

STUDIES ON COMBINING ABILITY AND HETEROSIS IN GLADIOLUS (*Gladiolus hybridus*)

L.M. Kispotta, K.K. Jha, Punam Horo, S.K. Tirkey, Sanyat Misra and S. Sengupta
Department of Horticulture, Birsa Agricultural University, Ranchi-834006

Abstract: The present investigation entitled “Line x Tester analysis for combining ability in Gladiolus (*Gladiolus hybridus*)” was taken up to evaluate some of the available germplasm of gladiolus for their future utilization in crop improvement programme. The parents and crosses differed significantly for almost all the characters. The mean value of the crosses was at par with their respective parental mean in almost all the characters. The genotypic and phenotypic coefficient of variation was higher for character for the no. of florets open at a time, spike length and vase life. Large no. of crosses was found to give significant heterosis over mid parent and better parent.

White Prosperity x Ammerican Beauty, Urmil x Candyman, Sunset Sky x Ammerican Beauty was the crosses which recorded maximum positive heterosis over better parent.

In correlation study days taken for spike emergence, bud initiation, no. of floret per spike was found to be positively and significantly correlated with the days taken for the 1st floret to open, no. of floret open at a time, spike length and vase life.

Keywords: Gladiolus, Combining ability, Heterosis, Heterobeltiosis.

INTRODUCTION

Gladiolus, a majestic bulbous ornamental crop grown through out the world, belongs to family ‘Iridaceae’ and its origin is South Africa. It is called the ‘Queen of bulbous flowers’. It comprises of about 300 species in which 250 are wild and 50 of garden origin. The modern garden gladioli have developed through natural and manmade crosses. India has suitable agro-climatic conditions for gladiolus cultivation, and hence it is grown over an area of 1200 ha with a production of 1905.88 lakh spikes. This flower crop possesses a great potential for export market. It is also a popular decorative plant for use in herbaceous borders, bedding and for growing in pots and bowls.

Gladiolus is very rich in its varietal wealth and every year there is an addition of new varieties, hence varietal evaluation and creation of new varieties offers scope to improve the existing cultivars or genotypes in gladiolus. In gladiolus the most common method of improvement is through hybridization. Since the gladiolus is highly heterozygous, it becomes more essential to evaluate. To create demand for cutflower in the fast growing cities of

Northern Transitional tract, introduction and popularization is also needed. Any attempt made to encourage cut flower production in the region not only helps the florists and consumers to get fresh and quality cut flowers regularly but also helps the small and marginal farmers in the region to improve their economic condition.

Commercial success of any crop depends upon the availability of suitable cultivars to suit the particular environment and needs of the consumer. Florists and flower lovers look for newer cultivars with different colour, good spike yield and vase life in gladiolus. Keeping this in view an experiment was planned in the Department of Horticulture, BAU, Ranchi.

Material and methods

An experiment was carried out with ten varieties of Gladiolus, Seven female lines viz. Jester, Urmil, Summer Sunshine, White Prosperity, Punjab Dawn, , Summer Pearl, Sunset Sky and three male testers viz. Candyman, Ammerican Beauty and Eighth Wonder. Crossing was by following line x tester method of breeding. Hybridization work with seven lines and three testers was done during rabi season 2009. Seeds of twenty one crosses were obtained from the parents in the month of April- May 2010. Seeds were sown for getting the cormels. These cormels were replanted further two seasons to attain standard size of corms. Thus the twenty one crosses along with ten parents were grown in the rabi season 2013 in a Randomised block design with three replications and the observations were recorded to study the, heterosis and combining ability.

Result and Discussion

Table 1. Mean sum of squares due to parents, hybrids (F₁s) and parent v/s hybrids for different characters in Gladiolus.

Sl.No.	Characters	Parents	F ₁ s	Parent v/s F ₁ s	Error
	D.F.	9	20	1	
1	Wt. of corm	16.94	62.85	305.77	2.21
2	Size of corm	0.74	0.90	0.117	0.07
3	Sprouting % of corm	213.58	1739.72	11467.12	2.53
4	Days taken for spike emergence	39.08	1588.03	100.24	1.49
5	Days taken for bud initiation	77.60	1773.75	460.76	1.49
6	Days taken for 1 st floret to show colour	38.34	2210.69	176.19	1.54
7	Days taken for 1 st floret to open	45.94	2370.90	153.81	1.96
8	No. of floret / spike	21.93	41.63	174.16	0.81
9	No. of floret open at a time	7.732	6.218	3.15	0.70

10	Diameter of floret	4.30	40.28	1.21	0.09
11	Spike length	429.15	2329.13	722.42	0.72
12	Vase life	4.14	30.05	0.017	0.12

The analysis of variance for combining ability (table1) for growth characters revealed that the main sum of squares due to parents and F1s was highly significant for sprouting percentage and spike length. While the variance due to parents versus F1s was found significant for all the traits except for size of the corm and the interaction between parents and F1s for the expression of growth traits. The ratio of GCA and SCA variance (table 2) indicating that preponderance of additive gene effect for all the growth characteristics.

Table 2. Mean sum of squares for combining ability with respect to different characters in Gladiolus.

