80	66.28	120.21	128.97	124.59	7.00	7.65	7.33
ACC-05	33.87	34.56	34.22	57.02	58.18	57.60	69.85	71.41	70.63	5.43	5.66	5.55
ACC-06	47.05	48.55	47.80	73.46	75.29	74.38	131.45	133.81	132.63	7.10	7.78	7.44
ACC-07	40.86	41.77	41.32	82.25	80.91	81.58	84.05	85.23	84.64	5.55	6.05	5.80
ACC-08	35.88	37.43	36.66	69.83	68.45	69.14	127.85	131.63	129.74	6.00	5.51	5.76
ACC-09	34.20	35.02	34.61	64.25	65.40	64.83	121.55	123.21	122.38	6.45	7.10	6.78
ACC-10	44.87	46.21	45.54	77.27	79.90	78.59	129.54	128.14	128.84	6.11	6.51	6.31
ACC-11	43.77	44.97	44.37	77.90	79.10	78.50	131.66	133.69	132.68	7.00	7.30	7.15
ACC-12	50.26	51.84	51.05	63.07	64.19	63.63	87.28	85.75	86.52	7.66	7.00	7.33
ACC-13	50.90	51.70	51.30	85.90	87.98	86.94	137.25	139.65	138.45	7.33	7.92	7.63
ACC-14	42.55	44.56	43.56	64.95	66.47	65.71	88.55	90.46	89.51	6.35	6.95	6.65
ACC-15	49.10	49.90	49.50	83.55	84.70	84.13	131.45	133.81	132.63	7.58	8.25	7.91
ACC-16	37.85	39.14	38.50	83.31	84.95	84.13	121.55	123.33	122.44	6.24	6.93	6.59
ACC-17	47.11	48.43	47.77	73.85	74.79	74.32	99.25	97.87	98.56	6.25	6.48	6.37
ACC-18	47.88	48.68	48.28	84.25	86.00	85.13	126.75	126.90	126.83	6.55	7.21	6.88
ACC-19	36.75	37.65	37.20	88.50	89.63	89.07	128.54	130.31	129.43	7.60	7.99	7.80
ACC-20	37.05	38.07	37.56	70.05	68.57	69.31	97.45	99.45	98.45	6.00	6.66	6.33
CD at 5%	5.714	4.071	4.893	4.705	3.730	4.218	5.726	5.989	5.858	1.335	1.290	1.313
SE(d)	2.236	2.115	2.176	2.458	2.882	2.670	2.762	2.548	2.655	0.231	0.549	0.390
SE(m) ±	1.892	1.348	1.620	1.558	1.235	1.397	1.896	1.983	1.940	0.442	0.427	0.435
CV	6.781	7.883	7.332	4.345	4.562	4.454	3.112	3.052	3.082	10.212	11.113	10.663

(Year-1: 2011-12; Year-2: 2012-13)

4.1.1.4.6 Field life of spike

Genotypes differed significantly with respect to field life of spike days taken for spoilage of spike. The range recorded was from 5.55 to 7.91 days. Maximum field life (7.91 days) for spike was showed by ACC-15. The minimum field life for spike (5.55 days) was recorded by ACC-05.

Low genotypic and medium phenotypic co-efficient of variation was recorded i.e. 1.07% and 18.22%, respectively, and low heritability (0.66%) with low genetic advance as per cent mean (0.13%) was observed.

4.1.1.4.7 Number of corm per plant

Genotypes differed significantly with respect to the numbers of corm plant⁻¹. The range recorded was from 1.00 cm to 5.43 cm. The maximum corm number was recorded in ACC-04 (5.43), which was followed by genotypes ACC-10 (5.37), ACC-15 (4.55) and so on. The lowest corm number (1.00) was recorded in the genotypes ACC-07.

High genotypic and phenotypic co-efficient of variation was recorded i.e. 41.35% and 47.85%, respectively, and high heritability (74.75%) with high genetic advance as per cent mean (73.61%) was observed.

4.1.1.4.8 Size of corm (Diameter)

There were significant differences among the genotypes with respect to the diameter of corms. The diameter was in between range of 2.72 to 6.59 cm. The maximum (6.59 cm) diameter of corm was recorded in ACC-20, which was followed by ACC-01 (5.59 cm), ACC-18 (5.50 cm) and so on. The minimum diameter (2.72 cm) was recorded ACC-16.

Low genotypic and high phenotypic co-efficient of variation was recorded i.e. 7.96% and 29.94%, respectively, and low heritability (6.91%) with low genetic advance as per cent mean (4.36%) was observed.

4.1.1.4.9 Weight of corm per plant

The genotypes exhibited highly significant differences for the weight of corms plant⁻¹. The range was from 16.70 to 105.33 g. The highest corm weight was produced by ACC-04 (105.33 g), which was followed by ACC-01 (90.67 g), ACC-09 (86.73 g) and so on. The lowest weight (16.70 g) of the daughter corm was recorded in ACC-16.

High genotypic and phenotypic co-efficient of variation was recorded i.e. 69.19% and 69.71%, respectively, and high heritability (98.52%) with high genetic advance as per cent mean (141.47%) was observed.

4.1.1.4.10 Number of cormels per plant

There were significant differences among the genotypes with respect to this character. The range recorded was from 11.33 to 78.33 cormels. The maximum number of cormels plant⁻¹ (78.33) was produced by ACC-16, which was followed by genotypes ACC-08 (74.33), ACC-01 (70.67) and so on. The minimum number of cormels per plant was recorded (11.33) in ACC-05.

High genotypic and phenotypic co-efficient of variation was recorded i.e. 57.08% and 58.37%, respectively, and high heritability (95.60%) with high genetic advance as per cent mean (114.96%) was observed.

4.1.1.4.11 Size of cormel (Diameter)

There were significant differences among the genotypes tested with respect to diameter of cormels. The range was between 2.72 cm to 5.71 cm. The maximum cormel size was observed in ACC-01 (5.71 cm) which was followed by the ACC-04 and ACC-12 (5.48 and 5.41 cm, respectively). The minimum noticed in the ACC-16 (2.72 cm).

Medium genotypic and high phenotypic co-efficient of variation was recorded i.e. 10.04% and 21.80%, respectively, and low heritability (21.65%) with low genetic advance as per cent mean (9.53%) was observed.

4.1.1.4.12 Weight of cormel per plant

Significant differences were recorded with respect to average weight of the cormels and ranged from 17.40 to 99.14 g. ACC-08 was significantly superior over all other genotypes (99.14 g), which was followed by ACC-10 (81.62 g), ACC-11 (81.55 g) and least average corm weight (17.40 g) was produced by ACC-19.

High genotypic and phenotypic co-efficient of variation was recorded i.e. 47.55% and 48.45%, respectively, and high heritability (96.31%) with high genetic advance as per cent mean (96.12%) was observed.

Table 11. Mean performance of twenty genotypes of gladiolus for yield characters

Accession No.	Corms plant ⁻¹			Corm diameter (cm)			Corm weight plant ⁻¹ (g)		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	3.50	3.95	3.73	5.11	6.06	5.59	89.45	91.89	90.67
ACC-02	2.02	2.20	2.11	3.35	3.83	3.59	34.98	36.03	35.51
ACC-03	2.52	2.96	2.74	5.05	5.25	5.15	79.54	81.75	80.65
ACC-04	5.11	5.75	5.43	4.85	5.39	5.12	102.85	107.81	105.33
ACC-05	2.15	3.29	2.72	4.55	4.99	4.77	35.00	35.73	35.37
ACC-06	1.37	1.51	1.44	3.85	4.15	4.00	22.01	23.08	22.55
ACC-07	0.97	1.03	1.00	4.75	4.86	4.81	82.55	83.82	83.19
ACC-08	3.15	3.42	3.29	4.36	4.57	4.47	25.75	26.42	26.09
ACC-09	2.55	3.00	2.78	4.58	4.66	4.62	85.75	87.71	86.73
ACC-10	5.26	5.47	5.37	3.43	3.55	3.49	18.24	18.64	18.44
ACC-11	3.13	3.31	3.22	4.00	4.26	4.13	24.89	25.85	25.37
ACC-12	3.21	3.52	3.37	5.01	5.33	5.17	16.79	17.88	17.34
ACC-13	3.12	3.53	3.33	4.35	4.65	4.50	22.95	24.00	23.48
ACC-14	4.25	4.80	4.53	4.18	4.35	4.27	17.25	17.75	17.50
ACC-15	4.10	4.99	4.55	4.35	4.65	4.50	21.95	22.36	22.16
ACC-16	2.35	2.49	2.42	2.62	2.82	2.72	16.24	17.16	16.70
ACC-17	1.61	1.75	1.68	4.44	4.59	4.52	26.05	27.00	26.53
ACC-18	2.75	2.85	2.80	5.45	5.55	5.50	26.55	28.12	27.34
ACC-19	1.10	1.24	1.17	3.95	4.07	4.01	45.25	46.25	45.75
ACC-20	1.59	1.75	1.67	6.45	6.73	6.59	34.95	36.28	35.62
CD at 5%	1.344	1.314	1.329	1.660	1.362	1.511	5.996	6.350	6.173
SE(d)	0.445	0.328	0.387	0.325	0.812	0.569	2.118	2.895	2.507
SE(m) ±	0.451	0.441	0.446	0.557	0.457	0.507	2.012	2.131	2.072
CV	22.161	23.145	22.653	20.151	21.011	20.581	8.239	8.412	8.326

(Year-1: 2011-12; Year-2: 2012-13)

Table 12. Mean performance of twenty genotypes of gladiolus for yield characters

Accession No.	Cormels plant ⁻¹			Cormels diameter (cm)			Cormels weight plant ⁻¹ (g)		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	69.19	72.15	70.67	5.47	5.95	5.71	25.95	26.82	26.39
ACC-02	17.23	17.86	17.55	3.91	3.97	3.94	49.01	50.06	49.54
ACC-03	18.22	19.15	18.69	4.95	5.07	5.01	25.11	25.84	25.48
ACC-04	18.90	19.10	19.00	5.15	5.82	5.48	27.55	28.29	27.92
ACC-05	11.00	11.66	11.33	4.15	4.00	4.08	33.98	35.08	34.53
ACC-06	28.20	28.64	28.42	4.38	4.56	4.47	25.22	25.59	25.41
ACC-07	50.45	50.79	50.62	4.56	4.67	4.62	22.96	24.25	23.61
ACC-08	74.11	74.55	74.33	4.00	4.22	4.11	98.34	99.94	99.14
ACC-09	25.06	26.46	25.76	4.30	4.11	4.21	27.15	28.35	27.75
ACC-10	35.21	36.13	35.67	3.95	4.10	4.03	80.85	82.39	81.62
ACC-11	35.13	36.21	35.67	4.45	4.57	4.51	80.95	82.15	81.55
ACC-12	58.25	59.75	59.00	5.31	5.51	5.41	65.95	66.70	66.33
ACC-13	27.95	28.66	28.31	4.02	4.21	4.12	67.45	66.49	66.97
ACC-14	21.35	20.16	20.75	4.66	4.86	4.76	55.13	56.35	55.74
ACC-15	24.65	25.11	24.88	4.05	4.20	4.13	40.27	41.47	40.87
ACC-16	77.64	79.02	78.33	2.68	2.75	2.72	43.89	45.15	44.52
ACC-17	55.98	57.39	56.69	5.00	4.83	4.92	63.55	61.95	62.75
ACC-18	22.96	22.05	22.51	4.56	4.92	4.74	58.75	60.36	59.56
ACC-19	36.07	34.75	35.41	4.56	5.43	5.00	16.80	18.00	17.40
ACC-20	15.21	15.70	15.46	4.86	4.19	4.53	44.25	45.48	44.87
CD at 5%	7.632	6.941	7.287	0.828	1.023	0.926	7.701	7.469	7.585
SE(d)	3.532	3.167	3.350	0.532	0.448	0.490	3.537	3.689	3.613
SE(m) ±	2.543	2.313	2.428	0.276	0.341	0.309	2.566	2.489	2.528
CV	11.872	12.325	12.099	13.881	15.268	14.575	9.231	8.994	9.113

(Year-1: 2011-12; Year-2: 2012-13)

Table 13. Mean, range, variances, genotypic and phenotypic coefficient of variation, heritability and genetic advance for different traits (using pooled data)

Characters	Mean	Range	G.V.	P.V.	G.C.V. (%)	P.C.V. (%)	Heritability (%)	GAM (%)
Plant height	70.90	47.61	183.29	205.03	19.10	20.20	89.40	37.19
Leaves per plant	6.70	4.34	0.26	4.55	7.66	31.85	5.71	3.80
Leaves length	39.94	20.95	32.18	48.93	14.20	17.51	65.77	23.72
Days to spike initiation	66.59	22.34	24.67	39.02	7.46	9.38	63.22	12.22
Days to full emergence of spike	69.56	22.67	26.29	44.77	7.37	9.62	58.72	11.64
Days to bud separation	72.81	25.34	33.08	47.10	7.90	9.43	70.23	13.64
Days to show colour	75.59	24.68	33.45	51.26	7.65	9.47	65.26	12.73
Days to open floret	76.93	29.67	46.29	55.83	8.84	9.71	82.91	16.59
Days to flowering	79.82	21.99	32.35	47.08	7.13	8.60	68.71	12.17
Length of floret	9.09	4.19	0.17	4.77	4.50	24.03	3.56	1.74
Diameter of floret	9.07	9.90	3.42	9.25	20.38	33.52	36.97	25.53
Florets per spike	13.03	8.00	3.52	7.50	14.40	21.01	46.93	20.34
Flower stalk girth	25.70	25.99	41.32	52.02	25.01	28.06	79.43	45.93
Length of rachis	43.00	17.09	27.50	37.13	12.20	14.17	74.06	21.62
Length of spike	73.89	31.47	84.30	95.78	12.43	13.24	88.01	24.01
Weight of spike	111.80	67.82	443.60	455.17	18.84	19.08	97.46	38.31
Field life	6.75	2.86	0.01	1.51	1.07	18.22	0.66	0.13
Corms per plant	2.97	4.43	1.51	2.02	41.35	47.85	74.75	73.61
Corm diameter	4.58	3.86	0.13	1.88	7.96	29.94	6.91	4.36
Corm weight	42.12	88.63	849.07	861.84	69.19	69.71	98.52	141.47
Cormels per plant	36.45	67.01	432.86	452.76	57.08	58.37	95.60	114.96
Cormels diameter	4.53	2.99	0.21	0.97	10.04	21.80	21.65	9.53
Cormels weight	48.10	81.74	522.96	543.00	47.55	48.45	96.31	96.12

G.V.: Genotypic variance; P.V.: Phenotypic variance; GCV: Genotypic coefficient of variation; PCV: Phenotypic coefficient of variation; GAM: Genetic Advance as per cent mean

Plates 4. Gladiolus germplasm used in investigation



ACC-01



ACC-02



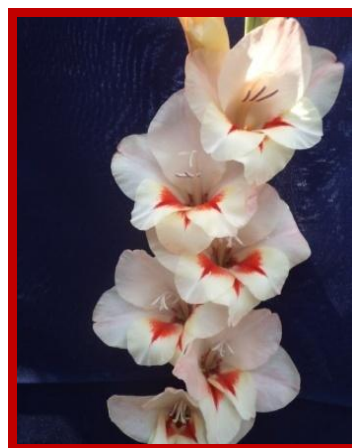
ACC-03



ACC-04



ACC-05



ACC-06



ACC-07



ACC-08



ACC-09



ACC-10



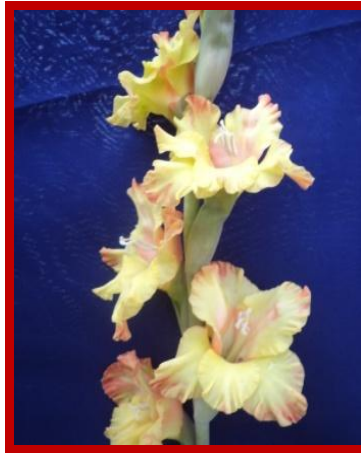
ACC-11



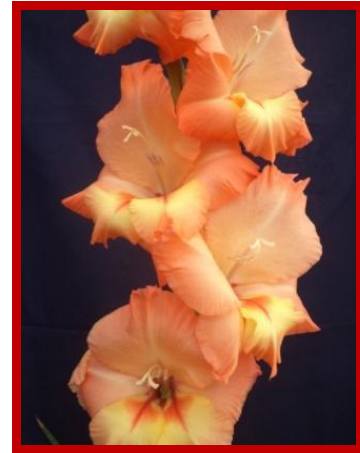
ACC-12



ACC-13



ACC-14



ACC-15



ACC-16



ACC-17



ACC-18



ACC-19



ACC-20

4.1.2 Correlation co-efficient

The genotypic and phenotypic correlation coefficients are presented in Table 14. Correlation studies were carried out to understand the intensity and direction of association among the eleven characters namely height of plant, number of leaves plant⁻¹, length of leaves, days to spikes initiation, days taken for showing colour, days taken for flowering, length of floret, number of florets spike⁻¹, length of the rachis, length of spike and weight of spike. The results are presented in different headings.

4.1.2.1 Genotypic and phenotypic correlations

In general, genotypic correlation coefficients were higher than the phenotypic correlation coefficients among the characters. This indicates the presence of inherent association between various characters.

4.1.2.1.1. Height of plant

The plant height had highly significant and positive correlation with number of leaves per plant (rg: 0.990; rp: 0.477), length of leaves (rg: 0.960; rp: 0.695), number of florets spike⁻¹ (rg: 0.480; rp: 0.346), length of spike (rg: 0.490; rp: 0.455) and weight of spike (rg: 0.690; rp: 0.643) both at genotypic and phenotypic level, respectively. It has shown strong positive and significant correlation with length of florets (rg: 0.340) at genotypic level. It had negative and significant correlation with days taken for spike initiation (rg: -0.590; rp: -0.437), days taken to show colour (rg: -0.610; rp: -0.489) and days taken for flowering (rg: -0.610; rp: -0.443) at both levels. This character exhibited non significant and positive association with length of rachis (rg: 0.160; rp: 0.110) at both level whereas, it is correlated negatively and non significantly with length of floret (rg: -0.033) at genotypic level.

4.1.2.1.2. Number of leaves per plant

The number of leaves plant⁻¹ was significant and positively correlated with length of leaves (rg: 0.980; rp: 0.373), length of spike (rg: 0.910; rp: 0.332) and weight of spike (rg: 0.910; rp: 0.319) both at genotypic and phenotypic level, respectively. It has shown strong positive and significant correlation with length of florets (rg: 0.610), number of florets spike⁻¹ (rg: -0.930) and length of rachis (rg: 0.560) at genotypic level. It is also associated negatively but significantly with days taken for spike initiation (rg: -0.860), days taken to show colour and (rg: -0.980), days taken for flowering (rg: -0.910) at genotypic level whereas, it correlated negatively and non significantly with days taken for spike initiation (rp: -0.231),

days taken to show colour (rp: -0.084), days taken for flowering (rp: -0.119) and length of florets (rp: -0.052) at phenotypic level. It had positive and non significant correlation with number of florets spike⁻¹ (rp: 0.139) and length of rachis (rp: 0.050) at phenotypic level.

