Short Communicaton

Evaluation of African marigold (*Tagetes erecta* L.) genotypes for yield and resistance to bacterial wilt pathogen, *Ralstonia solanacearum*

C. Umesh[1], U.Sreelatha[2*], P. Sainamole Kurian[2] and C. Narayanankutty[3]

[1]*Dscign Biosys Pvt Ltd., Gerupalya, Kumbhalgodu, Bengaluru 560 074, Karnataka, India.*
[2] *College of Horticulture, Vellanikkara, Thrissur 680 656, Kerala, India.*
[3]*Agricultural Research Station, Mannuthy, Thrissur 680 651, Kerala, India.*

Received 09 April 2018; received in revised form 02 June 2018; accepted 04 June 2018

Abstract
Eight African marigold (*Tagetes erecta* L.) genotypes (5 F_1 hybrids, 2 varieties and 1 local collection) were evaluated for yield and resistance to bacterial wilt during June to September 2016 in a bacterial wilt sick plot at Agricultural Research Station, Mannuthy. F_1 hybrids evaluated were Maria 91, Rupa, Sakura 031, Royal Orange and P-4. Along with the F_1 hybrids, two varieties from IIHR *viz*., Arka Agni and Arka Bangara 2, and one local collection, M-1, were also included in the study. The genotypes showed wide variation with respect to plant characters, floral characters, yield and yield attributes as well as bacterial wilt incidence.The genotype'P-4' was found promising with good plant characters, high yield (1.036 kg/plant), and large sized flowers but was moderately susceptible to bacterial wilt. The local collection 'M-1' was found completely resistant to bacterial wilt but had low yield (0.234 kg/plant) and poor quality flowers, while the F_1hybrid 'Sakura 031' was found highly susceptible with 100 per cent wilt incidence.

Key words: African marigold, Bacterial wilt, Marigold genotypes, *Tagetes erecta*, *Ralstonia solanacearum*

African marigold (*Tagetes erecta* L.) is an important annual flower crop which gained popularity among the growers due to its easiness in cultivation and wide adaptability. It is mainly grown for the loose flowers, used for making garlands, wreaths and religious offerings, and is also ideal for garden display, both in beds and pots. Carotenoids from marigold are used in human food stuffs as they are nutritious in nature.

In Kerala also, the demand for this crop has increased recently and marigold cultivation has gained popularity. Of late, most of the farmers have turned to F_1 hybrids and improved varieties for cultivation as the local collections used earlier were of low yield and with poor quality flowers. However, many growers cultivating F1 hybrids face heavy losses of plants due to bacterial wilt disease, which is very difficult to manage. Bacterial wilt disease caused by *Ralstonia solanacearum* is severe and common in solanaceous vegetables in Kerala and the same pathogen causes wilt in African marigold too. Identification of genotypes having desirable floral characters with good yield along with resistance to bacterial wilt is essential for successful cultivation of marigold in the state. Considering the importance, the present investigation was undertaken with the objective to evaluate African marigold genotypes for high yield with resistance to bacterial wilt.

The study was carried out during June-September 2016 in a bacterial wilt sick plot at Agricultural Research Station, Mannuthy. The experiment was laid out in Randomized Block Design (RBD) with three replications. The plot size was 2m x 1m, with

*Author for correspondences: Phone: 91-9446619610; Email: sreeu2005@gmail.com

eight plants per plot per replication. Among the eight genotypes of African marigold included for the experiment, there were 5 F_1 hybrids (Maria 91, Rupa, Sakura 031, Royal Orange and P-4), 2 IIHR varieties (Arka Agni and Arka Bangara 2) and one local collection (M-1).

Seeds of all the genotypes except the IIHR varieties were sown in protrays filled with potting mixture comprised of cocopeat, vermiculite and perlite in the ratio of 3:1:1, and rooted cuttings of both the varieties from IIHR were procured. One month old seedlings and rooted cuttings were transplanted in the main field at a spacing of 50 x 50 cm. Fertilizer application was done as per package of practice recommended by KAU. Observations were recorded on plant characters, floral characters, yield, yield attributes and bacterial wilt incidence. Plants in the experimental field were daily observed for bacterial wilt symptoms which were confirmed by ooze test, and the bacteria were isolated and identified as *Ralstonia solanacearum* and further ascertained by conducting Koch's postulates. Per cent disease incidence (PDI) was calculated using the flowing formula:

$$PDI = \frac{\text{Number of plants wilted}}{\text{Total number of plants}} \times 100$$

The intensity of the disease incidence in selected genotypes was scored as per the score chart followed by Sinha et al. (1988).