Sl.No.	Traits	Sources		
		GCA	SCA	GCA/SCA
	D.F.	9	21	
1	Wt. of corm	218.17	1257.14	0.17
2	Size of corm	7.08	18.01	0.39
3	Sprouting % of corm	1905.16	34794.57	0.05
4	Days taken for spike emergence	412.32	31760.64	0.01
5	Days taken for bud initiation	341.69	35475.08	0.02
6	Days taken for 1 st floret to show colour	472.51	44213.87	0.01
7	Days taken for 1 st floret to open	512.88	47419.39	0.01
8	No. of floret / spike	177.60	832.61	0.21
9	No. of floret open at a time	19.95	124.36	0.16
10	Diameter of floret	67.65	805.64	0.08
11	Spike length	7416.71	46582.70	0.15
12	Vase life	55.16	601.17	0.09

Table 3a: Estimates of general combining ability (gca) effects for different characters

Parents	Seed setting /capsule	Germination % of Seeds	Seed survival %	No of seeds to attain std size	Wt.of corm (g)	Size of corm (cm)	Sprouting % of corm	Days taken for spike emergence	Days taken for bud initiation	Days taken for 1 st floret to show colour
Lines										
Jester	1.48	-4.50*	2.94** *	3.25***	-0.24	-0.34***	10.52***	7.07***	7.81***	12.49***
Urmil	1.75	-5.44**	2.87** *	3.20***	2.31***	0.31**	8.99***	6.47***	6.97***	7.16***
Summer Sunshine	-0.50	-0.02	-2.11*	-2.24***	-3.09***	0.34***	-15.69***	-13.46***	-15.17***	-17.47***
White Prosperity	-0.23	4.11*	-0.58	4.38***	2.31***	0.30**	12.35***	6.18***	6.39***	4.91***
Punjab Dawn	0.19	0.96	-2.40**	-5.64***	-6.33***	-0.61***	-24.03***	-17.49***	-17.81***	-21.09***
Summer Pearl	-1.28	1.55	-0.52	-0.89	2.01***	0.12	6.84***	1.98***	2.92***	4.40***
Sunset Sky	-1.41	3.36	-0.21	-2.06**	3.02***	-0.11	1.02	9.25***	8.88***	9.60***
Testers										
Candyman	-0.61	-0.83	-0.92	0.05	0.93**	0.13*	-3.45***	-4.71***	-5.03***	-5.31***
Ammerican Beauty	-0.42	0.19	-0.41	-1.26**	-1.32***	-0.12	-7.43***	-2.56***	2.65***	-4.55***
Eighth Wonder	1.03	0.64	1.33*	1.21**	0.39	-0.01	10.88***	7.28***	7.68***	9.85***
S.E.(gi)+-	0.57	1.14	0.52	0.38	0.32	0.06	0.34	0.26	0.26	0.27
C.D.at 5%	1.15	2.32	1.06	0.76	0.65	0.12	0.70	0.53	0.53	0.54
C.D.at 1%	1.55	3.10	1.42	1.02	0.87	0.166	0.94	0.72	0.71	0.73
S.E(gi-gj)+-	0.811	1.62	0.74	0.53	0.45	0.08	0.49	0.37	0.37	0.38
C.D.at 5%	1.63	3.28	1.50	1.08	0.92	0.17	0.99	0.76	0.75	0.77
C.D.at 1%	2.19	4.39	2.01	1.45	1.24	0.23	1.33	1.02	1.01	1.03

Table 3b: Estimates of general combining ability (gca) effects for different characters

Parents	Days taken for 1 st floret to open	No of floret per spike	No of floret open at a time	Diameter of floret(cm)	Spike lengyh(cm)	No of shoots per plant	Vase life (days)
Lines							
Jester	12.53***	0.27	0.14	0.01	4.47***	0.19**	0.28*
Urmil	7.04***	2.18***	0.47***	1.68***	23.29***	-0.03	2.19***
Summer Sunshine	-18.49***	-2.37***	-1.62***	-1.68***	-13.11***	-0.03	-1.90***
White Prosperity	5.69***	0.58***	0.75***	0.44***	5.53***	-0.03	1.62***
Punjab Dawn	-22.00***	-3.82***	-1.20***	-4.41***	-32.33***	-0.03	-3.45***
Summer Pearl	5.20***	1.01***	0.84***	2.59***	2.22***	-0.03	0.48***
Sunset Sky	10.02***	2.14***	0.62***	1.36***	9.93***	-0.03	0.77***
Testers							
Candymon	-5.76***	0.48***	-0.03	0.73***	5.55***	-0.03	-0.18*
Ammerican Beauty	-4.69***	-1.45***	-0.31***	-1.61***	-11.54***	0.06	-1.03***
Eighth Wonder	10.44***	0.97***	0.33***	0.88***	5.99***	-0.03	1.22***
S.E.(gi)+-	0.30	0.09	0.06	0.06	0.18	0.03	0.07
C.D.at 5%	0.61	0.18	0.12	0.13	0.37	0.08	0.15
C.D.at 1%	0.82	0.25	0.16	0.18	0.50	0.10	0.20
S.Em(+.)	0.43	0.13	0.08	0.09	0.26	0.05	0.10
C.D.at 5%	0.87	0.26	0.17	0.19	0.53	0.11	0.21
C.D.at 1%	1.16	0.35	0.23	0.25	0.70	0.15	0.29

The general combining ability effects of 7 female lines x 3 male testers were estimated separately and presented in table 3(a). Though none of the parent was found to be good general combiner in desirable direction for all characters. For earliness, the parents Jester, Urmil, White Prosperity, Summer Pearl, Sunset sky and Eighth wonder exhibited negative gca effects. For earliness two female lines had significant negative gca for no. of spike emergence. Summer Sunshine (- 13.46) and Punjab Dawn (-17.49) were the good general combiners for earliness for spike emergence.

Number of floret per spike is an important qualitative character by which demand of the flower stalk varies. Hence Urmil, White Prosperity, Summer Pearl, Sunset sky and Eighth wonder can be used as in breeding programme for their high gca. Length of the spike determines the market value, for which Urmil, White Prosperity, Summer Pearl, Sunset sky, candyman and Eighth wonder can be exploited in breeding experiment. Vase life is an important character for demand of a flower in the market. The parents Urmil, White Prosperity, and Eighth wonder can be exploited in breeding programmed for developing variety with extended vase life. The above mentioned parents are good general combiner for respective traits. This is in accordance with the findings of Singhai Assawamane (1982), Meerow et al.(1990), Pant et al.(1998), Pant et al. (2000), Kumar et al.(2008), Singh et al. (2010) in marigold, Maria et al. (2011).