4.1.2.1.3 Length of leaves

The length of leaves was significant and positively correlated with length of spike (rg: 0.650; rp: 0.465) and weight of spike (rg: 0.630; rp: 0.490) both at genotypic and phenotypic level, respectively. It has shown strong positive and significant correlation with number of florets spike⁻¹ (gp: 0.380) at genotypic level. It is also associated negatively but significantly with days taken to show colour (rg: -0.420; rp: -0.288), days taken for flowering (rg: -0.420; rp: -0.286) at both level. It has shown strong negative and significant correlation with days taken for spike initiation (rg: -0.470) at genotypic level whereas this character shown negative and non significant correlation with days taken for spike initiation (rp: -0.191) too at phenotypic level. It is also correlated non significantly with length of florets (rg: -0.220; rp: -0.057) in negative way and positively with length of rachis (rg: 0.250; rp: 0.267) at both level but the same character was positively and non significantly with length of florets (rp: 0.223) at phenotypic level.

4.1.2.1.4 Days to spikes initiation

The positive and significant correlation was observed in days to spikes initiation with days taken to show colour (rg: 0.930; rp: 0.776) and days taken for flowering (rg: 0.950; rp: 0.704) at both genotypic and phenotypic levels, respectively. It has negative and significant correlation with length of florets (rg: -0.910 rp: -0.277), length of spike (rg: -0.370; rp: -0.274) and weight of spike (rg: -0.500; rp: -0.403) at both genotypic and phenotypic level. It has shown strong negative and significant correlation with length of florets (rg: -0.280) at genotypic level. It had negative and non significant correlation with number of florets spike⁻¹ (rg: -0.240; rp: -0.096) at both level whereas it's negative and non significant correlation shown with length of rachis (rg: -0.106) at genotypic level.

Table 14. Estimates of genotypic correlation (r_g) and phenotypic correlation (r_p) among different characters in gladiolus (using pooled data)

		1	2	3	4	5	6	7	8	9	10	11
1	r_g	1.000	0.990**	0.960**	-0.590**	-0.610**	-0.610**	0.340*	0.480**	0.160	0.490**	0.690**
	r_p	1.000	0.477**	0.695**	-0.437**	-0.489**	-0.443**	0.033	0.346*	0.110	0.455**	0.643**
2	r_g		1.000	0.980**	-0.860**	-0.980**	-0.910**	0.610**	0.930**	0.560**	0.910**	0.910**
	r_p		1.000	0.373**	-0.231	-0.084	-0.119	-0.052	0.139	0.050	0.332*	0.319*
3	r_g			1.000	-0.470**	-0.420**	-0.420**	-0.220	0.380**	0.250	0.650**	0.630**
	r_p			1.000	-0.191	-0.288*	-0.286*	-0.057	0.223	0.267	0.465**	0.490**
4	r_g				1.000	0.930**	0.950**	-0.910**	-0.240	-0.280*	-0.370*	-0.500**
	r_p				1.000	0.776**	0.704**	-0.277*	-0.096	-0.106	-0.274*	-0.403**
5	r_g					1.000	0.970**	-0.990**	-0.340*	-0.270*	-0.430**	-0.560**
	r_p					1.000	0.742**	-0.161	-0.096	-0.247	-0.269*	-0.460**
6	r_g						1.000	-0.900**	-0.250	-0.210	-0.380**	-0.530**
	r_p						1.000	-0.281*	-0.184	-0.206	-0.262	-0.437**
7	r_g							1.000	-0.440**	-0.040	0.760*	0.880**
	r_p							1.000	0.079	0.099	0.099	0.158
8	r_g								1.000	0.250	0.190	0.470**
	r_p								1.000	0.241	0.125	0.294*
9	r_g									1.000	0.370**	0.210
	r_p									1.000	0.255	0.180
10	r_g										1.000	0.660**
	r_p										1.000	0.607**
11	r_g											1.000
	r_p											1.000

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

1. Plant height

2. Number of leaves plant⁻¹

3. Leaves length

4. Days to spike initiation

5. Days to show colour

6. Days to flowering

7. Length of floret

8. Number of florets spike⁻¹

9. Length of rachis

10. Length of spike

11. Weight of spike

4.1.2.1.5 Days to show colour

The duration required to show colour was significant and positively correlated with days taken for flowering (rg: 0.970; rp: 0.742) at both genotypic and phenotypic levels, respectively whereas it is also associated negatively and significantly with length of spike (rg: -0.430; rp: -0.269) and weight of spike (rg: -0.560; rp: -0.460) at both level. It is correlated negatively and significantly with length of florets (rg: -0.990), number of florets spike⁻¹ (rg: -0.340) and length of rachis (rg: -0.270) at phenotypic level but this same characters also shown non significant and negative correlation with length of florets (rp: -0.161), number of florets spike⁻¹ (rp: -0.096) and with length of rachis (rp: -0.247) at phenotypic level.

4.1.2.1.6 Days to flowering

The negative and significant correlation was observed in days to flowering with length of florets (rg: -0.900; rp: -0.281) and weight of spike (rg: -0.530; rp: -0.437) at both genotypic and phenotypic levels, respectively. The floret length showed negative and highly significant correlation with length of spike (rg: -0.380) at genotypic level whereas negative and non significant correlation with length of spike (rp: -0.262) at phenotypic level. It has negative and non significant correlation with number of florets spike⁻¹ (rg: -0.250; rp: -0.184) and length of rachis (rg: -0.210; rp: -0.206) at both genotypic and phenotypic level.

4.1.2.1.7 Floret length

The positive and significant correlation was observed in length of floret with length of spike (rg: 0.760) and weight of spike (rg: 0.880) at genotypic level only. It is correlated negatively and significantly with number of florets spike⁻¹ (rg: -0.440) at genotypic level. It's negative and non significant correlation was observed with length of rachis (rg: -0.040) at genotypic level whereas at phenotypic level, it's negative and non significant correlation was observed with number of florets spike⁻¹ (rp: 0.079), length of rachis (rp: 0.099), length of spike (rp: 0.099) and weight of spike (rp: 0.158).

4.1.2.1.8 Number of florets per spike

Number of florets spike⁻¹ was significant and positively correlated with weight of spike (rg: 0.470; rp: 0.294) at both genotypic and phenotypic levels, respectively. It has positive and non significant correlation with length of rachis (rg: 0.250; rp: 0.241) and length of spike (rg: 0.190; rp: 0.125) at both level.

4.1.2.1.9 Rachis length

The spike rachis length was found positive and highly significant correlation with length of spike (rg: 0.370) at genotypic level only whereas it's positive and non significant correlation showed with length of spike (rp: 0.255) at phenotypic level. It had positive and non significant correlation with weight of spike (rg: 0.210; rp: 0.180) at both genotypic and phenotypic levels, respectively.

4.1.2.1.10 Length of spike

Spike length was significant and positively correlated with weight of spike (rg: 0.660; rp: 0.607) at both genotypic and phenotypic levels, respectively.

4.1.3 Path coefficient analysis

The correlation coefficients only indicate the relationship of independent variable with the dependent variable without specifying cause and effect relationship. Using Path coefficient analysis, it is possible to resolve the correlations, which will provide direct and indirect contribution of different quantitative traits. The analysis was done for weight of spike as yield, which is dependent variable. Phenotypic paths for the dependent variable were computed. The phenotypic path coefficients are presented in Table 15.

4.1.3.1 Genotypic path coefficient analysis for weight of spike

The path analysis of spike yield (average spike weight plant⁻¹ in g) was done with eleven independent character involving growth, flowering and yield characters.

4.1.3.1.1 Plant of height

Plant height showed positive direct effects (1.347) towards yield of spike, further it was recorded positive indirect effect towards number of leaves plant⁻¹ (0.006), days taken to show colour (0.142), length of floret (0.045), number of florets spike⁻¹ (0.072), length of rachis (0.012) and length of spike (0.265). However, it recorded negative indirect effect with length of leaves (-0.891), days taken for spike initiation (-0.266) and days taken for flowering (-0.042).

4.1.3.1.2 Number of leaves per plant

Number of leaves plant⁻¹ showed negative direct effects (-0.003) towards yield of spike, further, it was recorded positive indirect effect with plant height (2.911), days taken to show colour (0.324), length of floret (0.08), number of florets spike⁻¹ (0.17), length of rachis

(0.04) and length of spike (0.656)., however, it recorded negative indirect effect with length of leaves (-2.302), days taken for spike initiation (-0.386) and days taken for flowering (-0.083).

4.1.3.1.3 Length of leaves

Average length of leaves showed negative direct effects (-0.929) towards yield of spike, while it was recorded positive indirect effect with plant height (1.293), number of leaves plant⁻¹ (0.007), days taken to show colour (0.099), number of florets spike⁻¹ (0.058), length of rachis (0.018) and length of spike (0.354). However, it recorded negative indirect effect with days taken for spike initiation (-0.21), days taken for flowering (-0.029), length of floret (-0.029).

4.1.3.1.4 Days taken for spike initiation

The days to spike initiation showed positive direct effects (0.449) towards yield of spike, further it was also recorded positive indirect effect with length of leaves (0.434) and days taken for flowering (0.08). However, it recorded negative indirect effect with plant height (-0.799), number of leaves plant⁻¹ (-0.002), days taken to show colour (-0.264), length of floret (-0.144), number of florets spike⁻¹ (-0.036), length of rachis (-0.02), length of spike (-0.202).

4.1.3.1.5 Days taken for first floret to show colour

Days taken to show first colour produced negative direct effects (-0.234) towards yield of spike, further it was also recorded positive indirect effects with length of leaves (0.393), days taken for spike initiation (0.506), days taken for flowering (0.081). However, it recorded negative indirect effect with plant height (-0.819), number of leaves plant⁻¹ (-0.004), length of floret (-0.176), number of florets spike⁻¹ (-0.051), length of rachis (-0.019), length of spike (-0.233).

4.1.3.1.6 Days taken for flowering

Days taken to flowering showed positive direct effects (0.069) towards yield of spike, further it was also recorded positive indirect effect with length of leaves (0.393) and days taken for spike initiation (0.518). However, it recorded negative indirect effect with plant height (-0.817), number of leaves plant⁻¹ (-0.003), days taken to show colour (-0.273), length

of floret (-0.157), number of florets spike⁻¹ (-0.038), length of rachis (-0.015) and length of spike (-0.207).

4.1.3.1.7 Length of floret

The length of floret showed positive direct effects (0.130) towards yield of spike, further it was also recorded positive indirect effect with plant height (0.462), number of leaves plant⁻¹ (0.002), length of leaves (0.205), days taken to show colour (0.317) and length of spike (0.41). However, it recorded negative indirect effect with days taken for spike initiation (-0.497), days taken for flowering (-0.083), number of florets spike⁻¹ (-0.066), length of rachis (-0.003).

4.1.3.1.8 Number of florets per spike

Number of florets spike⁻¹ showed positive direct effects (0.151) towards yield of spike, further it was also recorded positive indirect effect with plant height (0.646), number of leaves plant⁻¹ (0.003), days taken to show colour (0.079), length of rachis (0.018) and length of spike (0.103). However, it recorded negative indirect effect with length of leaves (-0.356), days taken for spike initiation (-0.106), days taken for flowering (-0.017), length of floret (-0.057).

4.1.3.1.9 Length of rachis

Length of rachis showed positive direct effects (0.072) towards yield of spike, further it was also recorded positive indirect effect with plant height (0.215), number of leaves plant⁻¹ (0.002), days taken to show colour (0.062), number of florets spike⁻¹ (0.038) and length of spike (0.199). However, it recorded negative indirect effect with length of leaves (-0.236), days taken for spike initiation (-0.124), days taken for flowering (-0.015), length of floret (-0.005).

4.1.3.1.10 Length of spike

Length of spike showed positive direct effects (0.543) towards yield of spike, further it was also recorded positive indirect effect with plant height (0.657), number of leaves plant⁻¹ (0.003), days taken to show colour (0.1), length of floret (0.098), number of florets spike⁻¹ (0.029), length of rachis (0.026). However, it recorded negative indirect effect with length of leaves (-0.605), days taken for spike initiation (-0.167), days taken for flowering (-0.026).

Table 15. Direct (diagonal) and indirect effects of different traits on spike weight (using pooled data)

	1	2	3	4	5	6	7	8	9	10	Correlation with Y
1	1.347	0.006	-0.891	-0.266	0.142	-0.042	0.045	0.072	0.012	0.265	0.643**
2	2.911	-0.003	-2.302	-0.386	0.324	-0.083	0.08	0.17	0.04	0.656	0.319*
3	1.293	0.007	-0.929	-0.21	0.099	-0.029	-0.029	0.058	0.018	0.354	0.490**
4	-0.799	-0.002	0.434	0.449	-0.264	0.08	-0.144	-0.036	-0.02	-0.202	-0.403**
5	-0.819	-0.004	0.393	0.506	-0.234	0.081	-0.176	-0.051	-0.019	-0.233	-0.460**
6	-0.817	-0.003	0.393	0.518	-0.273	0.069	-0.157	-0.038	-0.015	-0.207	-0.437**
7	0.462	0.002	0.205	-0.497	0.317	-0.083	0.130	-0.066	-0.003	0.41	0.158
8	0.646	0.003	-0.356	-0.106	0.079	-0.017	-0.057	0.151	0.018	0.103	0.294*
9	0.215	0.002	-0.236	-0.124	0.062	-0.015	-0.005	0.038	0.072	0.199	0.180
10	0.657	0.003	-0.605	-0.167	0.1	-0.026	0.098	0.029	0.026	0.543	0.607**

Residual value: 0.48002

1. Plant height

2. Number of leaves plant⁻¹

3. Leaves length

4. Days to spike initiation

5. Days to show colour

6. Days to flowering

7. Length of floret

8. Number of florets spike⁻¹

9. Length of rachis

10. Length of spike

11. Weight of spike

Experiment -II

4.2 Studies on seed setting in cross combinations and the combining ability of seed characters

The reproductive parameters of crosses considered were days to capsule set, days to capsule maturity, length of capsule, weight of dry capsule, capsule set percentage, harvest percentage of capsule, number of seeds capsule⁻¹ and weight of 100 seeds. The data recorded of these reproductive parameters were taken considering the date of pollination among the different genotypes and presented in table 16 to 20.

4.2.1 Seed setting in cross combinations of gladiolus genotypes

4.2.1.1 Seed setting in cross combinations of twenty gladiolus genotypes

4.2.1.1.1 Capsule set percentage

Genotypes differed significantly with respect to setting percentage of capsule. The range recorded was from 13.01 to 97.08%. Maximum percentage (97.08%) for capsule setting was showed by ACC-15, which was followed by ACC-14 (95.06%), ACC-11 (85.00%) and so on. The minimum percentage of capsule (13.01%) was produced by ACC-02, which was followed by ACC-10 (15.25%), ACC-12 (47.03%) and so on.

4.2.1.1.2 Capsule harvest percentage

Genotypes differed significantly with respect to harvest percentage of capsule. The range recorded was from 16.99 to 90.06%. Maximum harvest percentage was showed by ACC-15 (90.06%), which was followed by ACC-14 (80.01%), ACC-04 (69.94%) and so. The minimum percentage of capsule (16.99%) was harvest was from ACC-17.

4.2.1.1.3 Number of seeds per capsule

Significant differences were found among the genotypes with respect to average number of seeds capsule⁻¹. The data revealed a range of 7.58 to 61.74 of seed number. The maximum seed number (61.74) was recorded in ACC-04, which was followed by ACC-15 (60.53), ACC-11 (60.41) and so on. The lowest number of the seed (7.58) was recorded by ACC-01 which was followed by ACC-17 (7.87), ACC-19 (8.33) and so on.

Table 16. Seed setting in cross combinations of twenty gladiolus genotypes

Accession No.	Capsule set percent			Capsule harvest percent			Seed capsule ⁻¹		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
ACC-01	49.51	50.45	49.98	29.98	30.00	29.99	7.27	7.89	7.58
ACC-02	12.51	13.50	13.01	**	**	**	**	**	**
ACC-03	72.50	71.68	72.09	29.85	30.50	30.18	19.90	20.96	20.43
ACC-04	83.50	84.55	84.03	69.88	70.00	69.94	60.85	62.62	61.74
ACC-05	--	--	--	--	--	--	--	--	--
ACC-06	--	--	--	--	--	--	--	--	--
ACC-07	--	--	--	--	--	--	--	--	--
ACC-08	70.80	71.50	71.15	25.95	26.00	25.98	21.05	21.48	21.27
ACC-09	83.75	84.50	84.13	41.50	42.55	42.03	21.00	21.66	21.33
ACC-10	14.55	15.95	15.25	**	**	**	**	**	**
ACC-11	84.45	85.55	85.00	61.50	62.75	62.13	59.81	61.00	60.41
ACC-12	46.75	47.30	47.03	27.14	27.86	27.50	23.45	24.72	24.09
ACC-13	86.44	87.55	87.00	56.55	57.50	57.03	30.54	32.12	31.33
ACC-14	95.21	94.90	95.06	78.75	81.45	80.10	23.85	24.29	24.07
ACC-15	96.50	97.65	97.08	89.52	90.60	90.06	60.35	60.71	60.53
ACC-16	61.40	62.86	62.13	48.37	51.63	50.00	15.87	16.30	16.09
ACC-17	82.22	83.77	83.00	16.48	17.50	16.99	7.57	8.17	7.87
ACC-18	49.25	50.95	50.10	**	**	**	**	**	**
ACC-19	50.38	51.62	51.00	24.73	25.26	25.00	8.00	8.66	8.33
ACC-20	58.95	61.50	60.23	44.67	45.35	45.01	20.14	20.82	20.48
SE(m) ±	2.221	2.321	2.271	1.131	1.053	1.092	0.881	0.983	0.932
CD at 5%	6.685	6.986	6.836	3.404	3.170	3.287	2.652	2.959	2.806

(Year-1: 2011-12; Year-2: 2012-13) [-genotypes failed to produce capsule and *stating that capsule developed aborted (without seed)]

4.2.1.2 Seed setting in cross combinations of five gladiolus genotypes

4.2.1.2.1 Days taken for capsule set

Data presented in Table 17 revealed that significant differences regarding the days required for setting of capsules among the crosses were observed and varied from 15.63 to 28.79 days. The maximum number of days for setting of capsule (28.79 days) was taken by the cross ACC-11×ACC-13, which was followed by the cross ACC-13×ACC-13 (28.04 days), ACC-13×ACC-15 (27.99 days), ACC-04×ACC-13 (27.35 days) and so on. The least days for setting of capsule were recorded in cross ACC-11×ACC-04 (15.63 days).

4.2.1.2.2 Days taken for capsule maturity

Significant differences regarding the days to capsule maturity were observed among the crosses and varied from 29.65 to 45.02 days. The cross ACC-13×ACC-13 took maximum days (45.02 days) to capsule maturity which was closely followed by crosses ACC-04×ACC-11 (44.00 days), ACC-11×ACC-13 (43.64 days), where as the cross ACC-11×ACC-04 took the minimum days (29.65 days) to attain the stage of maturity.

