



Seed setting, combining ability and heterosis studies in gladiolus (*Gladiolus grandiflorus*)

SURESH K MAHATO and SUBHENDU S GANTAIT*

Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal 736 165, India

Received: 21 March 2019; Accepted: 08 September 2019

ABSTRACT

The seed setting, combining ability and heterobeltiosis analysis was carried out in gladiolus (*Gladiolus grandiflorus* L.) based on 5×5 full diallel mating for different traits utilizing five genotypes, viz. ACC-15, ACC-13, ACC-11, ACC-14 and ACC-04 for the experiment. Experimental results revealed that days required for maturity of capsules, harvest percentage of capsule, number of seeds per capsule, hundred seeds weight and seed germination percentage were varied significantly among the crosses. The maximum harvestable capsules was recorded in ACC-13 $\times$ ACC-14 and its reciprocal cross while maximum number of seeds per capsule was found in the cross ACC-15 $\times$ ACC-13. The genotypes, viz. ACC-15, ACC-11 and ACC-14 were good general combiners for most characters for many traits. ACC-04 $\times$ ACC-14 had the highest SCA effects for diameter of cormel and can be used in both yield and quality improvement. Though, most of crosses showed a negative mid-parent and high-parent heterosis, hybrids expressing the highest MPH and HPH heterosis overall, were ACC-15 $\times$ ACC-13, ACC-14 $\times$ ACC-15 and ACC-04 $\times$ ACC-14.

Key words: Combining ability, Diallel, Gladiolus, Heterosis, Seed set

Gladiolus (*Gladiolus grandiflorus* L.) or sword lily belongs to the family Iridaceae is an ornamental bulbous plant native to South Africa. The crossing of gladioli genotypes in a diallel fashion is the specific and effective technique for the measurement, identification and selection of superior genotypes (Poon *et al.* 2012, Gantait *et al.* 2016). In diallel analysis general combining ability is regarded as additive gene action and specific combining ability reflects non-additive gene actions. Estimates of additive and non-additive gene action are important in early stages of breeding procedures. 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). Heterosis results from combined action and interaction of allelic and non-allelic factors and is commonly closely and positively correlated with heterozygosity (Kumar *et al.* 2008). Though heterosis in gladiolus has been studied and F_1 's have been commercially utilized in some countries to some extent but in overall, the contribution and information available on combining ability and heterosis studies in geophytes is

very meager. This is the present need to sort out the best possible cross combinations of gladioli genotypes for seed setting along with to identify suitable parents having good combining ability and high heterosis for seed and seedling characters. So, the full diallel analysis in gladiolus was carried out for preliminary evaluation of genetic stocks for use in hybridization programme.

MATERIALS AND METHODS

An experiment was conducted to investigate cross combinations and the combining ability of seed characters involving five genotypes which represents diverse morphological characters of gladiolus at the Horticultural Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during 2012-14. The five superior genotypes, viz. ACC-15, ACC-13, ACC-11, ACC-14 and ACC-04 were crossed in a full diallel mating design (5×5) according to the formula designed by Griffing (1956). The F_1 pods were harvested at full physiological maturity, when the capsules start to burst. All seeds of parental genotypes and hybrids were raised in seedbeds to produce seedlings. The data were collected for five randomly selected plants from each parent and F_1 's. Seed setting in cross combinations were realised through observation of parameters, viz. number of days taken for maturity of capsule, capsule harvest percent, number of seeds set per capsule, weight of 100 seeds and germination percentage. For combining ability of seed characters days required to germination, germination percentage, germination speed,

*Corresponding author e-mail: ssgflori@gmail.com

seedling vigour index, seedling length and size of cornel (diameter) were recorded. Diallel analysis was performed to calculate general combining ability (GCA) and specific combining ability (SCA) according to the Griffing's (1956) method, where parents, F_1 's and reciprocals are included. The data was analyzed with Agrobases (2000) using a fixed model. Two types of heterosis, viz. mid-parent heterosis (MPH) and high parent heterosis (HPH) were analyzed based on the mean values of the genotypes in this study as formula recommended by Falconer and Mackay (1996).

