International Journal of Research in Agronomy 2024; 7(8): 246-252

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(8): 246-252
Received: 05-06-2024
Accepted: 11-07-2024

Aparna Dhulipalla
Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh, India

V Vijaya Bhaskar
College of Horticulture, Dr. Y.S.R. Horticultural University, Chinalatarapi, Kandukuru, SPSR Nellore district, Andhra Pradesh, India

AVD Dorajeerao
College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh, India

P Subbaramamma
College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh, India

K Uma Krishna
College of Horticulture, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh, India

Corresponding Author:
Aparna Dhulipalla
Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh, India

Effect of spacing, source of nitrogen fertilizer and sodium nitro Prusside on growth and yield of African marigold (*Tagetes erecta* L.) during summer in Andhra Pradesh

Aparna Dhulipalla, V Vijaya Bhaskar, AVD Dorajeerao, P Subbaramamma and K Uma Krishna

DOI: https://doi.org/10.33545/2618060X.2024.v7.i8d.1225

Abstract
An experiment was conducted to find out the impact of spacing, sodium nitroprusside spray and sources of nitrogenous fertilizers on growth and yield of African marigold cv. Bidhan Marigold -2 in summer during 2017 - 2019 at Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem. Results revealed that plants grown at wider spacing (60 x 30 cm) with application of 581 kg ha^{-1} nitrate form of nitrogen (calcium nitrate) and two sprays of 200 µM sodium nitroprusside recorded maximum values for all the vegetative and yield parameters except for plant height, internodal length, days taken for first flower bud appearance, days for 50% flowering and flower yield ha^{-1}. Closer spacing (45 x 30 cm) with application of nitrate form of nitrogen (calcium nitrate) and two sprays of 200 µM SNP recorded maximum flower yield ha^{-1} (224.23 q) due to accommodation of more number of plants per unit area.

Keywords: Calcium nitrate, marigold summer cultivation, ammonium sulphate, sodium nitro-prusside, spacing, urea

Introduction
African marigold (*Tagetes erecta* L.) is one among the predominant loose and cut flowers grown in Andhra Pradesh. Marigold belongs to the family Asteraceae and is native of Mexico. The name marigold is derived from "Mary's Gold", as earlier Christians placed flowers instead of coins on Mary's altar as an offering. Vast quantities of marigold flowers are used in making garlands for various social, cultural and religious functions, decorations during weddings and in festivals. Among the commercial loose flowers cultivated in Andhra Pradesh, the area under marigold cultivation is 5,971 ha with a total production of 61,356 MT of loose flowers (DOH, 2017) [1]. It is one of the most suitable flower crops next to jasmine in summer season. Global warming is a major constraint for better performance of any crop under the present situations causing abiotic stress which is one of the primary reasons for crop loss or causing a reduction in yield of crops up to or more than 50% in average yield of crops. The productivity and quality of any crop under abiotic stress can be improved by adopting several approaches like use of plant growth regulators / chemicals and by adopting certain special horticultural practices like modifying plant micro climate. The yield of marigold is influenced by the abiotic stress to a large extent. To overcome this and to make summer cultivation of marigold profitable the present study was taken up with different spacing's to modify the plant micro climate and different nitrogen fertilizers, different concentrations of sodium nitro prusside to induce abiotic stress tolerance.

Materials and Methods
The experiment was carried out at the Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari district of Andhra Pradesh during the period from 2017 - 18 to 2018-19.

The location falls under 'Agro-climatic Zone-10 of East Coastal Plains and Hills' (Krishna-Godavari Zone) that experiences hot and humid summer with mild winter receiving an average annual rainfall of 900 mm. One month old rooted cuttings of African marigold cv. 'Bidhan Marigold -2' were used in the present investigation. African marigold cv. 'Bidhan Marigold -2' is a selection of cultivar 'Siracole'.

