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Studies on the effect of bio-inoculants and gibberellic acid on flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

Anshuman Singh and Ashok Kumar

Abstract
The present investigation was carried out to "Studies on the effect of bio-inoculants and Gibberellic acid on flowering of African marigold (*Tagetes erecta* L.)" at the Main Experiment Station, Department of Floriculture & Landscape, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during winter season in the year 2019-2020 and 2020-21. The experiment was conducted in Randomized Block Design (Factorial) with 12 treatments replicated thrice to assess the effect Bio-Inoculants and Gibberellic Acid on flowering attributes of African Marigold.
During the investigation, the treatment A_3G_4 (Azotobacter by soil treatment 4L/ha and Gibberellic acid 200 ppm) has given the maximum beneficial effect on the flowering parameters (days to first bud initiation (40.67, 38.67 days), days to first flowering(50.67, 49.00 days), days taken 50% flowering (63.00, 61.33 days), duration of flowering (54.00 and 55.00 days), length of flower stalk (8.67,9.33cm), number of flowers per plant (55.33, 56.33) fresh weight of flower (10.89, 11.33 g), dry weight of flower (0.98, 0.98) and flower diameter (7.89, 8.00 cm) during winter season in the year 2019-2020 and 2020-21 as compared to individual application of GA_3 and Azotobacter treatments but their interaction effect was found non-significant.

Keywords: Bio fertilizer, plant growth regulators, growth, marigold

Introduction
The African marigold (*Tagetes erecta* L.) is a popular annual flower that is prized for its beauty and extended blooming period. It is a member of the Asteraceae family and is endemic to Central and South America, particularly Mexico. The Portuguese introduced marigold to India (Kalpan, 1960) [7]. The current marigold growing area in India is 55890 ha, with a production of 5.1 lakh MT. Karnataka has the highest marigold production in India, with 74,900 MT produced from a 9100 ha area. From a total area of 7780 hectares, Madhya Pradesh produces the most (85,070 MT).
Marigold grown in all seasons, rainy and winter crops being the most common in eastern Uttar Pradesh. The name *Tagetes* comes from Etruscan Tagetes, which refers to the ease with which the genus' plants emerge each year, either from seeds generated the previous year or from stems that renew from the stump already in place. African marigold (*Tagetes erecta*), French marigold (*Tagetes patula*), Signet marigold (*Tagetes tenuifolia*), and tiny marigold (*Tagetes tenuifolia*) are the most commonly cultivated Tagetes species (*Tagetes minuta*).
Marigold has numerous applications. Marigold is a multipurpose crop that yields a brilliant harvest. It's widely grown as a loose bloom throughout India. The loose flowers are used to make garlands, baskets, and veni, among other things. The petals are frequently used to create unique greeting cards, stationary, envelopes, and corporate gifts by embedding them in handmade paper. It's also utilized as a flavouring agent in a variety of bread goods, dairy products, yoghurt, and ice cream, and its powder and extracts have been allowed for use as sole colourants in chicken feed. Marigolds have also been identified as a food plant for some Lepidoptera caterpillars, such as the dot moth, as well as a nectar source for other butterflies. Marigold is a highly successful nematode control crop when used as a trap crop for nematode (*Helicoverpa armigera*) management in tomato fields. Marigold is becoming a more important commercial source of carotenoid pigments. The primary pigment in the flowers is xanthophyll, of which lutein accounts for 80 to 90% in the form of palmitic and myristic acid esters. Tagetes oil is an aromatic oil derived from *Tagetes minuta* that is used as a fly repellant and has larvicidal qualities. Mexican marigold plants grow to be between 50 and 100 cm tall.