RESULTS AND DISCUSSION

Seed setting and germination in cross combinations:

The data showed that the days required for maturity of capsules, harvest percentage of capsule, number of seeds per capsule and weight of hundred seed weight were varied significantly among the crosses (Table 1). The cross ACC-15 × ACC-14 took minimum days (30.39) to attain the stage of maturity. The maximum percentage of capsule harvest

(85.33%) was recorded from crosses ACC-14 × ACC-13. The highest number of seeds per capsule was produced by the cross ACC-15 × ACC-13 (71.00). The highest weight of hundred seed was produced by the cross ACC-15 × ACC-14 (4.71 g). Data revealed the significant variations among the crosses of genotypes for the character percentage of germination (Table 1). The maximum percentage of germination (75.88%) was recorded in genotype ACC-04 × ACC-14. Poon *et al.* (2012) found similar results in capsule harvest and seed setting per capsule in gladiolus. Anandhi *et al.* (2013) corroborate the findings same as pod setting in *Gloriosa superba*. Mahato and Gantait (2017) demonstrated similar results on seed setting behaviour of some gladiolus genotypes through cross pollination. Takatsu *et al.* (2005) reported the germination rates of the gladiolus F_1 seeds ranged from very low to high percentage. Hossain *et al.* (2012) also observed variations for number of seed per capsule and weight of thousand seed.

Combining ability of seed characters: The data revealed

Table 1 Seed setting in cross combinations of gladiolus genotypes through full diallel

Cross	Days to capsule maturity			Capsule harvest percent			Number of seeds per capsule			Hundred seeds weight (g)			Seed germination percent		
	Y-1*	Y-2*	P*	Y-1	Y-2	P	Y-1	Y-2	P	Y-1	Y-2	P	Y-1	Y-2	P
ACC-15 × ACC-15	37.68	40.35	39.02	49.18	51.00	50.08	45.27	48.08	46.67	1.25	1.17	1.21	32.56	34.20	33.38
ACC-15 × ACC-13	34.00	36.30	35.15	49.00	51.20	50.10	70.00	72.00	71.00	1.72	1.29	1.51	59.74	61.73	60.74
ACC-15 × ACC-11	36.63	39.44	38.04	74.35	76.32	75.33	54.00	56.00	55.00	2.50	3.00	2.75	56.75	53.37	55.06
ACC-15 × ACC-14	28.54	32.23	30.39	62.22	64.00	62.22	29.04	33.62	31.33	4.57	4.85	4.71	30.55	32.11	31.33
ACC-15 × ACC-04	40.66	42.62	41.64	49.21	51.10	50.16	22.30	18.35	20.33	2.80	2.12	2.46	26.17	28.02	27.10
ACC-13 × ACC-15	40.22	42.49	41.36	24.33	25.67	25.00	66.34	71.00	68.67	1.65	1.72	1.69	39.53	42.55	41.04
ACC-13 × ACC-13	43.26	46.77	45.02	73.00	77.21	75.11	45.71	47.63	46.67	3.78	3.91	3.85	34.86	36.10	35.48
ACC-13 × ACC-11	38.32	40.98	39.65	61.10	63.23	62.17	24.00	26.00	25.00	3.00	3.22	3.11	44.19	46.35	45.27
ACC-13 × ACC-14	34.25	38.08	36.17	86.33	87.67	87.00	30.18	38.47	34.33	2.65	2.93	2.79	22.15	24.13	23.14
ACC-13 × ACC-04	38.43	42.15	40.29	53.11	47.54	50.33	20.10	23.24	21.67	1.22	1.01	1.12	31.44	34.88	33.16
ACC-11 × ACC-15	41.55	43.75	42.65	46.33	53.67	50.00	21.57	24.42	23.00	2.85	3.79	3.32	29.65	31.21	30.43
ACC-11 × ACC-13	42.76	44.52	43.64	35.73	38.26	37.00	23.12	25.54	24.33	2.82	2.55	2.68	42.15	44.85	43.50
ACC-11 × ACC-11	36.54	37.46	37.00	59.33	64.67	62.00	58.29	63.05	60.67	1.82	1.50	1.66	74.50	76.50	75.50
ACC-11 × ACC-14	36.20	39.84	38.02	61.33	63.10	62.22	28.58	34.07	31.33	4.10	4.30	4.20	17.50	18.62	18.06
ACC-11 × ACC-04	27.65	31.65	29.65	36.00	38.44	37.22	33.57	37.77	35.67	1.34	1.50	1.42	24.75	25.95	25.35
ACC-14 × ACC-15	40.38	38.00	39.19	46.10	53.90	50.00	8.57	6.09	7.33	2.40	2.73	2.56	45.35	47.25	46.30
ACC-14 × ACC-13	30.25	33.75	32.00	86.67	87.33	87.00	51.40	56.60	54.00	1.85	1.52	1.68	34.56	36.35	35.46
ACC-14 × ACC-11	34.55	38.74	36.65	34.71	39.67	37.19	7.00	9.00	8.00	1.16	1.90	1.53	24.55	26.49	25.52
ACC-14 × ACC-14	38.90	41.14	40.02	46.80	53.85	50.33	18.60	22.06	20.33	2.15	2.00	2.07	26.57	28.68	27.63
ACC-14 × ACC-04	39.50	40.50	40.00	46.67	53.33	50.00	15.07	17.17	16.12	1.73	1.84	1.79	39.55	42.47	41.01
ACC-04 × ACC-15	39.65	41.65	40.65	48.20	52.32	50.26	22.00	21.33	21.67	1.40	1.21	1.31	30.00	32.00	31.00
ACC-04 × ACC-13	39.55	42.78	41.17	23.00	27.66	25.33	67.92	69.42	68.67	1.29	1.30	1.30	54.25	56.41	55.33
ACC-04 × ACC-11	42.50	45.50	44.00	36.07	38.09	37.08	21.57	27.09	24.33	2.94	1.95	2.45	40.25	42.53	41.39
ACC-04 × ACC-14	36.25	38.33	37.29	59.67	65.14	62.40	62.17	59.16	60.67	1.57	1.62	1.60	74.35	77.41	75.88
ACC-04 × ACC-04	37.75	40.30	39.03	47.13	53.33	50.23	9.55	5.10	7.33	2.00	2.63	2.32	73.95	76.05	75.00
LSD _{at 0.05}	7.619	7.349	2.596	11.68	10.71	10.55	6.12	6.22	8.04	4.687	5.044	1.673	6.97	6.69	6.61

