

Original Research Article

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Effect of *Azotobacter* Isolates on Growth of African Marigold (*Tagetes erecta* L.)

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A B S T R A C T

The present investigation entitled “to study the effect of *Azotobacter* isolates on growth of African marigold (*Tagetes erecta* L.)” (Variety – Omni Yellow) at PG farm of Rajarshee Chatrapati Shahu Maharaj College of Agriculture, Kolhapur during *summer* season of the year 2020-21. The randomized block design (RBD) was used for the field experiment. The results of investigation showed that the application of 75% RDN + 100% RDP and K + seedling + soil both treated with commercial strain of *Azotobacter* (*Azotobacter chroococcum*) found more effective and showed profuse growth and yield characters of African marigold followed by the treatment 75% RDN + 100% RDPK + seedling + soil both treated with Strain – A of *Azotobacter* (ATHM₁) and 75% RDN + 100% RDPK + seedling + soil treated with Strain – B of *Azotobacter* (ATKM₃). These treatments were statistically at par with one another and superior over other treatments. The treatment 75% RDN + 100% RDPK + seedling + soil both treated with commercial strain of *Azotobacter* (*Azotobacter chroococcum*) showed profuse effect on the growth parameter *viz.* maximum plant height (74.53 cm), primary branches (19.50), secondary branches (61.87) and plant spread (50.63 cm). It enhanced the flowering parameters *viz.* number of buds (17.92), number of flowers (9.30), flower diameter (7.56 cm) and weight of single flower (16.26 gm) and maximum yield per plot (15.86 kg), and total yield (16.31 t/ha). It has also increase a available N in soil (177.88 kg/ha) followed by the results of treatment 75% RDN + 100% RDPK + seedling + soil both treated with Strain – A of *Azotobacter* (ATHM₁) gave plant height (73.97cm), primary branches (19.40), secondary branches (60.80) and plant spread (48.39cm), number of buds (16.99) number of flowers (8.78), flower diameter (7.16 cm) and weight of single flower (15.78 gm) and gave yield per plot (14.72 kg) and total yield (15.05 t/ha), also has increase a available N content of soil (175.77 kg/ha). Thus, the present investigation confined that an application of *Azotobacter* strains with the seedling dip treatment and soil drenching found to be more effective along with 75 % RDN, and 100% RDPK and saving of 25% dose of nitrogen.

Keywords

Tagetes erecta L,
Virgin Marry',
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Introduction

Marigold (*Tagetes erecta* L.) belongs to family *Asteraceae* (Compositae), is one of the most important hardy flower crops grown commercially in different parts of the world (Kumawat *et al.*, 2017). It also called as ‘Virgin Marry’, ‘friendship flower’ in United States and ‘Student lumen’ (student’s flower) in Germany.

In India, it is one of the most commonly grown loose flowers and extensively used on religious and social functions because of its wider adaptability to various soils and climatic conditions, easy cultivation, profuse flowering habit, short duration to produce marketable flowers and good keeping quality (Singh *et al.*, 2001; Asif, 2008; Rolaniya *et al.*, 2017). In India, the marigold occupied area 68.33 thousand hectare and production was 607.97 thousand metric tons in 2016-17 (Department of Agriculture, Co-operation and Farmer’s Welfare). It is widely cultivated in Madhya Pradesh, Maharashtra, Gujarat, Haryana, Tamil Nadu, Rajasthan, West Bengal and Delhi.

Nitrogen is a major macronutrient often limiting growth and economic yield of crop. It is found in chlorophyll, the green pigment of leaves that enables the plant to transfer energy from sunlight by photosynthesis and hence influences cell size, leaf area, and photosynthetic activity and is a key element in amino acids, proteins, chlorophyll and root development.

Deficiency of nitrogen results in yellowing of older leaves due to drop of chlorophyll content, symptoms first appear on old leaves. Nitrogen is most expensive nutrient to supply and may also have environmental impact Biofertilizer are economical, eco-friendly and good source of nutrients.

The N-fixing biofertilizer fixes the atmospheric nitrogen in soil in available form and plays important role in improve the soil health through early nutrient availability. *Azotobacter* is genus of Gram negative motile, oval or spherical bacteria that

are thick walled cyst. They are aerobic, free living soil microbes that play an important role in nitrogen fixation. *Azotobacter* is free-living nitrogen fixing bacteria which fix 20- 25 kg nitrogen per hectare.