4.2.1.2.3 Length of capsule

Significant differences were observed among the genotypes with respect to average length of capsule. Crosses had displayed a range of differences among them in between 2.85 to 5.11 cm. The longest capsule was produced by the cross ACC-15×ACC-13 (5.11 cm) which was closely followed by the crosses ACC-15×ACC-11 (4.85 cm), ACC-15×ACC-15 (4.63 cm) and so on. The shortest capsule (2.85 cm) was recorded in cross ACC-13×ACC-15.

4.2.1.2.4 Weight of dried capsule

Crosses had displayed significant differences among them in respect of capsule weight. It ranges from 0.30 to 0.98 g. High capsule weight was recorded from the cross ACC-15×ACC-13 (0.98 g) which was closely followed by the crosses ACC-14×ACC-13 (0.95 g), ACC-11×ACC-11 (0.92 g) and so on. The lowest capsule weight was recorded from the cross ACC-04×ACC-15 (0.30 g).

4.2.1.2.5 Capsule set percentage

There significant differences were noticed among the crosses with respect to setting percentage of capsule. There had variation (25.00 to 99.26%) in setting of capsules among the crosses. The cross ACC-15×ACC-13 produced the maximum percentage of capsule (99.26%). Capsule percentage was found least in cross ACC-13×ACC-15 (25.00%).

4.2.1.2.6 Capsule harvest percentage

Significant differences regarding the harvest percentages of capsule were observed among the crosses and varied from 9.16 to 85.33%. The maximum percentage of capsule harvest was from two crosses ACC-14×ACC-13 (85.33 %) which was followed by crosses ACC-13×ACC-13 (75.11%), ACC-13×ACC-14 (71.29%) and so on. The minimum percentage of capsules was produced by cross ACC-04×ACC-13 (9.16%).

4.2.1.2.7 Number of seeds per capsule

Significant differences regarding seed number capsule⁻¹ were noticed among the genotypes and varied from 7.33 to 71.00. The highest number of seed capsule⁻¹ was produced by the cross ACC-15×ACC-13 (71.00) which was followed by the cross ACC-04×ACC-13 and ACC-13×ACC-15 (68.67 and 68.67 respectively) and so on. The cross ACC-14×ACC-15 and ACC-04×ACC-04 produce the lowest number of seed capsule⁻¹ (7.33).

4.2.1.2.8 Weight of hundred seed

There were significant differences among the genotypes with respect to weight of seed (100 seeds in g). There had difference in weight of hundred seed among the crosses. The highest weight of hundred seed was produced by the cross ACC-15×ACC-14 (4.71 g) and which was followed by the crosses ACC-11×ACC-14 (4.20 g), ACC-13×ACC-13 (3.85 g) and so on. The lowest weight of hundred seed was produced by the cross ACC-13×ACC-04 (1.12 g) which was followed by crosses ACC-15×ACC-15 (1.21 g), ACC-04×ACC-13 (1.30 g) and so on.

Plates 5. Seeds and capsules of crossed genotypes



ACC-15 X ACC-13



ACC-15 X ACC-11



ACC-15 X ACC-14



ACC-15 X ACC-04



ACC-13 X ACC-15



ACC-13 X ACC-11



ACC-13 X ACC-14



ACC-13 X ACC-04



ACC-11 X ACC-15



ACC-11 X ACC-13



ACC-11 X ACC-14



ACC-11 X ACC-04



ACC-14 X ACC-15



ACC-14 X ACC-13



ACC-14 X ACC-11



ACC-14 X ACC-04



ACC-04 X ACC-15



ACC-04 X ACC-13



ACC-04 X ACC-11



ACC-04 X ACC-14

Table 17: Seed setting in cross combinations of five gladiolus genotypes through full diallel

Crosses		Days to capsule set			Days to capsule maturity			Capsule length (cm)			Dry capsule weight (g)		
		Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
1	ACC-15 x ACC-15	22.35	23.78	23.07	37.68	40.35	39.02	4.50	4.76	4.63	0.79	0.84	0.82
2	ACC-15 x ACC-13	21.35	23.63	22.49	34.00	36.30	35.15	5.03	5.18	5.11	0.96	0.99	0.98
3	ACC-15 x ACC-11	21.66	24.47	23.07	36.63	39.44	38.04	4.75	4.94	4.85	0.56	0.61	0.59
4	ACC-15 x ACC-14	18.65	22.65	20.65	28.54	32.23	30.39	3.76	3.88	3.82	0.50	0.54	0.52
5	ACC-15 x ACC-04	25.29	27.13	26.21	40.66	42.62	41.64	3.55	3.49	3.52	0.30	0.34	0.32
6	ACC-13 x ACC-15	26.95	29.03	27.99	40.22	42.49	41.36	2.92	2.78	2.85	0.86	0.90	0.88
7	ACC-13 x ACC-13	27.04	29.04	28.04	43.26	46.77	45.02	4.25	4.11	4.18	0.81	0.77	0.79
8	ACC-13 x ACC-11	21.58	23.71	22.65	38.32	40.98	39.65	3.58	3.71	3.65	0.55	0.59	0.57
9	ACC-13 x ACC-14	20.33	22.65	21.49	34.25	38.08	36.17	3.47	3.59	3.53	0.46	0.49	0.48
10	ACC-13 x ACC-04	26.30	24.11	25.21	38.43	42.15	40.29	4.38	4.47	4.43	0.46	0.42	0.44
11	ACC-11 x ACC-15	24.22	26.42	25.32	41.55	43.75	42.65	4.10	4.30	4.20	0.70	0.73	0.52
12	ACC-11 x ACC-13	27.82	29.76	28.79	42.76	44.52	43.64	3.83	4.10	3.97	0.59	0.63	0.61
13	ACC-11 x ACC-11	23.85	25.84	24.85	36.54	37.46	37.00	3.06	3.16	3.11	0.90	0.94	0.92
14	ACC-11 x ACC-14	20.76	20.25	20.51	36.20	39.84	38.02	4.36	4.49	4.43	0.68	0.75	0.72
15	ACC-11 x ACC-04	14.47	16.78	15.63	27.65	31.65	29.65	3.72	3.95	3.84	0.80	0.76	0.78
16	ACC-14 x ACC-15	23.04	25.04	24.04	40.38	38.00	39.19	3.59	3.79	3.69	0.44	0.40	0.42
17	ACC-14 x ACC-13	19.65	21.77	20.71	30.25	33.75	32.00	3.77	3.88	3.83	0.92	0.98	0.95
18	ACC-14 x ACC-11	19.55	22.59	21.07	34.55	38.74	36.65	4.16	4.32	4.24	0.81	0.77	0.79
19	ACC-14 x ACC-14	21.54	19.32	20.43	38.90	41.14	40.02	3.59	3.70	3.65	0.52	0.56	0.54
20	ACC-14 x ACC-04	24.66	26.03	25.35	39.50	40.50	40.00	3.12	3.19	3.16	0.42	0.47	0.45
21	ACC-04 x ACC-15	24.66	25.54	25.10	39.65	41.65	40.65	3.14	3.21	3.18	0.27	0.33	0.30
22	ACC-04 x ACC-13	26.65	28.05	27.35	39.55	42.78	41.17	3.88	3.94	3.91	0.62	0.66	0.64
23	ACC-04 x ACC-11	25.41	27.84	26.63	42.50	45.50	44.00	4.45	4.65	4.55	0.65	0.68	0.67
24	ACC-04 x ACC-14	26.75	27.33	27.04	36.25	38.33	37.29	3.39	3.51	3.45	0.53	0.55	0.54
25	ACC-04 x ACC-04	23.01	25.01	24.01	37.75	40.30	39.03	3.88	4.08	3.98	0.31	0.34	0.33
SE(m) ±		2.549	2.328	2.439	2.548	2.458	2.503	1.115	1.162	1.139	0.055	0.065	0.060
CD at 5%		7.622	6.961	7.292	7.619	7.349	7.484	3.334	3.474	3.404	0.164	0.194	0.179

(Year-1: 2012-13; Year-2: 2013-14)

Table 18: Seed setting in cross combinations of five gladiolus genotypes through full diallele

Crosses		Capsule set percent			Capsule harvest percent			Seed capsule ⁻¹			Hundred seed weight (g)		
		Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
1	ACC-15 x ACC-15	56.33	58.94	57.64	49.18	51.00	50.08	45.27	48.08	46.67	1.25	1.17	1.21
2	ACC-15 x ACC-13	97.34	101.18	99.26	49.00	51.20	50.10	70.00	72.00	71.00	1.72	1.29	1.51
3	ACC-15 x ACC-11	74.35	76.32	75.33	44.50	48.50	46.50	54.00	56.00	55.00	2.50	3.00	2.75
4	ACC-15 x ACC-14	82.37	85.21	83.79	62.22	64.00	62.22	29.04	33.62	31.33	4.57	4.85	4.71
5	ACC-15 x ACC-04	92.55	97.73	95.14	49.21	51.10	50.16	22.30	18.35	20.33	2.80	2.12	2.46
6	ACC-13 x ACC-15	24.33	25.67	25.00	8.96	9.89	9.43	66.34	71.00	68.67	1.65	1.72	1.69
7	ACC-13 x ACC-13	83.06	85.78	84.42	73.00	77.21	75.11	45.71	47.63	46.67	3.78	3.91	3.85
8	ACC-13 x ACC-11	97.59	94.79	96.19	61.10	63.23	62.17	24.00	26.00	25.00	3.00	3.22	3.11
9	ACC-13 x ACC-14	86.33	87.67	87.00	69.73	72.85	71.29	30.18	38.47	34.33	2.65	2.93	2.79
10	ACC-13 x ACC-04	96.46	98.59	97.53	53.11	47.54	50.33	20.10	23.24	21.67	1.22	1.01	1.12
11	ACC-11 x ACC-15	93.35	96.11	94.73	46.33	53.67	50.00	21.57	24.42	23.00	2.85	3.79	3.32
12	ACC-11 x ACC-13	45.87	48.98	47.43	35.73	38.26	37.00	23.12	25.54	24.33	2.82	2.55	2.68
13	ACC-11 x ACC-11	59.33	64.67	62.00	59.35	63.47	61.41	58.29	63.05	60.67	1.82	1.50	1.66
14	ACC-11 x ACC-14	64.34	68.84	66.59	61.33	63.10	62.22	28.58	34.07	31.33	4.10	4.30	4.20
15	ACC-11 x ACC-04	91.45	95.21	93.33	36.00	38.44	37.22	33.57	37.77	35.67	1.34	1.50	1.42
16	ACC-14 x ACC-15	73.25	75.52	74.39	46.10	53.90	50.00	8.57	6.09	7.33	2.40	2.73	2.56
17	ACC-14 x ACC-13	86.67	87.33	87.00	84.35	86.31	85.33	51.40	56.60	54.00	1.85	1.52	1.68
18	ACC-14 x ACC-11	41.65	43.89	42.77	34.71	39.67	37.19	7.00	9.00	8.00	1.16	1.90	1.53
19	ACC-14 x ACC-14	93.31	97.45	95.38	46.80	53.85	50.33	18.60	22.06	20.33	2.15	2.00	2.07
20	ACC-14 x ACC-04	50.76	52.29	51.53	46.67	53.33	50.00	15.07	17.17	16.12	1.73	1.84	1.79
21	ACC-04 x ACC-15	95.91	98.12	97.02	48.20	52.32	50.26	22.00	21.33	21.67	1.40	1.21	1.31
22	ACC-04 x ACC-13	23.00	27.66	25.33	9.19	9.13	9.16	67.92	69.42	68.67	1.29	1.30	1.30
23	ACC-04 x ACC-11	48.66	46.53	47.60	36.07	38.09	37.08	21.57	27.09	24.33	2.94	1.95	2.45
24	ACC-04 x ACC-14	59.67	65.14	62.40	60.22	62.06	61.14	62.17	59.16	60.67	1.57	1.62	1.60
25	ACC-04 x ACC-04	73.25	75.50	74.38	47.13	53.33	50.23	9.55	5.10	7.33	2.00	2.63	2.32
SE(m) ±		2.441	2.897	2.669	3.896	3.573	3.735	2.040	2.073	2.057	1.563	1.682	1.623
CD at 5%		7.320	8.687	8.004	11.683	10.714	11.199	6.117	6.216	6.167	4.687	5.044	4.866

(Year-1: 2012-13; Year-2: 2013-14)

4.2.1.2.9 Days taken for germination

It is evident from the data presented in Table-19 that genotypes showed significant differences with respect to days required for germination. Among these genotypes, significantly maximum number of days for germination (35.81 days) was recorded in genotype ‘ACC-11×ACC-15’ which was followed by genotypes ‘ACC-11×ACC-04’ (32.59 days), ‘ACC-13×ACC-11’ (30.27 days) and so on. The genotype ‘ACC-14×ACC-04’ took least (20.41 days) for germination among the different genotypes.

4.2.1.2.10 Germination percentage

All genotypes significantly influenced the germination percentage and showed significant differences in germination percentage of different genotype’s seeds. Data revealed that the maximum germination percentage (75.88%) was recorded in genotype ‘ACC-04×ACC-14’ which was followed by genotypes ‘ACC-11×ACC-11’ (75.50 %), ‘ACC-04×ACC-04’ and ‘ACC-11×ACC-11’ (75.00% and 75.00%, respectively), and so on. The minimum percentage of germination was recorded in genotype ‘ACC-11×ACC-14’ (18.06 %).

4.2.1.2.11 Germination speed

Significant differences were recorded with respect to germination speed. It ranged from 0.65 to 3.34. The genotype ‘ACC-04×ACC-04’ was superior over all other genotypes (3.34) which were followed by genotypes ‘ACC-04×ACC-14’ (3.20), ‘ACC-11×ACC-11’ (2.78) and so on. The least value of germination speed (0.65) was recorded in the genotypes ‘ACC-11×ACC-14’.

4.2.1.2.12 Seedling vigour index

The seedling vigour among the genotypes differed significantly as in Table 20. There were significant differences with respect to vigour index of seedling and value was ranges 132.04 to 684.72. The maximum value of vigour index (684.72) was recorded in the genotypes ‘ACC-04×ACC-14’, which was followed by the genotypes ‘ACC-04×ACC-04’ (663.50), ‘ACC-15×ACC-13’ (516.32) and so on. The minimum vigour index (132.04) was recorded in the genotypes ‘ACC-11×ACC-14’.

Table 19: Averages of parents and progeny for measured characteristics of gladiolus

Crosses		Days to germination			Germination percent			Germination speed		
		Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
1	ACC-15 x ACC-15	18.28	22.97	20.62	32.56	34.20	33.38	1.57	1.65	1.61
2	ACC-15 x ACC-13	25.94	28.00	24.97	59.74	61.73	60.74	2.38	2.50	2.44
3	ACC-15 x ACC-11	22.10	24.10	23.10	56.75	53.37	55.06	2.38	2.32	2.35
4	ACC-15 x ACC-14	22.40	22.93	22.67	30.55	32.11	31.33	1.42	1.34	1.38
5	ACC-15 x ACC-04	28.23	31.62	29.93	26.17	28.02	27.10	0.91	0.95	0.93
6	ACC-13 x ACC-15	25.50	26.46	25.98	39.53	42.55	41.04	1.60	1.65	1.63
7	ACC-13 x ACC-13	19.47	21.87	20.67	34.86	36.10	35.48	1.65	1.69	1.67
8	ACC-13 x ACC-11	29.27	31.27	30.27	44.19	46.35	45.27	1.47	1.50	1.49
9	ACC-13 x ACC-14	19.91	23.90	21.91	22.15	24.13	23.14	1.06	1.10	1.08
10	ACC-13 x ACC-04	25.00	23.00	24.00	31.44	34.88	33.16	1.37	1.33	1.35
11	ACC-11 x ACC-15	36.81	34.80	35.81	29.65	31.21	30.43	0.78	0.82	0.80
12	ACC-11 x ACC-13	24.42	24.41	24.42	42.15	44.85	43.50	1.68	1.72	1.70
13	ACC-11 x ACC-11	27.09	25.81	26.45	74.50	76.50	75.50	2.75	2.80	2.78
14	ACC-11 x ACC-14	25.54	27.42	26.48	17.50	18.62	18.06	0.63	0.66	0.65
15	ACC-11 x ACC-04	34.59	30.59	32.59	24.75	25.95	25.35	0.72	0.76	0.74
16	ACC-14 x ACC-15	25.67	29.68	27.67	45.35	47.25	46.30	1.68	1.73	1.71
17	ACC-14 x ACC-13	23.33	27.32	25.33	34.56	36.35	35.46	1.57	1.61	1.59
18	ACC-14 x ACC-11	27.00	25.00	26.00	24.55	26.49	25.52	0.97	1.00	0.99
19	ACC-14 x ACC-14	30.00	26.00	28.00	26.57	28.68	27.63	0.94	0.92	0.93
20	ACC-14 x ACC-04	22.41	18.40	20.41	39.55	42.47	41.01	1.98	2.02	2.00
21	ACC-04 x ACC-15	25.67	25.67	25.67	30.00	32.00	31.00	1.27	1.31	1.29
22	ACC-04 x ACC-13	22.00	24.00	23.00	54.25	56.41	55.33	2.39	2.44	2.42
23	ACC-04 x ACC-11	19.44	21.50	20.47	40.25	42.53	41.39	2.02	2.14	2.08
24	ACC-04 x ACC-14	25.64	21.70	23.67	74.35	77.41	75.88	3.16	3.23	3.20
25	ACC-04 x ACC-04	21.35	23.31	22.33	73.95	76.05	75.00	3.31	3.37	3.34
SE(m) ±		1.238	1.785	1.512	2.328	2.237	2.283	0.231	0.208	0.220
CD at 5%		3.705	5.343	4.524	6.968	6.695	6.832	0.691	0.623	0.657

(Year-1: 2012-13; Year-2: 2013-14)

Table 20: Averages of parents and progeny for measured characteristics of gladiolus