Reaction	Per cent disease incidence
R (Resistant)	< 10
MR (Moderately resistant)	>10-20
MS (Moderately susceptible)	>20- 30
S (Susceptible)	>30 -70
HS (Highly susceptible)	>70 -100

Statistical analysis was done using OP-STAT (Sheoran *et al*., 1998).

Data with respect to plant characters *viz*., plant height, plant spread, stem girth, number of primary branches and leaf area are presented in Table 1. Floral characters *viz*., days to bud initiation, days to flower opening, diameter of flower, stalk length and petal yield per flower, yield and yield attributes like fresh number of flowers per plant flower weight and flower yield in different genotypes of marigold are presented in Table 2 and data regarding bacterial wilt incidence viz. per cent disease incidence (PDI), days to wilt and reaction of the genotypes are given in Table 3.

Plant characters

Significant difference was noticed among genotypes with respect to plant height both at 30 and 60 days after planting (DAP). At 30 DAP, plant height was significantly greater in Maria 91 (81.51 cm), followed by P-4 (58.54 cm) and Royal Orange (55.43 cm). Plant height was the lowest for M-1 (20.58 cm). However, at 60 DAP, greatest height was recorded in Royal Orange (129.27 cm), followed by P-4 (119.87cm) and Maria 91(113.87 cm), and these genotypes were on par. At 60 DAP the lowest height was observed in M-1 (66.15 cm).

Table 1. Plant characters in African marigold genotypes

Genotypes	Plant height (cm)		Plant spread (cm)		Stem girth (cm)		Primary branches (number)		Leaf area (cm^2)
	30days	60days	30days	60days	30days	60days	30days	60days	
Maria91	81.51	113.87	78.24	97.74	6.55	7.51	11.12	14.20	40.67
Rupa	48.38	97.67	63.24	92.24	5.56	7.28	12.95	15.54	25.74
Sakura031	41.45	77.12	57.29	57.75	5.43	7.00	13.50	13.84	22.29
RoyalOrange	55.43	129.27	68.01	103.49	4.84	7.83	13.01	15.19	34.86
P-4	58.54	119.87	66.03	107.48	6.05	8.52	12.87	15.49	34.85
ArkaAgni	33.20	92.37	43.41	82.42	4.10	7.32	6.62	09.45	28.80
Arka Bangara2	26.20	89.51	28.66	82.46	3.66	7.46	5.87	08.87	21.07
M-1	20.58	66.15	46.13	94.46	4.31	8.35	7.99	13.00	68.75
C.D.(0.01)	05.22	14.06	14.98	14.92	0.87	NS	2.50	03.32	9.12
S.E(m±)	01.70	4.59	4.89	4.87	0.27	0.45	0.81	01.08	2.97

Table 2. Floral characters and yield of African marigold genotypes

Genotypes	Days to bud initiation	Days to flower opening	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Petal yield/ flower (g)	No. of flowers/ plant	Yield/ plant (kg)
Maria 91	31.00	10.70	7.75	8.67	13.43	8.96	20.41	0.153
Rupa	28.12	10.49	9.06	7.29	23.36	18.16	80.33	0.772
Sakura 031	28.20	10.91	7.37	5.85	14.46	10.66	18.15	0.192
Royal Orange	30.13	14.19	7.53	11.12	13.40	9.86	65.83	0.466
P-4	28.70	13.27	9.08	11.26	22.66	16.56	116.91	1.036
Arka Agni	29.45	12.16	6.75	11.18	11.76	9.03	45.29	0.359
Arka Bangara 2	28.38	13.15	7.37	11.74	13.90	10.30	49.04	0.438
M-1	50.62	14.15	6.45	6.11	11.66	8.13	36.41	0.234
C.D. (0.01)	6.05	NS	0.44	0.96	3.28	3.82	26.56	0.244
S.E(m±)	1.97	0.92	0.14	0.31	1.07	1.24	8.67	0.08

Table 3. Bacterial wilt incidence in African marigold genotypes

Genotypes	Bacterial wilt incidence (%)	Days to wilt	Reaction of genotypes
Maria 91	45.83 (6.82)	45.33	S
Rupa	70.83 (7.92)	66.94	HS
Sakura 031	100.00 (10.05)	43.88	HS
Royal Orange	25.00 (5.09)	68.33	MS
P-4	25.00 (4.99)	68.50	MS
Arka Agni	29.16 (4.78)	72.04	MS
Arka Bangara 2	12.50 (3.25)	67.75	MR
M-1	0.00(1.00)	*	R
C.D. (0.01)	3.39	13.65	
S.E(m±)	1.10	4.38	

