Evaluation of growth parameters and yield attributes of marigold genotypes under humid tropical plains

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Abstract

The study was conducted at department of Floriculture & Landscape Architecture, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, to evaluate 20 marigold genotypes with 12 testers (10 African marigold (*Tagetes erecta*) and 2 French marigold (*Tagetes patula*) genotypes) and 8 lines for the production of F1 hybrids, during 2019-20 and 2020-21. Pooled data analysis of vegetative parameters showed the superiority of tester genotype KAU-M 21 in terms of plant height (43.77 cm), plant spread (31.97 cm), number of primary branches (7.87) and stem girth (4.12 cm), while KAU-M 1 showed the superiority in total leaf area (47.27 cm^2). Among the lines, KAU-M 42 showed good performance for all the vegetative parameters. Analytical study on floral characters highlighted that the testers, KAU-M 1 and KAU-M 40, produced larger flowers (6.3 cm and 5.80 cm diameter) having significantly more individual flower weight (9.70 g and 7.85 g) and ray floret weight (5.60 g and 3.50 g) respectively. French marigold genotypes KAU-M 48 and KAU-M 47 showed earliest bud initiation (17.92 and 19.37 days) and earlier flower opening (35 and 37.75 days). KAU-M 46 produced maximum number of flowers per plant (103.37), while KAU-M 2, KAU-M 1, KAU-M 19 and KAU-M 40 recorded maximum yield that ranged from 215 to 243 g/plant. Among the lines, KAU-M 6 recorded highest number of flowers and yield per plant (92.32 and 228.99 g) followed by KAU-M 5, KAU-M 16 and KAU-M 42. Among the testers, shelf life of flowers differed significantly and majority of the genotypes recorded a shelf life ranging from 2.0 to 2.67 days. The total carotenoid content was significantly higher in KAU-M 47 and KAU-M 48 (4.85 and 2.26 mg/g respectively) among the testers, and KAU-M 18 and KAU-M 42 (2.01 mg/g and 1.49 mg/g respectively) among the lines. KAU-M 1 and KAU-M 5 recorded the highest lutein content (102.3 mg/g and 62.3 mg/g) among the testers and lines, respectively.

Keywords: Carotenoid, Genotypes, Lines, Lutein, Marigold, *Tagetes erecta*, *Tagetes patula*, Testers.

Introduction

Marigold (*Tagetes* spp.), a member of the family Asteraceae, is an important annual flower crop in India. This commercial crop has wide range of uses such as loose flowers; as ornamental in gardens and also as a source of natural carotenoid pigment which is having many industrial applications. Among the 33 species of *Tagetes, T. erecta* and *T. patula,* are the two species grown commercially in the country for their attractive flowers. Apart from the popular varieties, many F1 hybrids, both inter varietal and inter specific, have been chosen for cultivation in India. The evaluation studies of such hybrids have proven their susceptibility to the bacterial wilt disease, which is one of the major barriers in commercialisation of this crop in Kerala (Umesh et al., 2018; Jeevan et al., 2019). Hence, considering the importance of the crop, F1 hybrids with superior commercial traits for yield with good quality flowers as well as resistance to bacterial wilt, are needed. Marigold being a highly cross pollinated crop, there

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is every chance of loss of stable performance for the open pollinated varieties over the years. Therefore the development of F1 hybrids plays a vital role with respect to earliness, profuse and uniform flowering, biotic and abiotic stress resistance and higher yield. Production of F1 hybrids in marigold is rather easier, thanks to the male sterility expressed in the crop. Keeping an outlook on these points and objectives, a study was conducted in the Department of Floriculture & Landscape Architecture, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, on genetic improvement of *Tagetes* spp. exploiting the genetic male sterility system of the crop for the development of F1 hybrids having superior qualities with respect to yield and bacterial wilt resistance.