Crosses		Seedling vigour index			Seedling length (cm)			Seedling weight (g)			Corm diameter (cm)		
		Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
1	ACC-15 x ACC-15	470.35	479.76	475.06	13.94	14.51	14.23	15.80	15.30	15.55	1.54	1.62	1.58
2	ACC-15 x ACC-13	512.79	519.85	516.32	8.53	8.47	8.50	15.80	16.16	15.98	1.59	1.63	1.61
3	ACC-15 x ACC-11	398.65	406.65	402.65	7.28	7.33	7.31	14.35	14.05	14.20	1.49	1.53	1.51
4	ACC-15 x ACC-14	196.35	200.48	198.42	6.55	6.10	6.33	11.63	11.02	11.33	1.06	1.10	1.08
5	ACC-15 x ACC-04	376.02	384.04	380.03	14.04	14.00	14.02	13.00	13.55	13.28	1.39	1.43	1.41
6	ACC-13 x ACC-15	361.75	400.09	363.92	8.82	8.92	8.87	13.00	13.45	13.23	1.38	1.34	1.36
7	ACC-13 x ACC-13	307.85	312.39	310.12	8.73	8.74	8.74	12.90	12.76	12.83	1.22	1.28	1.25
8	ACC-13 x ACC-11	428.06	434.12	431.09	9.41	9.63	9.52	14.00	14.35	14.18	1.48	1.46	1.47
9	ACC-13 x ACC-14	153.70	157.76	155.73	6.49	6.97	6.73	10.00	9.77	9.88	1.05	1.12	1.09
10	ACC-13 x ACC-04	317.26	321.55	319.41	9.25	10.00	9.63	12.80	12.74	12.77	1.21	1.26	1.24
11	ACC-11 x ACC-15	194.25	198.44	196.35	6.59	6.31	6.45	11.20	11.44	11.32	1.04	1.12	1.08
12	ACC-11 x ACC-13	448.32	445.10	446.71	10.54	10.00	10.27	15.22	15.63	15.43	1.47	1.57	1.52
13	ACC-11 x ACC-11	475.35	478.43	476.89	6.20	6.43	6.32	15.90	15.43	15.67	1.58	1.62	1.60
14	ACC-11 x ACC-14	131.04	133.04	132.04	7.61	7.00	7.31	9.93	9.82	9.87	0.99	1.03	1.01
15	ACC-11 x ACC-04	215.55	221.92	218.74	8.80	8.45	8.63	11.96	11.36	11.66	1.12	1.10	1.11
16	ACC-14 x ACC-15	280.75	290.95	285.85	6.18	6.16	6.17	12.28	12.90	12.59	1.13	1.17	1.15
17	ACC-14 x ACC-13	309.02	314.29	311.66	9.39	8.20	8.79	12.00	12.14	12.07	1.09	1.15	1.12
18	ACC-14 x ACC-11	157.53	164.36	160.95	6.50	6.12	6.31	9.83	10.00	9.92	0.97	1.08	1.03
19	ACC-14 x ACC-14	211.20	217.20	214.20	7.90	7.61	7.75	11.84	11.31	11.57	1.10	1.05	1.08
20	ACC-14 x ACC-04	350.25	360.25	355.25	8.60	8.72	8.66	12.71	13.00	12.86	1.29	1.36	1.33
21	ACC-04 x ACC-15	290.63	294.85	292.74	9.37	9.50	9.44	12.22	12.64	12.43	1.15	1.11	1.13
22	ACC-04 x ACC-13	453.95	455.36	454.66	8.33	8.10	8.22	14.90	14.22	14.56	1.50	1.53	1.52
23	ACC-04 x ACC-11	279.55	282.53	281.04	6.58	7.00	6.79	11.87	11.62	11.75	1.15	1.20	1.17
24	ACC-04 x ACC-14	681.85	687.59	684.72	9.02	9.02	9.02	17.63	18.02	17.83	1.69	1.72	1.71
25	ACC-04 x ACC-04	660.00	667.00	663.50	8.90	8.80	8.85	16.00	16.40	16.20	1.59	1.65	1.62
SE(m) ±		4.892	4.991	4.942	0.883	0.917	0.900	0.413	0.405	0.409	0.071	0.059	0.065
CD at 5%		14.676	14.973	14.825	2.649	2.751	2.700	1.239	1.215	1.227	0.213	0.177	0.195

(Year-1: 2012-13; Year-2: 2013-14)

4.2.1.2.13 Length of seedling

All genotypes significantly influenced the seedling length and showed significant differences in seedling length. It is revealed that the maximum length of seedling (14.23 cm) was recorded in genotypes 'ACC-15×ACC-15' which was followed by genotypes 'ACC-15×ACC-04' (14.02), 'ACC-11×ACC-13' (10.27 cm) and so on. The minimum was recorded in 'ACC-14×ACC-15' (6.17 cm).

4.2.1.2.14 Weight of seedling

All genotypes significantly influenced the weight of seedling and showed significant differences in weight of different genotype's seedling. Data revealed that the maximum weight of seedling (17.83 g) was recorded in genotype 'ACC-04×ACC-14' which was followed by genotypes 'ACC-04×ACC-04' (16.20 g), 'ACC-15×ACC-13' (15.98 g), 'ACC-11×ACC-11' (15.67 gm) and so on. The minimum weight of seedling was recorded in genotype 'ACC-11×ACC-14' (9.87 g).

4.2.1.2.15 Size of corm (Diameter)

It is evident from the data presented in Table-20 that genotypes showed significant differences with respect to diameter of corm. Among these genotypes, significantly maximum diameter of corm (1.71 cm) was recorded in genotype 'ACC-04×ACC-14' which was followed by genotypes 'ACC-04×ACC-04' (1.62 cm), 'ACC-15×ACC-13' (1.61 cm) and so on. The genotype 'ACC-11×ACC-14' produced least (1.01 cm) for diameter of cormel among the different genotypes.

4.2.2 Combining ability of seed characters

4.2.2.1 General and specific combining ability effects

It is an important indicator of the potential of parental lines for generating superior breeding populations. A small or negative combining ability effect indicates a poor ability to transfer its genetic superiority to hybrids (Cruz and Regazzi, 1994). The largest positive values have the largest effects. On the other hand, the largest negative values have the smallest effects (Tenkouano *et al.*, 1998).

In this study, the GCA: SCA ratio for each trait is listed in Table 21. A high ratio means that additive gene action is predominant.

4.2.2.1.1 Days taken for germination

ACC-15 and ACC-11 ranked first and second highest and were significantly different from all the other parents in GCA. ACC-04 ranked the lowest and also significantly lower than other parents.

In germination time, the largest positive SCA effect was in 'ACC-13×ACC-15' which was significantly different from other crosses, followed by 'ACC-15×ACC-11', 'ACC-11×ACC-14'. The largest different significant negative effect was measured for 'ACC-14×ACC-04'.

The GCA: SCA ratio was 0.55. It shows the SCA variance was higher than GCA variance.

4.2.2.1.2 Germination Percentage

The highest GCA for germination percent was measured for parent ACC-14 which was significantly higher than all the other parents. The largest negative effect was calculated for ACC-04, differing significantly from other parents.

The 'ACC-04×ACC-15' had the highest rank for SCA, which were significantly different from the other parents. 'ACC-13×ACC-14' had the largest significant different negative effect, followed by 'ACC-11×ACC-14'.

The ratio of GCA:SCA was 0.34, which indicated that a large part of total genetic variability in germination percent was the result of non-additive gene action.

4.2.2.1.3 Germination speed

ACC-15 and ACC-04 ranked first and second respectively and differ significantly from each other. The remaining parents ACC-13, ACC-11 and ACC-14 differ significantly from each other. The ACC-13 had the lowest negative value.

From the SCA data, 'ACC-13×ACC-14' had the highest value, and it was not significantly different from the other crosses. The largest negative effect was for 'ACC-15×ACC-04' and it was significantly lower than for other crosses.

A GCS: SCA ratio of 0.41 was calculated for the value of germination speed.

Table 21. GCA and SCA effects and their mean square ratio for measured characteristics in gladiolus (using pooled data)

GCA effects	Days to germination	Germination percent	Germination speed	Seedling vigour index	Seedling length (cm)	Seedling weight (g)	Cormel diameter (cm)
ACC-15	15.26	-1.98	17.19	8.26	3.95	-16.63	-24.52
ACC-13	-10.22	9.87	-9.31	-15.64	-0.45	4.66	-4.31
ACC-11	15.08	-8.29	-7.41	44.85	2.69	-8.50	14.09
ACC-14	8.73	11.43	-2.82	-30.11	9.08	16.32	-5.21
ACC-04	-28.85	-11.03	2.36	-7.36	-15.28	4.16	19.95
LSD(0.01)	0.798	0.933	0.905	0.377	0.893	0.818	0.931
SCA effects							
ACC-15 x ACC-15	15.26	-1.98	17.19	8.26	3.95	-16.63	-24.52
ACC-15 x ACC-13	2.34	-30.61	-7.97	74.94	-25.12	-5.60	43.74
ACC-15 x ACC-11	80.79	6.23	-70.31	87.32	48.37	-31.01	-82.31
ACC-15 x ACC-14	-9.51	59.69	1.33	-73.99	11.29	0.26	3.55
ACC-15 x ACC-04	-2.86	-14.28	-70.26	-4.90	26.47	15.11	5.85
ACC-13 x ACC-15	91.39	-14.23	-45.68	21.67	-1.52	-25.43	-8.13
ACC-13 x ACC-13	-10.22	9.87	-9.31	-15.64	-0.45	4.66	-4.31
ACC-13 x ACC-11	-7.62	55.82	-0.42	-64.95	-8.63	56.58	-32.05
ACC-13 x ACC-14	-70.67	-62.59	48.23	2.77	-43.45	43.79	122.96
ACC-13 x ACC-04	-1.96	1.03	9.31	8.36	2.21	-60.24	58.74
ACC-11 x ACC-15	-6.65	-33.96	16.07	-6.98	9.49	20.51	6.30
ACC-11 x ACC-13	-55.06	12.27	22.06	3.56	-35.41	15.40	-36.58
ACC-11 x ACC-11	15.08	-8.29	-7.41	44.85	2.69	-8.50	14.09
ACC-11 x ACC-14	63.70	-50.99	-3.37	16.40	1.19	-56.64	-12.04
ACC-11 x ACC-04	21.92	50.74	-46.49	-106.63	16.93	10.44	-109.98
ACC-14 x ACC-15	53.46	9.54	-50.94	39.75	32.75	-32.81	-52.39
ACC-14 x ACC-13	23.97	-6.72	23.78	-7.03	-1.11	-9.67	50.20
ACC-14 x ACC-11	-26.10	11.75	-26.24	-46.73	54.05	16.61	-80.22
ACC-14 x ACC-14	8.73	11.43	-2.82	-30.11	9.08	16.32	-5.21
ACC-14 x ACC-04	-69.94	-4.96	32.09	-14.83	-3.51	73.30	7.05
ACC-04 x ACC-15	-49.82	77.16	17.57	-48.37	-4.51	51.08	-60.56
ACC-04 x ACC-13	-15.81	-45.91	16.26	1.17	-16.11	5.10	59.12
ACC-04 x ACC-11	-11.63	24.26	20.77	10.21	3.85	-31.29	-4.01
ACC-04 x ACC-14	29.21	-46.43	-14.18	6.13	-26.80	11.56	130.69
ACC-04 x ACC-04	-28.85	-11.03	2.36	-7.36	-15.28	4.16	19.95
LSD(0.01)	0.673	0.798	0.791	0.993	0.667	0.957	0.599
GCA: SCA mean square ratio							
	0.55	0.34	0.41	4.92	0.36	1.06	0.25

4.2.2.1.4 Seedling vigour index

The largest positive GCA effect for seedling vigour index value was measured for ACC-11, which was significantly different from the other parents. The smallest negative value was for ACC-04.

‘ACC-15×ACC-11’ had the highest positive SCA effect, which was significantly different from the other crosses. ‘ACC-11×ACC-04’ had the largest negative SCA. A common GCA: SCA ratio of 4.92 confirmed the importance of additive gene action.

4.2.2.1.5 Length of seedling

In this study, ACC-14 had the largest positive GCA effects for length of seedlings. These values differ significantly from other parents. ACC-04 ranked the lowest and differ significant from other parents.

‘ACC-14×ACC-11’ had the highest positive SCA effect which was significantly different from the other crosses. The largest negative effect was ‘ACC-13×ACC-14’ and it was significantly lower than other crosses. The ratio of GCA: SCA was 0.36. It indicated the non-additive gene action was significant.

4.2.2.1.6 Weight of seedling

ACC-14 ranked first respectively for measured GCA effects of seedling weight. On the other hand, ACC-15 had the smallest value of seedling weight.

In SCA of weight of seedlings, ‘ACC-14×ACC-04’ had the highest positive value which was significantly higher than others crossing. The lowest value of SCA value was ‘ACC-13×ACC-04’, and it was not significantly different from other crosses. The ratio of GCA: SCA was 1.06. It indicated that additive gene action was predominant.

4.2.2.1.7 Diameter of cormel

In Table 21, the highest GCA value of diameter of cormels was for ACC-04. But it was not significantly higher than the other parents.

‘ACC-04×ACC-14’ and ‘ACC-13×ACC-14’ had the two highest SCA values of the crosses. The ‘ACC-14×ACC-11’ had the lowest value of all the crosses. They were significantly different from each other.

The GCA: SCA ratio of diameter of cormels was small (0.25). It indicated the non-additive gene action was higher than additive gene action.

4.2.3 Heterosis in gladiolus

Mid-parent heterosis (MPH) and high-parent heterosis (HPH) was measured for all the characteristics. Estimated values were listed in Table 22. If the heterosis value is negative, it is indicated that there is no heterosis or a lack of heterosis.

4.2.3.1 Days taken for germination

Most of the F₁ hybrids expressed positive MPH for days taken to germination. The F₁ hybrid variety 'ACC-11×ACC-15' expressed the highest MPH (52.15%) and only 8 of the 20 F₁ hybrids had negative MPH. In case of HPH, Only three F₁ hybrids expressed negative HPH and the hybrid 'ACC-11×ACC-15' (73.64%) had the highest HPH, followed by 'ACC-13×ACC-11' (47.83%) while least was recorded in hybrid 'ACC-11×ACC-14' (0.11%).

4.2.3.2 Germination Percentage

Eight of the 20 F₁ hybrids had positive mid-parent heterosis and highest heterosis was expressed by hybrid 'ACC-15×ACC-13' (76.43%). Most of the F₁ hybrids expressed negative HPH for percentage of germination except in 'ACC-15×ACC-13' (71.19%), 'ACC-14×ACC-15' (38.73%), 'ACC-13×ACC-15' (15.67%), and 'ACC-04×ACC-14' (1.18%).

4.2.3.4 Germination speed

Six of the twenty hybrids were positive MPH for germination speed. The hybrid 'ACC-04×ACC-14' (49.66%) had the highest positive MPH, followed by 'ACC-15×ACC-13' (48.32%). Most of the hybrids had negative HPH except the highest heterosis was for hybrid 'ACC-15×ACC-13' (45.49%) followed by 'ACC-14×ACC-15' (5.93%).

4.2.3.5 Seedling vigour index

Almost all the F₁ hybrids had negative MPH for seedling vigour index value except the 4 hybrids 'ACC-15×ACC-13', 'ACC-11×ACC-13', 'ACC-14×ACC-13' and 'ACC-04×ACC-14'. The hybrid 'ACC-04×ACC-14' (56.03%) had the highest positive MPH. The highest HPH was found in 'ACC-15×ACC-13' (8.69%) followed by 'ACC-04×ACC-14' (3.20%) and 'ACC-14×ACC-13' (0.50%).

Table 22. Heterosis (%) estimates of various characteristics in gladiolus (using pooled data)

Cross	Days to germination		Germination percent		Germination speed		Seedling vigour index		Seedling length (cm)		Seedling weight (g)		Corm diameter (cm)	
	MPH	HPH	MPH	HPH	MPH	HPH	MPH	HPH	MPH	HPH	MPH	HPH	MPH	HPH
ACC-15 x ACC-13	21.50	21.95	76.43	71.19	48.32	45.49	31.52	8.69	-26.00	-40.28	12.56	2.71	14.29	2.33
ACC-15 x ACC-11	-1.84	12.03	1.14	-27.07	7.21	-15.34	-23.45	-30.20	-28.82	-48.62	-9.00	-9.33	-4.93	-5.62
ACC-15 x ACC-14	-6.77	9.91	2.72	-6.13	8.25	-14.63	-42.43	-58.23	-42.39	-55.50	-16.42	-27.13	-18.55	-31.29
ACC-15 x ACC-04	39.35	45.13	-49.99	-63.87	-62.43	-72.16	-33.24	-42.72	21.52	-1.48	-16.33	-17.99	-11.99	-13.17
ACC-13 x ACC-15	26.45	26.91	19.21	15.67	-1.08	-2.97	-7.30	-23.39	-22.81	-37.70	-6.81	-14.97	-3.96	-14.01
ACC-13 x ACC-11	29.00	47.83	-18.42	-40.04	-33.32	-46.58	-2.80	-25.27	26.50	8.96	-0.48	-9.48	3.56	-7.87
ACC-13 x ACC-14	-9.60	7.02	-26.67	-34.79	-17.27	-35.67	-40.60	-49.78	-18.39	-23.00	-19.01	-23.01	-6.44	-12.57
ACC-13 x ACC-04	12.13	17.23	-39.98	-55.79	-46.07	-59.52	-34.39	-51.86	9.55	8.89	-11.99	-21.13	-13.49	-23.46
ACC-11 x ACC-15	52.15	73.64	-44.11	-59.70	-63.79	-71.41	-62.67	-65.96	-37.19	-54.66	-27.50	-27.76	-32.21	-32.71
ACC-11 x ACC-13	4.08	19.28	-21.61	-42.39	-23.81	-38.96	0.72	-22.57	36.42	17.51	8.32	-1.48	6.79	-5.00
ACC-11 x ACC-14	-2.74	0.11	-64.97	-76.07	-64.88	-76.57	-66.62	-77.11	3.91	-5.72	-27.54	-37.02	-24.47	-36.67
ACC-11 x ACC-04	33.60	45.91	-66.32	-66.43	-75.96	-77.98	-64.73	-67.03	13.83	-2.45	-26.79	-27.99	-31.06	-31.48
ACC-14 x ACC-15	13.80	34.15	51.81	38.73	34.33	5.93	-17.06	-39.83	-43.84	-56.63	-7.13	-19.04	-13.28	-26.85
ACC-14 x ACC-13	4.52	23.74	12.36	-0.08	21.78	-5.30	18.88	0.50	6.59	0.57	-1.09	-5.97	-4.27	-10.54
ACC-14 x ACC-11	-4.50	-1.70	-50.51	-66.20	-46.59	-64.36	-59.31	-72.10	-10.35	-18.66	-27.12	-36.66	-23.19	-35.59
ACC-14 x ACC-04	-18.90	-8.61	-20.09	-45.32	-6.36	-40.16	-19.05	-46.46	4.38	-2.07	-7.34	-20.59	-1.85	-18.11
ACC-04 x ACC-15	19.50	24.45	-42.79	-58.67	-47.84	-61.35	-48.58	-55.88	-18.17	-33.65	-21.71	-23.26	-29.51	-30.45
ACC-04 x ACC-13	7.46	12.34	0.17	-26.22	-3.57	-27.62	-6.60	-31.48	-6.56	-7.12	0.29	-10.13	6.16	-6.08
ACC-04 x ACC-11	-15.27	-7.46	-45.00	-45.18	-32.20	-37.89	-54.69	-57.64	-10.44	-23.25	-26.24	-27.45	-27.33	-27.78
ACC-04 x ACC-14	-5.96	5.97	47.88	1.18	49.66	-4.35	56.03	3.20	8.71	2.00	28.41	10.06	26.26	5.35

MPH-Mid Parent Heterosis; HPH-High Parent Heterosis

4.2.3.6 Length of seedling

For seedling length 9 of all 20 F₁ hybrids had positive MPH. The hybrid 'ACC-11×ACC-13' (36.42%) had the highest MPH, followed by 'ACC-13×ACC-11' (26.50%). The hybrid 'ACC-11×ACC-13' (17.51%) also had the highest positive HPH among five positive HPH values followed by 'ACC-13×ACC-11' (8.96%).