Flowering characteristics

Two female lines recorded negative estimates of gca effect for the days taken for spike emergence. The same was recorded in Summer Sunshine (- 13.46) and Punjab Dawn (- 17.49). Five female lines showed significant gca for this character.

Two testers recorded highly significant negative gca effect for days taken for the 1st floret to show color. They are Candyman, which recorded - 5.31 gca effect and - 4.55 gca effect for the days taken for 1st floret to show color.

Five female lines recorded positive estimates of gca effect for the no. of floret per spike. Among the five female lines as mentioned above Sunset Sky recorded 2.14 gca effect which was the best general combiner. Two males Candyman and Eighth Wonder were found significant for the gca in respect of floret numbers. Here Candyman recorded 0.48 gca effect and Eighth Wonder recorded 0.97 gca effect for the no. of floret per spike.

Five female lines recorded positive significant gca effects values for the no. of floret open at a time. Summer Sunshine recorded 1.62 gca effect and had the highest significant gca effect.

In testers Eighth Wonder recorded positive significant gca effect for the no. of floret open at a time.

The line Punjab Dawn recorded - 4.41 gca effect which was negative gca for the diameter of the floret and. Ammerican Beauty the only male recorded negative estimates of gca effect for the diameter of floret. The best combiner for diameter of floret was Summer Pearl with 2.59 gca effect.

Two lines recorded negative significant gca effect for the spike length. They are Summer Sunshine recorded -13.11 gca effect and Punjab Dawn recorded -32.33 gca effect for the spike length. The line Sunset Sky recorded 9.93 gca effect which was the highest positive significant gca effect for the spike length.

Among the testers Eighth Wonder recorded 5.99 gca effect which was the highest significant positive gca effect for the spike length.

Expect for Summer Sunshine and Punjab Dawn all the female lines recorded positive significant gca effect for vase life. Among the lines Urmil -2.19 gca effects had recorded highest positive gca effect for vase life. Among the testers Eighth Wonder 1.22 gca effect had highly positive significant value for gca effects.

The estimated range of variation of sca effects for days taken for spike emergence was recorded from -51.46 to 33.03, wherein the former was found in the cross combination of Summer Sunshine x Ammerican Beauty and the latter was found in the cross combination of Summer Sunshine x Candyman.

Days taken for bud initiation

In estimation of sca effects in days taken for bud initiation six cross combination were recorded negative and was found to be significant. The highest negative sca effect was recorded as -53.88 in the cross combination of Summer Sunshine x Ammerican Beauty.

Days taken for first floret to show color

The estimate range of sca effect for days taken for 1st floret to show color recorded from -54.03 to 58.41 were in the former was recorded in the cross combination of Punjab Dawn x Ammerican Beauty and the latter was recorded in the cross combination of Summer Sunshine x Ammerican Beauty, respectively.

The cross Punjab Dawn x Candyman with a value of -54.03 exhibited highly significant negative sca effect for the days taken for 1st floret to show color.

Two lines and two testers were found negative significant gca effect for days taken for the 1st floret to open.

The highest negative estimate for sca was found in the cross Summer Sunshine x Ammerican Beauty with value of -60.38.

Among the line Summer Sunshine was the good general combiner for the days taken for the 1t floret to open. This might be due to the non additive effect of the genes.

The female lines sunset sky, urmil, Summer Sunshine had positive estimate for gca effect for no. of floret per spike. The male tester Candyman was significant for gca in respect of number of floret per spike. The cross Summer Sunshine x Candyman exhibited positive significant sca effect for the no. of floret per spike.

Five female lines and two lines exhibited significant positive estimates of gca effect for the no. of floret open at a time. Summer sunset was highly suitable combiner for this character.

Nine crosses recorded high positive significant sca effect for no. of floret per spike. The cross Punjab Dawn x Eighth Wonder had the highest positive significant sca effect for this trait.

Three female lines and two male testers exhibited positive significant estimates of gca effect for the diameter of floret. Summer pearl was highly suitable combiner for floret diameter.

Ten crosses recorded positive significant sca effect, among them Summer Sunshine x Candyman had the highest Significant sca effect.

Spike length is the contributing effect of many qualitative characters of plants genetic makeup and environmental too, almost all the scientists working on the combining ability of gladiolus studied the spike length as the major component.

Among the 7 female lines Urmil exhibited thr highest positive significant estimates of gca effect with respect to the spike length.

Among the tester Candyman and Eighth Wonder were having significant positive gca effect.

The cross of Summer Sunshine x Candyman exhibited the highest sca effect for spike length in gladiolus.

This is in accordance with the findings of Singh et al. (2010), Kumar et al. (2009), Song (2006), Kumar et.al.(2004) in china aster, Mohanti et al.(2003).

For the vase life, five female lines exhibited positive significant positive gca effect. Among the testers Eighth Wonder has positive significant gca effect estimate for vase life. The cross Punjab Dawn x Eighth Wonder recorded positive significant sca effects estimate for vase life.