Materials and Methods

The evaluation of the parental genotypes was conducted under the open condition during November to February in two successive years *viz.,* 2019-2020 and 2020-2021. The experiment was laid out in RBD with two replications, with a plot size of 2 m^2 and a spacing of 0.4 x 0.4 m. Evaluation of 12 testers (10 genotypes of *Tagetes erecta* and 2 genotypes of *Tagetes patula*) and 8 male sterile lines was conducted for vegetative, floral and post-harvest factors. Since the observations were needed to be analysed in depth, the fertile plants of male sterile populations known as the maintainer lines were taken for evaluation. Seeds were sown in protrays in a mix of cocope at, vermiculite and perlite of 3:1:1 ratio. One month old seedlings were transplanted in the field, which were dripfertigated and mulched with 30 µ silver black plastic mulch film. Five plants each from two replications were observed for vegetative, floral, yield and postharvest parameters and the data of the two years were pooled and statistically analysed.

Results and Discussion

Statistical analysis revealed the significant difference among the marigold genotypes for various growth parameters. The analysis of variance for vegetative, floral and yield characters of testers and lines are shown in Table 1 and 2**.**

Considering the analysis of vegetative characters of testers (Table 3**)**, KAU-M 21 and KAU-M 4 were found to be significantly superior (43.77 and 43.34 cm respectively) with respect to plant height. Plant spread also differed significantly among the genotypes, where, KAU-M 21 (31.97 cm), KAU-M 46 (31.69 cm) and KAU-M 1 (34.02 cm) showed greatest plant spread which were on par statistically. Significant variations were also noted in case of number of primary branches and stem girth. KAU-M 21 was found to be superior with regard to number of primary branches (7.87) which was found to be on par with all the other testers except KAU-

Table 1. Analysis of variance for various characters of testers

Source of variance	df	Plant height (cm)	Plant spread (cm)	No.of primary branches	Stem girth (cm)	Days to bud initiation	Days to full opening	Flower Diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	No. of flowers/ plant	Flower yield/ plant (g)
Genotypes (Factor A)	1	5.19*	0.037	30.25*	1.77	0.81	4349.30*	0.06	1.15	53.29*	0.79	22.11*	6.96*
Year (Factor B)	11	60.48*	32.21*	2.25*	19.52*	511.88*	206.71*	32.87*	42.76*	83.57*	168.51*	110.16*	64.50*
Interaction (A xB)	11	10.99*	24.65*	4.74*	7.75*	47.71*	251.69*	30.38*	43.73*	18.26*	42.43*	12.20*	2.74*

*Significant at 5% probability level

Table 2. Analysis of variance for various characters of maintainer lines

Source of variance	df	Plant height (cm)	Plant spread (cm)	No.of primary branches	Stem girth (cm)	Days to bud initiation	Days to full opening	Flower Diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	No. of flowers/ plant	Flower yield/ plant (g)
Genotypes (Factor A)	1	0.53	52.04*	24.65*	7.49*	13.03*	2.23	5.34*	5.14*	25.19*	1.87	138.54*	8.81*
Year (Factor B)	7	7.55*	14.84*	7.17*	3.94*	68.72*	4.49*	10.28*	10.41*	19.01*	23.54*	24.46*	7.09*
Interaction (A xB)	7	18.34*	22.79*	9.17*	4.78*	23.77*	0.99	2.79*	0.94	2.79*	6.06*	73.89*	34.02*

*Significant at 5% probability level

Table 3. Mean performance of Marigold testers for vegetative parameters

Genotypes	Plant height (cm)	Plant spread (cm)	No. of primary branches	Stem girth (cm)	Leaf area (cm^2)
KAU-M 1	33.35	34.02	6.95	3.74	47.268
KAU-M 2	27.51	25.23	5.41	3.71	18.859
KAU-M 4	43.34	29.01	7.20	3.19	17.794
KAU-M 8	40.07	25.79	7.30	3.36	22.868
KAU-M 11	40.26	29.20	7.20	3.33	21.340
KAU-M 15	40.70	27.41	7.42	2.81	18.925
KAU-M 19	34.59	29.84	7.42	2.78	21.449
KAU-M 21	43.77	31.97	7.87	4.12	22.322
KAU-M 40	36.20	26.27	7.20	3.09	20.009
KAU-M 46	34.54	31.69	7.47	4.52	16.089
KAU-M 47	25.56	19.15	6.77	1.61	7.404
KAU-M 48	26.22	20.14	6.17	1.55	6.447
CD	2.43	2.34	1.29	0.59	5.27

M 48 (6.17) and KAU-M 2 (5.41). With regard to stem girth, KAU-M 46 was superior among the testers (4.52 cm), which was found to be on par with KAU-M 21 (4.12 cm). Leaf area is the vegetative parameter which also showed a notable variation among the testers. The genotype KAU-M1 was found to have the largest leaf area (47.27 cm2) compared to the other 11 tester genotypes.