4.2.3.7 Weight of seedling

Highest positive MPH was expressed by 'ACC-04×ACC-14' (28.41%) followed by 'ACC-15×ACC-13' (12.56%). Sixteen F₁'s had negative heterosis values. The hybrid 'ACC-04×ACC-14' (10.06%) had the highest HPH value whereas eighteen of 20 F₁ hybrids had negative HPH values.

4.2.3.8 Diameter of corm

Five of the 20 F₁ hybrids had positive MPH. The hybrid 'ACC-04×ACC-14' (26.26%) expressed the highest MPH, followed by 'ACC-15×ACC-13' (14.29%). Eighteen of the 20 F₁ hybrids had negative HPH. The hybrid 'ACC-04×ACC-14' (5.35%) also expressed the highest HPH of 20 crosses.

EXPERIMENT-III

4.3 Studies on *in-vitro* seed germination and growth of gladiolus

The result of the present objective studying *in-vitro* seed germination and raising of gladiolus as affected by different plant growth regulators are presented in this chapter. Seeds of various genotypes viz ACC-15, ACC-13, ACC-11, ACC-14 and ACC-04 were cultured in MS media supplemented with various concentrations of Gibberellic acid (GA₃) in combination with Kinetin (Kn).

In the present research for germinating, the seeds were cultured in germ bottle on standard Murashige & Skoog medium containing 3% sucrose and 0.6% agar along with different concentrations of GA₃ (1.0 to 5.0 mg l⁻¹) and Kn (0.5 mg l⁻¹) in combination. The various seed germination and growth of seedlings parameters like days to complete germination, germination percentage, germination speed, germination value, seedling vigour index, length of seedling and weight of seedling were recorded. Survival percentage of seedling was studied using different ratio

of hardening media viz: vermiculite and sand (1:1), garden soil and sand (1:1), vermiculite and vermicompost (1:1) and garden soil, sand and vermicompost (1:1:1).

4.3.1 Days taken for germination

The data on effect of genotypes and media on days to complete germination in gladiolus are presented in Table 23 and it is evident that application of different concentrations of GA₃ along with Kinetin significantly influenced the variation on time required for germination.

Among different genotypes of Gladiolus, germination time varied from 13.05 to 17.02 days and genotype ACC-15 took minimum time (13.05 days) for complete germination followed by genotypes ACC-13 (13.85 days), ACC-04 (15.11days) and ACC-14 (16.22 days) while maximum days required for germination was taken by genotype ACC-11 (17.02 days).

A perusal of data reveals that the minimum days required for germination (13.85days) was obtained on medium MGK₆ and followed by MGK₅ (14.27 days) media. A closer view of data exhibit that day to germination decreased with higher concentrations of GA₃ along with Kinetin.

The interaction effect of medium and genotype was non significant. However, the minimum days (11.97 days) for germination in ACC-15 were found on MGK₆ medium and the maximum (18.00 days) in ACC-11 on MGK₁ medium.

4.3.2 Germination Percentage

The percentage of germination was depicted in Table 23 of different genotypes which was varied from 89.48 to 91.85 %. The maximum percent germination was observed in genotype ACC-15 (91.85 %) followed by genotypes, ACC-13 (91.26%), ACC-14 (90.56%) and ACC-04 (90.62 %) while minimum germination percentage was observed in genotype ACC-11 (89.48%).

Per cent germination response varied among 80.21 to 98.07% on the different media tested. Maximum (98.07 %) germination was observed on MGK₆ medium and moderate response (80.21 to 97.92%) was observed on all other media used. A closer view of data exhibit that increased concentrations of GA₃ along with kinetin also increased the per cent germination.

The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum (99.80%) germination on MGK₆ followed by ACC-13 (99.11%) and the minimum (79.53%) in ACC-11 on MGK₁ medium.

4.3.3 Germination Speed

Among different genotypes of *Gladiolus*, speed of germination varied from 5.28 to 7.16 and maximum germination speed (7.16) was observed in genotype ACC-15 followed by genotypes, ACC-13 (6.64), ACC-14 (6.01) and ACC-14 (5.65). Least speed of germination was observed in genotype ACC-11 (5.28).

There were significant effect of GA₃ and kinetin in germination speed. The maximum germination speed (7.20) was observed in MGK₆ while the least germination speed (4.93) was recorded in MS with no growth regulators (MGK₁).

The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum value (8.69) of germination speed on MGK₆ followed by ACC-13 (7.89) and the minimum value (4.42) for germination speed in ACC-11 on MGK₁ medium.

4.3.4 Germination Value

The germination value was recorded in different genotypes of *gladiolus* which was evident from Table 23. Genotype ACC-15 recorded maximum germination value (13.22) followed by genotypes, ACC-13 (13.13), ACC-04 (13.10) and ACC-14 (13.01) and least was observed in genotype ACC-11 (12.98).

Application of GA₃ and Kinetin at various combinations influenced the germination value and all growth regulators combination showed significant increase in germination value over the control (MGK₁). Data presented at table 23 clearly revealed that the maximum germination value (14.33) of *gladiolus* was recorded in MGK₆ medium. The medium representing control (MGK₁) which does not received any growth regulators showed minimum germination value (11.52).

The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum germination value (14.50) of on MGK₆ followed by ACC-04 (14.33) and the minimum (11.44) germination value in ACC-11 on MGK₁ medium.

4.3.5 Seedling Vigour Index

The seedling vigour index of different genotypes of gladiolus was tabulated and it was observed maximum in genotype ACC-15 (866.60) followed by genotypes ACC-13 (844.34), ACC-04 (808.35) and ACC-11 (763.94). Genotype ACC-14 recorded the minimum seedling vigour index (758.69) (Table 23).

The seedling vigour in concentrations of GA₃ and Kinetin differed significantly. The MGK₆ medium showed maximum seedling vigour (1197.67) followed by MGK₅ medium (1074.25) while the minimum seedling vigour (452.77) was noticed on MS medium without growth regulators (MGK₁) representing control.

The interaction effect of medium and cultivar was significant and the ACC-15 recorded the maximum value for seedling vigour index (1320.67) of on MGK₆ followed by ACC-13 (1258.74) and the minimum value (422.40) for seedling vigour in ACC-11 on MGK₁ medium.

4.3.6 Length of seedling

The longest seedling was noticed in genotype ACC-15 (8.90 cm) followed by genotypes, ACC-13 (8.65 cm), ACC-04 (8.61 cm) and ACC-11 (8.22 cm) whereas minimum length of seedling was produced by genotype ACC-14 (8.12 cm) as in Table 23.

The average length of seedlings increased gradually with higher concentration of GA₃ in combination with Kinetin in the MS medium. The maximum average length of seedlings was recorded on MGK₆ medium (11.12 cm) followed by MGK₅ (10.57 cm), MGK₄ (8.88 cm) and so on.

The interaction effect of medium and cultivars was found to be non significant. However, the maximum length of seedling (11.73 cm) was observed in ACC-13 with MGK₆ and the minimum (5.31 cm) in ACC-11 with MGK₁ medium.

4.3.7 Fresh weight of seedling

Fresh weight of seedling varied from 386.84 to 399.66 mg and maximum fresh weight of seedling (399.66 mg) was recorded in genotype ACC-11 followed by genotypes, ACC-15 (394.53 mg), ACC-04 (390.88 mg) and ACC-13 (387.90 mg) whereas minimum fresh weight was noticed in genotype ACC-14 (386.84 mg).

The weight of the seedling differed significantly among the medium as shown in Table 23. The maximum weight (604.70 mg) of the seedling was achieved in MGK₆ medium which is followed by the MGK₅ medium (571.83 mg) while the minimum weight of the seedling (126.10 mg) was achieved in MGK₁ medium containing no growth regulators.

The interaction effect of medium and cultivars was found to be significant and the maximum weight of seedling (691.63 mg) was observed in ACC-15 with MGK₆ and the minimum (123.00 mg) in ACC-11 with MGK₁ medium.

4.3.8 Survival percentage of seedling

The percentage of survival of different gladiolus genotypes was shown in Table 23. The genotype ACC-15 was recorded the maximum percent survival (92.61%) followed by genotypes, ACC-13 (92.47%), ACC-14 (92.05%) and ACC-04 (91.47%). The minimum survival percentage was given by the genotype ACC-11 (90.59%)

Per cent survival response varied among 87.12 to 97.22% on the different hardening media tested as revealed in Table 23. Maximum survival (97.22%) was observed on VSM medium followed by other media VVM (94.24%) containing vermiculite. A closer view of data exhibits that presence of vermiculite along with others hardening media increased the per cent survivability.

The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum (97.87%) survival on VSM and the minimum (85.53%) in ACC-11 on GSV medium.

Table 23. Effect of GA₃ along with Kinetin on germination and growth characteristics and the influence of hardening medium on survivability of gladiolus

Genotypes	DTG	GP	GS	GV	SVI	SL	SW	Genotypes	SP
ACC-04	15.11	90.62	6.01	13.10	808.35	8.61	390.88	ACC-04	91.57
ACC-11	17.02	89.48	5.28	12.98	763.94	8.22	399.66	ACC-11	90.59
ACC-15	13.05	91.85	7.16	13.22	866.60	8.90	394.53	ACC-15	92.61
ACC-13	13.85	91.26	6.64	13.13	844.34	8.65	387.90	ACC-13	92.47
ACC-14	16.22	90.56	5.65	13.01	758.69	8.12	386.84	ACC-14	92.05
SE(m)	0.234	0.456	0.101	0.240	5.641	0.239	2.690	SE(m)	0.502
CD at (5%)	0.665	1.292	0.285	NS	15.997	NS	7.628	CD at (5%)	1.434
Medium									
MGK ₁	16.38	80.21	4.93	11.52	452.77	5.64	126.10	VSM	97.22
MGK ₂	15.83	85.87	5.48	12.44	603.86	7.03	233.69	GSM	88.85
MGK ₃	15.24	87.88	5.82	12.94	682.34	7.76	290.81	VVM	94.24
MGK ₄	14.74	94.58	6.48	13.34	839.41	8.88	524.65	GSV	87.12
MGK ₅	14.27	97.92	6.96	13.97	1074.25	10.57	571.83		
MGK ₆	13.85	98.07	7.20	14.33	1197.67	11.12	604.70		
SE(m)	0.257	0.499	0.110	0.263	6.179	0.262	2.947	SE(m)	0.449
CD at (5%)	0.728	1.415	0.312	0.745	17.523	0.743	8.356	CD at (5%)	1.283
Interaction									
ACC-04X MGK ₁	16.38	80.13	4.89	11.50	442.32	5.52	125.98	ACC04X VSM	97.67
ACC-04X MGK ₂	15.84	85.77	5.41	12.52	600.39	7.00	233.08	ACC04X GSM	88.46
ACC-04X MGK ₃	15.25	87.90	5.76	12.96	703.20	8.00	332.30	ACC04X VVM	93.93
ACC-04X MGK ₄	14.85	94.43	6.36	13.34	869.70	9.21	533.64	ACC04X GSV	86.30
ACC-04X MGK ₅	14.40	97.87	6.80	13.97	1057.00	10.80	547.30		
ACC-04X MGK ₆	13.93	97.60	6.83	14.33	1177.51	11.10	572.97		
ACC-11X MGK ₁	18.00	79.53	4.42	11.44	422.40	5.31	123.00	ACC11X VSM	96.03
ACC-11X MGK ₂	17.88	85.11	4.76	12.26	611.94	7.19	231.96	ACC11X GSM	88.00
ACC-11X MGK ₃	17.24	87.13	5.05	12.87	672.64	7.72	324.30	ACC11X VVM	92.81
ACC-11X MGK ₄	16.70	94.07	5.63	13.22	783.60	8.33	526.11	ACC11X GSV	85.53
ACC-11X MGK ₅	16.27	95.34	5.86	13.83	977.24	10.25	576.30		
ACC-11X MGK ₆	16.03	95.70	5.93	14.23	1115.79	10.54	616.30		
ACC-15X MGK ₁	14.47	81.63	5.64	11.64	502.84	6.16	128.89	ACC15X VSM	97.87
ACC-15X MGK ₂	13.80	86.63	6.28	12.57	657.52	7.59	236.48	ACC15X GSM	89.53
ACC-15X MGK ₃	13.22	88.46	6.69	13.02	718.30	8.12	133.51	ACC15X VVM	95.03
ACC-15X MGK ₄	12.73	95.03	7.47	13.43	884.73	9.31	500.39	ACC15X GSV	88.00
ACC-15X MGK ₅	12.13	99.53	8.21	14.13	1177.44	10.73	676.30		
ACC-15X MGK ₆	11.97	99.80	8.69	14.50	1320.67	11.50	691.63		
ACC-13X MGK ₁	15.50	80.14	5.17	11.57	471.22	5.88	128.78	ACC13X VSM	97.85
ACC-13X MGK ₂	14.61	86.30	5.91	12.55	563.54	6.53	234.41	ACC13X GSM	89.13
ACC-13X MGK ₃	14.10	88.00	6.24	12.99	694.32	7.89	332.43	ACC13X VVM	95.00
ACC-13X MGK ₄	13.58	95.00	7.00	13.40	855.00	9.00	532.16	ACC13X GSV	87.90
ACC-13X MGK ₅	13.00	99.00	7.62	14.03	1161.27	10.87	530.00		
ACC-13X MGK ₆	12.30	99.11	7.89	14.27	1258.74	11.73	569.63		
ACC-14X MGK ₁	17.53	79.60	4.54	11.46	425.06	5.34	123.87	ACC14X GSM	96.76
ACC-14X MGK ₂	17.00	85.53	5.06	12.29	585.88	6.85	232.52	ACC14X VVM	89.11
ACC-14X MGK ₃	16.37	87.90	5.37	12.85	623.21	7.09	331.51	ACC14X VVM	94.44
ACC-14X MGK ₄	15.84	94.37	5.96	13.28	804.03	8.52	530.93	ACC14X GSV	87.87
ACC-14X MGK ₅	15.56	97.87	6.29	13.87	998.27	10.20	529.23		
ACC-14X MGK ₆	15.02	98.13	6.66	14.30	1115.67	10.73	572.97		
SE(m)	0.574	1.116	0.246	0.588	13.817	0.586	6.589	SE(m)	1.003
CD at (5%)	NS	NS	NS	NS	39.184	NS	18.685	CD at (5%)	N.S

MGK₁ : MS (without GA₃)
 MGK₂ : MS + 1 mg l⁻¹ GA₃ + 0.5 mg l⁻¹ Kn
 MGK₃ : MS + 2 mg l⁻¹ GA₃ + 0.5 mg l⁻¹ Kn
 MGK₄ : MS + 3 mg l⁻¹ GA₃ + 0.5 mg l⁻¹ Kn
 MGK₅ : MS + 4 mg l⁻¹ GA₃ + 0.5 mg l⁻¹ Kn
 MGK₆ : MS + 5 mg l⁻¹ GA₃ + 0.5 mg l⁻¹ Kn
 VSM : Vermiculite + Sand (1:1)
 GSM : Garden soil + Sand (1:1)
 VVM : Vermiculite + Vermicompost (1:1)
 GSV : Garden soil + Sand+ Vermicompost (1:1:1)

DTG : Days to germination
 GP : Germination Percent (%)
 GS : Germination Speed
 GV : Germination Value
 SVI : Seedling Vigour Index
 SL : Seedling Length (cm)
 SW : Seedling Weight (mg)
 SP : Survivability Percent (%)

Plates 6. *In-vitro* germination and raising of gladiolus seedling



Plates 6.1 Culture of seeds



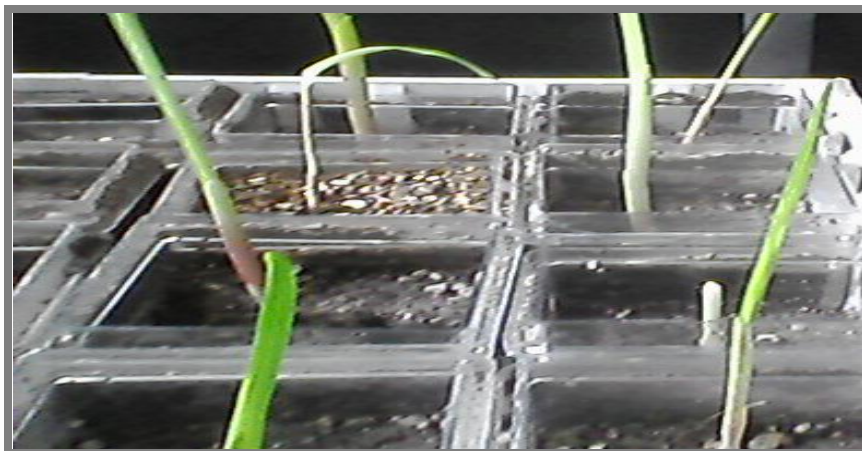
Plates 6.2 *In-vitro* germination of seeds



Plates 6.3 Growth of seedling



Plates 6.4 Seedlings ready for transfer



Plates 6.5 Survivability of gladiolus seedlings

Experiment-I**5.1 Studies on assessment of the *per se* performance of gladiolus genotypes**

Evaluation of gladiolus genotypes for breeding during 2011-13 and true seed production through full diallele analysis was made during 20012-14. Various factors are responsible for a successful breeding program in a crop. Among them, the most important ones are number of days taken for spike initiation, first floret to open, spike length, spike girth, rachis length, spike weight and number of florets spike⁻¹. In addition to these, several other factors like plant height, number of leaves, floral characters etc. were also considered as these are the factors which ultimately decide the yield and quality of flower spikes. If genotypes have such desirable characters as mentioned above it would be considered as a good cut flower genotypes even though it has one or more other less important characters.

5.1.1 Mean performance of gladiolus genotypes

The genotypes have shown significant differences for the plant height, number of leaves and leaves length at the stages of 60 days growth (60 DAP). They exhibited significant differences with respect to plant height. The genotype ACC-13 recorded the highest plant height whereas ACC-05 was found to be the shortest.

Based on height gladiolus genotypes can be categorised into 3 classes (NRC Orchid, Mini Mission and Bulletin No-2).

Class	Description	Genotypes Included
Dwarf	50 cm	ACC-02, ACC-05 and ACC-07
Medium	50-100 cm	ACC-01, ACC-03, ACC-04, ACC-06, ACC-08, ACC-09, ACC-10, ACC-11, ACC-12, ACC-13, ACC-14, ACC-15, ACC-16 ,ACC-17, ACC-18, ACC-19 and ACC-20
Tall	More than 100 cm	Nil

As far as number of leaves plant⁻¹ was concerned ACC-13 recorded the maximum and ACC-05 the least. Height of plant also influenced the leaves length and maximum leaves length was recorded in case of ACC-13 while minimum in ACC-05. These trends may be attributed to the inherent growth character of the genotypes.

