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Influence of various Nutrients and Biostimulant on Vegetative and Floral Attributes of African Marigold (*Tagetes erecta* L.) cv. Inca Yellow

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ABSTRACT: Supplementation of different essential nutrients along with biostimulant plays a crucial role in the proper growth and development of marigold ensuring improved flower quality. These inputs actively contribute to the overall well-being of the plant and act as catalysts, facilitating important organic processes within the plant. With this in mind, an experiment spanning two consecutive years, *viz*., 2018-19 and 2019-20, was conducted during the winter season at the Floriculture Research Field of the Dept. of Floriculture and Landscaping in the Biotechnology-cum-Tissue Culture Centre (BTCC) premises, College of Agriculture, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha. The focus of this study was to investigate the impact of applying various nutrients (0.4% $MgSO_4$, 0.4% $ZnSO_4$, and 0.2% Borax) and a biostimulant (0.2% Humic acid), either separately or in combination, on the growth and floral characteristics of African marigold cv. Inca Yellow. The research findings revealed that foliar application of 0.4% $MgSO_4$ resulted in the highest plant height (24.67 cm), basal stem diameter (6.79 mm) and plant spread (22.23 cm (E-W), 22.70 cm (N-S)) along with earliest first bud initiation (22.60 days) and first flowering (40.64 days). Moreover, maximum number of flowers per plant (25.57) was observed in plants treated with a combination of 0.2% Humic acid and 0.4% $MgSO_4$.

Keywords: Marigold, plant nutrition, humic acid, yield enhancement, crop quality.

INTRODUCTION

Marigold (*Tagetes* spp.), a member of the Asteraceae family, holds a distinguished position as one of the world's most popular and economically significant ornamental crops. In India, it is favoured among flower growers due to its remarkable adaptability to various agro-climatic conditions, extended blooming period, short growth duration, relatively extended shelf life, a diverse array of flower shapes and colours, and ease of cultivation. The genus *Tagetes* encompasses approximately 55 species (Hernandez and Ham 2007), among which the African marigold (*Tagetes erecta* L.) and French marigold (*Tagetes patula* L.) are the two most extensively cultivated species. India stands as one of the leading global producers of marigolds, with its widespread cultivation across different climatic regions. Among the African marigold varieties, the Inca series of hybrids holds a special place as a preferred choice among the marigold growers. These marigold plants are well-known for their compact growth and are highly sought after for their prolific production of large, double blooms. Marigold demonstrates a positive response towards nutrient supply. Apart from the major nutrients such as nitrogen, phosphorus, and potassium, other essential nutrients assume a vital role in promoting proper growth and development of marigold. These nutrients not only contribute to the plant's general well-being but also act as facilitators, catalyzing organic processes within the plant.

Magnesium plays several essential roles in plants, as it forms part of chlorophyll, chromosomes, and polyribosomes. Moreover, magnesium supports the synthesis of oils and fats, assists in the movement of starch, and facilitates various catalytic processes within plants. When used as a foliar treatment, magnesium sulfate has demonstrated its effectiveness in enhancing the nutrient status of crops encountering deficiencies. Studies have indicated that its application can raise chlorophyll levels and lead to increased vegetative yield (Kumar *et al.*, 2018). Zinc has a pivotal function in different biosynthesis processes occurring in plants. It serves as a co-factor for a multitude of enzymes and exerts an influence on diverse biological mechanisms, including photosynthesis, nucleic acid metabolism, and biosysnthesis of carbohydrates and proteins (Choudhary *et al.*, 2016). Furthermore, zinc has been observed to play a role in the production of tryptophan, a precursor to auxin. Consequently, a deficiency in zinc has been linked to a reduction in auxin levels within the plants (Balakrishnan *et al.*, 2007). Boron holds significant importance in various plant processes, impacting functions such as sugar translocation, membrane permeability, photosynthesis, cell elongation, division, and the synthesis of cell walls. It plays a vital role in nitrogen fixation, protein synthesis, amino acid metabolism, and nitrate metabolism. Furthermore, boron contributes to the maintenance of the structural integrity cell wall by forming bonds with pectic polysaccharides. Additionally, it directly influences critical reproductive stages, including fertilization, pollen germination, flower and seed development, and fruit abscission. This crucial element is primarily concentrated in the meristematic regions of plants, such as the tips of roots and shoots, emerging leaves, and buds (Kumar *et al.*, 2018). Humic Acid (HA), an important constituent of organic humus, assumes a vital role in both plant development and soil enhancement (Benedetti *et al.*, 1996). Physically, it improves the soil water retention and supports the maintenance of a healthy soil structure. Biologically, it promotes the proliferation of beneficial soil organisms, while chemically, it acts as a complex that adsorbs and retains inorganic plant nutrients (Brannon and Sommers 1985). Humic acid, a polymeric organic compound occurring naturally, has diverse functions in the natural world (Schnitzer and Khan 1972; Sposito, 1989). It is generated through the microbial decomposition of organic matter and can be found in soils, oceans, rivers, peat, and lignite coals (Lawson and Stewart 1989). The capacity of humic acid to form complexes facilitates the transformation of various elements into forms that are accessible to plants (Vaughan and Donald 1976). This, in turn, stimulates growth, enhances nutrient availability, boosts soil fertility, and increases yield. However, not much of studies have been carried out till date to examine the influence of nutrients like Mg, Zn, and B, and biostimulant like Humic acid on Inca cultivars. The investigation was carried out to shed some light on the above-mentioned aspect.

