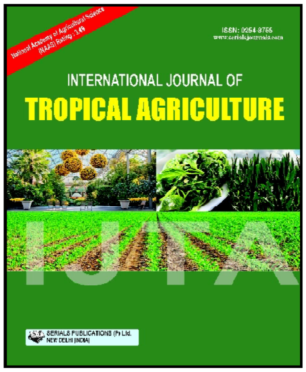

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Integrated nutrient management of African Marigold (*Tagetes erecta* L.) productivity in reclaimed sodic soils

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Abstract: In this study, the effect of integrated nutrient management practices on productivity of an important floricultural plant i.e. African Marigold (*Tagetes erecta* L.) has been quantified in reclaimed sodic soil The field experiment was conducted in randomized block design with 14 treatments (T1- 100% Nitrogen-N, T2- 100% N + *Azotobacter*, T3- 100% N + Phosphate Solobulizing Bacteria-PSB, T4- 100% N + *Azotobacter* + PSB, T5- 75% N, T6- 75% N + *Azotobacter*, T7- 75% N + PSB, T8- 75% N + *Azotobacter* + PSB, T9- 50% N, T10- 50% N + *Azotobacter*, T11- 50% N + PSB, T12- 50% N + *Azotobacter* + PSB, T13- *Azotobacter* + PSB, T14- Control) in three replications. The growth and productivity in terms of different morphological, physiological and yield traits and soil reclamation in terms of soil available nutrients and microbial population were measured. The highest nutrient (N, P, and K) availability and bacterial population was found in soils treated with 75%N + Azotobacter + PSB (T8) while the lowest was observed in control. The fast initiation (35.3 days after plantation) and opening (53.7 days) of flower buds in tested crop was observed after application of 75%N + Azotobacter + PSB (T_8). The study reveals enhanced number of flowers per plant, maximum size of flowers and maximum flower weight in T8 as compared to other treatments, and the lowest was observed in control.

Key words: bio-fertilizer, floriculture, marigold, nutrient management, sodic soils

INTRODUCTION

Marigold (*Tagetes erecta* L.) is one of the most popular and commercial flowering annual plants, cultivated in different parts of the country at commercial level. It has great demand for garland, cut flowers and decorative purposes at various kinds of religious and social functions. Therefore, it is important to accelerate the productivity of this crop in reclaimed sodic soil conditions. Nutrients play an important role in growth and development of any crop. Continuous and indiscriminate use of chemical fertilizers alters the soil fertility, leading to soil pollution and ultimately poor crop yield. It is therefore, necessary to restrict their use. However, considering recent concept of integrated nutrient management system, which has currently a special significance in crop production to address the sustainability problem and is being practiced in several crops. Integration of biofertilizers and organic manures reduce the consumption of inorganic fertilizers and increase the quality and quantity of flowers. Efficacy of the inorganic fertilizers is increased when they are combined with organic manures. Application of farmyard manure (FYM) increased the population of micro-flora mainly Azotobacter[1] (Gupta *et al.*, 1999). The integrated nutrient management (INM) means the supply of nutrients to the plants from various sources. INM includes the intelligent and efficient use of inorganic, organic and biological resources so as to sustain optimum yield, improve or maintain the soil chemical and physical properties and provide crop nutrition packages, which are technically sound, economically viable, practically feasible and environmentally safe. The main aim of INM is to utilize all the sources of plant nutrients in a judicious and efficient manner. Keeping above benefiting points in view, an investigation was carried out on integrated nutrient management in African marigold (*Tagetes erecta* L.) in reclaimed sodic soil. The broad objective was to find out the effect of INM on quality production of African Marigold.