*Y-1, Year-1; Y-2, Year-2; P, Pooled.

that with respect to days required to germination the parent ACC-15 ranked first (Table 2). The largest positive SCA effect was in crosses ACC-13 $\times$ ACC-15. The highest GCA for germination percent was measured for parent ACC-14 while the crosses ACC-04 $\times$ ACC-15 had the significantly highest rank for SCA. The parent, ACC-15 ranked first in GCA for germination speed. The largest positive GCA effect for seedling vigour index value was measured for ACC-11 wherein ACC-15 $\times$ ACC-11 had the highest positive SCA

effect. The highest GCA value for diameter of cormels was for ACC-04. Variances due to GCA exceeded the variances due to SCA for most of the characters. 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

Table 2 GCA and SCA effects and mean square ratio for some characteristics in gladiolus

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

diameter of cormel. 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 $\times$ ACC-13 for cormel diameter, ACC-15 $\times$ ACC-11 for days to germination, seedling vigour index, and seedling length in most of the characteristics. It is an important indicator of the potential of parental lines for generating superior breeding populations. 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. Hemanth Kumar *et al.* (2008) observed similar findings in gladiolus based on 7 $\times$ 7 half diallel that the varieties American Beauty, Summer Sunshine and Priscilla as good general combiners and additive type of gene action for many traits. Kipsotta *et al.* (2017) showed similar combining ability in gladiolus by L $\times$ T analysis.

Heterosis: Mid-parent heterosis (MPH) and high-parent heterosis (HPH) was measured for all the characteristics (Table 3). Most of the F_1 hybrids expressed positive MPH for days taken to germination. The F_1 hybrid variety ACC-11 $\times$ ACC-15 expressed the highest MPH (52.15%). The hybrid ACC-11 $\times$ ACC-15 had the highest HPH (73.64%). Eight of the 20 F_1 hybrids had positive mid-parent heterosis