Similar results in the vegetative parameters with significant differences could also be observed among the maintainer lines of marigold (Table 4). Among the 8 lines evaluated, KAU-M 22 was found to be superior in plant height (43.54 cm), which was on par with KAU M 42 (41.00 cm), KAU-M 23 (40.75 cm) and KAU-M 18 (40.71 cm). With regard to the character plant spread, KAU-M 5 was superior (34.60 cm) which was followed by KAU-M 23 (29.17 cm) and KAU- M 42 (28.66 cm). Significantly superior stem girth was observed in KAU-M 5, KAU-M 42, KAU-M 6 and KAU-M 16 (4.25 cm, 4.07 cm, 3.96 cm and 3.67 cm respectively). The line KAU-M 18 produced maximum number of primary branches (8.76) which was on par with KAU-M 23 (7.92), KAU-M 42 (7.56) and KAU-M 6 (7.47). Greatest leaf area was observed in KAU-M 42, KAU-M 5 and KAU-M 6 (23.60 cm^2, 23.29 cm^2 and 23.19 cm^2 respectively). The value of KAU-M 16 (19.82 cm^2) was found on par with these lines.

From the study, prominent variations were observed among the genotypes (testers and lines) for the different vegetative characters. Since these parameters are being controlled by genetic factors and environmental conditions to an extent, the significant differences among the genotypes in two consecutive years might be due to the genetic makeup and additive gene action. These results on vegetative parameters are found to be in conformity with the studies of Singh and Misra (2008), Narsude et al., (2010) and Pal and Kumar (2010) and in African marigold and Nagashree and Kulkarni (2019) in French marigold.

Table 4. Mean performance of maintainer lines of Marigold for vegetative parameters

Genotypes	Plant height (cm)	Plant spread (cm)	No. of primary branches	Stem girth (cm)	Leaf area (cm^2)
KAU-M 5	37.57	34.60	6.30	4.25	23.29
KAU-M 6	39.39	27.22	7.47	3.96	23.19
KAU-M 16	37.54	25.02	4.74	3.67	19.82
KAU-M 18	40.71	26.47	8.76	3.26	18.74
KAU-M 22	43.54	26.85	6.42	3.04	18.74
KAU-M 23	40.75	29.17	7.92	3.15	16.37
KAU-M 24	32.65	24.47	6.36	3.07	16.85
KAU-M 42	41.00	28.66	7.56	4.07	23.60
CD	3.62	2.50	1.41	0.75	3.92

Table 5. Mean performance of Marigold testers for floral parameters

Genotypes	Days for bud initiation	Days for full floweropening	Flower Dia. (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)
KAU-M 1	47.05	70.80	6.30	4.75	9.70	5.60
KAU-M 2	34.90	57.70	4.97	6.02	4.80	1.50
KAU-M 4	33.32	52.92	5.07	7.96	4.35	1.40
KAU-M 8	21.80	41.50	4.60	7.13	4.40	2.05
KAU-M 11	26.75	46.05	5.00	8.62	4.65	2.35
KAU-M 15	40.25	65.73	4.75	7.12	5.27	1.77
KAU-M 19	22.80	54.05	5.67	5.90	4.90	1.65
KAU-M 21	27.95	49.10	5.57	7.67	7.50	2.20
KAU-M 40	23.10	50.15	5.80	7.37	7.85	3.50
KAU-M 46	23.80	52.40	3.8	6.09	3.80	1.50
KAU-M 47	19.37	37.75	3.22	6.92	1.31	0.44
KAU-M 48	17.92	35.00	5.02	4.42	0.611	0.18
CD	**1.19**	**1.92**	**0.43**	**0.57**	**0.82**	**0.32**