The experiment was laid out in a Randomized Block Design (RBD) with factorial concept and replicated twice with a plot size of 3.0 m x 3.2 m. The 27 treatment combinations consist of three spacing's, three concentrations of sodium nitro prusside and fertilizers of three nitrogen sources. Treatments include T_1 - 45 cm x 30 cm + 0 µM SNP (Water spray) + Urea, T_2 - 45 cm x 30 cm + 0 µM SNP (Water spray) + Calcium nitrate, T_3 - 45 cm x 30 cm + 0 µM SNP (Water spray) + Ammonium sulphate, T_4 - 45 cm x 30 cm + 100 µM SNP + Urea, T_5 - 45 cm x 30 cm + 100 µM SNP + Calcium nitrate, T_6 - 45 cm x 30 cm + 100 µM SNP + Ammonium sulphate, T_7 - 45 cm x 30 cm + 200 µM SNP + Urea, T_8 - 45 cm x 30 cm + 200 µM SNP + Calcium nitrate, T_9 - 45 cm x 30 cm + 200 µM SNP + Ammonium sulphate, T_{10} - 45 cm x 40 cm + 0 µM SNP (Water spray) + Urea, T_{11} - 45 cm x 40 cm + 0 µM SNP (Water spray) + Calcium nitrate, T_{12} - 45 cm x 40 cm + 0 µM SNP (Water spray) + Ammonium sulphate, T_{13} - 45 cm x 40 cm + 100 µM SNP + Urea, T_{14} - 45 cm x 40 cm + 100 µM SNP + Calcium nitrate, T_{15} - 45 cm x 40 cm + 100 µM SNP + Ammonium sulphate, T_{16} - 45 cm x 40 cm + 200 µM SNP + Urea, T_{17} - 45 cm x 40 cm + 200 µM SNP + Calcium nitrate, T_{18} - 45 cm x 40 cm + 200 µM SNP + Ammonium sulphate, T_{19} - 60 cm x 30 cm + 0 µM SNP (Water spray) + Urea, T_{20} - 60 cm x 30 cm + 0 µM SNP (Water spray) + Calcium nitrate, T_{21} - 60 cm x 30 cm + 0 µM SNP (Water spray) + Ammonium sulphate, T_{22} - $S_3N_2F_1$:60 cm x 30 cm + 100 µM SNP + Urea, T_{23} - 60 cm x 30 cm + 100 µM SNP + Calcium nitrate, T_{24} - 60 cm x 30 cm + 100 µM SNP + Ammonium sulphate, T_{25} -60 cm x 30 cm + 200 µM SNP + Urea, T_{26} - 60 cm x 30 cm + 200 µM SNP + Calcium nitrate and T_{27} - 60 cm x 30 cm + 200 µM SNP + Ammonium sulphate.

Fresh solutions of SNP concentrations 100 µM and 200 µM were prepared by dissolving 0.1 mg and 0.2 mg of SNP in water by using 1000 ml volumetric flask freshly just before spraying. Sodium nitroprusside solution of desired concentration was sprayed at 20 and 40 days after transplanting (DAT) as per the treatment during the morning hours using manual sprayer. Soil application of different nitrogenous fertilizer *viz.*, urea @ 193 kg ha^{-1}, calcium nitrate @ 581 kg ha^{-1} and ammonium sulphate @ 425 kg ha^{-1} was done in several split doses at an interval of 15 days throughout the crop growth period. Recommended dose of fertilizer *i.e.*, 90-90-75 kg ha^{-1} of NPK was applied. Entire dose of phosphorus was applied in the form of single super phosphate as a basal dose just before planting. Potassium was applied in the form of MOP in five splits at an interval of 15 days along with nitrogen. Observations on vegetative growth, flowering and yield parameters were recorded at 150 DAT for ten plants randomly tagged with a label in each treatment and replication. The data recorded was tabulated and subjected to statistical analysis as per the procedure explained by (Gomez and Gomez, 1984) [2] and the statistical significance was tested as per F-test at 5% level of probability. The differences among treatment means were tested by using the critical difference (CD) at the same level of probability.

Results and Discussion

Interaction effect of spacing, SNP and source of nitrogen fertilizer on vegetative parameters of African marigold Bidhan Marigold – 2: The data presented in Table 1 revealed that the highest plant height of 98.18 cm was recorded with 200 µM sodium nitro prusside (SNP) spray and calcium nitrate ($Ca(NO_3)_2$) as nitrogen source at closer spacing of 45 x 30 cm (T_8) which was followed by 100 µM SNP and $Ca(NO_3)_2$ at the same spacing (94.30 cm) (T_5). The increased plant height among the various interaction effects might be attributed to the combined positive effects of the SNP and $Ca(NO_3)_2$ compared to rest of the treatments under closer spacing like less light penetration into the canopy and low light availability which might have resulted in an increase in internodal length by etiolating effect, since the auxin synthesized is subjected to less photo oxidation and destruction resulting in taller plants production under closing spacing along with suppression of auxin degradation by SNP through inhibition of Indole acetic acid (IAA) degrading enzyme (IAA oxidase) and also regulating auxin-mediated processes during plant growth (Simontacchi *et al.*, 2013) [3] and playing significant role in the regulation of auxin-induced plant growth.