MATERIALS AND METHODS

The study was conducted on the African marigold cv. Inca Yellow at the Floriculture Research Field of the Dept. of Floriculture and Landscaping in the Biotechnology-cum-Tissue Culture Centre (BTCC) premises, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. A total of 11 different treatments were employed in the experiment, with one of these treatments serving as a control where no nutrients were applied. The nutrients and biostimulant were administered through foliar application. The treatments, each identified by a specific code, were as follows: T_1 (Control), T_2 (0.2% Humic acid), T_3 (0.4% $MgSO_4$), T_4 (0.5% $ZnSO_4$), T_5 (0.2% Borax), T_6 (0.2% Humic acid + 0.4% $MgSO_4$), T_7 (0.2% Humic acid + 0.5% $ZnSO_4$), T_8 (0.2% Humic acid + 0.2% Borax), T_9 (0.2% Humic acid + 0.4% $MgSO_4$ + 0.5% $ZnSO_4$), T_{10} (0.2% Humic acid + 0.4% $MgSO_4$ + 0.2% Borax), and T_{11} (0.2% Humic acid + 0.4% $MgSO_4$ + 0.5% $ZnSO_4$ + 0.2% Borax). One week after transplanting, the plants were sprayed with the solutions using a hand sprayer. This spraying procedure was carried out during the early morning and late afternoon hours on non-windy days to optimize the absorption of the solutions by the plants.

Seven plant parameters were observed and data was recorded. These traits were inclusive of both vegetative growth and floral development. The traits under investigation were plant height (cm), basal stem diameter (cm), plant spread (east-west) (cm), plant spread (north-south) (cm), days to first bud initiation, days to first flowering, and number of flowers per plant. The observations were recorded on selected plants and flowers following the standard procedure. Subsequently, the collected data was subjected to statistical analyses using analysis of variance (ANOVA), and the means were compared using the Duncan Multiple Range Test (DMRT) based on the method described by Wahua (1999). The statistical analyses were carried out using the R programming software.

RESULTS AND DISCUSSION

The effect of nutrients and a biostimulant on different vegetative and floral parameters is presented in Table 1 & Table 2. The foliar application of T_3 demonstrated highest plant height of 24.85 cm, 24.48 cm, and 24.67 cm in 1st year, 2nd year, and pooled data, respectively. The data was at par with the outcomes obtained from the application of T_5, T_6, T_7, T_8, T_9, T_{10}, and T_{11} in 1st year, and in 2nd year, with the applications of T_5, T_6, T_7, T_8, T_{10} and T_{11}. Furthermore, for the pooled data of both the years, the influence of T_5, T_8, and T_{11} on plant height was at par with the best treatment. However, lowest plant height of 20.67 cm, 20.03 cm, and 20.35 cm for 1styear, 2nd year, and pooled mean, respectively was recorded in T_1. The foliar application of $MgSO_4$ exhibited an improved effect on the plant height in African marigold cv. Inca Yellow for both the years. $MgSO_4$ plays an essential role in plant respiration and enzyme system activation. It also confirms yield improvement and enhanced crop quality. The findings are in accordance with Biradar *et al.* (2017) in chrysanthemum and Shyala *et al.* (2019) in African marigold.