Evaluation of floral parameters has also shown prominent variation among the testers. (Table 5). French marigold genotypes, KAU-M48 and KAU-M 47 showed earliest bud initiation (17.92 and 19.37 days respectively) followed by KAU-M 8 (21.80 days). Regarding the days for full flower opening, KAU-M 48 and KAU-M 47 exhibited the lowest number of days (35.00 and 37.75 days respectively), followed by KAU-M 8 (41.50 days). Among the testers, largest flowers were observed in KAU-M 1(6.30 cm) followed by KAU-M 40 and KAU-M 19 with flower diameters of 5.80 cm and 5.67 cm respectively. Significantly shorter flower stalks were recorded in KAU-M 48 (4.42 cm) and KAU-M 1(4.75 cm), whereas longest flower stalks were recorded in KAU-M 11 (8.62 cm). Individual flower weight and ray florets weight was found to be highest in KAU-M 1 (9.70 g and 5.60 g respectively) followed by KAU-M 40 (7.85 g and 3.50 g respectively).

Since the parameters such as flower size, shelf life, total carotenoid and lutein content of the parental lines have to be taken in depth, the fertile plants of parental male sterile populations known as maintainer lines were selected for the analysis. There were significant variations in the floral characters among the lines (Table 6). Genotype KAU-M 18 took the lowest number of days for bud initiation (17.60) and full flower opening (39.80 days) followed by KAU-M 42 (19.40 and 42.00 days respectively) and KAU-M 16 (20.43 and 41.18 days respectively). Regarding the flower diameter, KAU-M16, KAU–M 42 and KAU-M 23 produced significantly larger flowers (6.25, 6.22 and 6.16 cm respectively) compared to other lines. With regard to the stalk length, significantly shorter flower stalks were recorded in KAU-M 23(6.13 cm) and KAU-M 24(6.04 cm), whereas longer stalks were observed in KAU-M 5, KAU-M 6, KAU-M 22 and KAU-M 42 (8.10 cm, 8.15 cm, 8.06 cm and 7.87

Table 6. Mean performance of maintainer lines of Marigold for floral parameters

Genotypes	Days for bud initiation	Days for full floweropening	Flower Dia. (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)
KAU-M 5	20.90	74.70	4.80	8.10	6.30	1.80
KAU-M 6	28.41	49.71	5.14	8.15	5.95	1.15
KAU-M 16	20.43	41.18	6.25	7.05	7.52	3.32
KAU-M 18	17.60	39.80	5.17	7.21	4.75	1.85
KAU-M 22	30.14	53.91	5.25	8.06	4.70	1.42
KAU-M 23	20.90	47.60	6.16	6.13	9.25	3.80
KAU-M 24	24.37	44.45	5.60	6.04	4.85	1.60
KAU-M 42	19.40	42.00	6.22	7.87	7.75	2.40
CD	1.64	16.30	0.54	0.82	1.16	0.59

cm respectively). Among the lines, maximum flower weight (9.25 g) was recorded in KAU-M23, followed by KAU-M 42 (7.75g) and KAU-M 16 (7.52 g), while the greatest weight of ray florets (3.80 g) was also observed in KAU- M23 followed by KAU-M 16 (3.32 g) and KAU-M 42 (2.40 g).

Similar to the case of vegetative growth parameters, floral characters of genotypes are also highly influenced by its genetic makeup as well as environmental factors. Hence the recorded variations observed among the genotypes in terms of these characters, especially days to bud initiation and opening, full flower opening and flower size might be due to the difference in genotypic expression and additive gene action. The results are in conformity with Singh et al., (2003), Narsude (2010), Mahantesh (2017) and Naik et al., (2019).

Analytical data observed on yield attributes (number of lowers per plant and flower yield per plant) and post-harvest parameters (vase life, total carotenoid and lutein content) have also been recorded with significant differences among the genotypes (Table 7). Among the testers, the number of flowers per plant was the greatest for KAU-M 46 (103.37), followed by KAU-M 2 and KAU-M 8 (90.64 and 90.07 respectively). Regarding the yield per plant, KAU-M 2 was found to be significantly superior (247.46 g) among the genotypes. The value was found to be on par with that of KAU-M 1(243.22 g) and KAU-M19 (222.93 g), followed by KAU-M 40 (217.30 g). The lowest yield was observed in French marigold genotype KAU-M47 (13.29 g).