The genotypes have shown significant differences for the time taken to initiate spike. Genotype ACC-11 was the earliest to initiate the spikes while ACC-05 was taken maximum days compared to the other genotypes. On an average they took 57.33 to 79.67 days to initiate their spikes. These variations may be attributed to the different inherent characters of genotypes and some even to the agro-climatic conditions of the particular area. Genotypes have maintained the differences noticed in the number of days taken for spike initiation for the other characters such as number of days taken for complete emergence of spike, first floret to show colour and first floret to open. The results indicated that there is a particular set of period for each genotype for the flowering. The average number of days taken for first floret to open was 69.33 to 93.33 days and ACC-14 was the earliest to open the first flower and the ACC-05 was the last.

Based on days to bloom gladiolus genotypes can be categorised into 3 classes (NRC Orchid, Mini Mission and Bulletin No-2).

Class	Description	Genotypes Included
Early Season	Flower within 60 days after planting	Nil
Mid Season	Flower within 60-90 days after planting	ACC-01, ACC-02, ACC-03, ACC-04, ACC-06, ACC-07, ACC-08, ACC-09, ACC-10, ACC-11, ACC-12, ACC-13, ACC-14, ACC-15, ACC-16, ACC-17, ACC-18, ACC-19 and ACC-20
Late Season	Flower after 90 days of planting	ACC-05

Spike characters are important ones with regard to cut flower production in gladiolus. The genotypes under study have shown significant differences with respect to spike length which is one of the important characters for quality assessment. The range was from 57.60 cm to 89.07 cm. The genotype ACC-19 possessed the longest spikes which is a desirable character for a cut flower, as it will have more number of floret spike⁻¹ and will last longer in the fields. The lowest spike length was recorded in the ACC-05. Spike girth is a crucial character since it determines the sturdiness of the cut flower. Mahanta and Paswan (1995) recognized sturdiness of the cut flower as one of the important characters. The maximum diameter of the floret was recorded in ACC-18 (15.00 cm), which was followed by ACC-10 (11.31 cm), ACC-06 (11.22 cm), ACC-19 (11.15 cm) and so on

and least was recorded in the ACC-05 (5.10 cm). These differences in genotypes may be attributed to their inherent characters.

Based on florets size (diameter) genotypes can be grouped into 5 groups (NRC Orchid, Mini Mission and Bulletin No-2).

Floret Size (cm)	Designation	Class	Genotypes Included
< 6.4	Miniature	1.	ACC-02 and ACC-05
≥ 6.4 to < 8.9	Small	2.	ACC-04, ACC-11, ACC-12, ACC-13, ACC-14, ACC-17 and ACC-20
≥ 8.9 to < 11.4	Medium	3.	ACC-01, ACC-03, ACC-06, ACC-07, ACC-08, ACC-09, ACC-10, ACC-15 and ACC-16
≥ 11.4 to 14.0	Large	4.	ACC-19
> 14.0	Giant	5.	ACC-18

Spike weight is another important crucial character for a cut flower variety. The importance of weight comes into picture during cut flower handling, packing and transportation, especially in air cargo charges for export purposes which are quite high under Indian conditions. In fact, this heavy spike weight is one of the major problems in boosting gladiolus exports from India though it can be successfully grown out door. So, it should be less comparatively to reduce the transportation costs. In this study, the range of average spike weight obtained was from 70.63 to 138.45 g. The lowest spike weight was recorded in ACC-05 and the maximum was in the ACC-13. However, it is the inherent character of the genotypes. Along with these spike characters, number of florets spike⁻¹ is also important for a cut flower variety as it will decide the attractiveness of the spike and vase life of the spike. If more number of florets is there the spike will last for longer period. ACC-13 produced maximum number of florets spike⁻¹ followed by ACC-11, ACC-15 and so on. The lowest floret number was recorded in ACC-18.

Based on the number of florets per spike genotypes can be categorised into 4 grades (Wilfret, 1980).

Grade	Minimum number of florets spike ⁻¹	Genotypes Included
Fancy	16	ACC-13
Special	15	ACC-01, ACC-06, ACC-11, ACC-14 and ACC-15
Standard	12	ACC-03, ACC-04, ACC-07, ACC-08, ACC-09, ACC-10, ACC-17 and ACC-19
Utility	10	ACC-02, ACC-05, ACC-12, ACC-16 and ACC-20

For a successful breeding programme field life is an important factor as it provides the opportunities for maximum number of crossing and may coincide the time of pollen and stigma maturity. The preference of breeders depends on the field life of the spikes along with other good qualities of spikes as colour of floret, spike length and the number of florets spike⁻¹. In the present investigation, genotypes have shown significant differences for the field life period. The range observed was from 5.55 days to 7.91 days. ACC-15 remained attractive for longer period and obtained spike life of 7.91 days followed by ACC-19 (Table 10), while shorter spike life (5.55) was recorded for ACC-05. Similar variations in spike quality parameters of gladiolus varieties were quoted by the workers viz Rani *et al.* (2007) and Swaroop and Singh (2007) in gladiolus.

The genotype ACC-15 showed the maximum field life period which may be attributed to its longer spike length and more number of florets spike⁻¹ which help the spike to retain attractiveness for a longer period. For the good appearance, the florets in a spike should also be attractive. Florets should be big and arranged in a compact manner on only one side of the rachis. Length and diameter should be high to have attractive big floret. With respect to length of the floret the genotypes significant differences were observed among the genotypes. In case of floral diameter, maximum floral diameter was obtained in ACC-18 and the least was in ACC-05.

Along with all these growth and flower characters a good cut flower genotypes should also produce of big sized daughter corms and good number of cormels for the future planting. In the present investigation, the genotypes have shown varied response with respect to the weight and number of cormels produced. Average weight of the individual corm plant⁻¹ was highest in ACC-04 which is good for having a good planting in the next season. The production of daughter corms of more weight may be attributed to the good vegetative growth of the plants in the initial stages, which supplies good amount of photosynthates for storage in the corms which are also the storage organs. There should be good production of cormels to have the good amount of planting material

for the next generations. The range obtained was from 11.33 to 78.33 cormels plant⁻¹. Highest number of cormels per plant was recorded in ACC-16 and the least was in ACC-05.

5.1.2 Genetic studies of gladiolus genotypes

Genetic variability, its nature and magnitude among the genotypes form a base for any successful breeding and crop improvement programme. It is not just enough if we know the extent of variability, as the extent of heritability and genetic advance present in the crop are important tool for a breeder. Without the knowledge of these, the selection would be unfruitful. As we are aware most of the characteristics are inter-related in plants and the selection based on a single characteristics may influence the other traits. Therefore, the method of direct selection based on single characteristics may not be that effective and it necessitates study of inter-relationships among the characteristics for improvement through breeding. Further, correlating yield and other traits may not give a complete idea. Inter relationships that exist among the traits, which influence the yield directly or indirectly, have to be worked out by going in for path co-efficient analysis.

With this perspective, in the present study, twenty genotypes of gladiolus were evaluated for twenty three parametric characters to estimate phenotypic and genotypic coefficient of variability, heritability in broad sense and per cent genetic advance as per cent mean. The association among the characters and their direct as well as indirect effects on yield were also computed.

Analysis of variance of all the twenty three characteristics revealed that significant differences existed between the genotypes. The differences observed among the genotypes with respect to the characteristics studied may be due to their genetic make-up. The range in the observations recorded reflect the extent of phenotypic variability which comprising of genotypic variance and interaction between them. However, the inherent genotypic variability cannot be ascertained considering the range. This can be better known by determining the total genetic variability in the existing genotypes after partitioning the phenotypic variance.

The range in the values reflect the amount of variability, which is not very reliable since it includes genotypic, environmental and genotype x environmental interaction components and does not reveal as to which character is showing higher degree of variability. Further, the phenotype of a character is the manifestation of number of genes controlling the character and the nature of gene

action is influenced by additive gene effect (heritable), dominance (non-heritable) and epistasis (non-allelic interaction).

Data pertaining to mean, range, variances, genotypic and phenotypic co-efficient of variation, heritability and genetic advance as per cent mean has been presented in Table 13.

In the present study, the phenotypic co-efficient of variation were higher than the genotypic co-efficient of variation for all the characters, which indicated greater genotype and environment interaction. Similar results were also obtained in China aster (Ravikumar and Patil, 2003), in dahlia (Singh, 2003), in chrysanthemum (Pal and Santhy, 2002), in African marigold (Nandakishore and Raghava, 2001) and (Mishra *et al.*, 2013) in chrysanthemum. Narrow differences between genotypic and phenotypic coefficients of variation were also recorded for all the characters indicating little environmental influence on the expression of character.

The high genotypic co-efficient of variation was recorded for diameter of floret, flower stalk girth, number of corms per plant, weight of corm, number of cormels per plant and cormels weight. The moderate genotypic co-efficient was recorded for plant height, leaves length, number of floret spike⁻¹, rachis length, spike length, spike weight and cormel diameter.

The low genotypic co-efficient of variation was recorded for number of leaves plant⁻¹, days to spike initiation, days to full emergence of spike, days to bud separation, days to show colour, days taken to open floret, days to flowering, floret length, field life and corm diameter.

The characters plant height, leaves length, number of floret spike⁻¹, rachis length, spike length, spike weight and diameter of cormel had shown medium genotypic co-efficient of variation and high genotypic co-efficient of variation for diameter of floret, flower stalk girth, number of corms plant⁻¹, weight of corm, number of cormels plant⁻¹ and cormels weight. The moderate genotypic co-efficient was recorded for plant height, leaves length, number of floret spike⁻¹, rachis length, spike length, spike weight and cormel diameter coupled with narrow difference between the genotypic and phenotypic co-efficient of variation, hence, could be utilized in further breeding programme.

The effectiveness of selection for any character depends not only on the amount of variability but also on the extent to which the variability is heritable. The magnitude of heritable variability is the most important aspect of the genetic constitution of the breeding material, which

has close bearing on the response to selection (Panse, 1967). The genotypic co-efficient of variation together with heritability estimates would give the best picture of the amount of advancement to be achieved through selection. The heritable portion of variability was thus determined with the help of broad sense heritability estimates (Burton, 1952). Heritability includes additive, dominant and epistatic genic effects.

Though, heritability estimates are useful while making selection based on phenotype, their use would be limited as they are influenced by the biometrical method adopted, generation of hybrid, sample size of the experimental material and environment. Therefore, heritability along with genetic advance is more useful in predicting the resultant effect of selecting the best individuals (Johnson *et al.*, 1955).

In the present study, the magnitude of heritability in broad sense was high for all the characters except for number of leaves plant⁻¹, floret length, diameter of floret, number of floret spike⁻¹, field life, corm diameter and cormel diameter (Table 13). The high heritability for most of the quantitative traits has also been reported Ravikumar and Patil (2003) in China aster, and Kumar *et al.* (2012) in Gerbera. Such high heritability estimates have been found to be helpful in making selection of superior genotypes on the basis of phenotypic performance with respect to the quantitative traits in gladiolus (Ravikumar and Patil, 2003).

Johnson *et al.* (1955) suggested that heritability along with genetic advance is more useful in predicting the resultant effect of selecting the best individuals. In the present study, high heritability coupled with high genetic advance as per cent mean was recorded for characters plant height, leaves length, flower stalk girth, rachis length, spike length, spike weight, number of corms plant⁻¹, corm weight, number of cormels plant⁻¹ and cormel weight, indicating the possible role of additive gene action. Talukdar *et al.* (2003) in Chrysanthemum, Kumari *et al.* (2011) in Gerbera, Vikas *et al.* (2011) in Dahlia and Sharma and Raghuvanshi (2011) in Marigold also recorded high heritability with high genetic advance in most of the characters. High heritability associated with high genetic advance proves more useful for efficient improvement of a character through selection.

High heritability with moderate genetic advance was recorded for days to spike initiation, days to full emergence of spike, days to bud separation, days to show colour, days to open first

floret and days to flowering, indicating presence of dominant and epistatic gene effects inferring that these characters could be improved through hybridization.

Correlation analysis is a biometrical technique used to find out the nature and degree of associations among various traits. Knowledge of association among the traits is necessary for making indirect selection for improvement of economically important traits. The expression of a character in a plant is the sequence of a chain of inter-relationships between characters either directly or through other events. Character association as correlation is a measure of the degree of association prevailing between highly heritable characters with most economic characters and gives better understanding of the contribution of each trait in building up of the genetic makeup of the crop. The phenotypic correlations indicate the extent of the observed relationship between two characters. This does not give true genetic picture of the relationship because it includes both heritable and non heritable association. Genotypic correlations provide an estimate of inherent association between genes controlling any two characters. High positive correlation between the traits indicates that selection for improvement of one characteristics leads to the simultaneous improvement in the other characteristics. Hence it is of greater significance and could be effectively utilized in formulating an effective selection scheme.

It is an established fact that there exists a complex association among different characteristics in the plant system and the characters do not exist in isolation. Yield is a complex trait, the expression of which depends upon the action and multiple interactions of various components. Correlation measures the degree of association between the characters. In the present study, it was observed that for most of the characters genotypic correlation coefficients were higher than phenotypic correlation coefficients. Similar trend has been observed by various workers including Lal *et al.* (1985); Gowda (1989) and Misra and Saini (1990). These findings therefore indicate that though there is strong inherent association between, various characters, the phenotypic expression is lessened under the influence of environment.

In the present investigation, the estimates of genetic correlations in general were higher than phenotypic correlations, indicating the presence of inherent association between various characters. In all instances, however, more reliance may be placed on the genotypic correlation. Higher magnitude of genetic correlation coefficient was observed in China aster (Baweja, 2000), Dahlia (Mishra *et al.* 1987) and African marigold (Janakiram and Rao, 1995).

The plant height exhibited positive significant correlation at genotypic and phenotypic level with number of leaves plant⁻¹, length of leaves, number of florets spike⁻¹, length of spike and weight of spike. Lal *et al.* (1985) also observed similar results. Number of leaves plant⁻¹ had positive significant correlation with length of leaves, length of spike and weight of spike. This may be due to increased photosynthesis (Pasannavar, 1994). The length of leaves was significant and positively correlated with length of spike and weight of spike.

Number of days taken for spikes initiation showed positive correlation with days taken to show colour, days taken for flowering. Hegde (1994) also reported that days for spike emergence showed highly significant positive correlation with days for first bud loosen. Number of days taken for first floret to open had shown highly significant correlation with days taken for flowering, length of spike and weight of spike at both level. Similarly Basavaraddy (2004) reported that number of days taken for first floret to open had shown significant correlation with weight of spike. Minimum duration for completion flowering is very much essential for expansion of any crop commercially. Duration to flowering had positive correlation with length of florets and weight of spike.

In the present study, length of floret had positive correlation with length of spike and weight of spike at genotypic level. Number of florets spike⁻¹ had positive significant correlation with weight of spike at both levels. By increasing number of florets spike⁻¹, we can increase the weight of spike in gladiolus. Though, Sandhu *et al.* (1990) observed high positive correlation between spike length and number of florets spike⁻¹ but the findings of Mishra and Saini (1990) and Hegde (1994) indicated a weak negative correlation of spike length with number of florets. The spike rachis length was found positive and highly significant correlation with length of spike at genotypic level only whereas it's positive and non significant correlation showed with length of spike at phenotypic level. Length of spike showed strong and significant correlation with weight of spike. So by selecting the longer spike we can have good and heavy spikes.

An association between two traits is product of the interaction of direct and indirect causes. Correlation coefficient measures only the extent of association between any two characteristics but fails to give a complete picture of the other characters involved in the complicated pathway leading to the end point. Thus, correlation coefficients together with path coefficients values will be more useful in finding out the characters associations.

Path coefficient analysis furnishes a means of partitioning the direct and the indirect effects through variables and measures, the relative importance of the causal factor involved. The values assigned, to these paths in terms of path coefficients is defined as the portion of the standard deviation of an independent variable arising as a result of the variation in the dependent variable.

An association between two traits is not a simple relationship but it is rather product of direct and indirect causes. Correlation coefficient measures only the extent of association between any two characteristics but fails to give a complete picture of the other characteristics involved in the complicated path way leading to the end point. Therefore, significant correlation is no proof of direct or causal relationship. The indirect association becomes more complex and perplexing as more and more variables are considered. Thus correlation coefficients together with path coefficient values will be more useful in finding out characteristics associations.

A dependent character like spike weight is controlled by several component characters which are interrelated in a complex manner and these mutual associations will influence the net association observed between a component and yield and a change in any one component is likely to disturb the whole network of cause and effect relationship. So, each component has two paths of action like direct effect on spike weight and indirect effects through other components which are not revealed from the mere correlation studies.

Spike characters are very important with respect to cut flower production of quality gladiolus spikes. Among the characters spike weight is considered to be important and contributing greater to its commercial quality.

Path analysis is useful in unravelling these two effects and was first suggested by Wright (1921). This is simply a standardized partial regression analysis which is based on cause and relationship which serves to analyse by sub dividing correlation in a causal scheme. Dewey and Lu (1959) were perhaps the first to adopt this technique in the determination of seed yield components in crested wheat grass and they demonstrated the utility of this method in plant selection. Since then, it is being extensively utilised by plant scientists so as to get a clean picture of association of various plant characters.

In the present investigations, it was observed that plant height showed positive direct effects towards yield of spike, further it was recorded positive indirect effect towards number of leaves plant⁻¹, days taken to show colour, length of floret, number of florets spike⁻¹, length of

rachis and length of spike. However, it recorded negative indirect effect with length of leaves, days taken for spike initiation and days taken for flowering.

The other characters like days to spike initiation, days to flowering, length of floret, number of florets spike⁻¹, length of rachis and length of spike exhibited a positive direct effect on spike weight. However, number of leaves plant⁻¹, length of leaves and days to show colour exerted negative direct effect on spike weight.

Maximum positive direct effect on spike weight was exerted by height of plant followed by plant number of days taken for first spike initiation, days to flowering and length of spike. Hegde (1994) reported that number of days to first bud to loosen and marketable spikes had positive direct effect on spike length.

Number of leaves plant⁻¹, length of leaves days to show colour recorded negative but negligible direct effect with spike length. It is suggested that for the improvement of gladiolus both for market value and maintaining quality, plant height, number of florets spike⁻¹, rachis length, days for first floret to open, length of spike are of primary importance. The characters having indirect positive effect on spike length could also be considered for evolving new types in this crop.

Experiment –II

5.2 Studies on seed setting in cross combinations and the combining ability of seed characters

5.2.1 Seed setting in twenty genotypes of gladiolus

Open pollination and crosses were made among the collected germplasm of gladiolus to study the seed setting in different cross combinations which gives an idea on per cent seed setting in different cross combination, nature and compatibility of crossing with desired parents.

The genotypic differences existed with regard to setting of capsules and seed production quality of gladiolus. Number of quality seed plant⁻¹ is very much important as it decides for the future planting and breeding program of gladiolus genotypes. Along with all this capsule setting and capsule harvest characters a good flower genotypes should also confirmed the crossing compatibility among the different genotypes and give scope for future breeding programme with objectives of producing healthy and viable seeds for next generations. In the present investigation, the genotypes have shown varied response with respect to the setting percentage of capsule and

number of mature capsule harvested but some were shrunk and died irrespective of the cross combination. Many of the capsules failed to reach the harvestable stage. Post fertilization barrier was observed in some crosses. This may be due to embryos abortion and degeneration during embryogenesis.