Values in parentheses are transformed data

*Not included for days to wilt as it was wilt free

S -Susceptible, HS -Highly susceptible, MS-Moderately susceptible, MR-Moderately resistant, R-Resistant

Plant height is attributed to be an important varietal character that depends upon the genetic constitution. Variations among marigold genotypes with respect to plant height have been reported by many workers (Khanvilkar *et al*., 2003; Bharathi and Jawaharlal, 2014; Deepa and Patil 2016; Deepa *et al*., 2016; Manik and Sharma, 2016).

Genotypes also showed significant variations with respect to plant spread. At 30 DAP, plant spread was greatest for Maria 91 (78.24 cm), followed by Royal Orange (68.01 cm) and P-4 (66.03 cm). Arka Bangara 2 recorded the lowest spread of 28.66 cm at 30 DAP. Greatest plant spread at 60 DAP was observed in P-4 (107.48 cm) followed by Royal Orange (103.49 cm) and Maria 91 with a spread of 97.74 cm. Lowest plant spread at 60 DAP was recorded in Sakura 031 (57.75 cm). It was noticed that genotypes with more height recorded greater plant spread and this might be due to direct relationship between these two characters. Raghuvanshi and Sharma (2011) reported a positive relationship between plant height and plant spread. Stem girth recorded at 30 DAP varied significantly among the genotypes. Both Maria 91 and P-4 were on par, recording stem girths of 6.55 cm and 6.05 cm respectively. Both varieties from IIHR *viz*., Arka Agni (4.10 cm) and Arka Bangara 2 (3.66 cm), recorded lowest stem girth. However, at 60 DAP stem girth was on par for all the genotypes.

Significant differences were noticed in the number of primary branches among the genotypes both at 30 and 60 DAP. The genotypes Sakura 031, Royal Orange, Rupa, P-4 and Maria 91 showed greatest numbers of primary branches, ranging from 11.12 - 13.50 at 30 DAP and these were on par. At 60 DAP, along with the five above mentioned genotypes, M-1 also showed higher number of primary branches. However, primary branches were the lowest for Arka Agni and Arka Bangara 2, both at 30 and 60 DAP. Variations in number of primary branches might be due to genetic makeup and such variations in marigold have already reported by Bharathi and Jawaharlal (2014), Deepa and Patil (2016) and Manik and Sharma (2016).

Significant differences were observed among the genotypes in leaf area. The genotype M-1 recorded highest leaf area (68.75 cm^2) followed by Maria 91 (40.67cm^2), while lowest leaf area was observed in

Arka Bangara 2 (21.07 cm^2). The variation in leaf area among the various genotypes might be attributed to genetic makeup as has been reported by Raghuvanshi and Sharma (2011) and Rao *et al*.(2005) in marigold.

Floral characters

Except for the genotype M-1, all other genotypes took almost the same number of days (ranging from 28.12 – 31.0) for bud initiation and they were statistically on par. However, M-1 took the longest period to initiate bud (50.62 days) and it was significantly late when compared to all other genotypes. This difference in days to bud initiation might be attributed to the genetic makeup of the types studied. The result is in agreement with the findings of Bharathi and Jawaharlal (2014), Singh and Singh (2010) and Yuvraj and Dhatt (2014). However, no significant difference was observed among the genotypes for days to initiation of flower opening and all the genotypes initiated flower opening within 10.49 to 14.19 days after bud initiation.

Significant variations were observed for flower diameter among the genotypes which ranged from 6.45 cm - 9.08 cm. The genotype P-4 recorded the greatest flower diameter measuring 9.08, cm which was on par with Rupa (9.06 cm), while the genotype M-1 recorded the lowest flower diameter (6.45 cm). All other genotypes were on par. The variation in flower diameter among the genotypes might be due to their genetic makeup that would have influenced higher nutrient uptake (Anuradha *et al*., 1990). The flower diameter was controlled by genotype-environmental interaction effects.These results were in agreement with those of Manik and Sharma (2016), Choudhary *et al*. (2014) and Deepa and Patil (2016).

Stalk length was significantly higher for Arka Bangara 2 (11.74 cm), P-4 (11.26 cm), Arka Agni (11.18 cm) and Royal Orange (11.12 cm) and these genotypes were on par with respect to the parameter. Flower stalk lengths in Maria 91 and Rupa were 8.67 cm and 7.29 cm respectively. The stalk length was minimum in the genotype 'Sakura 031' (5.85 cm), which was on par with the M-1 (6.11 cm). Variations in stalk length among African marigold genotypes were reported by Karuppaiah and Kumar (2011).