Table 4a: Estimates of specific combining ability (sca) effects for different characters

Crosses	Seed setting /capsule	Germination % of Seed	Seed survival%	No of seeds to attain std size	Wt.of corm (g)	Size of corm (cm)	Sprouting % of corm	Days taken for spike emergence	Days taken for bud initiation	Days taken for 1 st floret to show colour
Jester x Candymon	-0.39	6.56*	-0.31	1.93	1.49	-0.03	2.02*	4.03	4.85***	2.86***
Jester x Amm Beauty	-1.04	-2.21	0.01	-2.03	0.14	0.15	4.77***	4.67	4.87***	4.17***
Jester x E. Wonder	1.44	-4.35	0.30	0.10	-1.64	-0.11	-6.79***	-8.70	9.73***	-7.03***
Urmilx Candymon	1.93	-0.26	3.05*	2.44*	1.99*	0.01	2.99**	-0.51	-1.50*	0.26
Urmilx Amm Beauty	-2.96	0.52	-1.76	0.34	0.15	0.10	5.24***	4.14	5.32***	6.97***
Urmilx E. Wonder	1.03	-0.26	-1.29	-2.78**	-2.15*	-0.11	-8.23***	-3.63	-3.82***	-7.23***
Sum Sunshinex Candymon	-1.28	1.76	2.17	4.42***	4.43** *	0.82***	28.51***	33.03	34.70***	36.89***
Sum Sunshinex Amm Beauty	2.07	-2.13	-3.02*	-7.01***	- 5.46** *	-0.94***	- 46.16***	-51.46	-53.88***	58.41***
Sum Sunshine x E. Wonder	-0.79	0.37	0.85	2.59*	1.03	0.12	17.65***	18.43	19.18***	21.52***
W.Proserperity x	0.25	-3.69	-0.37	-0.07	1.03	0.16	7.56***	2.45	3.08***	5.31***

Candymon										
W.Prospert y x Amm Beauty	0.00	3.15	0.27	0.57	3.21** *	0.38*	7.75***	-4.70	-4.30***	-3.99***
W.Prospert y x E. Wonder	-0.25	0.54	0.10	-0.50	- 4.24** *	-0.53**	- 15.32***	2.26	1.23	-1.32
Punjab Dawn x Candymon	-1.24	-6.88*	- 5.02** *	-5.68***	- 6.08** *	-0.56**	- 41.81***	-45.29	-48.86***	-54.03***
Punjab Dawn x Amm Beauty	0.78	2.73	3.04*	4.16***	0.03	0.02	24.65***	31.30	32.63***	36.08***
Punjab Dawn x E. Wonder	0.46	4.14	1.98	1.53	6.05** *	0.55**	17.16***	13.99	16.23***	17.95***
Summ Pearl x Candymon	2.36	1.21	1.40	-0.27	-0.02	0.10	6.09***	1.05	2.48**	4.09***
Summ Pearl x Amm Beauty	1.11	-2.49	1.07	1.63	0.19	0.25	4.13***	8.50	7.50***	7.59***
Summ Pearl x E. Wonder	-3.48*	1.28	-2.48	-1.36	-0.18	-0.35*	- 10.22***	-9.54	-9.97***	-11.68***
Sunset Sky x Candymon	-1.64	1.31	-0.93	-2.76**	- 2.84**	-0.50**	-5.37***	5.25	5.25***	4.62***
Sunset Sky x Amm Beauty	0.05	0.43	0.38	2.34*	1.72	0.05	-0.38	7.56	7.87***	7.59***

Sunset Sky x E. Wonder	1.59	-1.74	0.54	0.42	1.12	0.45**	5.75***	-12.81***	-13.13	-12.21***
S.E.(sca)+-	1.51	3.04	1.39	1.00	0.86	0.16	0.92	0.70	0.70	0.71
C.D.at 5%	3.06	6.14	2.81	2.03	1.73	0.32	1.86	1.42	1.41	1.44
C.D.at 1%	4.10	8.22	3.77	2.72	2.32	0.43	2.49	1.90	1.89	1.93
S.E.(Sij- Skl)+-	2.14	4.30	1.97	1.42	1.21	0.22	1.30	0.99	0.99	1.01
C.D.at 5%	4.33	8.69	3.98	2.87	2.45	0.46	2.63	2.01	2.00	2.05
C.D.at 1%	5.80	11.63	5.33	3.84	3.28	0.62	3.52	2.69	2.68	2.74

This is in accordance with the findings of Singhai Assawamanee (1982), Meerow et al.(1990), Pant et al.(1998), Pant et al. (2000), Kumar et al.(2008), Singh et al. (2010) in marigold, Maria et al. (2011).

Among the parents Summer Sunshine and Punjab Dawn were good general combiners for earliness for bud initiations and days taken for 1st floret to show color. The best combinations were Summer Sunshine x Ammerican Beauty with value of -53.88 and Punjab Dawn x Candyman having a value of -48.86 being the highest negative gca and sca effects respectively.

Significant gca for No. of floret per spike was reported by Kumar et. al. (2011), Raghava(1993), Patli (1994). Good combiner by Kumar et.al. (2008), Timchenko (1990).

The female line Summer Sunshine and Punjab Dawn also recorded the highly significant negative gca effect for days taken for the 1st floret to show color. The male tester Candyman and Ammerican Beauty were significant gca for the same.

The cross Punjab Dawn x Candyman with a value of -54.03 exhibited highly significant negative sca effect for the days taken for 1st floret to show color.

Two lines and two testers were found negative significant gca effect for days taken for the 1st floret to open.

The highest negative estimate for sca was found in the cross Summer Sunshine x Ammerican Beauty with value of - 60.38 for first floret opening.

Among the line Summer Sunshine was the good general combiner for the days taken for the 1t floret to open. This might be due to the non additive effect of the genes.*

The female lines sunset sky, urmil, Summer Sunshine had positive estimate for gca effect for no. of floret per spike. The male tester Candyman was significant for gca in respect of number of floret per spike. The cross Summer Sunshine x Candyman exhibited positive significant sca effect for the no. of floret per spike.

Five female lines and two lines exhibited significant positive estimates of gca effect for the no. of floret open at a time. Summer sunset was highly suitable combiner for this character.

Nine crosses recorded high positive significant sca effect for no. of floret per spike. The cross Punjab Dawn x Eighth Wonder had the highest positive significant sca effect for this trait.