MATERIALS AND METHODS

The present investigation was carried out at Distant Research Centres (Geharu Campus) of CSIR-National Botanical Research Institute, Lucknow (Uttar Pradesh). To study the integrated nutrient management in African marigold under partially reclaimed soil, a field experiment was conducted during 2015-16. The experimental site is located between latitude $26^0$43'03"N and longitudes 80^0 50' 02"E at an altitude of 120 m above the mean sea level. The climate of this region is characterized by long and intensive hot summer low and irregular rainfall and long mild winter. The area receives an annual rainfall of 80 -100 cm, 70% of which is concentrated in the month of July-September. The initial properties of the soil were pH- 8.4, EC- 0.30 (mS/*cm*), organic carbon- 4.2g kg^{-1}, available N- 159 kg ha^{-1}, available P- 12.8 kg ha^{-1}, Available K- 180 kg ha^{-1}. The experiment comprising 14 treatment combinations *viz.*, T1- 100% N, T2- 100% N + *Azotobacter*, T3- 100% N + PSB, T4- 100% N + *Azotobacter* + PSB, T5- 75% N, T6- 75% N + *Azotobacter*, T7- 75% N + PSB, T8- 75% N + *Azotobacter* + PSB, T9- 50% N, T10- 50% N + *Azotobacter*, T11- 50% N + PSB, T12- 50% N + *Azotobacter* + PSB, T13- *Azotobacter* + PSB, T14- Control with 3 replication under randomized block design. The nitrogenous fertilizer was given through Urea and Urea was applied at the time of sowing and nitrogen applied in three splits i.e. 1/3 at the time of sowing, 1/3 at the time of tillering and rest 1/3 at the time of panicle initiation. Azotobacter @ 2 kg/ha was applied through seedlings root treatments for few minutes before transplanting while PSB @ 2 kg/ha was applied through soil treatment at the time of transplanting. The data recorded on various parameters of growth, flowering behaviour, yield attributes and flower yield were subjected to statistical analysis[2] (Panse and Sukhatme, 1989). Macronutrients from different leaf samples from each treatment were also analysed by various protocols[3] (Schuman, G. E, M. A. Stanley, and D. Knudsen, 1973). Seed treated by the bio-fertilizers as per treatment at the time of sowing. d seedlings were transplanted in ridges and furrows with a spacing of 50 cm x 20 cm between row to row and plant to plant respectively. Uniform cultural practices like irrigation, hoeing and weeding, plant protection measures were adopted the crop time. Effect of different nutrient management which involved in different treatment was tested and data on various vegetative and flowering parameters was recorded and statistically analyzed using standard method[4] (Panse and Sukhatme, 1967). Different soil properties like soil pH, electrical conductivity, organic carbon, vailable nitrogen, phosphorus, and potassium were measured in oven dry soil samples using standardized methods proposed by various scientific communities and organizations[5] (Kalra & Maynard 1991).

RESULTS AND DISCUSSION

Nutrient availability and bacterial population

The results regarding plant height as presented in Table 1 showed significant effect of organic and inorganic fertilizer application. The results indicated that varying doses of organic, inorganic and combinations of plant nutrients significantly influenced nutrient availability and bacterial population (Table 1). All the treatments showed significant response over control (T_1). Results indicated that significantly highest availability of nitrogen (405.80 kg ha^{-1}), P (22.44 kg ha^{-1}), and K (212.48 kg ha^{-1}) was observed in T_8 (75%N + Azotobacter + Phosphate Solobulizing Bacteria-PSB) while the lowest availability of nitrogen (220.14 kg ha^{-1}), P (15.84 kg ha^{-1}), and K (166.64 kg ha^{-1}) was observed in control. The bacterial population ($26.40*10^5$ to $64.16*10^5$ per gram of soil) was recorded in T_8 (75%N + Azotobacter + Phosphate Solobulizing Bacteria-PSB) while the lowest bacterial population was observed in control.

Growth, yield, and quality parameter

The observation related to days taken to first flower bud initiation, days taken to first flower bud opening, duration of flowering, number of flowers per plant,

Table 1
Changes in sodic soil properties after harvest of Marigold (Average ± SEM)

Properties	*pH*	*EC*	*OC*	*N*	*P*	*K*	*Bacteria*
Treatments							
T1	10.46	1.98	0.73±0.23	371.40	17.84	201.42	32.16
T2	9.95	0.99	0.33±0.11	401.62	18.20	207.42	40.16
T3	9.88	1.13	0.46±0.11	374.78	20.20	205.80	38.12
T4	9.64	0.87	0.42±0.11	404.82	21.42	210.42	52.14
T5	8.20	0.75	0.44±0.23	330.42	17.62	189.43	34.12
T6	8.20	0.57	0.33±0.11	344.16	17.92	193.80	44.16
T7	9.51	0.90	0.46±0.11	325.14	18.80	190.42	42.18
T8	10.30	1.92	0.27±0.11	350.80	19.44	196.84	54.16
T9	10.14	1.33	0.73±0.23	282.84	17.21	178.34	36.80
T10	10.87	1.00	0.33±0.11	294.36	17.50	183.48	50.12
T11	10.46	1.98	0.46±0.11	284.16	18.74	183.62	48.16
T12	9.95	0.99	0.27±0.11	300.16	19.20	186.42	58.46
T13	9.88	1.13	0.68±0.23	234.86	16.00	170.82	60.88
T14 (Control)	10.87	1.00	0.71±0.24	220.14	15.84	166.64	30.14