Highest petal yield of 18.16 g was observed in Rupa, followed by P-4 (16.56 g), and these genotypes were on par. It was observed that genotypes with greatest flower diameter and flower weight yielded high petal weight. The findings of the study are in accordance with those of Manik and Sharma (2016).

Yield and Yield attributes

Number of flowers per plant differed significantly among the genotypes and it was highest in P-4 (116.91) followed by Rupa (80.33) and lowest in Sakura 031 (18.15). The variation in number of flowers per plant might be due to hereditary traits of the genotypes. Difference in the photosynthetic efficiency of genotypes might have enhanced food accumulation resulting in better plant growth and subsequently higher number of flowers per plant (Sunitha *et al*., 2007). The findings of the study are also in accordance with those of Manik and Sharma (2016), Karuppaiah and Kumar (2011), Naik *et al*. (2005) and Yuvraj and Dhatt (2014).

Highest fresh flower weight was recorded in Rupa (23.36 g) followed by P-4 (22.66 g) and these were found significantly higher when compared to all other genotypes. Flower weight appeared to be associated with diameter of flower as was evident from the results of the study. Therefore, it could be concluded that the variation in fresh flower weight among the genotypes might be due to their genetic makeup. These results were also in accordance with the findings of Rao and Moon (2005), Narsude *et al*. (2010), and Deepa *et al*. (2016).

Yield per plant was the highest in P-4 (1.036 kg)and this was followed by Rupa (0.772 kg) and the lowest yield per plant was recorded in Maria 91 (0.153 kg). Enhanced flower yield in certain genotypes could

be due to more number of large sized flowers having higher flower weight. High yield might have been contributed by either low incidence of bacterial wilt or extended period of survival of plants in the field (Rao and Moon, 2005; Manik and Sharma, 2016; Yuvraj and Dhatt, 2014).

Bacterial wilt incidence

The percent disease incidence (PDI) and average number of days to wilt to show the maximum PDI observed in each genotype and reactions of the genotypes are given in Table 3. Significant differences were observed with respect to bacterial wilt incidence among the genotypes. The genotype M-1 did not show any incidence of bacterial wilt while the genotype Sakura 031 showed 100 per cent disease incidence followed by 70.83 PDI in Rupa and 45.83 PDI in Maria 91. This variation among the genotypes could be due to interaction between environment and genetic makeup. Baruah *et al*. (2000) and Bora *et al*. (2011) reported similar results while screening brinjal cultivars. The variation in disease incidence might also be dependent upon the bacterial inoculum concentration in the soil. Mondal *et al*. (2011) reported bacterial wilt incidence in marigold ranging from 2.76 – 62.23 per cent in various locations of West Bengal.

Based on the PDI, the genotypes were classified as per the score followed by Sinha *et al*. (1988) and it could be inferred that there were two highly susceptible genotypes (Sakura 031 and Rupa), one susceptible genotype (Maria 91), three moderately susceptible genotypes (Royal Orange, P-4, Arka Agni), one moderately resistant genotype (Arka Bangara 2) and one resistant genotype (M-1).

Performance of a genotype in the field is determined not only by the per cent bacterial wilt incidence but also by the number of days it survived in the field. The genotypes Sakura 031 and Maria 91 were the earliest to wilt which might have resulted in low yield in these genotypes. All other genotypes except M-1 (wilt free) showed wilting at a later stage of flowering that might have allowed some harvest of flowers. Better yield in Rupa might be attributed to this reason even though the genotype recorded a PDI of 70.83.

There were significant variations in plant and floral characters, yield and yield attributes as well as bacterial wilt incidence among the African marigold genotypes included in the study.The genotype P-4 was found to be promising with good plant characters, high yield, large sized flowers and with moderate susceptibility to bacterial wilt. The genotype M-1 was 100 per cent resistant whereas the genotype Sakura 031 was found to be 100 per cent susceptible to bacterial wilt.

Acknowledgement

The authors are thankful to Agricultural Research Station, Mannuthy, Kerala Agricultural University, Thrissur, Kerala for providing the facilities for the research work.

References

Anuradha, K., Pampapathy, K., and Narayana, N. 1990. Effect of nitrogen and phosphorus in flowering, yield and quality of marigold. Indian J. Hortic. 47**:** 353-357.