Rest of the vegetative characters like highest number of primary branches (15.72), secondary branches (50.77), maximum plant spread in East – West (31.88 cm) and North – South (61.20 cm) directions, highest leaf area (56.30 dm^2), stem diameter (1.48 cm), specific leaf weight (17.76 mg cm^{-2}), maximum total fresh biomass (2659.50 g), total dry matter (502.34 g) and minimum internodal length (30.40 cm) was recorded with 200 µM SNP and $Ca(NO_3)_2$ as nitrogen source at wider spacing of 60 x 30 cm (T_{26}). Closer spacing of 45 x 30 cm with water spray (0 µM SNP) and urea as nitrogen source (T_1) recorded lowest values in terms of primary branches (7.97), secondary branches (30.31), maximum plant spread in East – West (19.90 cm) and North – South (22.16 cm) directions, highest leaf area (36.78 dm^2), stem diameter (0.59 cm) specific leaf weight (6.27 mg cm^{-2}), maximum internodal length (77.75 cm), total fresh biomass (687.25 g) and total dry matter (129.85 g).

The highest number of primary branches may be due to greater availability of plant nutrients, water and better sunlight exposure under wider spacing coupled with the combined beneficial effects of SNP and $Ca(NO_3)_2$ in terms of improved growth might have been better utilized by plants at wider spacing due to less competition from neighboring plants unlike in case of narrow spacing where the decrease in number of primary branches per plant is attributed to the competitive growth correlation from vertical growth (Rajanna, 2001) [4]. More number of primary branches production ultimately produced more number of secondary branches. The impact of spacing followed by SNP concentration was more on production of lateral branches compared to nitrogen source. The production of more number of primary branches at wider spacing and heat alleviation through nitric oxide (NO) released from SNP by increasing the rate of photosynthesis and photosynthates production also increased the secondary branches. SNP significantly reduced the high temperature induced lipid peroxidation, H_2O_2 content and increased the chlorophyll content, ascorbate (AsA), glutathione (GSH) and GSH/ glutathione disulfide (GSSG) ratio thus increasing the photosynthesis and protecting the plants from heat stress. Supplementation with SNP also up-regulated the activities of ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione reductase (GR), glutathione-S-transferase (GST), catalase (CAT) and glyoxalase I (Gly I) and also through up-regulating antioxidant defence and glyoxalase system protect the plants from high temperature induced oxidative stress. (Mirza *et al*, 2012) [5]. From the results it is obvious that among the interaction effects, the impact of spacing was more than the impact of SNP and $Ca(NO_3)_2$ in production of lateral branches which had indirect influence on internodal length even though favourable conditions were created by SNP and $Ca(NO_3)_2$ through production of more number of lateral branches.

At wider spacing with the combined positive effects of the SNP and $Ca(NO_3)_2$ the plant spread increased in both E-W and N-S directions and that might be due to improved photosynthesis by decreased chlorophyll damage with SNP spray which also counteracts oxidative damage by decreasing the generation of reactive oxygen species (ROS) and increases the nutrient uptake whereas calcium dependent protein kinases (CDPKs), mitogen-activated protein kinases (MAPK/MPKs) and NO are the signaling molecules involved in activation of stress responsive genes which together with transcriptional factors activate stress responsive genes in plants. (Ahmad *et al.*, 2012) [6]. This also resulted in increased leaf number and leaf area. The relative growth rate and net assimilation rate of $Ca(NO_3)_2$ applied plants is high from the beginning resulting in improved vegetative parameters like lateral spread, more number of branches and leaves which leads to increased leaf area at particular spacing. The minimum leaf area of 36.78 dm^2 recorded at closer spacing of 45 x 30 cm with 0 µM SNP spray and urea is due to more competition between plants for nutrients and sun light resulting in poor root spread coupled with less readily available form of nitrogen in the form of urea and no heat alleviation mechanism by SNP.