Among the maintainer lines, KAU-M 6 was found to be the superior genotype producing maximum number of flowers per plant (92.32), followed by KAU-M 18 (74.01) and KAU-M 16 (72.75). Flower yield per plant was recorded superior in KAU-M 6 (228.99 g) which was found to be on par with KAU-M 5 (221.04 g) and KAU-M 42(220.62 g) (Table 8).

Flower yield can be contributed by the factors like number of flowers per plant and individual flower weight. The number of flowers may be decided by the number of primary branches. Hence the significant difference in the flower yield might be due to the significant variation in these parameters. Also, since these characters are definitely being controlled by the genetic factors, the genetic makeup and additive gene action of these factors of genotypes may also have contributed to these variations. Similar results have been recorded by Bhanupratap et al., 1999, Naik et al., (2005), Patil et al., (2011) and Kumar et al., (2015).

Table 7. Mean performance of Marigold testers for yield and post-harvest characters

Genotypes	No. of flowers/ plant	Flower yield/ plant (g)	Shelf life (days)	Total carotenoid content (mg/g)
KAU-M 1	67.56	243.22	2.67	1.99
KAU-M 2	90.64	247.46	2.67	0.95
KAU-M 4	82.36	186.30	2.00	0.22
KAU-M 8	90.07	207.76	2.00	0.28
KAU-M 11	59.13	160.30	1.67	0.94
KAU-M 15	73.25	203.45	2.00	0.88
KAU-M 19	56.46	222.93	2.00	0.55
KAU-M 21	22.08	75.69	2.67	0.43
KAU-M 40	56.49	217.30	2.67	0.83
KAU-M 46	103.37	200.89	2.00	0.22
KAU-M 47	11.27	13.29	1.67	4.85
KAU-M 48	50.76	61.34	1.33	2.26
CD	7.67	28.29	0.74	0.16

Post-harvest parameters like shelf life of flowers, total carotenoid and lutein content were also been recorded with significant variation among the testers (Table 7). Shelf life was found to be on par among

Table 8. Mean performance of maintainer lines of Marigold for yield and post-harvest characters

Genotypes	No. of flowers/ plant	Flower yield/ plant (g)	Shelf life (days)	Total carotenoid content (mg/g)
KAU-M 5	68.15	221.04	2.33	1.28
KAU-M 6	92.32	228.99	2.00	0.62
KAU-M 16	72.75	186.25	2.67	0.55
KAU-M 18	74.01	187.05	2.00	2.01
KAU-M 22	60.12	124.69	2.00	0.43
KAU-M 23	49.92	181.87	2.33	0.53
KAU-M 24	55.19	178.00	1.67	1.11
KAU-M 42	56.56	220.62	2.33	1.49
CD	8.40	38.39	NS	0.24

many genotypes *viz.,* KAU-M1, KAU-M2, KAU-M21, KAU-M 40, KAU-M 4, KAU-M8, KAU-M 19 and KAU-M15, which ranged between 2.00 and 2.67 days. The total carotenoid content was the highest in the French marigold genotypes KAU-M 47 and KAU-M 48 (4.85 and 2.26 mg/g), followed by KAU-M 1(1.99 mg/g). Unlike the total carotenoid content, highest content was recorded in KAU-M 1 (102.3 mg/g) followed by KAU-M 2 (63.2 mg/g), KAU-M 48 (62.4 mg/g) and KAU-M 47 (61.2 mg/g) (Table 9).