Baruah, S. J. N., Binoy, M., and Rachid, H. A. 2000. Yield potentiality of some brinjal cultivars in severely bacterial wilt infected condition. Vegetable Sci. 27(1): 76-77.

Bharathi, U. T. and Jawaharlal, M. 2014. Evaluation of African marigold (*Tagetes erecta* L). genotypes for growth and flower yield under Coimbatore conditions. Trends Biosciences 7(16): 2197-2201.

Bora, G. C., Devi, J., Gogoi, S., Deka, A., Bhattacharyya, A. K., and Paswan, L. 2011.Evaluation of varieties of brinjal (*Solanum melongena* L.) for resistance to bacterial wilt in North East India. Curr. Adv. Agric. Sci. 3(1): 36-38.

Choudhary, M., Beniwal, B. S., and Kumari, A. 2014. Evaluation of marigold genotypes under semi-arid conditions of Haryana. Ann. Hortic.7(1): 30-35.

Deepa, V. P. and Patil, V. S. 2016. Evaluation of marigold hybrids (*Tagetes* spp.) for their growth and yield potential under Dharwad condition. J. Farm. Sci. 29 (2): 235-237.

Deepa, V. P., Patil, V. S., Venugopal, C. K., Biradar, M. S., and Sridhar, K. 2016. Study on the growth and yield attributes of marigold (*Tagetes* spp.) hybrids under Dharwad condition. HortFlora. Res. Spectrum 5(1): 43-47.

Karuppaiah, P. and Kumar, P. S. 2011. Variability, heritability and genetic advance for yield, yield attributes and xanthophyll content in African marigold (*Tagetes erecta* L.). Crop Res. 41 (1, 2 & 3): 117-119.

Khanvilkar, M. H., Kokate, K. D., and Mahalle, S. S. 2003. Performance of African marigold (*Tagetes erecta* L.) in North Konkan Coastal Zone of Maharashtra. J. Maharashtra Agric. Univ. 28(3): 333-334.

Manik, H. and Sharma, G. 2016. Promising marigold genotypes for flower and xanthophyll yield under Chattisgarh plains condition. Adv. Life Sci. 5(7): 2659-2662.

Mondal, B., Bhattacharya, I., and Khatua, D. C. 2011. Crop and weed host of *Ralstonia solanacearum* in West Bengal. J. Crop Weed. 7(2):195-199.

Naik, B. H., Patil, A. A., and Basavaraj, N. 2005.Analysis of variance and environmental indices for different traits of African and French marigold genotypes. Karnataka J. Agric. Sci. 18 (3): 752-757.

Narsude, P. B., Kadam, A. S., and Patil, V. K. 2010.Studies on the growth and yield attributes of different African marigold (*Tagetes erecta* L.) genotypes under Marathwada conditions. Asian J. Hortic. 5(2): 284-286.

Raghuvanshi, A. and Sharma, B. P. 2011.Varietal evaluation of French marigold (*Tagetes patula* L.) under mid-hill zone of Himachal Pradesh. Prog. Agric. 11(1): 123-126.

Rao, C. C and Moon, S. S. 2005. Effect of sowing date on growth and flower yield of African marigold (*Tagetes erecta* L.). Karnataka J. Hortic. 1(2): 70-75.

Rao, C. C., Goud, P. V., Reddy, K. M., and Padmaja, G. 2005. Screening of African marigold (*Tagetes erecta* L.) cultivars for flower yield and carotenoid pigments. Indian J. Hortic. 62(3): 276-279.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C and Pannu, R. S. 1998. Statistical software package for agricultural research workers. Recent advances in information theory, statistics and computer applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar (139-143).

Singh, A. K. and Singh, D. 2010. Genetic variability, heritability and genetic advance in marigold. Indian J. Hortic. 67(1): 132-136.

Sinha, S. K., Mishra, B., Singh, D. R., and Jain, B. P. 1988. Reaction of wilt resistant tomato variety and lines to *Pseudomonas solancearum*. ACIAR Bacterial Wilt Newsletter 4: 3.

Sunitha, H. M., Ravi, H., Vyakaranahal, B. S., and Bablad, H. B. 2007. Effect of pinching and growth regulators on plant growth, flowering and seed yield in African marigold (*Tagetes erecta* L.). J. Ornamental Hortic. 10(2): 91-95.

Yuvraj and Dhatt. K. K. 2014. Studies on genetic variability, heritability and genetic advance in marigold. Indian J. Hortic. 71(4): 592-594.