The differences regarding the percentage of capsule setting were observed among the genotypes and varied from 13.01% to 97.08%. Maximum success for capsule setting and more number of harvestable capsules was obtained from genotype ACC-15 but maximum number of seeds capsule⁻¹ was observed in ACC-04 whereas least success for capsule setting was recorded in ACC-01 and less number of harvestable capsules was obtained from genotype ACC-17. There had difference in availability of seeds capsule⁻¹ among the gladiolus genotypes and ranges from 7.58 to 61.74. Maximum number of seeds was obtained from the capsule of genotypes like ACC-04, ACC-15, ACC-11 and so on.

5.2.2 Seed setting in five genotypes of gladiolus

Considering the crossing parameters, variation were observed for days to capsule set, days to capsule maturity, length of capsule (cm), number of seed capsule⁻¹ and test weight of seed (g). Mean data indicated that all the crosses produced more or less gladiolus true seed. Differences regarding the days to capsule maturity were observed among the crosses and varied from 29.65 days to 45.02 days. The cross ACC-13×ACC-13 took maximum days (45.02 days) to capsule maturity which was closely followed by crosses ACC-04 × ACC-11, ACC-11×ACC-13 and so on where as cross ACC-11×ACC-04 took the minimum days (Table 17). Mirsa (1978) reported that the genotype required about four to six weeks of pollination to capsule maturity. The longest capsule was produced by cross ACC-15×ACC-13 whereas minimum length of capsule was recorded in ACC-13×ACC-15. High capsule weight was recorded from the cross ACC-15×ACC-13 and lowest capsule weight was recorded from the cross ACC-04×ACC-15. The number of seed capsule⁻¹ ranged from 7.33 to 71.00. The highest number of seed capsule⁻¹ was produced by the cross ACC-15×ACC-13 while the lowest number of seed capsule⁻¹ was produced by the cross ACC-14×ACC-15 and ACC-04×ACC-04. Mirsa and Choudhry (1976) reported that Gladioli set seed abundantly and about 60 seeds are normally formed in three chambers of each capsule. There had difference in weight of hundred seed among the crosses. The highest 100 seed weight was produced by the cross ACC-15×ACC-04 and which was followed by the crosses ACC-11×ACC-

14, ACC-13×ACC-13 and so on. The lowest test weight of seed was produced by the cross ACC-13×ACC-04.

5.2.3 Combining ability of seed characters

It is an important indicator of the potential of parental lines for generating superior breeding populations. A small or negative combining ability effect indicates a poor ability to transfer its genetic superiority to hybrids (Cruz and Regazzi, 1994). The largest positive values have the largest effects. On the other hand, the largest negative values have the smallest effects (Tenkouano *et al.*, 1998). A high ratio means that additive gene action is predominant.

Variances due to general combining ability (GCA) exceeded the variances due to specific combining ability (SCA), for most the characters and were also significant. These high GCA and SCA values indicated that their inheritance was predominantly governed by additive and additive epistatic components of genetic variance. The genotypes ACC-15, ACC-11 and ACC-14 were good general combiners for most characters, while, ACC-13 and ACC-04 were good general combiners for the seedling weight and ACC-04 especially for diameter of cormel.

Significant SCA effects were found for most of germination and growth characteristics. ‘ACC-15×ACC-11’ had the highest SCA effects for most of characteristics except Germination speed, seedling weight and diameter of cormel. ‘ACC-04×ACC-14’ had the highest SCA effects for diameter of cormel, and can be used in both yield and quality improvement.

Some crosses with high GCA parents of certain characteristics had a high tendency to improve mean performance and had high SCA effects, like parent ‘ACC-15×ACC-13’ for cormel diameter, ‘ACC-15×ACC-11’ for days to germination, seedling vigour index, and seedling length in most of the characteristics.

In this study, GCA: SCA ratio was lower for most of the characters. It indicated that a large part of the total genetic variability for most traits were the result of non- additive gene action.

5.2.4 Heterosis in gladiolus

Although additive type of gene action was noticed for many traits but heterosis in gladiolus was weakly expressed and low range of heterosis was noticed for growth attributes as reported by Kumar *et al.* (2008).

In the present investigation, the genotypes have shown varied response with respect to the days required for germination, germination percent, germination speed, seedling vigour index and seedling length. Germination is the emergence and development of seedling from seed. Data pertaining to the germination percentage showed the mean values of different genotypes. The genotypes ‘ACC-04×ACC-14’, ‘ACC-11×ACC-11’ and ‘ACC-04×ACC-04’ attained the maximum (75.00 %) level of germination followed by ‘ACC-04×ACC-13’, ‘ACC-15×ACC-11’ whereas, the minimum (18.06%) germination percentage was exhibited by the genotypes ‘ACC-11×ACC-14’. Data regarding germination speed presented in the Table 19 shows statistically significant differences among different genotypes. It can be seen that the genotypes ‘ACC-04×ACC-04’ produced the maximum value (3.34%) of germination speed, whereas minimum was in genotypes ‘ACC-11×ACC-14’. With respect to seedling vigour value and seedling length the genotypes showed significant differences among the genotypes. As far as seedling vigour index is concerned, maximum seedling vigour was obtained in the genotypes ‘ACC-04×ACC-14’ and least was in ‘ACC-11×ACC-14’. The longest seedling was produced by the genotypes ‘ACC-15×ACC-15’ whereas minimum length of seedlings was recorded in genotypes ‘ACC-14×ACC-15’.

In this study, most of crosses showed a negative mid-parent and high-parent heterosis. The characteristics that determined germination value had high MPH and HPH values, days taken for germination (MPH from 52.15 to -18.90%; HPH from 73.64 to -8.61%), percentage of germination (MPH from 76.43 to -66.32%; HPH from 71.19 to -76.07%) and speed of germination (MPH from 49.66 to -75.96%; HPH from 45.49 to -77.98%). Compared to growth related characteristics, the growth characteristics had lower mid-parent and high-parent heterosis. The hybrids resulted high MPH and HPH heterosis for length of seedling was ‘ACC-11×ACC-13’ (36.42% and 17.51%) respectively.

The three hybrids expressing the highest MPH and HPH heterosis overall, were ‘ACC-15×ACC-13’, ‘ACC-14×ACC-15’ and ‘ACC-04×ACC-14’.

The heterosis of yield related characteristics was high, and they also had high combining ability. It means those characteristics can be improved in early generations by selection. A breeding program utilizing heterosis to improve yield characteristics could be expected to be successful.

Experiment–III

5.3 Studies on *in-vitro* seed germination and growth of gladiolus

5.3.1 Effect of GA₃ along with Kinetin on germination and growth characteristics and the influence of hardening medium on survivability of gladiolus

A seed is regarded as germinated following the emergence and development of a seedling from the seed embryo (Willan, 1985). Germination of a seed in a laboratory test is the emergence and development of a seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable soil conditions (Anonymous, 2006).

Gladiolus seed germination depends not only on the type of medium employed but also on the type of genotypes used in the medium and has also been reported to play a critical role in seed germination as gibberellins which are active as plant hormones and known to stimulate seed germination in a wide range of plant species is also depends on the species for their predominant active gibberellic acid (Thomas *et al.*, 2005). But seed germination and seedling growths are known to be regulated also by exogenous hormones. Hence various concentrations of GA₃ in different concentration along with Kinetin were added to MS medium to improve the response further. The observations were taken on complete germination from the date of first emergence of radical of seeds after seed culture.

It is evident that application of different concentrations of GA₃ along with Kinetin on seeds of different gladiolus genotype significantly influenced the variation on time required for germination and their germination percent. The minimum time (13.05 days) for germination was observed in ACC-15 while maximum (17.02 days) in ACC-11. In case of germination percent, maximum germination response (91.85%) was observed in ACC-15 and minimum response (89.48%) was from ACC-11. The difference in genotypes with respect to germination response might be due to differences in magnitude of dormancy because of differences in endogenous hormonal levels (Hussey, 1977). Moreover, the effect genotypes on germination response in the present investigation also find supports of Seetharamu (1993) and Aarti and Shobha Murthy (2001) who mentioned variations in pollen germination in various genotypes of gladiolus. Similar observation were also obtained by Tajbakhsh *et al.* (2006) who reported that the genotypic effect of barley varieties showed significant difference on germination percentage.

The minimum days required for germination (13.85 days) was obtained on medium MGK₆ and followed by MGK₅ (14.27 days) media. The same medium supported maximum germination response (98.07%). Germination was significantly enhanced on inclusion of higher concentrations of GA₃ along with Kinetin and resulted in increased germination percent of gladiolus seeds. The results corroborate the findings of the experiments conducted by Mello *et al.* (2009). They observed that germination days were decreases by increasing concentration of GA₃ with higher Kinetin rate. Moreover GA₃ application reduces the time required for germination of seed and found to be most effective in inducing early seed germination. The present study has also confirmed the positive effects of GA₃ on the percentage of seed germination. An improvement in seed germination with application of GA₃ was also reported by Mello *et al.* (2009). There are also some reports in this regard which indicate that kinetin in combination with GA₃ enhanced germination and seedling growth in chick pea (Kaur *et al.*, 1998) as cytokinin have very active metabolism in all phases of germination, from inhibition to radical emergence and up to the start of seedling establishment (Nikolic *et al.*, 2006). The interaction effect of genotype and medium was non significant in terms of days taken for complete germination and germination percent. However, MS medium supplemented with GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) was found to be the most appropriate condition for fastest germination of seeds of ACC-15 which was completed within 11.97 days whereas ACC-11 took maximum (18.00 days) in on MGK₁ medium. In terms of germination response, the ACC-15 recorded the maximum (99.80%) germination on MGK₆ followed by ACC-13 (99.11%) and the minimum (79.53%) in ACC-11 on MGK₁ medium. Payghamzadeha and Kazemitabar (2014) also found insignificant result with respect to walnut germination percentage in interaction of cultivars and plant growth regulators.

Among different genotypes of Gladiolus, speed of germination varied from 5.28 to 7.16 and maximum germination speed (7.16) was observed in genotype ACC-15. Least speed of germination was observed in genotype ACC-11 (5.28). The differences in germination responses might be due to genotypic differences (Nagaraju *et al.*, 2002). Speed of germination varies from variety to variety (Lokhande *et al.*, 2014). Klavina *et al.* (2004) also reported differences among the species with respect to *in vitro* seed germination time. The seed germination rate of gladiolus in hormone free MS medium and MS medium supplemented with various concentrations of GA₃ and Kinetin was found to be variable. The rate of seed germination was more in MS medium supplemented with hormone. The maximum germination speed (7.20) was observed in MGK₆

while the least germination speed (4.93) was recorded in MS with no growth regulators (MGK₁). Maximum germination speed is a desirable trait and higher dose of GA₃ was found to effect the days required for germination. Increase in the germination speed required for germination by application of higher GA₃ rate was reported by Dhoran and Gudadhe (2012) and opined that treatments with high concentrations of GA₃ are effective in overcoming dormancy and causing rapid germination of seed. The interaction effect of medium and genotype was non significant. However ACC-15 recorded the maximum value (8.69) of germination speed on MGK₆ followed by ACC-13 (7.89) and the minimum value (4.42) for germination speed in ACC-11 on MGK₁ medium.

The germination value was recorded in different genotypes of gladiolus which was evident from Table 23. Genotype ACC-15 recorded maximum germination value (13.22) and least was observed in genotype ACC-11 (12.98). The present study also showed that gladiolus genotypes did not have a significant effect on germination value. The relative influence of the genotypes on tissue response has been a matter of controversy. Vasil and Vasil (1986) suggested that the differential response of the genotypes may be due to differential expression, which in turn, depends upon the spatial and temporal distribution of their physiological and developmental stages. Germination value of seed has been influenced by all growth regulators combination and showed significant increase in germination value over the control (MGK₁). Maximum germination value (14.33) of gladiolus was recorded in MGK₆ medium. The germination value (11.52) was significantly lower on medium without phytohormone. Increasing the concentration of phytohormone increased germination value. The beneficial effect of higher concentrations of GA₃ in germination value improvement had been reported by Kedia *et al.* (2012) and opined that germination with maximum values for germination in *Eclipta alba* seeds were recorded on pre-treated with 5 mg l⁻¹ GA₃. The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum germination value (14.50) of on MGK₆ followed by ACC-13 (14.27) and the minimum germination value (11.44) in ACC-11 on MGK₁ medium.

Seedling vigour as the sum total of all seed characteristics, which indicates the capacity of metabolic activity and performance of the seed during germination and seedling emergence, and also considered as an important factor because it is an indicator of seedling establishment (Bewley *et al.*, 2000). The seedling vigour index of different genotypes of gladiolus was tabulated and it

was observed maximum in genotype ACC-15 (866.60) and genotype ACC-14 recorded the minimum seedling vigour index (758.69) (Table 23). The variations in responses among the cultivars might be due to variation in the endogenous hormonal levels of cultivars due to the genotypic differences in biosyntheses of hormones. The effect of genotypes on seedling growth in the present investigation also find supports of Yabuya *et al.* (1991) who have mentioned variations in the varietal response. There are several reports which show increase in vigour index due to PGRs and other chemicals and pre-sowing treatments with PGRs have generally been applied to enhance seedling vigour in various crop plants (Lokhande *et al.*, 2014). The MGK₆ medium showed maximum seedling vigour (1197.67) followed by MGK₅ medium (1074.25) while the minimum seedling vigour (452.77) was noticed on MS medium without growth regulators (MGK₁) representing control. The application of growth regulators have extensively used for growth and development of seedlings in *in-vitro* condition (Raghav and Kasera, 2012) which may also affect the seedling vigour value. Moreover, Dhoran and Gudadhe (2012) reported highest vigour index (820) during light period in GA₃ treated seedlings. The interaction effect of medium and genotype was significant and the ACC-15 recorded the maximum value for seedling vigour index (1320.67) of on MGK₆ followed by ACC-13 (1258.74) and the minimum value (422.40) for seedling vigour in ACC-11 on MGK₁ medium.

The longest seedling was noticed in genotype ACC-15 (8.90 cm) followed by genotypes, ACC-13 (8.65 cm), ACC-04 (8.61 cm) and ACC-11 (8.22 cm) whereas minimum length of seedling was produced by genotype ACC-14 (8.12 cm) as in Table 23. The present study also showed that gladiolus genotypes did not have a significant effect on length of seedling. Vasil and Vasil (1986) suggested that the differential response of the genotypes may be due to differential expression, which in turn, depends upon the spatial and temporal distribution of their physiological and developmental stages. However, the difference in length of seedlings of the genotypes might be due to the variations in varietal responses. The hormone concentration on MS significantly influenced the length of seedling and use of GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) resulted in significantly higher length (11.12 cm) than the other medium. The average length of seedlings increased gradually with higher concentration of GA₃ in combination with Kinetin in the MS medium. This might be due to enhancement of plant growth by application of growth regulators as reported by Hernandez, (1997) and Ashraf *et al.* (1987) and the present study also revealed beneficial effects of GA₃ and Kinetin on seedling length. An improvement in plant height and

shoot length (Naeem *et al.*, 2004) with application of GA₃ was also reported. Kedia *et al.* (2012) obtained significant value for shoot length as compare to control on application of GA₃ whereas they found significant shoot length of *D. purpurea* on Kinetin application. It has been observed that shoot length increases as rate of GA₃ increases with Kinetin and such findings are in close agreement of Naeem *et al.* (2004) that showed significant increase in shoot length on application of combined of GA₃, IAA and Kinetin. The interaction effect of medium and cultivars was found to be non significant. However, the maximum length of seedling (11.73 cm) was observed in ACC-13 with MGK₆ and the minimum (5.31 cm) in ACC-11 with MGK₁ medium.

Fresh weight of seedling varied from 386.84 to 399.66 mg and maximum fresh weight of seedling (399.66 mg) was recorded in genotype ACC-11 whereas minimum fresh weight (386.84 mg) was noticed in genotype ACC-14. The difference in genotypes with respect to weight of seedling might be due to differences in compositions of different genotypes as these are strongly influenced by cultivar (Pettigrew and Dowd, 2012) because cultivar variation in seed physical or chemical characteristics is the result of both genetic and environmental factors (Snider *et al.*, 2014) and there is relationship between seedling vigour and the amount of stored chemical energy available for post-germinative growth prior to photosynthetic autotrophy of the developing seedling (Bartee and Krieg, 1974). Similar results were obtained on weight of seedling. The maximum weight (604.70 mg) of the seedling was achieved in MGK₅ medium supplied with GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) while the minimum weight of the seedling (126.10 mg) was achieved in MGK₁ medium containing no growth regulators. The favourable effect of cytokinin is due to the fact that its role in enhancement of shoots development and cell division. Patil *et al.* (2012) reported that fresh weight were found higher in the seedlings obtained on cytokinins containing medium as compared to auxins containing medium. Moreover the effect of PGRs application on fresh weight in the present investigation also find supports of Raghav and Kasera (2012) who opined that application of growth regulators have extensively used for growth and development of seedlings in *in-vitro* condition but many workers has reported that Kinetin showed inhibition in shoot length and number of internodes like in Lentil by Naeem *et al.* (2004), in Morning Glory by (Kaul and Farooq, 1994) and in Okra by (Chaudhary and khan, 2000) but it may associated with a significant expansion in diameter of shoot and an increase in area of leaves as well as their number resulted in overall gain in weight of seedlings (Naeem *et al.*, 2004). The interaction effect of medium and genotypes was found to be significant and the maximum weight

of seedling (691.63 mg) was observed in ACC-15 with MGK₆ and the minimum (123.00 mg) in ACC-11 with MGK₁ medium. Payghamzadeha and Kazemitabar (2014) also found significantly higher fresh weight in the interaction of walnut cultivars and PGR.

The survival of plants was quite satisfactory and appeared to be correlated with the overall growth of seedling, as the genotype ACC-15 that had higher overall values also had higher survival of plants. The ACC-15 had best survival percentage followed by ACC-13, ACC-14, ACC-04 and ACC-11. The results are deviate from the findings of Rumuynin *et al.* (1990) and Misra and Singh (1999) who reported a very wide variation in the survival of different cultivars. The maximum survivability of the seedling was achieved in VSM medium supplemented with vermiculite + sand (1:1) which is followed by the medium containing vermiculite + vermicompost (1:1). Media containing vermiculite was superior for increasing survival percent of gladiolus seedlings. Hegde and Kuruvinashetty (1998) also achieved the maximum survival rates of 95% of micropropagated plants of gladiolus, when planted out in vermiculite as compared to soil. The interaction effect of medium and cultivar was non significant. However, the ACC-15 recorded the maximum (97.87%) survival on VVM and the minimum (85.53%) in ACC-11 on GSV medium.

Experiment-I

A study on the evaluation of some gladiolus genotypes to find out the extent of variability, combining ability and *in-vitro* germination potential was carried out during 20011-14 in the Horticultural Farm as well as Biotech laboratory of Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari. The results obtained from this investigation are summarized here under.