T1- 100% N, T2- 100% N + *Azotobacter*, T3- 100% N + PSB, T4- 100% N + *Azotobacter* + PSB, T5- 75% N, T6- 75% N + *Azotobacter*, T7- 75% N + PSB, T8- 75% N + *Azotobacter* + PSB, T9- 50% N, T10- 50% N + *Azotobacter*, T11- 50% N + PSB, T12- 50% N + *Azotobacter* + PSB, T13- *Azotobacter* + PSB, T14- Control size of flower, and weight of flower are presented in Table 2. The results showed that varying doses of organic, inorganic and their combinations of plant nutrients significantly influenced growth, yield, and quality of African marigold (Table 2). All the treatments showed significant response over control (T_1). Early flowering was noted under T_8 (75%N + Azotobacter + Phosphate Solobulizing Bacteria-PSB) as compared to other treatments. Application of 75%N + Azotobacter + PSB (T_8) provided early first flower bud initiation (35.26 day), less time for first flower bud opening (47.80 day) as compared to control. Significantly longer duration (74.13 day) of flowering was observed in T_8. Significantly maximum number of flowers per plant (53.66), size of flowers (7.80 cm) and weight of flowers (10.55 g per flower) were observed in T_8 (75%N + Azotobacter + Phosphate Solobulizing Bacteria-PSB), as compared to other treatments, while minimum number of flowers per plant (34.80), size of flowers (5.22 cm), and weight of flowers (8.35 g per flower) were observed in control. These findings corroborate with the reports by other researchers in marigold[5] (Yadav *et al.,* 2000) and calendula[6] (Shashidara and Gopinath, 2002). Similar observations have also been reported in marigold[6, 7, 8] (Kumar *et al.*, 2003 in aster, Gupta *et al.*, 1999, Chandrikapure *et al,* 1999 and Syamal *et al.*, 2006).

Changes in soil properties

Significant effect of different treatments and cultivation of marigold on sodic soil properties was observed. The highest decrease in soil pH and electrical conductivity was found in treatment of 75% N (T5) and treatment 75% N + *Azotobacter* (T6). This is likely due to applications of nitrogen which