It also produces hormone like IAA & GA₃, Vitamin like biotin (Vit B₇) & folic acid and with judicious use of organic matter ensures good growth and increase productivity, (Kader, 2002 and Jadhav *et al.*, 2014). Other important feature of *Azotobacter* sp. is the association with root exudates, which helps in modification of nutrient uptake by the plants (Narula and Gupta, 1986).

Nitrogen fixing bacteria are beneficial for improving crop growth and quality of product by producing phytohormones, enhancing the uptake of plant nutrients by plant roots and thus help in sustainable crop production through maintenance of soil productivity.

Materials and Methods

Seedling and soil treatment and sowing

For the experiment Omni Yellow variety African marigold was used. Seedlings of this variety were transplanted after seedling dip treatment with efficient isolate A, B and Commercial strains of *Azotobacter*@ 25 ml/L as per experimental treatment except the uninoculated control with spacing of 45cm × 45cm After that soil treated with respective two efficient strains and commercial strains as per the treatment details.

Observations to be recorded

Plant height (in cm)
Number of primary and secondary branches
Plant spread (E – W and N – S) (in cm)
Number of flowers per plant
Fresh weight of single flower (in gm)
Average diameter of flower
Yield per plot/ per hectare

Table.1 Treatment details

T₁	75% RDN and 100% RDPK (75: 100: 100 NPK kg ha⁻¹) + Soil + Seedling both treat with efficient strain – A of <i>Azotobacter</i>(ATHM₁)
T₂	75 % RDN and 100 % RDPK (75: 100:100 NPK kg ha ⁻¹) + Soil without treatment + Seedling treat with efficient strain – A of <i>Azotobacter</i>
T₃	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil treatment with efficient strain – A of <i>Azotobacter</i> + Seedlings without treatment
T₄	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil + Seedling both treat with strain – B of <i>Azotobacter</i> (ATKM ₃)
T₅	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil without treatment + Seedling treatment with strain – B of <i>Azotobacter</i>
T₆	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil treatment with strain – strain B + Seedling without treatment
T₇	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil + Seedling treatment with commercial strain of <i>Azotobacter</i>
T₈	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil without treatment + Seedling treatment with commercial strain of <i>Azotobacter</i>
T₉	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil treatment with commercial strain of <i>Azotobacter</i>
T₁₀	75 % RDN and 100 % RDPK (75: 100: 100 NPK kg ha ⁻¹) + Soil + Seed both without treatment
T₁₁	100 % RDF (100: 100: 100 NPK kg ha ⁻¹) Soil + Seedling both without treatment

Results and Discussion

Effect of *Azotobacter* isolates and commercial strain on growth of African marigold

Plant height

Average results showed that maximum plant height (58.50 cm) was recorded in treatment T₇ followed by T₁ and T₄ with values 58.14 cm and 57.10cm

respectively and significantly at par with each other. The minimum plant height (51.34cm) was recorded by treatment T₁₀

Primary branches

Maximum number of primary branches (17.06) was recorded in T₇ followed by (16.87) in T₁ and (16.47) T₄ with values. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The least number of primary branches (14.00) was obtained in treatment T₁₀.

Secondary branches

The maximum numbers of secondary branches (37.05) recorded in T₇ followed by T₁ and T₄ with values of 36.72 and 35.61 respectively. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The least number of secondary branches (30.82) was obtained in treatment T₁₀.

Plant spread

The average results of plant spread at all the growth stages showed that the maximum plant spread (38.13 cm) was recorded by T₇ followed by T₁ and T₄ with average plant spread 36.53 cm and 35.61 cm. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The minimum plant spread (30.61cm) was recorded by treatment T₁₀. The results were represented in Table -1. The obtained results of plant growth parameters showed agreement with the results of Gupta (1997), who stated that the growth parameters like plant height and number of branches per plant were significantly increased in treatment receiving *Azotobacter* in African marigold. Nair *et al.*, (2005) studied the effect of *Azotobacter* on the growth of China aster cv. Local Pink and concluded that the maximum values for plant growth parameters were observed under soil application of *Azotobacter*+ 75% of the recommended N rate. Kumar and Kumar (2017) studied the combined and alone application of biofertilizers and stated that the *Azotobacter* + PSB + 75% NPK showed significant response on plant growth parameters.