Three female lines and tow male testers exhibited positive significant estimates of gca effect for the diameter of floret. Summer pearl was highly suitable combiner for floret diameter.

Ten crosses recorded positive significant sca effect, among them Summer Sunshine x Candyman had the highest Significant sca effect.

Spike length is the contributing effect of many qualitative characters of plants genetic makeup and environmental too, almost all the scientists working on the combining ability of gladiolus studied the spike length as the major component.

Among the 7 female lines Urmil exhibited thr highest positive significant estimates of gca effect with respect to the spike length.

Among the tester Candyman and Eighth Wonder were having significant positive gca effect.

The cross of Summer Sunshine x Candyman exhibited the highest sca effect for spike length in gladiolus.

This is in accordance with the findings of Singh et al. (2010), Kumar et al. (2009), Song (2006), Kumar et.al.(2004) in china aster, Mohanti et al.(2003).

For the vase life, five female lines exhibited positive significant positive gca effect. Among the testers Eighth Wonder has positive significant gca effect estimate for vase life. The cross Punjab Dawn x Eighth Wonder recorded positive significant sca effects estimate for vase life.

Table 4b: Estimates of specific combining ability (sca) effects for different characters

Crosses	Days taken for 1 st floret to open	No of floret per spike	No of floret open at a time	Diameter of floret(cm)	Spike lengyh(cm)	No of shoots per plant	Vase life (days)
Jester x Candymon	2.73**	0.17	0.30	1.62***	14.41***	-0.91	0.32
Jester x Amm Beauty	3.60***	0.23	0.35*	0.35	2.43***	0.38***	0.03
Jester x E. Wonder	-6.33***	-0.40	-0.66***	-1.97***	-16.84***	-0.19	-0.35
Urmilx Candymon	0.42	2.05***	0.65***	1.04***	-0.08	0.03	1.34***
Urmilx Amm Beauty	7.89***	0.05	-0.34*	-0.89***	-0.66	-0.06	0.25
Urmilx E. Wonder	-8.31***	-2.11***	-0.31	-0.16	0.74	0.03	-1.59***
Sum Sunshinex Candymon	38.76***	3.81***	1.14***	3.99***	33.39***	0.03	-1.59***
Sum Sunshinex Amm Beauty	-60.38***	-6.19***	-2.05***	-6.22***	-45.59***	-0.06	-5.46***
Sum Sunshine x E. Wonder	21.62***	2.38***	0.91***	2.23**8	12.21***	0.03	2.16***
W.Prosperty x Candymon	4.71***	2.25***	0.49**	1.26***	14.61***	0.03	0.18
W.Prosperty x Amm Beauty	-1.89*	-1.48***	0.84***	1.05***	0.70	-0.06	1.63***
W.Prosperty x E. Wonder	-2.82**	-0.77**	-1.33***	-2.31***	-15.30***	0.03	-1.82***
Punjab Dawn	-55.80***	-6.68***	-2.75***	-5.83***	-43.46***	0.03	-4.75***

x Candymon							
Punjab Dawn x Amm Beauty	36.13***	4.72***	1.26***	3.05***	28.63***	-0.06	2.37***
Punjab Dawn x E. Wonder	19.67***	1.96***	1.49***	2.78***	14.83***	0.03	2.38***
Summ Pearl x Candymon	4.53***	0.90***	0.34*	-0.43*	7.05***	0.03	2.12***
Summ Pearl x Amm Beauty	7.33***	1.10***	0.02	2.19***	2.94***	-0.06	0.43*
Summ Pearl x E. Wonder	-11.87***	-2.00***	-0.36*	-1.76***	-9.99***	0.03	-2.55***
Sunset Sky x Candymon	4.64***	-2.50***	-0.17	-1.67***	-25.92***	0.03	-2.50***
Sunset Sky x Amm Beauty	7.31***	1.57***	-0.09	0.47*	11.56***	-0.06	0.74***8
Sunset Sky x E. Wonder	-11.96***	0.94***	0.27	1.19***	14.36***	0.03	1.76***
S.E.(sca)+-	0.80	0.24	0.16	0.17	0.49	0.10	0.20
C.D.at 5%	1.63	0.49	0.32	0.35	0.99	0.21	0.41
C.D.at 1%	2.18	0.66	0.43	0.48	1.32	0.28	0.54
S.E.(Sij- SkI)+-	1.14	0.34	0.22	0.25	0.69	0.14	0.28
C.D.at 5%	2.31	0.70	0.46	0.50	1.40	0.29	0.58
C.D.at 1%	3.09	0.94	0.61	0.67	1.87	0.40	0.77

Sprouting is an important trait to realize the potential in economic yield as less time as possible. For maximum sprouting 13 crosses exhibited significant and positive sca effects of which Summer Sunshine x Candyman, Punjab dawn x Ammerican Beauty, Summer Sunshine x Eighth Wonder are the best hybrids for good sprouting. Good sprouting Percentage give good population and hence good yield of flower stalks.

Earliness is an important trait in the commercial cultivation of flowers. Among the 21 crosses for early spike emergence, 7 crosses exhibited significant and negative (desirable) sca effects of which Punjab Dawn x Candyman, Sunset sky x Eighth Wonder, Summer Pearl x Eighth Wonder and Jester x Eighth Wonder are best hybrids.

Summer Pearl X candyman, summer Pearl x Eighth Wonder and Urmil x Candyman exhibited heterobeltiosis similar results were obtained by Hemantkumar et. al.(2008).

Spike length is an important character for the quality of the flower and also affects the presence of number of floret in an spike. Among 21 hybrids only 11 hybrids showed significant sca effects. Among those Summer Sunshine X Candyman, Punjab Dawn x Ammerican Beauty, Punjab Dawn x Eighth Wonder , Sunset Sky x Eighth Wonder are the best hybrids.