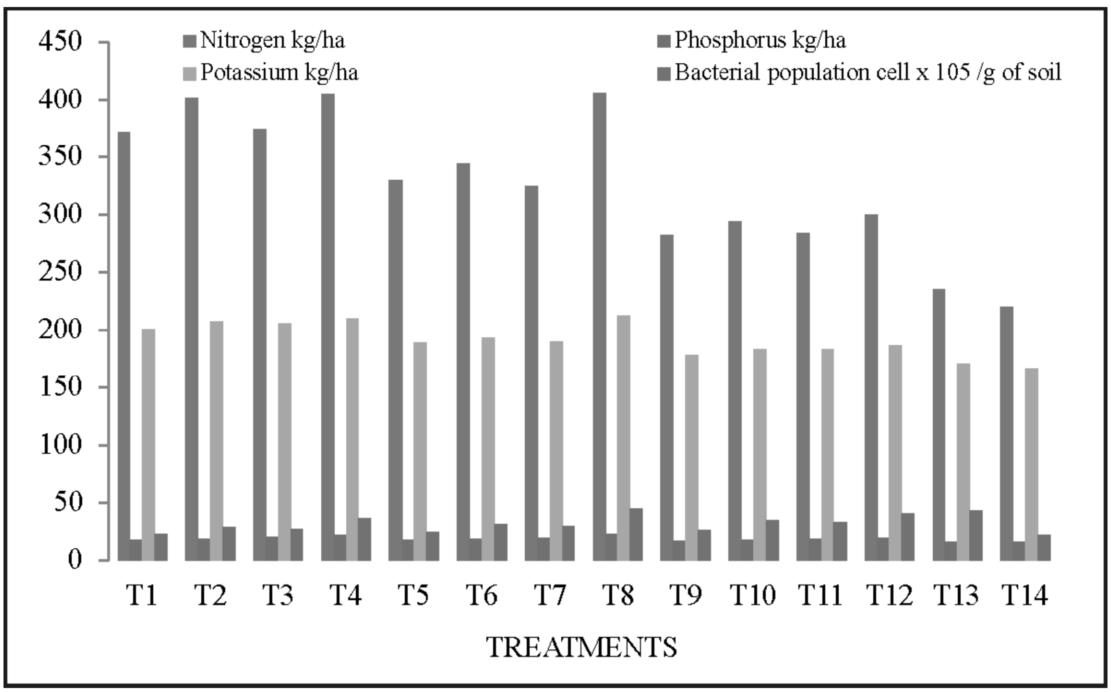
Table 2
Growth Parameter

Properties	*Plant height (cm)*	*Number of branches*	*Plant spread (cm)*	*Flower yield (q/ha)*	*Leaf macronutrient*		
					N	*P*	*K*
Treatments							
T1	10.46	1.98	44.85	371.40	2.11	0.53	2.28
T2	9.95	0.99	46.86	401.62	2.23	0.54	2.34
T3	9.88	1.13	48.20	374.78	2.15	0.58	2.30
T4	9.64	0.87	51.15	404.82	2.28	0.68	2.43
T5	8.20	0.75	45.25	330.42	1.92	0.36	2.14
T6	8.20	0.57	47.78	344.16	2.02	0.41	2.20
T7	9.51	0.90	18.81	325.14	1.96	0.46	2.16
T8	10.30	1.92	52.00	350.80	2.07	0.50	2.24
T9	10.14	1.33	42.35	282.84	1.76	0.20	2.00
T10	10.87	1.00	143.38	294.36	1.84	0.24	2.08
T11	10.46	1.98	43.92	284.16	1.80	0.29	2.04
T12	9.95	0.99	44.45	300.16	1.88	0.32	2.12
T13	9.88	1.13	41.80	234.86	1.72	0.18	1.96
T14 (Control)	10.87	1.00	40.44	220.14	1.69	0.16	1.92

T1- 100% N, T2- 100% N + *Azotobacter*, T3- 100% N + PSB, T4- 100% N + *Azotobacter* + PSB, T5- 75% N, T6- 75% N + *Azotobacter*, T7- 75% N + PSB, T8- 75% N + *Azotobacter* + PSB, T9- 50% N, T10- 50% N + *Azotobacter*, T11- 50% N + PSB, T12- 50% N + *Azotobacter* + PSB, T13- *Azotobacter* + PSB, T14- Control increase the level of bi-carbonates in soil and which in turn changes the direction and magnitude of soil pH[10] (Rietz and Haynes, 2003). The moderate decrease in these atributes were found in various treatments like 100% N + *Azotobacter* (T2), 100% N + PSB (T3), 100% N + *Azotobacter* + PSB (T4), 75% N + PSB (T7), 50% N + *Azotobacter* + PSB (T12), and *Azotobacter* + PSB (T13). Slight decrease or no change in soil organic carbon was observed in almost all treatments after cultivation of Marigold in sodic soil. Generally in short life crops, accumulation of soil organic matter is low and its decomposition process takes time and it might be the reason for no change in carbon content of the soil. On the other hand, a significant increase in available soil nitrogen, phosphorus, potassium and bacterial population was found. Application of nitrogen, *Azotobacter* and PSB had direct effect on increasing the availability of these nutrients. Change in microbial population is always very significant to any change in soil system because microbes and their activities are very sensitive to little environmental change[11] (Singh, 2016).