The root is cylindrical, with a fibrous branching system that is shallow. The stem is striated, sometimes ridged, smooth or slightly ridged, cylindrical, oval, herbaceous to slightly woody, and has resin channels in the bark that are scented when squeezed. pinnate, comprised of 11 to 17 leaflets, lanceolate to linear-lanceolate, up to 5 cm long and 1.5 cm wide, acute to acuminate, serrated to sub-holders, lower ones of each leaf usually setiform (in the shape of threads), superiors are occasionally totally setiform; with many spherical glands

Microbial inoculants of specific microorganisms, such as azotobacter, a free-living nitrogen-fixing bacteria, aid in improving soil fertility by accelerating biological nitrogen fixation from the atmosphere (approximately 25 to 30 l nitrogen per hectare), solubilizing insoluble nutrients in soil, generating small amounts of PGRs decomposing plant residues, improve flower quality by producing Phyto hormones, and enhancing plant nut uptake.

Gibberellic acid is vital for stalk elongation, flower induction, flower and seed development, and storage reserve mobilisation. Gibberellic acid has been discovered to be particularly effective in controlling chrysanthemum growth and flowering (Gautam *et al*., 2006) [4].

Materials and Methods

The experiment was laid out in Randomized Block Design (Factorial) with three replications and twelve treatments at Main Experimental Station, Horticulture, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya during the year 2019-2020 and 2020-21. Geographically, it is situated in typical saline alkali belt of Indo-Gangetic plains of eastern U.P. at 26.47-0 N latitude, 88.120 E longitudes and at an altitude of 113 meter from mean sea level. The region enjoys sub humid and subtropical climate receiving a mean annual rainfall of about 1215 mm out of which about 85% is concentrated from mid-June to end of September. The treatments are A_1(Control), A_2 (Azotobacter by root treatment 0.25g/15 plants), A_3(Azotobacter by soil treatment 4L/ha), G_1(Control) G_2 (Gibberellic acid 100 ppm spray at 30 DAT), G_3 (Gibberellic acid 150 ppm spray at 30 DAT), G_4 (Gibberellic acid 200 ppm spray at 30 DAT), A_1G_1(Control), A_1G_2 (Gibberellic acid 100 ppm spray at 30 DAT), A_1G_3 (Gibberellic acid 150 ppm spray at 30 DAT), A_1G_4(Gibberellic acid 200 ppm spray at 30 DAT), A_2G_1 (Azotobacter by root treatment @ 0.25%), A_2G_2 (Azotobacter by root treatment 0.25% +100ppm gibberellic acid at 30 DAT) A_2G_3 (Azotobacter by root treatment 0.25% +150ppm gibberellic acid at 30 DAT) A_2G_4 (Azotobacter by root treatment@0.25% + 200ppm gibberellic acid at 30 DAT) A_3G_1 (Azotobacter by soil treatment @4l/ha), A_3G_2 (Azotobacter by soil treatment @ 4l/ha +100ppm gibberellic acid at 30DAT), A_3G_3 (Azotobacter by soil treatment @ 4l/ha +150ppm gibberellic acid at 30DAT), A_3G_4 (Azotobacter by soil treatment @ 4l/ha +200ppm gibberellic acid at 30DAT).

The first year (2019-20) and Second year (2020-21), marigold seeds were sown in raised beds measuring 120×60×10cm. during the last week of September. A mixture of garden soil and coarse sand was used to enclose the seed beds. Seeds were sown in a clean line with a 4-5cm gap. After seeding, the nursery beds were covered by paddy straw as a mulch. Light irrigation provided at regular interval. Within 4-5 days of seeding, the seeds germinated, and the mulch layer was removed. The seedlings were hardened by withholding water for two to three days before being lifted. Watering was done in the morning, however, to help seedlings be lifted smoothly. Twenty-five days old seedlings were planted in the evening for their better survival. The plants of marigold were maintained healthy by using appropriate culture practice during the course of investigation and five plants were randomly selected from each plot and were tagged for recording various observations on days to first bud initiation, days to first flowering, days taken 50% flowering, duration of flowering, length of flower stalk, number of flowers per plant, fresh weight of flower, dry weight of flower and flower diameter. The obtained data had statistically analysed adopting procedure as given by Panse and Sukhatme (1985) [17].