Table 5a: Expression of heterosis in percentage over mid parent (MP) and better parent(BP) for different characters in Gladiolus

Crosses	Wt.of corm (g)		Size of corm (cm)		Germination% of corm		Days taken for spike emergence		Days taken for bud initiation	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Jester x Candyman	-11.71*	-	-5.58	-	-13.46	-	12.49**	12.05**	9.58**	9.48**
		25.04**		22.05**		21.63**				
Jester x Amm Beauty	-	-	-5.23	-	-14.83	-	9.73**	3.23**	6.79**	1.24
	23.24**	31.65**		20.49**		22.87**				
Jester x E. Wonder	-22.37	-	-7.09	-	-7.37	-	12.05**	11.71**	7.74**	7.10**
		29.99**		20.48**		16.11**				
Urmilx Candyman	-2.69	-	5.78	-5.67	-22.18	-	-1.10	-6.02**	-4.84**	-8.85**
		13.28**				22.18**				
Urmilx Amm Beauty	-	-	3.84	-5.74	-23.92	-	2.49*	1.71**	1.75	0.74
	15.31**	20.58**				23.92**				
Urmilx E. Wonder	-	-	3.76	-3.7	-19.08	-	12.30**	6.11**	9.61**	4.30**
	16.79**	20.91**				19.08**				
Sum Sunshinex Candyman	-	-	26.31**	14.17*	-19.01	-	16.02**	8.24**	13.62**	8.75**
	14.68**	24.71**				21.35**				
Sum Sunshinex Amm Beauty	-	-	-	-	-100	-100**	-100**	-100.0**	-	-
	65.59**	68.07**	24.31**	30.33**					100.00**	100.00**
Sum Sunshine x E. Wonder	-	-	9.69	3.27	-15.45	-	12.99**	4.82**	10.66**	5.21**
	26.37**	30.76**				17.89**				
W.Prosperty x Candyman	-	-	3.08	-2.36	-	-	7.37**	6.32**	3.25**	1.51
	11.72**	17.00**				10.45**	14.25**			
W.Prosperty x Amm Beauty	-6.69	-7.39	4.58	0.98	-	-	-6.08**	-10.59**	-8.65**	-11.89**
					14.54**	18.05**				
W.Prosperty x E. Wonder	-	-	-13.84*	-14.8*	-	-	25.87**	23.93**	18.80**	16.00**
	30.67**	30.20**			19.51**	22.81**				
Punjab Dawn x Candyman	-	-	-	-	-100**	-100**	-100**	-	-	-
	72.37**	77.68**	29.64**	40.94**				100.00**	100.00**	100.00**
Punjab Dawn x	-	-	18.35**	-	-	-	8.10**	6.01**	3.84**	3.80**

Amm Beauty	50.69**	58.35**		30.33**	34.42**	37.53**				
Punjab Dawn x E. Wonder	-9.78	- 22.89**	2.77	-10.5	- 23.07**	- 26.71**	4.45**	-0.19	2.19	-3.7**1
Summ Pearl x Candyman	- 16.5**1	- 22.17**	-6.33	-7.87	- 10.66**	- 21.23**	-3.00*	-5.73**	-2.79*	-4.93**
Summ Pearl x Amm Beauty	- 20.40**	- 21.70**	-6.86	-7.17	- 17.44**	- 27.17**	4.67**	1.53	1.53	-1.57
Summ Pearl x E. Wonder	- 13.28**	-13.49*	- 17.15**	- 19.38**	- 12.91**	- 23.22**	-0.35	-3.72*	-1.77	-4.57**
Sunset Sky x Candyman	- 20.47**	- 29.15**	- 23.71**	- 27.56**	- 37.37**	- 38.51**	14.70**	12.20**	7.69**	4.12**
Sunset Sky x Amm Beauty	-4.81	-10.78*	- 14.48**	- 17.21**	- 36.34**	- 37.51**	14.21**	10.05**	8.38**	6.28**
Sunset Sky x E. Wonder	1.81	-3.28	0.69	0.17	- 11.44**	- 13.07**	6.32**	3.39*	0.81	-3.18*
Range	-72.37 - 1.81	-77.68 - -3.28	-29.64 - 26.31	-40.94 - 14.17	-37.37 - 7.37	-38.51 - -3.07	-3.00- 25.87	-10.59- 23.93	-8.65- 13.62	-11.89- 16.00
S.Em(+)	1.05	1.21	0.19	0.22	1.12	1.30	0.86	0.99	0.85	0.99
C.D.at 5%	2.12	2.45	0.40	0.46	2.28	2.63	1.74	2.01	1.73	2.00
C.D.at 1%	2.84	3.28	0.53	0.62	3.05	3.52	2.33	2.69	2.32	2.68

Table 5b: Expression of heterosis in percentage over mid parent (MP) and better parent (BP) for different characters

Crosses	Days taken for 1st Floret to Show Colour		Days taken for 1 st floret to open		No of floret per spike		No of floret open at a time		Diameter of floret(cm)		Spike length(cm)		No of shoots per plant		Vase life (days)	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
Jester x Candyman	15.88**	14.03*	15.66**	13.59**	-1.80	-28.07**	2.33	-20.48**	22.00**	5.83*	18.19*	-3.63*	-14.29	-25.00*	6.88*	-12.58*
Jester x Amm Beauty	11.40**	3.58**	11.20**	3.41**	-14.73**	-36.15**	-0.79	-21.88**	-18.85**	-31.79*	-16.24*	-30.70**	42.8**6	25.00*	-6.50*	-23.33*
Jester x E. Wonder	23.58**	22.53*	25.15**	23.50**	-1.51	-27.56**	-1.72	-18.57**	-13.57**	-25.16*	-17.96*	-31.86**	-14.29	-25.00*	17.70**	-5.30
Urmilx Candyman	-1.28	-6.07**	-1.46	-6.44**	-0.79	3.07	1.30*	-8.43*	26.19**	15.58*	15.70*	0.78	-14.29	-25.00*	26.16**	16.56*
Urmilx Amm Beauty	1.58	0.75	2.51*	2.10	-24.74**	-28.95**	-24.50*	-28.75**	-18.92**	-28.21*	-2.92**	14.08**	14.29	25.00*	5.76*	-2.65
Urmilx E. Wonder	8.67**	2.66*	7.66**	1.76	-24.97**	-27.1988	-4.96	5.63	15.74**	5.80*	20.34*	6.97*	-14.29	-25.00*	11.27**	1.32
Sum Sunshinex Candymon	16.13**	13.26*	16.89**	14.21**	-13.11**	-21.49**	-27.78*	-37.35**	17.49**	11.95*	14.32*	-2.21*	0.00	0.00	-1.71	-4.64