The basal stem diameter was found to be maximum with the values of 6.84 mm (1st year), 6.73 mm (2nd year), and 6.79 mm (pooled data) with the spray of T_3. The figures were at par with the treatmentsT_2, and T_5 in the 1st year, and with the treatments T_2, T_5, T_{10}, and T_{11} in the 2nd year. However, the treatment T_2 remained at par with the best treatment for the pooled data of both the years. The least basal stem diameter for 1st year (5.58 mm), 2nd year (5.61 mm), and pooled mean of both years (5.71 mm) were recorded in control. The improvement in basal stem diameter with the application of $MgSO_4$ may be due to the role of magnesium in the energy metabolism as it is a co-factor of many enzymes acting on phosphorylated substrates (Hopkins, 1995). The results are similar to the findings of Kumar *et al.* (2018); Shyala *et al.* (2019) in African marigold.

The plant spread (E-W) was found to be highest (22.73 cm, 22.07 cm, 22.23 cm in 1st year, 2nd year, and pooled data, respectively) with the application of T_3. The figures stood at par with the treatments T_4, T_5, T_6, T_7, T_8, and T_9 in the 1st year, and in the 2nd year with all other treatments except T_{11} and T_1. However, for the pooled data of both the years, the treatments T_4, T_6, T_7, T_8, and T_9 remained at par with T_3. The plant spread (N-S) was also found to be best in the treatmentT_3 with the values 22.73 cm, 22.67 cm, and 22.70 cm in 1st year, 2nd year, and pooled data, respectively. The data was at par with all the treatments except T_{10} and T_1. But, for the pooled data of both the years, the treatments T_6, T_7, and T_4 remained at par with T_3. The lowest values for plant spread both E-W and N-S was recorded in control. The application of $MgSO_4$ enhances the total nutritional status of the crop. As it is a constituent of chlorophyll, it increases the chlorophyll content and vegetative yield. The results are in accordance with the findings of Biradar *et al.* (2017) in chrysanthemum and Kumar *et al.* (2018) in African marigold.

Foliar application of T_3 revealed the earliest first bud initiation for 1st year (22.67 days), 2nd year (22.53 days), and pooled data (22.60 days). The data was at par with all other treatments in both 1st year and 2nd year. However, for the pooled data of both the years, the treatments T_2, T_5, T_6, T_9, T_{10}, and T_{11} were at par with the best treatment. Enhanced days to first bud initiation with the application of $MgSO_4$ may be due to magnesium having a key role in the energy metabolism as it is a cofactor of many enzymes acting on phosphorylated substrates (Hopkins, 1995). The results were found to be similar with the studies of Kumar *et al.* (2018); Shyala *et al.* (2019) in African marigold.

Earliest days to first flowering was observed with the foliar application of T_3 exhibiting values of 40.54 days (1st year), 40.73 days (2nd year), and 40.64 days (pooled data) which was at par with the treatments T_9, T_7, T_2, T_6, and T_{11} in both 1st year and 2nd year. However, for the pooled data of both the years, the treatments T_9, T_7, and T_2 remained at par with T_3. On the other hand, most delayed days to first flowering was recorded in the plants of T_1. $MgSO_4$ enhanced the days to first flowering as it plays a crucial role in plant respiration and enzyme system activation. It also increases the yield with improved crop quality. The findings are in line with the studies of Biradar *et al.* (2017) in chrysanthemum, and Shyala *et al.* (2019) in African marigold.

The number of flowers per plant was maximum (25.60, 25.60, 25.57 for 1st year, 2nd year, and pooled data, respectively) with the spray of T_6 which was at par with all the treatments except T_{10}, and T_1 for 1st year, and 2nd year. However, for the pooled data of both the years, all the treatments except T_{10}, T_4 and T_1 stood at par with the best treatment. Humic acid influences over critical processes like cell membrane permeability, uptake of oxygen and phosphorus, respiration, photosynthesis, and the growth of root cells (Cacco and Agnolla 1984; Russo and Berlyn 1991).

Table 1: Effect of nutrients and biostimulant on different vegetative parameters of African marigold cv. Inca Yellow.