Results and Discussion

The statistical analysis of data (Table-1) revealed that the earliest first bud initiation (42.25 and 42.17), first flowering (55.75 and 55.50) and 50% flowering (65.33 and 64.25 days) was recorded in the plants treated with the treatment A_3 (Azotobacter by Soil Treatment 4L/ha) in during the both years 2019-20 and 2020-21 respectively, whereas the maximum period taken for days to first bud initiation, days to first flowering and 50% flowering was recorded with A_1 (control) 51.83 in 2019-20 and 51.42 in 2020-21 during the both years. Early bud initiation and First flowering in azotobacter-inoculated plants may be due to simple nutrient uptake and simultaneous transportation of growth-promoting compounds like cytokinin to axillary buds, resulting in apical dominance breaking. As a result, the plant has a better sink for rapid mobilization of photosynthates and an earlier transition from vegetative to the reproductive phase the present findings are in close agreement with Yadav *et al*. (2018) [22]; Kumar, A. and Kumar, A. (2018) [9] in marigold, Chaupoo *et al.* (2020) [3] reported hastened flower bud initiation in plants of marigold cv. Pusa Narangi Gainda treated with azotobacter.

The application of gibberellic acid has no significant effect on days to first bud initiation in the year 2019-20 while significant effect during the year (2020-21). The least number of days required for first bud initiation (45.11 and 43.11 days), first flowering (54.89 and 53.11 days) and 50% flowering (64.56 and 63.11 days) whereas the maximum days to first bud initiation, first flowering and 50% flowering with the treatment G_1 (Control) during the both year 2019-20 and 2020-21. The foliar application of GA_3 significantly induces early bud and flowering which might be attributed to an increase in endogenous gibberellins levels in the plants. GA_3 was also quite successful in shortening the juvenile period of plants due to its powerful ability of cell division and cell elongation, which induces early maturity in plants. Similar results were also reported by Salem *et al*. (2016) [18] reported a positive significant effect of application of gibberellic acid on flowers of gerbera (*Gerbera jamesonii*) cv Dennis treated with GA_3 150 ppm; Mishra *et al.* (2017) [13] concluded early flower bud initiation through the application of GA_3 300 ppm one month after transplanting in African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda.

The interaction of the application of the interaction of azotobacter with gibberellic acid was found statistically non-significant during both the years (2019-20 and 2020-21).

As shown in Table No 1 the longest duration of flowers (51.67 and 51.33 days), Longest length of flower stalk (7.67

and 8.58), maximum number of flowers per plant (44.83 and 45.50), Fresh Weight of per flower (9.16 and 9.92), Dry Weight of per flower (0.92 and 0.91) and Flower diameter (7.39 and 7.41) was observed under the Treatment A_3 (Azotobacter by Soil Treatment 4 l/ha) and shortest duration of flowering (40.92 and 41.17), flower stalk (6.42 and 6.25 cm), number if flowers per plant (32.92 and 33.50), Fresh Weight of per flower (7.61 and 7.83g), Dry Weight of per flower (0.76 and 0.76g) and Flower diameter (5.39 and 5.54 cm) observed under A_1 (Control) in during the both years 2019-20 and 2020-21 respectively. The application of azotobacter increased the availability of nitrogen and other nutrients as well as the secretion of growth-promoting hormones, which stimulates vegetative growth toward the development of superior flowering parameters. The present findings are in conformity with Mittal *et al.* (2010) [14], Kumawat *et al.* (2017) [11] described the positive response of marigolds to the inoculation of azotobacter. Kumar, A. and Kumar, A. (2018) [9] in marigold, Gawade *et al.* (2019) [5] explained the beneficial impact of azotobacter on the chrysanthemum cv. Ratlam Selection.