							*									
Sum Sunshinex Amm Beauty	- 100.00* *	- 100 .00 **	- 100. 00**	- 100. 00**	- 100. 00* *	- 100. 00**	- 100 .00 **	- 100. 00**	- 100. 00**	- 100 .00 **	- 100.00 **	- 100.0 0**	0.00	0.0 0	- 100.00**	- 100.00 **
Sum Sunshine x E. Wonder-	16.75**	13. 02* *	16.3 3**	13.1 2**	- 19.3 2**	- 26.6 7**	- 17. 56* *	- 22.8 6**	2.23	- 2.7 8	- 7.89**	- 19.63 **	0.00	0.0 0	2.42	-1.99
W.Prosperty x Candymon	5.35**	3.2 3*	4.96 **	2.40	- 11.3 1**	- 12.2 8**	1.9 6	-6.02	9.84 **	6.5 4**	9.08**	- 2.34* *	0.00	0.0 0	10.29**	-0.66
W.Prosperty x Amm Beauty	10.70**	- 14. 0** 3	- 7.12 **	- 10.0 1**	- 47.2 5**	- 48.4 3**	5.3 3	-1.25	- 17.0 2**	- 22. 37* *	- 24.64* *	- 31.41 **	0.00	0.0 0	17.34**	5.30
W.Prosperty x E. Wonder	16.75**	13. 55* *	15.8 2**	12.4 6**	- 27.6 8**	- 28.0 0**	- 20. 00* *	- 20.0 0**	- 21.8 3**	- 24. 33* *	- 22.44* *	- 29.09 **	0.00	0.0 0	5.22	-6.62*
Punjab Dawn x Candymon	- 100.00* *	- 100 .00 **	- 100. 00**	- 100. 00**	- 100. 00* *	- 100. 00**	- 100 .00 **	- 100. 00**	- 100. 00**	- 100 .00 **	- 100.00 **	- 100.0 0**	0.00	0.0 0	- 100.00**	- 100.00 **
Punjab Dawn x Amm Beauty	3.45**	1.7 2	3.37 **	1.23	- 22.6 2**	- 33.3 3**	- 8.9 4	- 30.0 0**	- 31.5 8**	- 45. 95* *	- 21.17* *	- 41.90 **	0.00	0.0 0	-23.58**	- 37.75* *
Punjab Dawn x E. Wonder	5.96**	0.9 3	8.35 **	4.09 **	- 27.7 0**	- 39.1 1**	22. 12* *	-1.43	-4.14	- 22. 20* *	- 15.25* *	- 37.34 **	0.00	0.0 0	5.53	- 15.23* *

Summ Pearl x Candymon	2.28*	- 0.6 3	2.42 *	-1.65	- 12.0 6**	- 18.4 2**	2.6 7	-7.23	25.8 0**	10. 58* *	2.76**	- 13.40 **	0.00	0.0 0	26.56**	7.28*
Summ Pearl x Amm Beauty	1.31	- 1.6 4	1.07	-0.51	- 21.5 7**	24.8 8**	- 7.4 8	- 15.0 0**	23.1 1**	4.7 9*	- 21.15* *	- 32.54 **	0.00	0.0 0	-2.75	- 17.88* *
Summ Pearl x E. Wonder	2.30*	- 1.3 5	2.66 *	-1.87	- 28.5 7**	- 33.3 3**	5.1 1	2.86	13.5 6**	- 0.3 6	- 14.98* *	- 26.96 **	0.00	0.0 0	-10.32**	25.17* *
Sunset Sky x Candymon	8.33**	4.3 6**	8.23 **	3.97 **	- 28.3 0**	- 33.3 3**	- 10. 81*	- 20.4 8**	-2.58	- 11. 41* *	- 33.22* *	- 39.12 **	0.00	0.0 0	-29.96**	- 35.76* *-
Sunset Sky x Amm Beauty	6.40**	4.1 8**	6.42 **	4.72 **	- 10.0 2**	- 13.6 2**	- 13. 10* *	- 21.2 5**	- 8.52 **	- 19. 56* *	- 8.62**	- 15.28 **	0.00	0.0 0	-3.62	- 11.92* *
Sunset Sky x E. Wonder	7.08**	2.4 1*	8.27 **	3.52 **	0.24	- 6.22 *	15. 56* *	11.4 3*	26.6 8**	14. 98* *	15.16* *	7.25* *	0.00	0.0 0	33.33**	20.53* *
Range	-1.28 - 23.58	- 6.0 7- 22. 53	- 7.12- 25.1 5	- 10.0 1- 23.5 0	- 47.2 5- 0.24	- 39.1 1- 3.07	- 24. 50 - 15. 56	- 37.3 5- 11.4 3	- 31.5 8- 26.6 8	- 45. 95 - 14. 98	-33.22 -20.34	- 41.90 -7.25	- 14.2 9- 42.8 6	- 25. 00- 25. 00	-23.58 - 33.33	-15.23 -23.81
S.Em(+.)	0.87	1.0 4	0.99	1.14	0.30	0.34	0.1 9	0.22	0.21	0.2 5	0.60	0.69	0.12	0.1 4	0.24	0.28
C.D.at 5%	1.77	2.0 5	2.00	2.31	0.60	0.70	0.4 0	0.46	0.43	0.5 0	1.21	1.40	0.25	0.2 9	0.50	0.58
C.D.at 1%	2.37	2.7 4	2.67	3.09	0.81	0.94	0.5 3	0.61	0.58	0.6 7	1.62	1.87	0.34	0.4 0	0.67	0.77