Table.2 Effect of *Azotobacter* isolate and commercial strain (*Azotobacter chroococcum*) on plant growth parameters of African marigold.

Tr. No.	At 15 DAT				At 30 DAT				At 45 DAT				At 60 DAT				Mean			
	Plant height (cm)	No. of primary branches	No. of secondary branches	Spreading (cm)	Plant height (cm)	No. of primary branches	No. of secondary branches	Spreading (cm)	Plant height (cm)	No. of primary branches	No. of secondary branches	Spreading (cm)	Plant height (cm)	No. of primary branches	No. of secondary branches	Spreading (cm)	Plant height (cm)	No. of primary branches	No. of secondary branches	Spreading (cm)
T ₁	37.51	15.00	0.33	25.11	59.87	15.53	35.13	32.21	61.19	17.53	50.40	40.33	73.97	19.40	60.80	48.39	58.14*	16.87*	36.72*	36.53*
T ₂	36.00	14.53	0.20	23.47	58.33	15.40	33.80	30.39	58.40	16.80	46.87	38.21	71.23	17.93	58.00	45.48	55.99	16.12	34.78	34.41
T ₃	34.25	13.60	0.07	21.75	55.23	15.00	31.47	29.47	57.73	16.07	46.00	36.81	70.55	17.13	57.07	43.76	54.44	15.45	33.67	32.95
T ₄	37.26	14.80	0.27	24.89	58.87	15.47	33.93	32.11	59.68	17.47	49.60	40.20	72.60	18.13	58.67	48.07	57.10*	16.47*	35.61*	35.61*
T ₅	34.08	13.20	0.00	20.24	54.83	15.20	31.20	29.21	56.25	15.53	45.80	36.55	70.87	16.93	54.07	43.31	54.01	15.12	32.82	32.33
T ₆	32.90	12.67	0.00	19.72	53.97	14.80	30.67	27.74	55.23	15.47	44.80	35.93	70.77	16.70	52.77	43.09	53.22	14.73	32.06	31.62
T ₇	37.62	15.07	0.67	26.00	60.05	16.07	35.27	32.66	61.79	17.60	50.60	43.25	74.53	19.50	61.87	50.63	58.50*	17.06*	37.05*	38.13*
T ₈	36.46	14.60	0.07	23.72	58.29	15.20	33.87	30.79	59.36	17.33	47.13	38.35	71.80	18.07	58.40	46.19	56.48	16.35	35.54	34.56
T ₉	34.50	14.27	0.00	22.08	55.23	14.80	31.87	29.86	58.20	16.13	46.07	36.92	70.47	17.27	57.53	44.38	54.60	15.62	34.07	33.31
T ₁₀	32.38	12.07	0.00	17.89	51.30	12.73	30.33	26.23	52.97	14.73	41.00	35.68	68.72	16.47	51.93	42.65	51.34	14.00	30.82	30.61
T ₁₁	35.93	14.40	0.07	23.16	55.64	14.07	32.47	30.13	58.33	16.53	46.40	37.13	70.81	17.87	57.67	44.65	55.18	15.99	34.00	33.77
SEm±	1.07	0.60	0.13	0.79	1.53	0.55	1.15	0.95	1.54	0.60	1.67	1.16	0.91	0.62	2.02	1.32	0.39	0.16	0.72	0.34
CD at 5%	3.07	1.73	0.38	2.34	4.39	1.58	3.30	2.80	4.44	1.74	4.81	3.43	2.62	1.78	5.81	3.90	1.12	0.45	2.06	0.98

Table.3 The effect of efficient isolates and commercial strain of *Azotobacter* (*Azotobacter chroococcum*) on flower parameters of African marigold (variety – Omni Yellow).