The increased thickness of stem could be ascribed to a better availability of nutrients per unit area due to sufficient space resulting in less competition among the plants. Liu and Shono (1999) [7] and Lee *et al.* (2000) [8] found that the activity of heat shock protein (HSP)26 gene was increased with application of SNP thereby increasing heat stress resistance. HSP26 gene was reported to have an important role in protecting the chloroplast against damage caused by oxidative stress as well as by heat stress. This results in normal photosynthetic activity and growth of the plant even under heat stress also which might be the reason for the maximum stem diameter. The increase in stem diameter with $Ca(NO_3)_2$ might be due to a larger transverse stem area, which has been associated to more vascular bundles and greater hydraulic conducting capacity. A larger hydraulic conductance implies a higher transport of water, which in turn facilitates translocation of nutrients from the roots to other plant parts, increasing nutrient use efficiency through nitrate form during stress conditions. Higher transport of water and nutrients through stems may affect the growth of flowers and leaf expansion. Similar result was obtained by Seyedi *et al.* (2013) [9] in Asiatic lilium.

Maximum specific leaf weight at wider spacing, high SNP dose and $Ca(NO_3)_2$ might be attributed to production of more number of leaves and dry matter at wider spacing, growth enhancing effect of SNP which releases NO required for cell elongation, cell division, and tissue differentiation (Fernández-Marcos *et al.*, 2012) [10] during high temperature stress resulting in increased production of leaf area and total dry matter that ultimately influences the specific leaf weight and readily available form of nitrogen through $Ca(NO_3)_2$.

These results indicate the superiority of the synergistic effect of $Ca(NO_3)_2$ and SNP over ammonium sulphate ($(NH_4)_2SO_4$) and SNP in increasing the leaf area and dry matter during high temperature.

The highest fresh weight and total dry matter of plants with wider spacing might be due to higher plant spread, more number of primary and secondary branches, leaf area and increased girth of the stem. Increased total fresh biomass plant^{-1} with increase in dose of SNP sprayed might be attributed to the fact that exogenous application of NO mitigated decrease in plant growth caused by heat through increasing antioxidant enzymes (super oxide dismutase (SOD), CAT, peroxidase (POX) which alleviates oxidative damage. It also accelerates proline accumulation, enhances photosynthesis and interacts with abscisic acid (ABA) to induce stomatal closure. NO also modify phytohormone signalling pathways thereby increasing the nutrient uptake and effective allocation of photoassimilates resulting in more growth and fresh weight of the plant. Exogenous NO might have enhanced the content of leaf chlorophyll to increase photosynthesis during senescence, in turn delayed plant senescence and improved growth during heat stress. $Ca(NO_3)_2$ supplies nitrogen in nitrate form which is easily absorbed and utilized for growth by plants compared to ammonical and amide forms of nitrogen supplied by $(NH_4)_2SO_4$ and urea respectively. Another reason might be that nitrate form is more efficient in utilising the excessive light available during heat stress compared to other forms for photosynthesis resulting in production of more growth in terms of lateral branches and leaf area which gives the maximum fresh weight of plant during heat stress. Calcium also plays a vital role in regulating a number of physiological processes in plants at tissue, cellular and molecular levels that influence both growth and responses to environmental stresses (Waraich *et al.*, 2011) [11] resulting in formation of more number of branches, leaves, increased girth of stem and more total fresh biomass plant^{-1}.

Interaction effect of spacing, SNP and source of nitrogen fertilizer on floral parameters of African marigold cv. Bidhan Marigold - 2

The data pertaining to interaction effect between spacing, SNP concentration and nitrogen source on floral parameters was depicted in Table 2. Plants sprayed with 200 µM SNP and $Ca(NO_3)_2$ at wider spacing of 60 x 30 cm (T_{26}) recorded maximum number of days for first flowering (48.85 days), maximum number of days for 50% flowering (64.28 days) and maximum flowering duration (92.30 days) whereas the minimum number of days for first flowering (35.15 days), 50% flowering (45.53 days) and flowering duration (61.88 days) was recorded in 0 µM SNP and urea as nitrogen source at closer spacing of 45 x 30 cm (T_1). Significant variation in number of days for first flowering, 50% flowering and flowering duration depending on the spacing might be due to the fact that, widely spaced plants remained in vegetative phase on account of lesser competition from the adjacent plants for space and light, thus delaying flowering. It may also be due to the reason that, closer spacing induced early flowering due to physiological maturity of shoots. In contrast, wider spacing recorded delayed flowering due to availability of more space for vegetative growth of plants.