Characters / Treatments	Plant height (cm)			Basal stem diameter (mm)			Plant spread (E-W) (cm)			Plant spread (N-S) (cm)		
	1st year (2018-19)	2nd year (2019-20)	Pooled	1st year (2018-19)	2nd year (2019-20)	Pooled	1st year (2018-19)	2nd year (2019-20)	Pooled	1st year (2018-19)	2nd year (2019-20)	Pooled
T_1	20.67 ^{c}	20.03 ^{e}	20.35 ^{f}	4.88 ^{d}	4.53 ^{d}	4.70 ^{g}	19.73 ^{c}	20.00 ^{b}	19.97 ^{c}	20.60 ^{c}	20.53 ^{b}	20.57 ^{e}
T_2	22.23 ^{bc}	22.09 ^{cd}	22.16 ^{de}	6.51 ^{ab}	6.61 ^{ab}	6.56 ^{ab}	20.27 ^{bc}	20.47 ^{ab}	20.13 ^{c}	21.07 ^{abc}	21.20 ^{ab}	21.13 ^{de}
T_3	24.85 ^{a}	24.48 ^{a}	24.67 ^{a}	6.84 ^{a}	6.73 ^{a}	6.79 ^{a}	22.73 ^{a}	22.07 ^{a}	22.23 ^{a}	22.73 ^{a}	22.67 ^{a}	22.70 ^{a}
T_4	22.50 ^{bc}	21.21 ^{de}	21.85 ^{e}	5.16 ^{cd}	4.89 ^{cd}	5.02 ^{fg}	21.80 ^{ab}	21.47 ^{ab}	21.63 ^{ab}	22.20 ^{abc}	22.00 ^{ab}	22.10 ^{abcd}
T_5	23.38 ^{ab}	23.55 ^{abc}	23.46 ^{abcd}	6.30 ^{ab}	5.96 ^{abc}	6.13 ^{bc}	21.00 ^{abc}	20.60 ^{ab}	20.80 ^{bc}	21.73 ^{abc}	21.40 ^{ab}	21.57 ^{bcde}
T_6	23.34 ^{ab}	23.17 ^{abc}	23.26 ^{bcd}	5.08 ^{cd}	5.47 ^{cd}	5.28 ^{defg}	22.40 ^{a}	21.47 ^{ab}	22.10 ^{a}	22.63 ^{a}	22.60 ^{a}	22.67 ^{ab}
T_7	23.18 ^{ab}	23.22 ^{abc}	23.20 ^{bcd}	5.74 ^{bcd}	5.55 ^{bcd}	5.65 ^{cdef}	21.53 ^{ab}	21.33 ^{ab}	21.43 ^{ab}	22.40 ^{ab}	22.27 ^{a}	22.33 ^{abc}
T_8	23.89 ^{ab}	23.93 ^{ab}	23.91 ^{abc}	5.27 ^{cd}	5.05 ^{cd}	5.16 ^{efg}	21.53 ^{ab}	21.20 ^{ab}	21.37 ^{ab}	21.67 ^{abc}	21.47 ^{ab}	21.57 ^{bcde}
T_9	22.93 ^{ab}	22.73 ^{bcd}	22.83 ^{cde}	5.05 ^{d}	4.93 ^{cd}	4.99 ^{fg}	21.67 ^{ab}	21.53 ^{ab}	21.60 ^{ab}	21.47 ^{abc}	21.27 ^{ab}	21.37 ^{cde}
T_{10}	23.44 ^{ab}	22.90 ^{abc}	23.17 ^{bcd}	5.94 ^{bc}	5.79 ^{abc}	5.86 ^{cd}	20.40 ^{bc}	20.20 ^{ab}	20.43 ^{bc}	20.67 ^{bc}	20.73 ^{b}	20.70 ^{e}
T_{11}	24.34 ^{ab}	24.17 ^{ab}	24.25 ^{ab}	5.65 ^{bcd}	5.89 ^{abc}	5.77 ^{cde}	20.20 ^{bc}	20.07 ^{b}	20.13 ^{c}	21.27 ^{abc}	21.20 ^{ab}	21.23 ^{cde}

N.B. Means with the same letters are not significantly different

Table 2: Effect of nutrients and biostimulant on different floral parameters of African marigold cv. Inca Yellow.