Heterosis study

Extensive studies have been made on the heterosis for several importance characters particularly flower quality for no. of floret per spike, Kumar et al. (1989), Raghava et al. (2009), Singh et al. (2009), Misra et.al. (2001), Kumar et al. (2008), The estimation of the extent of heterosis over mid Patil et al. (1994) in china aster, Raghava et al. (2009). For seed setting per capsule Poon (2012).

The estimation of the extent of heterosis over mid parents, male and female parents and over the best parent could be informative in identifying true heterotic cross combination. The heterotic responses were estimated for vase life, no. of floret per spike, no. of floret open at a time, spike length, floret diameter and some more characters of gladiolus. Marked heterosis was observed for most of the characters as shown in table no.9a & b. The expression and magnitude of heterosis, however, varied according to character. The range and average heterosis and number of crosses showing positive and negative estimates (in desired direction) over mid parent and better parent have been presented in table no.10.

With respect to the weight of the corm only one hybrid Sunset sky x Eighth Wonder having recorded 1.81, was found positively more than their mid parent and all the hybrids were found smaller than their mid parents.

Out of 21 crosses; nine crosses showed positive heterosis. Two crosses namely Punjab Dawn x American Beauty recorded a value of 12.35 and Summer Sunshine x Candyman recorded a value of 26.31 had positive significant heterosis. The highest heterobeltiosis was observed in the hybrid Summer Sunshine x Candyman which recorded a value of 14.17.

*The heterosis for sprouting percentage was observed in the hybrid_____

For the study of heterosis of day taken for spike emergence three crosses exhibited significant negative heterosis over mid parent. In the case of days taken for spike emergence earliness was the desirable traits in gladiolus. The highest heterobeltiosis was recorded in White Prosperity x American beauty which recorded the value of 10.59 with three other hybrids which also shows significant negative heterosis for days taken for spike emergence.

*Among 21 crosses, three crosses exhibited significant negative heterosis over mid parent and five crosses exhibited significant negative heterosis over better parent for the days taken for bud initiation. The maximum relative heterosis for this trait was recorded in crosses namely White prosperity x Eighth Wonder which recorded a value of 8.65 and the highest heterobeltiosis was recorded in cross which recorded 11.89 in the same cross.

The maximum heterosis and heterobeltiosis was recorded in the crossed Urmil x Candyman which recorded value of 1.28 and White prosperity x Ammerican Beauty which recorded a value of 14.03.

*The estimated heterosis of earliness in floret opening, the relative heterosis reanged from -7.12 to 25.15.

The no. of florets per spike are most important factor for heterosis breeding. In this study significant relative heterosis crosses was achieved in 20% of the hybrids.

The maximum relative heterosis value 0.79 and heterobeltiosis value 24.88 was recorded in the crosses Urmil x Candyman and Summer Pearl x Ammerican Beauty respectively. The cross compatible parents might have inherited more qualitative factor in offspring's. The heterosis for no. of florets per spike was also reported by _____*.

In case of no. of floret open at a time the maximum positive relative heterosis and heterobeltiosis was exhibited by sunset sky x Eighth Wonder which recorded a value of 15.56 and 11.43 respectively.

With regard to the diameter of the floret the maximum positive heterosius was observed in the cross of Sunset sky x Eighth Wonder having a value of 26.68 and the highest heterobeltiosis in urmil x Candyman having a value of 15.58.

Conclusion

In correlation study days taken for spike emergence, bud initiation, no. of floret per spike was found to be positively and significantly correlated with the days taken for the 1st floret to open, no. of floret open at a time, spike length and vase life.

References

- [1] Kumar, P. Hemant, Kulkarni, B.S., Jagadeesha, R.C., Reddy, B.S., Shirol, A.M. AND Mulge, R. (2008). Combining Ability and Heterosis for Growth Characters in Gladiolus (*Gladiolus hybridus*. Hort). *Karnataka J. Agric. Sci.*, 21 (4) (544-547).
- [2] Meerow, Alan W., Kane, Michael E. and Broschat, Timothy K. (1990). Breeding of new Hippeastrum cultivars using diploid species I. The F-1 evaluation. *Proc Fla State Hort. Soc.* 103: 168-170.
- [3] Mohanty Anita, Mohanty C.R., Mohapatra K.C. (2003). Combining ability for yield and it's components in marigold. *Journal of Ornamental Horticulture*.6 (1): 34-38.
- [4] Pant C.C., Lal S.D., Shah Deepak (1998). Combining Ability Studies in Gladiolus-I. *Journal of Ornamental Horticulture* 1(1): 32-36.

- [5] Pant C.C., Lal S.D., Shah Deepak (2000). Combining Ability Studies in Gladiolus-II Journal of Ornamental Horticulture 3(1): 43-47.
- [6] Singchai Assavamanee (1982). Hybridization and progeny study of selected introduced Gladiolus varieties [in Thailand]. Thesis Dissertation. Kasetsart Univ., Bangkok.
- [7] Timchenko, O. D.(1990). Study of varieties of *Gladiolus X hybridus* with a view to using them in breeding work. Ukraïns'kii Botanïchnii Zhurnal. 47 (4): 96-98.