Table 1: Effect of spacing, SNP and source of nitrogen fertilizers on vegetative parameters of African Marigold cv. Bidhan marigold – 2

Treatment	Plant height (cm)	No. of branches plant^{-1}		Internodal length (cm)	Plant spread (cm)		Leaf area (dm^{-2})	Stem diameter (cm)	Specific leaf weight (mg cm^{-2})	Total fresh biomass (g plant^{-1})	Total dry matter (g plant^{-1})
		Primary branches	Secondary branches		East-west	North-south					
T_1	77.75	7.97	30.31	52.10	19.90	22.16	36.78	0.59	6.27	687.25	129.85
T_2	87.40	10.07	33.27	45.20	26.26	24.43	43.06	0.72	7.40	975.25	184.19
T_3	82.68	9.08	32.17	46.30	21.53	22.87	39.03	0.65	6.78	848.75	160.24
T_4	83.35	10.47	35.20	44.20	22.78	27.80	42.77	0.69	7.91	995.75	188.22
T_5	94.30	11.91	38.54	43.20	26.35	34.51	48.34	0.79	10.77	1511.00	285.50
T_6	87.93	11.10	35.76	43.40	24.25	29.44	47.29	0.73	9.28	1188.00	224.46
T_7	89.88	12.70	39.26	43.20	25.15	34.75	48.78	0.82	11.68	1481.50	279.50
T_8	98.18	14.53	46.86	42.30	29.33	41.31	52.22	1.09	14.86	2180.00	411.52
T_9	92.75	13.07	41.88	42.50	28.06	37.26	49.42	0.95	13.31	1891.00	357.19
T_{10}	67.75	8.49	33.12	42.20	22.31	24.16	39.81	0.63	6.81	771.00	145.59
T_{11}	74.78	10.43	36.17	41.40	24.75	31.39	44.40	0.79	7.82	1073.25	202.69
T_{12}	70.80	9.40	34.00	41.50	23.55	27.91	40.66	0.71	7.31	889.50	167.94
T_{13}	72.20	10.91	37.03	41.20	24.11	31.00	45.72	0.78	8.59	1189.50	224.67
T_{14}	83.78	12.71	40.10	40.80	28.20	37.95	50.17	0.88	12.09	1954.75	368.67
T_{15}	78.23	11.50	38.33	40.90	26.67	35.10	48.61	0.83	10.45	1322.00	249.75
T_{16}	76.73	13.50	40.60	40.00	25.66	38.74	49.92	1.01	13.17	1699.25	320.48
T_{17}	87.68	15.00	48.63	39.10	29.13	47.35	53.68	1.29	16.27	2421.75	457.18
T_{18}	82.90	13.60	44.94	39.80	27.55	41.24	49.93	1.13	14.44	2100.75	396.81
T_{19}	73.08	8.80	34.24	39.00	22.51	32.66	41.77	0.70	7.56	849.75	160.48
T_{20}	80.90	10.85	37.34	37.40	25.57	51.19	46.26	0.87	8.43	1175.25	221.95
T_{21}	76.35	9.83	35.43	38.50	23.65	37.20	41.43	0.79	7.95	962.25	181.71
T_{22}	77.73	11.68	38.78	37.20	25.73	38.02	48.35	0.88	9.81	1556.75	293.80
T_{23}	89.28	13.31	41.51	35.30	29.03	56.84	52.14	1.02	13.90	2198.75	414.48
T_{24}	84.50	12.09	39.34	37.00	27.75	39.80	50.58	0.96	12.12	1395.25	263.54
T_{25}	81.63	14.07	43.08	35.20	28.76	44.13	52.18	1.12	14.30	1894.00	357.10
T_{26}	93.38	15.72	50.77	30.40	31.88	61.20	56.30	1.48	17.76	2659.50	502.34
T_{27}	89.70	14.20	46.49	34.30	29.65	48.05	52.85	1.33	16.07	2321.25	438.28
SEM±	0.25	0.01	0.07	0.07	0.15	0.11	0.05	0.003	0.016	23.93	4.53
CD	0.72	0.04	0.21	0.19	0.42	0.32	0.14	0.007	0.046	69.59	13.17