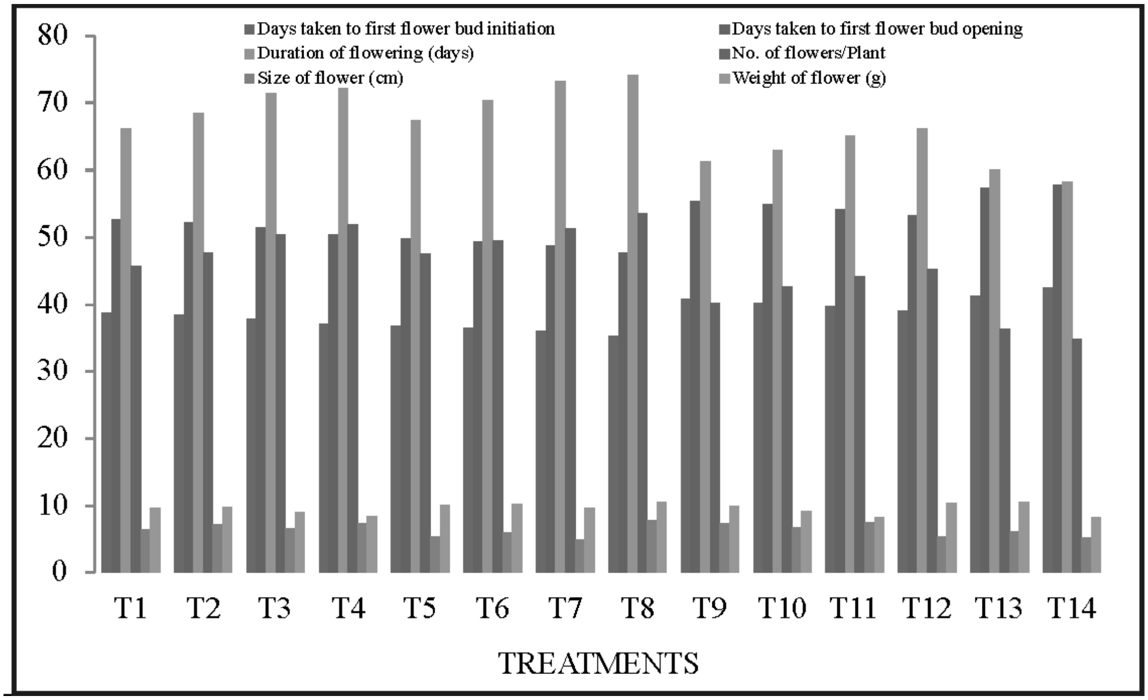
Leaf macronutrient

The results regarding leaf macronutrient as presented in Table 2 showed significant effect of organic and inorganic fertilizer application. The results indicated that varying doses of organic, inorganic and their



	Nitrogen	*Phosphorus*	*Potassium*	*Bacteria Population*
SE(D) ±	0.99	0.884	0.296	0.8715
CD at 5 %	2.036	1.817	0.609	1.792

Figure 1: Effect of integrated nutrient management on nutrient availability (N,P,K kg per ha) and total bacterial population (cell x 10^5 /g of soil) in African Marigold rhizosphere. T1- 100% N, T2- 100% N + *Azotobacter*, T3- 100% N + PSB, T4- 100% N + *Azotobacter* + PSB, T5- 75% N, T6- 75% N + *Azotobacter*, T7- 75% N + PSB, T8- 75% N + *Azotobacter* + PSB, T9- 50% N, T10- 50% N + *Azotobacter*, T11- 50% N + PSB, T12- 50% N + *Azotobacter* + PSB, T13- *Azotobacter* + PSB, T14- Control



	DFFBI	*DFFBO*	*Flowering time*	*No. of flowers/Plant*	*Size of flower (cm)*	*Weight of flower (g)*
SE(D) ±	0.63	0.891	0.888	3.17	0.5	0.35
CD at 5 %	1.3	1.832	1.627	3.54	0.44	0.36

Figure 2: Effect of integrated nutrient management on quality production of African Marigold. For treatments details please see figure 1 legend. DFFBI; days taken for first flower bud initiation, DFFBO; days taken for first flower bud opening.

combinations of plant nutrients significantly influenced nutrient availability. All the treatments showed significant response over control (T_4). Results indicated that significantly highest leaf macronutrient availability of N (2.28 kg ha^{-1}), P (0.68 kg ha^{-1}), and K (2.43 kg ha^{-1}) was observed in T_{13} (100%N + Azotobacter + PSB) while the lowest availability of nitrogen (1.72 kg ha^{-1}), P (0.8 kg ha^{-1}), and K (1.92 kg ha^{-1}) was observed in control[12] (Harborne 1998).

CONCLUSIONS

It is concluded from this experimentation that application of 75%N + Azotobacter + Phosphate Solobulizing Bacteria-PSB (T_8) provides early and quality flowering of African marigold with maximum no. of flower per plant (53.66), size of flower (7.80 cm), and weight of flower (10.55 g per flower). It is recommended for commercial cultivation of African marigold to get higher yield and return.

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