Characters / Treatments	Days to first bud initiation (days)			Days to first flowering (days)			Number of flowers per plant		
	1st year (2018-19)	2nd year (2019-20)	Pooled	1st year (2018-19)	2nd year (2019-20)	Pooled	1st year (2018-19)	2nd year (2019-20)	Pooled
T_1	25.13 ^{a}	24.87 ^{a}	25.00 ^{a}	44.50 ^{a}	44.47 ^{a}	44.48 ^{a}	17.87 ^{c}	19.27 ^{c}	18.57 ^{d}
T_2	24.00 ^{a}	23.73 ^{a}	23.80 ^{abcd}	41.58 ^{bcd}	41.80 ^{bcde}	41.69 ^{def}	22.93 ^{ab}	23.27 ^{abc}	23.10 ^{abc}
T_3	22.67 ^{a}	22.53 ^{a}	22.60 ^{d}	40.54 ^{d}	40.73 ^{e}	40.64 ^{f}	25.53 ^{a}	25.40 ^{ab}	25.50 ^{a}
T_4	24.53 ^{a}	24.33 ^{a}	24.43 ^{abc}	43.88 ^{ab}	43.87 ^{ab}	43.87 ^{ab}	21.60 ^{abc}	21.80 ^{abc}	21.70 ^{bc}
T_5	24.00 ^{a}	23.73 ^{a}	23.87 ^{abcd}	43.33 ^{abc}	43.40 ^{abc}	43.37 ^{abc}	25.20 ^{a}	25.20 ^{ab}	25.20 ^{a}
T_6	23.73 ^{a}	23.53 ^{a}	23.63 ^{abcd}	42.26 ^{abcd}	42.13 ^{bcde}	42.20 ^{cde}	25.60 ^{a}	25.60 ^{a}	25.57 ^{a}
T_7	25.00 ^{a}	24.67 ^{a}	24.83 ^{ab}	41.27 ^{cd}	41.13 ^{de}	41.20 ^{ef}	25.13 ^{a}	25.07 ^{ab}	25.10 ^{a}
T_8	22.67 ^{a}	23.40 ^{a}	23.05 ^{cd}	43.84 ^{ab}	43.73 ^{ab}	43.79 ^{ab}	24.20 ^{ab}	24.47 ^{ab}	24.33 ^{ab}
T_9	23.13 ^{a}	23.07 ^{a}	23.10 ^{bcd}	40.95 ^{cd}	41.27 ^{cde}	41.11 ^{ef}	22.47 ^{abc}	22.67 ^{abc}	22.57 ^{abc}
T_{10}	23.40 ^{a}	23.47 ^{a}	23.40 ^{abcd}	43.15 ^{abc}	43.13 ^{abcd}	43.14 ^{abcde}	19.73 ^{bc}	20.67 ^{bc}	20.20 ^{cd}
T_{11}	23.53 ^{a}	23.47 ^{a}	23.50 ^{abcd}	42.62 ^{abcd}	42.40 ^{abcde}	42.51 ^{bcde}	20.67 ^{abc}	24.40 ^{ab}	22.53 ^{abc}

N.B. Means with the same letters are not significantly different

Additionally, it encourages the growth of lateral roots and aids in the uptake of specific ions. Furthermore, humic acid serves as a source of carbon for nitrogen-fixing bacteria, contributing to its essential role in biological processes (Grzyb *et al.*, 2021; Tang *et al.*, 2021). It has been proven to play a vital role in various vegetative and reproductive characters (Ampong *et al.*, 2022). The combined application of humic acid and $MgSO_4$ boosted the flower yield. The findings are in accordance with the results of Das *et al.* (2020) in *Tagetes erecta*, Kumar *et al.* (2021) in tuberose, and Rajput *et al.* (2003) in *Tagetes minuta*.

CONCLUSION AND FUTURE SCOPE

Based on the findings of this study, it can be inferred that the most effective treatment for Inca Yellow cultivar was the foliar application of0.4% magnesium sulphate alone as well as in combination with 0.2% Humic acid. The use of various nutrients and biostimulant in plants reduces the reliance on chemical fertilizers, thereby enhancing soil health and promoting robust crop growth. This combination of nutrients and biostimulant can be recommended to the flower growers engaged in both loose flower production and the potted plant industry.

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Conflict of Interest. None.

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