Significant variation in number of days for first flowering, 50% flowering and flowering duration depending on SNP dose might be attributed to the fact that NO promotes vegetative growth especially under abiotic stresses (Song *et al.*, 2009) [12]. NO suppresses the transition to flowering not by disrupting the circadian clock but by affecting the expression of regulatory genes in flowering pathways. Elevated NO suppressed the floral meristem identity gene LFY and the floral promotion gene CO whereas high levels of NO enhanced the floral repressor FLC gene. (Nigel M. C and Fang-Qing G., 2005) [13]. He Y (2004) [14] reported that NO enhances FLC and suppresses CO and LFY mRNA levels. These genes control the transition from vegetative growth to flowering influenced by the photoperiod and the autonomous pathways. The increase in number of days taken for first flowering and 50% flowering with $Ca(NO_3)_2$ as nitrogen source might be due to the reason that the plants when nourished with adequate nitrogen in the form of nitrate along with calcium led to higher metabolic activity in leaves, synthesis of carbohydrates which in turn might have helped the plants to continue in the vegetative phase for longer time leading to the delayed flower bud initiation.

Delay in first flowering by the interaction effect of wider spacing, SNP and $Ca(NO_3)_2$ might be attributed to the availability of water and nutrients in abundance at wider spacing coupled with delayed senescence through reduced chlorophyll damage during high temperature by NO released by SNP which extends the vegetative growth period of plants under heat stress and $Ca(NO_3)_2$ fertilization might had beneficial effects of nitrate form of nitrogen like higher metabolic activity in leaves, synthesis of carbohydrates which in turn might have helped the plants to continue in the vegetative phase for longer time leading to the delayed flower bud initiation. The increased flowering days by $Ca(NO_3)_2$ application might be attributed to the mitigation of adverse effects of high temperature effectively by nitrate form of nitrogen and calcium as they play a vital role in number of physiological processes at tissue, cellular and molecular levels that influence both growth and responses to environmental stresses (Waraich *et al.*, 2011) [11]. This helped in extending the vegetative growth continuously along with flowering. These results indicate the combined positive effects of the SNP and $Ca(NO_3)_2$ under wider spacing compared to rest of the treatments and the superiority of the synergistic effect of $Ca(NO_3)_2$ and SNP over $(NH_4)_2SO_4$ and SNP in delaying the flowering through increased vegetative growth during high temperature stress.

The maximum flower diameter of 5.53 cm was recorded at wider spacing (60 x 30 cm) sprayed with 200 µM SNP and $Ca(NO_3)_2$ as fertilizer (T_{26}) whereas the minimum flower diameter of 3.74 cm was recorded at closer spacing (45 x 30 cm) sprayed with 0 µM SNP and urea as fertilizer (T_1). The increase in flower diameter with increase in SNP concentration might be due to the role NO has in elongation and growth of plants by influencing cell division and cell enlargement processes along with modifications at the hormonal levels as NO has been reported to act as a secondary messenger in various metabolic processes to support plant development resulting in enhancement of yield and quality parameters. (Neill *et al.*, 2003; Unsal and Arisan 2009) [15, 16]. Readily available nitrate form of nitrogen along with calcium is reported to improve nitrogen uptake by plants that have a positive influence on flower yield.

Higher propagation coefficient under calcium nitrate may be the result of the positive influence of calcium on meristem development.

Data pertaining to length of flower receptacle from Table 2 revealed that the maximum flower receptacle length of 2.46 cm was recorded at wider spacing (60 x 30 cm) sprayed with 200 µM SNP and $Ca(NO_3)_2$ as fertilizer (T_{26}) whereas the minimum flower receptacle length of 1.80 cm was recorded at closer spacing (45 x 30 cm) sprayed with 0 µM SNP and urea as fertilizer (T_1). This might be due to the role of NO released from SNP spray in elongation growth of plants by influencing cell division and cell enlargement processes (Gabaldon *et al.*, 2005) [17]. Similar result was obtained by Meng Wang *et al.* (2015) [18] in oriental lily. The increased length of flower receptacle with $Ca(NO_3)_2$ might be attributed to the vital role of calcium in regulating a number of physiological processes in plants at tissue, cellular and molecular levels that influence both growth and responses to environmental stresses (Waraich *et al.*, 2011) [11]. It is also attributed to the improved cell division, protein synthesis and carbohydrate metabolism with calcium and nitrate form of nitrogen compared to other forms of nitrogen.