Treat- Ments	At 30 DAT				At 45 DAT				At 60 DAT				Mean			
	No. of Buds per plant	No. of flowers per plant	Flower diameter (cm)	Single flower weight (gm)	No. of Bud per plant	No. of flowers per plant	Flower diameter (cm)	Single flower weight (gm)	No. of Bud per plant	No. of flowers per plant	Flower diameter (cm)	Single flower weight (gm)	No. of Buds	No. of flowers per plant	Flower diameter (cm)	Single flower weight (gm)
T ₁	22.00	5.13	6.93	23.37	21.47	10.47	8.35	15.92	23.00	19.53	6.20	8.06	16.99*	8.78*	7.16*	15.78*
T ₂	20.53	4.40	6.63	16.33	20.07	9.80	6.63	12.31	22.13	18.87	5.69	7.57	16.03	8.27	6.32	12.07
T ₃	19.80	3.87	6.33	13.26	19.33	8.60	6.33	11.23	21.00	17.20	5.43	5.64	15.35	7.42	6.03	10.04
T ₄	21.60	4.83	6.83	23.30	21.00	10.33	7.58	14.46	22.47	19.33	6.16	7.57	16.64*	8.62*	6.81*	15.13*
T ₅	19.07	3.60	6.14	12.43	19.33	9.53	6.03	11.06	20.07	16.80	5.36	5.64	14.89	7.48	5.85	9.71
T ₆	19.00	3.50	6.13	11.06	19.27	8.47	5.94	10.44	20.00	16.53	5.35	5.25	14.87	7.13	5.81	8.92
T ₇	24.47	5.67	7.83	23.52	22.60	10.53	8.43	17.06	23.07	21.00	6.43	8.21	17.92*	9.30*	7.56*	16.26*
T ₈	21.47	4.80	6.68	20.39	20.80	10.13	6.78	13.49	22.33	19.13	5.88	7.33	16.50	8.52	6.50	13.74
T ₉	20.47	3.93	6.35	13.55	19.40	8.93	6.36	11.65	21.00	18.60	5.48	6.34	15.54	7.87	6.06	10.51
T ₁₀	17.53	2.60	5.79	9.89	18.73	8.13	5.41	9.01	20.00	16.40	4.93	5.21	14.32	6.78	5.38	8.04
T ₁₁	20.53	4.07	6.61	14.50	19.47	9.40	6.62	12.29	21.67	18.73	5.66	6.76	15.74	8.05	6.30	11.18
SEm±	1.04	0.48	0.34	0.90	0.73	0.48	0.53	1.06	0.76	0.94	0.24	0.66	0.37	0.32	0.19	1.23
CD at 5%	2.98	1.39	0.99	2.58	2.11	1.40	1.52	3.05	2.19	2.71	0.70	1.89	1.06	0.92	0.54	3.63

Table.4 The effect of efficient isolates and commercial strain of *Azotobacter* (*Azotobacter chroococcum*) on the yield (per plot & hector) of African marigold (variety – Omni Yellow).

Treatments	At 1 st harvest		At 2 st harvest		At 3 rd harvest		Average Yield		Total Yield	
	Yield / plot (Kg)	Yield / ha (tones)	Yield / plot (Kg)	Yield / ha (tones)	Yield / plot (Kg)	Yield / ha (tones)	Yield / plot (Kg)	Yield / ha (tones)	Yield / plot (kg)	Yield / ha (tones)
T₁	4.37	4.50	5.45	5.60	4.90	5.04	4.91*	5.05*	14.72*	15.05*
T₂	3.83	3.94	4.37	4.50	3.91	4.02	4.04	4.16	12.12	12.47
T₃	3.79	3.90	3.26	3.35	3.12	3.21	3.39	3.49	10.17	10.46
T₄	4.32	4.44	5.35	5.51	4.80	4.94	4.82*	4.96*	14.47*	14.98*
T₅	3.76	3.87	3.55	3.65	3.01	3.10	3.44	3.54	10.32	10.62
T₆	3.73	3.84	3.40	3.50	2.95	3.04	3.36	3.46	10.08	10.37
T₇	4.88	5.02	5.76	5.92	5.22	5.37	5.29*	5.44*	15.86*	16.31*
T₈	3.84	3.95	4.40	4.53	3.99	4.11	4.08	4.20	12.24	12.59
T₉	3.82	3.93	4.01	4.13	3.46	3.56	3.77	3.88	11.30	11.63
T₁₀	2.81	2.89	3.03	3.12	2.55	2.62	2.80	2.88	8.39	8.63
T₁₁	3.99	4.10	4.34	4.47	3.73	3.84	4.02	4.14	12.06	12.41
SEm_±	0.27	0.28	0.46	0.47	0.31	0.32	0.17	0.18	0.52	0.45
CD at 5%	0.80	0.83	1.35	1.39	0.92	0.94	0.51	0.53	1.54	1.35

Effect of *Azotobacter* isolates and commercial strain on flowering parameter of African marigold

Number of buds per plant

The average results of treatment showed that maximum average numbers of buds (17.92) were recorded in treatment T₇ followed by T₁ and T₄ 16.99 and 16.64 respectively. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The minimum numbers of buds were observed in treatment.