6.1 Studies on assessment of the *per se* performance of gladiolus genotypes

- ❖ Based on height gladiolus genotypes categorised into 3 classes viz, ACC-02, ACC-05 and ACC-07 as dwarf, ACC-01, ACC-03, ACC-04, ACC-06, ACC-08, ACC-09, ACC-10, ACC-11, ACC-12, ACC-13, ACC-14, ACC-15, ACC-16, ACC-17, ACC-18, ACC-19 and ACC-20 as medium.
- ❖ Based on days to bloom gladiolus genotypes categorised into 3 classes viz, ACC-01, ACC-02, ACC-03, ACC-04, ACC-06, ACC-07, ACC-08, ACC-09, ACC-10, ACC-11, ACC-12, ACC-13, ACC-14, ACC-15, ACC-16 ,ACC-17, ACC-18, ACC-19 and ACC-20 as mid season whereas ACC-05 categorised as late season genotype.
- ❖ Based on florets size (diameter) genotypes grouped into 5 groups viz, ACC-02 and ACC-05 as Class-I (Miniature), ACC-04, ACC-11, ACC-12, ACC-13, ACC-14, ,ACC-17 and ACC-20 as Class-II (Small), ACC-01, ACC-03, ACC-06, ACC-07, ACC-08, ACC-09, ACC-10, ACC-15 and ACC-16 as Class-III (Medium), ACC-19 as Class-IV (Large) whereas ACC-18 designated as Giant (Class-V).
- ❖ Based on the number of florets per spike genotypes categorised into 4 grades viz, ACC-13 as Fancy grade, ACC-01, , ACC-06, ACC-11, , ACC-14 and ACC-15 as Special, ACC-03, ACC-04, ACC-07, ACC-08, ACC-09, ACC-10, ACC-17 and ACC-19 as Special while ACC-02, ACC-05, ACC-12, ACC-16 and ACC-20 are graded as Utility.
- ❖ Looking to overall performance of the genotypes, five genotypes were found to be promising and they are ACC-11, ACC-14, ACC-04, ACC-15 and ACC-13 for commercial cut flower production as well as for breeding purposes under terai region of West Bengal.

However, ACC-14, ACC-01 and ACC-09 were found suitable for maximum corm and cormel production. The range obtained was from 11.33 to 78.33 cormels plant⁻¹. Highest number of cormels plant⁻¹ was recorded in ACC-16 and the least was in ACC-05.

- ❖ The high genotypic co-efficient of variation was recorded for diameter of floret, flower stalk girth, number of corms per plant, weight of corm, number of cormels per plant and cormels weight. The moderate genotypic co-efficient was recorded for plant height, leaves length, number of floret spike⁻¹, rachis length, spike length, spike weight and cormel diameter.
- ❖ The magnitude of heritability in broad sense was high for most of the characters except for number of leaves per plant, floret length, diameter of floret, number of floret spike⁻¹, field life, corm diameter and cormel diameter.
- ❖ High heritability coupled with high genetic advance as per cent mean was recorded for characters plant height, leaves length, flower stalk girth, rachis length, spike length, spike weight, number of corms plant⁻¹, corm weight, number of cormels plant⁻¹ and cormel weight, indicating the possible role of additive gene action.
- ❖ The estimates of genetic correlations in general were higher than phenotypic correlations, indicating the presence of inherent association between various characters.
- ❖ In correlation studies, the plant height exhibited positive significant correlation at genotypic and phenotypic level with number of leaves plant⁻¹, length of leaves, number of florets spike⁻¹, length of spike and weight of spike.
- ❖ Days to first flower opening had highly significant and positively correlated with days to 50 per cent flowering, flower diameter and weight of flowers plant⁻¹.
- ❖ Number of leaves plant⁻¹ had positive significant correlation with length of leaves, length of spike and weight of spike.
- ❖ The length of leaves was significant and positively correlated with length of spike and weight of spike.
- ❖ Number of days taken for spikes initiation showed positive correlation with days taken to show colour, days taken for flowering.

- ❖ Number of days taken for first floret to open had shown highly significant correlation with days taken for flowering, length of spike and weight of spike at both level.
- ❖ Duration to flowering had positive correlation with length of florets and weight of spike.
- ❖ Length of floret had positive correlation with length of spike and weight of spike at genotypic level.
- ❖ Number of florets spike⁻¹ had positive significant correlation with weight of spike at both levels.
- ❖ The spike rachis length was found positive and highly significant correlation with length of spike at genotypic level only whereas it's positive and non significant correlation showed with length of spike at phenotypic level. Length of spike showed strong and significant correlation with weight of spike. So by selecting the longer spike we can have good and heavy spikes.
- ❖ In path analysis, plant height showed positive direct effects towards yield of spike, further it was recorded positive indirect effect towards number of leaves plant⁻¹, days taken to show colour, length of floret, number of florets spike⁻¹, length of rachis and length of spike. However, it recorded negative indirect effect with length of leaves, days taken for spike initiation and days taken for flowering.
- ❖ Days to spike initiation, days to flowering, length of floret, number of florets spike⁻¹, length of rachis and length of spike exhibited a positive direct effect on spike weight. However, number of leaves plant⁻¹, length of leaves and days to show colour exerted negative direct effect on spike weight.
- ❖ Maximum positive direct effect on spike weight was exerted by height of plant followed by plant number of days taken for first spike initiation, days to flowering and length of spike.
- ❖ Number of leaves plant⁻¹, length of leaves days to show colour recorded negative but negligible direct effect with spike length.

EXPERIMENT-II

6.2 Studies on seed setting in cross combinations and the combining ability of seed characters

Open pollination and crosses were made among the collected germplasm of gladiolus to study the seed setting in different cross combinations which gives an idea on per cent seed setting in different cross combination, nature and compatibility of crossing with desired parents. It is vegetatively propagated and more seed set per flower is desirable for diallele analysis. Therefore, seed setting and their combining ability was studied in different cross combinations. Results obtained and discussed are summarizing here under:

- ❖ The genotypes have shown varied response with respect to the setting percentage of capsule and number of mature capsule harvested but some were shrunked and died irrespective of the cross combination. Many of the capsules failed to reach the harvestable stage.
- ❖ The differences regarding the percentage of capsule setting were observed among the genotypes and varied from 13.01 to 97.08 %.
- ❖ Maximum success for capsule setting and more number of harvestable capsules was obtained from genotype ACC-15 but maximum number of seeds per capsule was observed in ACC-04 whereas least success for capsule setting was recorded in ACC-02 and less number of harvestable capsules was obtained from genotype ACC-17.
- ❖ There had difference in availability of seeds capsule⁻¹ among the gladiolus genotypes and ranges from 7.58 to 61.74. Maximum number of seeds was obtained from the capsule of genotypes like ACC-04, ACC-11, ACC-15, ACC-12 and so on.
- ❖ In seed setting studies among five genotypes, differences regarding the days to capsule maturity were observed among the crosses and varied from 29.65 days to 45.02 days.
- ❖ The cross ACC-13×ACC-13 took maximum days (45.02 days) to capsule maturity which was closely followed by crosses ACC-04×ACC-11 and ACC-11×ACC-13 whereas cross ACC-11×ACC-04 took the minimum days.
- ❖ The longest capsule was produced by cross ACC-15×ACC-13 whereas minimum length of capsule was recorded in ACC-13×ACC-15.

- ❖ High capsule weight was recorded from the cross ACC-15×ACC-13 and lowest capsule weight was recorded from the cross ACC-04×ACC-15.
- ❖ The number of seed capsule⁻¹ ranged from 7.33 to 71.00. The highest number of seed capsule⁻¹ was produced by the cross ACC-15×ACC-13 while the lowest number of seed capsule⁻¹ was produced by the cross ACC-14×ACC-15 and ACC-04×ACC-04.
- ❖ The maximum 100 seed weight was produced by the cross ACC-15×ACC-14. The lowest test weight of seed was produced by the cross ACC-13×ACC-04.
- ❖ Variances due to general combining ability (GCA) exceeded the variances due to specific combining ability (SCA), for most the characters and were also significant.
- ❖ The genotypes ACC-15, ACC-11 and ACC-14 were good general combiners for most characters, while, ACC-13 and ACC-04 were good general combiners for the seedling weight and ACC-04 especially for diameter of cormel.
- ❖ ‘ACC-15×ACC-11’ had the highest SCA effects for most of characteristics except Germination speed, Seedling weight and diameter of cormel.
- ❖ ‘ACC-04×ACC-14’ had the highest SCA effects for diameter of cormel, and can be used in both yield and quality improvement.
- ❖ Some crosses with high GCA parents of certain characteristics had a high tendency to improve mean performance and had high SCA effects, like parent ‘ACC-15×ACC-13’ for cormel diameter, ‘ACC-15×ACC-11’ for days to germination, seedling vigour index, and seedling length in most of the characteristics.
- ❖ GCA: SCA ratio was lower for most of the characters. It indicated that a large part of the total genetic variability for most traits were the result of non- additive gene action.
- ❖ The genotypes ‘ACC-04×ACC-14’ attained the maximum (75.88%) level of germination followed by ‘ACC-15×ACC-13’, ‘ACC-04×ACC-13’, ‘ACC-15×ACC-11’ whereas, the minimum (23.00%) germination percentage was exhibited by the genotypes ‘ACC-11×ACC-14’.
- ❖ Genotypes ‘ACC-04×ACC-04’ produced the maximum value (80%) of germination speed, whereas minimum was in genotypes ‘ACC-11×ACC-14’.

- ❖ Maximum seedling vigour was obtained in the genotypes ‘ACC-04×ACC-14’ and least was in ‘ACC-11×ACC-14’.
- ❖ The longest seedling length was produced by the genotypes ‘ACC-15×ACC-15’ whereas minimum length of seedlings was recorded in genotypes ‘ACC-14×ACC-15’.
- ❖ Most of crosses showed a negative mid-parent and high-parent heterosis.
- ❖ Germination value had high MPH and HPH values viz days taken for germination (MPH from 52.15 to -18.90% and HPH from 73.64 to -8.61%), percentage of germination (MPH from 76.43 to -66.32% and HPH from 71.19 to -76.07%) and speed of germination (MPH from 49.66 to -75.96% and HPH from 45.49 to -77.98%).
- ❖ The hybrids resulted high MPH and HPH heterosis for length of seedling was ‘ACC-11×ACC-13’ (36.42% and 17.51%) respectively.
- ❖ The three hybrids expressing the highest MPH and HPH heterosis overall, were ‘ACC-15×ACC-13’, ‘ACC-14×ACC-15’ and ‘ACC-04×ACC-14’.

EXPERIMENT –III

6.3 Studies on *in-vitro* seed germination and growth of gladiolus

Seed germination was observed on MS based medium with or without exogenous hormones. Gibberellins are known to stimulate seed germination in a wide range of plant species. Hence various concentrations of GA₃ in different concentration (0, 1, 2, 3, 4, 5 or 5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) were added to MS medium to improve the response further.

- ❖ The addition of GA₃ along with Kinetin concentrations significantly influenced the mean percent seed germination and reduced the time taken for development of gladiolus seeds.
- ❖ The minimum duration (13.05 days) for germination was observed in ACC-15 while maximum (17.02 days) in ACC-11. In case of germination percent, maximum germination response (91.85%) was observed in ACC-15 and minimum response (89.48%) was from ACC-11.
- ❖ The minimum days required for germination (13.85 days) was obtained on medium MGK₆ and followed by MGK₅ (14.27 days) media. The same medium supported 98.07% germination.

- ❖ MS medium supplemented with GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) was found to be the most appropriate condition for fastest seed germination of ACC-15 which was completed within 11.97 days.
- ❖ ACC-15 recorded the maximum (99.80 %) germination on MGK₆ and the minimum (79.53 %) in ACC-11 on MGK₁ medium.
- ❖ The maximum germination speed (7.20) was observed in MGK₆ while the least germination speed (4.93) was recorded in MS with no growth regulators (MGK₁).
- ❖ ACC-15 recorded the maximum germination speed (8.69) on MGK₆ and the minimum germination speed (4.42) in ACC-11 on MGK₁ medium.
- ❖ The MGK₆ medium showed maximum seedling vigour (1197.67) while the minimum seedling vigour (452.77) was noticed on MS medium without growth regulators (MGK₁) representing control.
- ❖ ACC-15 recorded the maximum value for seedling vigour index (1320.67) of on MGK₆ and the minimum seedling vigour (422.40) in ACC-11 on MGK₁ medium.
- ❖ GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) resulted in significantly higher length (11.50 cm) than the other medium.
- ❖ The maximum weight (604.70 mg) of the seedling was achieved in MGK₆ medium supplied with GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) while the minimum weight of the seedling (126.10 mg) was achieved in MGK₁ medium.
- ❖ The maximum weight of seedling (691.63 mg) was observed in ACC-15 with MGK₆ and the minimum (123.00 mg) in ACC-11 with MGK₁ medium.
- ❖ The ACC-15 had best survival percentage followed by ACC-11, ACC-14, ACC-04 and ACC-11. The maximum survivability of the seedling was achieved in VSM medium supplemented with vermiculite and sand (1:1) which is followed by the medium containing vermiculite and vermicompost (1:1).

CONCLUSION

Among 20 genotypes studied, five genotypes were found to be promising and they are ACC-11, ACC-14, ACC-04 'ACC-15' and ACC-13, thus can be recommended for commercial cut flower production as well as for breeding purposes under terai region of West Bengal. However, ACC-14, ACC-01 and ACC-09 could be taken up for maximum corm and cormel production.

The high genotypic co-efficient of variation was recorded for diameter of floret, flower stalk girth, number of corms plant⁻¹, weight of corm, number of cormels plant⁻¹ and cormels weight coupled with narrow difference between the genotypic and phenotypic co-efficient of variation, hence, could be utilized in further breeding programme. Therefore, based on variance analysis, it has been understood that these characters need to be given more weightage, while selecting parents for improvement of gladiolus.

High heritability coupled with high genetic advance as per cent mean was recorded for characters plant height, leaves length, flower stalk girth, rachis length, spike length, spike weight, number of corms plant⁻¹, corm weight, number of cormels plant⁻¹ and cormel weight indicating the possible role of additive gene action.

The estimates of genetic correlations in general were higher than phenotypic correlations, indicating the presence of inherent association between various characters.

The plant height exhibited positive significant correlation at genotypic and phenotypic level with number of florets spike⁻¹, length of spike and weight of spike whereas length of spike showed strong and significant correlation with weight of spike. So by selecting the taller plant and longer spike we can have good and heavy spikes.

The characters like plant height, days to spike initiation, days to flowering, length of floret, number of florets spike⁻¹, length of rachis and length of spike exhibited a positive direct effect on spike weight. The characters having indirect positive effect on spike length could also be considered for evolving new types in this crop.

Those considered best as maternal parents were ACC-04, ACC-11, ACC-13 ACC-14 and ACC-15, which gave a high capsule and seed set from open pollination.

Among 25 crosses, the cross ACC-15×ACC-13 was found to be superior for producing maximum capsules setting percentage of gladiolus and capsules having highest weight and

containing maximum number of seeds capsule⁻¹ but maximum number of harvestable capsules was obtained from cross ACC-13×ACC-14 and ACC-14×ACC-13.

Most of the genotypes of gladiolus being cultivated in this region are compatibly crossable for seed setting behaviour. Getting success in viable seed set is almost always difficult when crosses are from different genotypes. Hence, inclusion of ACC-13 as one of the parent will enhance the hybridization program in future.

Variances due to general combining ability (GCA) exceeded the variances due to specific combining ability (SCA), for most the characters and were also significant. These high GCA and SCA values indicated that their inheritance was predominantly governed by additive and additive epistatic components of genetic variance. The genotypes ACC-15, ACC-11 and ACC-14 were good general combiners for most characters.

Most of crosses showed a negative mid-parent and high-parent heterosis. Percentages of heterosis and heterobeltiosis values for seedling weight, seedling length and cormel diameter ranged from negative to positive. This showed that the existence of dominance or non-additive gene actions might be present in the hybrids.

The three hybrids expressing the highest MPH and HPH heterosis overall, were 'ACC-15×ACC-13', 'ACC-14×ACC-15' and 'ACC-04×ACC-14'.

The heterosis of germination and growth related characteristics like days to germination, germination speed, seedling vigour index was high. It means those characteristics can be improved in by selection.

Increasing the concentration of growth hormone increased germination and seedling growth values and MS medium supplemented with maximum GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) was found to be the most appropriate condition for fastest germination of gladiolus seeds.

The maximum survivability of the seedling was achieved in VSM medium supplemented with vermiculite and sand (1:1) which is followed by the medium containing vermiculite and vermicompost (1:1). Media containing vermiculite was superior for increasing survival percent of gladiolus seedlings.

PROPOSED RECOMMENDATIONS

Among 20 genotypes studied, five genotypes found to be promising and they are ACC-11, ACC-14, ACC-04 'ACC-15' and ACC-13, thus can be recommended for commercial cut flower production under terai region of West Bengal. Based on high genotypic co-efficient of variation, high heritability coupled with high genetic advance as per cent mean, positive significant correlation at genotypic and phenotypic level and positive direct effect recorded for characters, it has been understood that these characters need to be given more weightage, while selecting parents for improvement of gladiolus.

Among 20 genotypes, those considered best as maternal parents are ACC-04, ACC-11, ACC-13 ACC-14 and ACC-15 whereas genotypes ACC-15, ACC-11 and ACC-14 are good general combiners for germination and growth characters of seedling. The three hybrids expressing the highest MPH and HPH heterosis overall, are 'ACC-15×ACC-13', 'ACC-14×ACC-15' and 'ACC-04×ACC-14'. Hence, inclusion of ACC-04, ACC-13, ACC-14 and ACC-15 as parent may enhance the hybridization program deserving in future.

MS medium supplemented with maximum GA₃ (5.0 mg l⁻¹) along with Kinetin (0.5 mg l⁻¹) are most appropriate condition for fastest germination of gladiolus seeds and the maximum survivability of the seedling can achieve in VSM medium supplemented with vermiculite and sand (1:1) using genotype ACC-15.

FUTURE LINE OF WORK

Following are the points for future line of work in gladiolus:

- ❖ The suitable genotypes identified can further be taken for maximizing the corm and cormel production.
- ❖ The suitable genotypes having good flowering attributes and vase life can further be taken for study.
- ❖ The promising characters identified can further be taken for multi-seasonal trials to confirm their superiority.
- ❖ Different methods and techniques can be employed for producing high quality cut flowers using these genotypes.
- ❖ Keeping in view the economical importance of gladiolus, these genotypes could be used to boost up flower industry in the region.
- ❖ The identified superior traits could be used in gladiolus hybridization.
- ❖ The characters having highly significant and positive correlation with yield may be used for selection.
- ❖ More number of repeated crosses with superior genotypes may be taken up to obtain more seed setting.
- ❖ Keeping the finding of the present investigation, studies with respect to the optimum condition of germination of gladiolus seeds in controlled and uncontrolled temperature may be carryout.

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