Shelf life was not found to be significantly different among the maintainer lines. The highest carotenoid content was observed in KAU-M 18 (2.01 mg/g) followed by KAU-M 42 (1.49 mg/g) (Table 8), while KAU-M 5 recorded the highest lutein content in flowers (62.3 mg/g) followed by KAU-M 22 (59.3 mg/g) (Table 9). The genotype rich in carotenoid and lutein *viz*., KAU-M47, KAU-M48 and KAU M1 can be used for pigment extraction industry as well as solution for breeding pigment enrichment. Since these parameters are highly influenced by the genotypic constitution, genetic factors play an important role in the variation among the genotypes. The above findings are in conformity with the observations of Patil et al., (2011), Raghuvanshi and Sharma (2011) and Mahantesh (2017).

Table 9. Lutein content of Marigold genotypes

Genotypes (Testers)	Lutein content (mg/g)	Genotypes (Maintainer Lines)	Lutein content (mg/g)
KAU-M 1	102.3	KAU-M 5	62.3
KAU-M 2	63.2	KAU-M 6	57.3
KAU-M 4	55.9	KAU-M 16	56.0
KAU-M 8	56.4	KAU-M 18	55.2
KAU-M 11	58.1	KAU-M 22	59.3
KAU-M 15	55.4	KAU-M 23	55.8
KAU-M 19	55.5	KAU-M 24	53.9
KAU-M 21	56.4	KAU-M 42	55.8
KAU-M 40	54.7	-	-
KAU-M 46	52.8	-	-
KAU-M 47	61.2	-	-
KAU-M 48	62.4	-	-

Variability studies in this experiment have also come up with the findings regarding coefficient of variation (GCV and PCV) along with heritability and genetic advance (Table 10). High phenotypic and genotypic coefficient of variation could be observed in almost all vegetative, floral and yield parameters, except plant height (PCV = 19.16; GCV = 17.707), plant spread (PCV = 18.32; GCV = 17.05), flower diameter (PCV = 17.43; GCV = 16.56) and stalk length (PCV = 16.24; GCV = 15.11). Marked difference between GCV and PCV values for the factors 'number of primary branches' and 'days to full flower opening' gives the conformity of environmental influence.

Estimation of heritability along with genetic advance of various characters gives an effective way for the selection process. All the vegetative characters and floral characters (except days to full flower opening) and yield parameters were found

Table 10. Genetic parameters for morphological and yield traits of marigold genotypes

Factors	Gen.Var	Phen.Var	Env.Var	Cv (%)	Pcv (%)	Gcv (%)	Heritability	Gen.Adv (i=5%)
Plant height	42.71	50.00	7.29	7.32	19.16	17.70	0.85	33.71
Plant spread	20.66	23.87	3.20	6.71	18.32	17.05	0.87	32.68
Stem girth	0.49	0.62	0.12	11.05	24.71	22.10	0.80	40.72
No. of primary branches	1.88	2.95	1.07	13.22	21.96	17.54	0.64	28.85
Leaf area	60.02	64.65	4.64	10.69	39.93	38.47	0.93	76.35
Days to bud initiation	78.13	79.36	1.24	4.31	34.50	34.23	0.98	69.96
Days to full opening	133.63	228.94	95.31	19.29	29.90	22.85	0.584	35.96
Flower diameter	0.66	0.74	0.07	5.45	17.43	16.56	0.90	32.40
Stalk length	1.19	1.38	0.19	5.96	16.24	15.11	0.86	28.95
Weight of flower	3.91	4.03	0.12	6.86	39.92	39.33	0.97	79.81
Weight of ray florets	1.63	1.69	0.06	11.79	60.70	59.55	0.96	120.33
No.of flowers/plant	831.91	857.66	25.75	8.10	46.77	46.06	0.97	93.45
Flower yield/plant	7184.05	7695.93	511.87	12.72	49.30	47.64	0.93	94.81

to be showing high heritability along with high genetic advance which implies that these characters are governed by additive gene action, and the selection process based on these parameters could be advocated. Highest heritability was observed for the parameters days to bud initiation, leaf area, and flower yield, number of flowers per plant and flower weight. In case of the parameter 'days to full flower opening', low heritability with high genetic advance has been exhibited, which again shows that the character is governed by additive gene effects. But the low heritability may be due to the high influence of environmental factors. Similar findings are reported by Singh et al., (2007), Singh and Misra (2008), Singh and Kumar (2008) and Kumar and Senthil (2011).

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