Interaction effect of spacing, SNP and source of nitrogen fertilizer on yield parameters of African Marigold cv. Bidhan Marigold - 2

The data on the ten flower weight as tabulated in Table 3 revealed the maximum ten flower weight of 61.11 g in plants sprayed with 200 µM SNP and application of $Ca(NO_3)_2$ at 60 x 30 cm spacing (T_{26}) whereas the lowest ten flower weight of 35.26 g was recorded with water spray and urea at closer spacing of 45 x 30 cm (T_1). Better uptake of nutrients, water and sunlight resulting in improved production of photosynthates by plants at wider spacing coupled with significant increase in rate of photosynthesis by decreasing the chlorophyll damage during heat stress and delaying senescence by NO through SNP, significant increase in rate of nitrogen absorption and photosynthesis for faster growth, decrease in chlorophyll degradation by nitrate form of nitrogen coupled with positive role of calcium in physiological activities particularly during cell division and maintenance of cell turgidity might be the reason for improved ten flower weight compared to rest of the treatments.

Table 2: Effect of spacing, SNP and source of nitrogen fertilizers on floral parameters of African Marigold cv. Bidhan marigold – 2

Treatment	Days taken to first flower bud appearance	Days taken to 50% flowering	Duration of flowering (days)	Flower diameter (cm)	Length of flower receptacle (cm)
T_1	35.15	45.53	61.88	3.74	1.80
T_2	38.70	50.58	66.20	4.14	1.95
T_3	36.13	48.00	63.90	3.92	1.83
T_4	39.58	50.65	73.25	4.00	1.90
T_5	44.33	60.08	79.83	4.51	2.17
T_6	41.28	55.65	76.53	4.16	2.01
T_7	44.35	56.63	82.70	4.27	2.02
T_8	48.13	62.80	91.05	4.98	2.34
T_9	45.95	60.20	86.73	4.60	2.09
T_{10}	35.70	45.93	62.38	4.05	1.82
T_{11}	39.38	50.88	66.70	4.57	1.98
T_{12}	36.58	48.48	64.50	4.27	1.86
T_{13}	39.95	51.08	73.88	4.24	1.94
T_{14}	44.75	61.03	81.28	4.78	2.21
T_{15}	41.65	56.33	76.98	4.40	2.06
T_{16}	44.73	57.13	83.43	4.58	2.09
T_{17}	48.50	63.48	91.60	5.32	2.42
T_{18}	46.50	61.05	87.35	4.90	2.18
T_{19}	35.98	46.33	62.90	4.37	1.86
T_{20}	39.75	51.43	67.03	4.85	2.03
T_{21}	37.03	49.05	64.83	4.46	1.85
T_{22}	40.45	51.55	74.30	4.47	1.97
T_{23}	45.43	61.63	82.43	5.18	2.27
T_{24}	42.33	57.05	77.53	4.84	2.10
T_{25}	45.25	57.88	84.00	4.83	2.12
T_{26}	48.85	64.28	92.30	5.53	2.46
T_{27}	46.93	61.48	88.23	5.23	2.23
SEM±	0.03	0.02	0.04	0.008	0.003
CD	0.09	0.07	0.12	0.023	0.009

Pooled mean in Table 3 revealed highest number of flowers $plant^{-1}$ (54.76) at 60 x 30 cm with 200 µM SNP spray and $Ca(NO_3)_2$ application (T_{26}) whereas 45 x 30 cm with 0 µM SNP spray and urea application (T_1) recorded lowest number of flowers $plant^{-1}$ (34.56). Increased number of flowers $plant^{-1}$ at wider spacing could be due to production of more number of lateral branches and less competition between plants for nutrients coupled with delay in senescence by NO through SNP application resulting in increased flowering duration as NO increases the scavenging enzymes activity *viz.*, POX, CAT and SOD to eliminate ROS generated through heat stress at a faster rate providing favourable conditions for growth and flowering similar to that of normal conditions. Kaur *et al.* (2006) [19] in mung bean reported that exogenous application of 150 µM SNP increased the total yield, since SNP has potential for conversion of flowers to pods. This may be achieved through changes in endogenous hormonal levels leading to favourable allocation of photoassimilates. Yield characters *viz.* total pods $plant^{-1}$, pod setting percentage, seed yield $plant^{-1}$, number of seeds pod^{-1}, 100 seed weight and yield (kg ha^{-1}) increased with SNP treatment indicating stimulating efficiency of NO in developing sinks to utilize more assimilates. $Ca(NO_3)_2$ application improved nutrient availability by nitrate form of nitrogen which helped to enhance growth of plant, resulting in higher flower number plant^{-1}.