for percentage of germination. The highest heterosis was expressed by hybrid ACC-15 $\times$ ACC-13 (76.43%). Most of the F_1 hybrids expressed negative HPH for percentage of germination. Six of the 20 hybrids were positive MPH for germination speed and also most of the hybrids had negative HPH. Almost all the F_1 hybrids had negative MPH for seedling vigour index value. The hybrid ACC-04 $\times$ ACC-14 (56.03%) had the highest positive MPH while the highest HPH was found in ACC-15 $\times$ ACC-13 (8.69%). Highest positive MPH for seedling weight (28.41%) was expressed by hybrid ACC-04 $\times$ ACC-14. The hybrid ACC-04 $\times$ ACC-14 (10.06 %) had the highest HPH value. Five of the 20 F_1 hybrids had positive MPH for cormel diameter. The hybrid ACC-04 $\times$ ACC-14 expressed both the highest MPH and HPH for cormel diameter. The results corroborate the findings of Cantor *et al.* (2011) and Hort *et al.* (2012) in gladiolus hybrids evaluations. Kumari *et al.* (2018) also exhibited similar trend of significant heterosis in China aster through cross L $\times$ T analysis for flower yield. Hemanth Kumar *et al.* (2008) reported that 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. The heterosis of yield related characteristics was high with high combining ability.

Table 3 Heterosis (%) estimates of various characteristics in gladiolus

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

It is concluded that the maximum percentage of capsules was harvested from the cross ACC-13 × ACC-14 and its reciprocal cross ACC-15 × ACC-13 produced maximum number of seeds per capsule. Wherein the earliest capsule maturity was observed in cross ACC-15 × ACC-14. The genotypes, viz. ACC-15, ACC-11 and ACC-14 were good general combiners for most characters for many traits. The parental cross, ACC-04 × ACC-14 had the highest SCA effects for diameter of cormel, and can be used in both yield and quality improvement. Though, most of crosses showed a negative mid-parent and high-parent heterosis, 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.

ACKNOWLEDGEMENTS

Authors are grateful to DST, New Delhi for providing funding support through INSPIRE Fellowship and contingency grant to conduct the experiments.

REFERENCES

- Agrobase. 2000. Agrobase user's guide and reference manual. Agronomix Software inc., Canada.
- Anandhi S, Rajamani K and Jawaharlal M. 2013. Propagation studies on *Gloriosa superba*. *Medicinal and Aromatic Plant Research Journal* **1**: 1-4.
- Cantor M, Buta E and Pop R. 2011. Evaluation of promising hybrids of *Gladiolus hybridus* L. *Bulletin UASVM Horticulture* **68**: 303-08
- Falconer D S and Mackey F C. 1996. *Introduction to Quantitative Genetics*, 4th Edition. Longman, New York.
- Gantait S S, Mahato S K and Majumder J. 2016. Genetic variability, character association and path coefficient analysis in gladiolus for various quantitative traits. *Indian Journal of Horticulture* **73**: 564-69.
- Griffing B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Science* **9**: 463-93.
- Hemanth Kumar P, 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 Journal Agricultural Science* **21**: 544-47.
- Horț D, Cantor M, Buta E and Andriescu I. 2012. Researches regarding intraspecific hybridization of *Gladiolus* L. species in order to obtain novel ornamental varieties. *Bulletin UASVM Horticulture* **69**: 172-77
- Hossain M D, Bhuiyan M S R, Talukder K H, Islam M R and Syed M A. 2012. Study on vegetative propagating materials, flower characteristics and production of true seed through crossing among the different gladiolus genotypes. *Advances in Biological Research* **6**: 52-58.
- Kispotta L M, Jha K K, Horo P, Tirkey S K, Misra S and Sengupta S. 2017. Studies on combining ability and heterosis in gladiolus (*Gladiolus hybridus*). *International Journal of Science, Environment and Technology* **6**(1): 420-42.
- Kumar H P, 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 Journal of Agricultural Science* **21**: 544-47.
- Kumari P, Kumar R, Rao T M and Bharathi U. 2018. Exploitation of heterosis for growth, flower quality and yield traits in China aster (*Callistephus chinensis*). *Indian Journal of Agricultural Sciences* **88**:453-57
- Mahato S K and Gantait S S. 2017. Seed setting behaviour of some gladiolus genotypes through cross pollination. *Indian Horticulture Journal* **7**: 72-75.
- Poon T B, Pokhrel A, Shrestha S, Sharma S R, Sharma K R and Dev M B L. 2012. Influence of intervarietal and interspecific crosses on seed set of gladiolus under mid- hill environments of Dailekh condition. *Nepal Journal of Science and Technology* **13**(1): 17-24
- Takatsu Y, Suzuki K, Yamada T, Inoue E, Gonai T, Nogi M and Kasumi M. 2005. Interspecific hybridization of wild gladiolus species using a dendrogram based on RAPD analysis. *Acta Horticulturae* **673**: 475-80.