Similarly, the longest duration of flowers (48.89 and 49.22days), Longest length of flower stalk (7.78 and 8.00), maximum number of flowers per plant (46.00 and 46.67), Fresh Weight of per flower (9.52 and 9.67g), Dry Weight of per flower (0.91 and 0.91) and Flower diameter (6.74 and 7.02 cm) was observed under the Treatment G_4 (GA_3 200 ppm at 30 DAT) and shortest duration of flowering (42.00 and 40.67), flower stalk (6.11 and 6.56cm), number of flowers per plant (29.11 and 30.11), Fresh Weight of per flower (7.26 and 7.56g), Dry Weight of per flower (0.75 and 0.76) and Flower diameter (5.70 and 5.72) observed under A_1 (Control) in during the both years 2019-20 and 2020-21 respectively. The superior results of flower quality were obtained through the application of GA_3. The increased bloom diameter mediated by GA_3 administration could be due to increased cell division and cell enlargement as well as enhanced protein synthesis and dry matter accumulation. In case of duration of flowering with GA_3 was most likely to be attributed to a reduction in the juvenile period in the interphase of the cell cycle, as a reduction in the S-phase encourages the shoot apical meristem to commence producing buds instead of leaves and branches. (Khangjarakpam *et al*, 2019) [8]. Kumar *et al.* (2010) [10] and Nair *et al.* (2002) [15] found similar results in gerbera. Number of flowers per plant in marigold attributed to gibberellic acid treatment could be due to the production of a large number of laterals at an early stage of growth, which had sufficient time to accumulate carbohydrates for optimal flower bud differentiation leading to enhanced reproductive efficiency and photosynthesis in the restructured plant type, which subsequently boosted the number of flowers per plant. Similar results were also reported by Sarkar *et al.* (2019) [19] in marigold, Salem *et al.* (2016) [18] in Gerbera. Ardalani *et al.* (2014) [2] reported a beneficial effect of GA_3 on marigolds in improving flower quality parameters. Floral weight may result from GA_3-mediated growth, biomass production, and carbohydrate content in crop plants. The GA_3 application encouraged corella growth, pollen germination, and pollen tube growth, resulting in an increase in flower weight. The results are in agreement with Shinde *et al.* (2010) [20] in chrysanthemum, Manimaran *et al.* (2017) [12] in gladiolus and Imandi *et al.* (2017) [6] in marigold cv. Siracole, Syngkrem *et al.* (2018) [21] in white marigold and Pangrahi *et al.* (2020) [16] in gladiolus cv. Malaviya Kundan In both the years of investigation (2019-20 and 2020-21), the interaction of azotobacter and gibberellic acid was found non-significant.

Table 1: Effect of bio-inoculants and Gibberellic acid on flowering of African marigold