Number of flowers per plant

The maximum numbers of flowers (9.30) were observed in treatment T₇ followed by T₁ and T₄ with numbers of flowers 8.78 and 8.62 respectively. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The minimum number of flowers (6.78) was recorded by treatment T₁₀.

Flower diameter

The average maximum flower diameter (7.56 cm) recorded by treatment T₇ followed by and T₄ with diameter 7.16 cm and 6.81cm respectively. The treatments for T₇, T₁ and T₄ are significantly on par with one another. The minimum flower diameter (5.38 cm) was recorded by treatment T₁₀.

Weight of single flower

On an average, the maximum weight of a single flower (16.26gm) was recorded by treatment T₇ followed by T₁ and T₄ with weight of single flower 15.78gm and 15.13gm respectively. These three treatments were statistically significant and on par with one another. The minimum weight of a single flower (8.04gm) was recorded by treatment T₁₀. Results represented in Table- 2

The obtained results were agreement in the results of Nair *et al.*, (2005) who studied the effect of *Azotobacter* on China aster and found that the soil application of *Azotobacter* + 75% of the

recommended dose of N showed a significant effect on flower parameters. Syamal *et al.*, (2006) stated that an application of *Azotobacter*(@1.5kg/ha) + 75% RDF gave maximum numbers of flowers in marigold cv. 'Local'. Kumar and Kumar (2017) studied the combined and alone application of biofertilizers and stated that the *Azotobacter* showed a significant response in flowering parameters.

Effect of *Azotobacter* isolates and commercial strain on yield of African marigold

Yield per plot

The average maximum yield per plot (5.29 kg) was recorded by T₇ followed by (4.91 kg) in T₁ and (4.82 kg) in T₄. These three treatments were statistically significant and on par with one another. The average lower yield per plot (2.80 kg) was recorded by treatment T₁₀. The total maximum yield per plot (15.86 kg) was observed in treatment T₇ followed by (14.72 kg) in T₁ and (14.47 kg) in T₄. These three treatments were statistically significant and on par with one another. The lowest total yield per plot (8.39 kg) was recorded by treatment T₁₀.

Yield per hectare

The average results of yield per hector showed a similar sequence as above. The average maximum yield (5.44 t/ha) was recorded by treatment T₇ followed by T₁ and T₄ with yield 5.05 t/ha and 4.96 t/ha respectively. These treatments were statistically significant and on par with one another. The lowest yield (2.88 t/ha) resulted from treatment T₁₀.

The total maximum yield (16.31t/ha) was found in treatment T₇ followed by T₁ and T₄ with yield 15.0ha5 t/ and 14.98 t/ha respectively. However, these treatments were statistically significant and on par with one another. The lowest total yield (8.63t/ha) resulted from treatment T₁₀. (Table -3)

The results obtained in investigation showed agreement with Nandre (2005) who stated that an application of *Azotobacter* as soil application and a

75% recommended dose of nitrogen showed a significant effect on the yield of China aster. Rath *et al.*, (2005) revealed that an application of 75% of the recommended dose of N (150 kg/ha), a full dose of P and Kalong with *Azotobacter* and Phosphobacteria (PSB) as a seedling dip method had a significant effect on yield in African marigold.

Summary

Present investigation concluded that Application of *Azotobacter* strains as seedling dip treatment and soil drenching found to be more effective along with 75 % N, and 100% P and K. Application of commercial strain of *Azotobacter* (*Azotobacter chroococcum*) as seedling + soil treatment along with 75% N and 100% dose of P and K gives well plant establishment, profuse flowering and higher yield.

The treatment of efficient Strain-A (ATHM₁) as seedling + soil along with 75% N and 100% dose of P and K also showed the significant effect on growth of African marigold.

Thus, Strain –A of *Azotobacter* (ATHM₁) on par to the effects of commercial strain of *Azotobacter* (*Azotobacter chroococcum*) it can be applied to field with 75% N and 100% dose of P and K for getting profuse growth and higher yield. Also, it saves 25% dose of nitrogen.

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