Treatment	Days to first bud initiation		Days taken to first flowering		Days taken to 50% Flowering.		Duration of Flowering (Days)		Length of flower stalk (cm)		Number of flowers per plant		Fresh weight of per flower (g)		Dry weight of per flower. (g)		Flower diameter (cm)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
A_1	51.83	51.42	61.67	61.67	70.08	69.42	40.92	41.17	6.42	6.25	32.92	33.50	7.61	7.83	0.76	0.76	5.39	5.54
A_2	45.33	46.75	58.83	57.83	66.67	65.67	43.58	43.42	6.92	7.00	37.08	38.08	8.19	8.33	0.83	0.84	6.11	6.34
A_3	42.25	42.17	55.75	55.50	65.33	64.25	51.67	51.33	7.67	8.58	44.83	45.50	9.16	9.92	0.92	0.91	7.39	7.41
S.Em±	1.007	1.315	1.359	1.337	1.201	1.170	0.841	0.850	0.233	0.211	0.852	0.841	0.158	0.224	0.019	0.028	0.178	0.211
C.D.(P=0.05)	2.954	3.856	3.986	3.921	3.524	3.431	2.465	2.493	0.683	0.618	2.499	2.467	0.463	0.656	0.057	0.083	0.521	0.617
G_1	48.44	50.22	66.33	65.56	71.89	71.89	42.00	40.67	6.11	6.56	29.11	30.11	7.26	7.56	0.75	0.76	5.70	5.72
G_2	46.56	48.00	57.67	59.22	67.56	66.33	44.22	44.56	6.67	7.00	36.89	37.22	8.11	8.56	0.83	0.82	6.26	6.25
G_3	45.78	45.78	56.11	55.44	65.44	64.44	46.44	46.78	7.44	7.56	41.11	42.11	8.41	9.00	0.85	0.86	6.48	6.74
G_4	45.11	43.11	54.89	53.11	64.56	63.11	48.89	49.22	7.78	8.00	46.00	46.67	9.52	9.67	0.91	0.91	6.74	7.02
S.Em±	1.163	1.518	1.569	1.544	1.387	1.351	0.971	0.981	0.269	0.243	0.984	0.971	0.182	0.258	0.022	0.033	0.205	0.243
C.D.(P=0.05)	NS	4.453	4.603	4.528	4.069	3.962	2.847	2.878	0.789	0.714	2.886	2.848	0.535	0.758	0.066	0.096	0.602	0.713
A_1 G_1	53.67	54.00	66.67	67.00	76.67	77.33	38.00	38.00	5.67	5.33	25.67	26.00	6.67	7.00	0.69	0.70	4.89	4.93
A_1 G_2	52.33	53.00	62.00	63.00	70.00	69.00	39.67	40.33	6.33	6.00	30.67	31.00	7.33	7.67	0.73	0.73	5.33	5.12
A_1 G_3	51.00	51.67	59.67	59.67	67.33	66.33	42.33	42.33	6.67	6.67	36.33	37.67	7.67	8.00	0.77	0.76	5.55	5.89
A_1 G_4	50.33	47.00	58.33	57.00	66.33	65.00	43.67	44.00	7.00	7.00	39.00	39.33	8.78	8.67	0.86	0.85	5.77	6.22
A_2 G_1	46.33	50.33	66.33	65.33	71.00	70.33	39.33	39.00	6.00	6.33	28.33	30.67	7.11	7.33	0.73	0.74	5.44	5.66
A_2 G_2	45.67	48.00	57.00	57.67	66.33	65.33	41.33	41.00	6.67	6.67	36.00	36.33	8.33	8.33	0.84	0.84	6.11	6.18
A_2 G_3	45.00	45.00	56.33	55.00	65.00	64.00	44.67	45.00	7.33	7.33	40.33	41.00	8.44	8.67	0.85	0.86	6.33	6.66
A_2 G_4	44.33	43.67	55.67	53.33	64.33	63.00	49.00	48.67	7.67	7.67	43.67	44.33	8.89	9.00	0.89	0.90	6.55	6.85
A_3 G_1	45.33	46.33	66.00	64.33	68.00	68.00	48.67	45.00	6.67	8.00	33.33	33.67	8.00	8.33	0.82	0.83	6.77	6.55
A_3 G_2	41.67	43.00	54.00	57.00	66.33	64.67	51.67	52.33	7.00	8.33	44.00	44.33	8.66	9.67	0.92	0.88	7.33	7.44
A_3 G_3	41.33	40.67	52.33	51.67	64.00	63.00	52.33	53.00	8.33	8.67	46.67	47.67	9.11	10.33	0.95	0.96	7.55	7.66
A_3 G_4	40.67	38.67	50.67	49.00	63.00	61.33	54.00	55.00	8.67	9.33	55.33	56.33	10.89	11.33	0.98	0.98	7.89	8.00
S.Em±	2.015	2.630	2.718	2.674	2.403	2.340	1.681	1.700	0.466	0.421	1.704	1.682	0.316	0.448	0.039	0.057	0.355	0.421
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

On the basis of above studies, it may be concluded that the application of Azotobacter and GA_3 (Soil treatment with Azotobacter + spray of GA_3 200 ppm after 30 days of transplanting) may significantly improve the flowering and quality (Days to first bud initiation, Days taken to first flowering, Days taken to 50% Flowering, Duration of Flowering (Days), Length of flower stalk (cm), Number of flowers per plant, Fresh weight of per flower (g), Dry weight of per flower. (g) and Flower diameter) of the marigold plants. it can be recommended to obtained higher production and maximum return for marigold growers of Eastern Uttar Pradesh.

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