The flower yield plant^{-1} and flower yield ha^{-1} was significantly affected with spacing, SNP concentration and nitrogen source during heat stress on African marigold cv. Bidhan Marigold – 2. Data presented in Table 3 revealed highest flower yield plant^{-1} of 0.336 kg at (T_{26}) wider spacing of 60 x 30 cm with 200 µM SNP spray and $Ca(NO_3)_2$ whereas closer spacing of 45 x 30 cm with 0 µM SNP spray and urea application (T_1) recorded lowest flower yield plant^{-1} of 0.121 kg. Better yields under wider spacing might be due to more plant spread and more secondary laterals which resulted in more flower bearing surface. Better yields under higher concentration of SNP could be due to interaction of NO released by SNP with different plant hormones (Indole Acetic Acid (IAA); Gibberellic Acid (GA); Abscisic acid (ABA); Cytokinins (CKs) and ethylene) at different steps of signaling cascades to evoke various responses and finally increase the yield (Gracia-Mata and Lamattina, 2002) [20]. Calcium and nitrate form of nitrogen from $Ca(NO_3)_2$ might have induced better heat tolerance through delaying senescence, maintaining better water relations, increased antioxidant enzyme activities for faster removal of ROS generated as a result of heat stress and increased rate of photosynthesis under high temperatures.

Regarding flower yield ha^{-1}, the highest flower yield of 224.230 q ha^{-1} was recorded at (T_8) closer spacing of 45 x 30 cm with 200 µM SNP spray and $Ca(NO_3)_2$ application followed by 45 x 30 cm, 200 µM SNP spray and $(NH_4)_2SO_4$ application (T_9) with flower yield of 208.851q ha^{-1} which might be attributed to accommodation of more number of plants at closer spacing.

Hence it can be concluded that spraying of SNP and application of $Ca(NO_3)_2$ as nitrogen fertilizer effectively alleviates the heat stress during summer resulting in normal growth of plants without effecting the flower yield in African marigold cv. Bidhan Marigold - 2.

Table 3: Effect of spacing, SNP and source of nitrogen fertilizers on yield parameters of African Marigold cv. Bidhan marigold – 2

Treatment	Ten flower weight (g)	No. of flowers Plant^{-1}	Flower yield per plant (kg)	Flower yield (qha^{-1})
T_1	35.26	34.56	0.121	88.476
T_2	48.57	38.13	0.190	138.484
T_3	45.66	36.69	0.175	127.905
T_4	49.63	41.15	0.204	148.978
T_5	53.40	48.04	0.258	187.821
T_6	51.01	46.36	0.236	172.110
T_7	54.54	48.50	0.270	196.778
T_8	58.91	52.27	0.308	224.230
T_9	55.96	50.29	0.286	208.851
T_{10}	42.05	36.47	0.163	83.069
T_{11}	49.44	38.98	0.197	110.666
T_{12}	47.20	37.78	0.184	93.710
T_{13}	50.98	42.64	0.218	111.100
T_{14}	54.48	49.04	0.267	136.515
T_{15}	51.98	47.19	0.246	125.588
T_{16}	55.73	49.97	0.282	143.778
T_{17}	59.95	53.83	0.324	165.280
T_{18}	56.48	51.53	0.295	150.360
T_{19}	45.22	37.39	0.178	86.902
T_{20}	50.33	39.73	0.201	114.001
T_{21}	48.58	38.62	0.192	101.410
T_{22}	51.73	43.58	0.225	117.448
T_{23}	55.04	50.42	0.278	154.808
T_{24}	52.89	48.20	0.256	143.984
T_{25}	56.66	50.55	0.288	160.624
T_{26}	61.11	54.76	0.336	185.198
T_{27}	57.46	52.50	0.305	169.299
SEM±	0.06	0.05	0.0005	1.35
CD	0.18	0.15	0.0015	3.91

Conclusion

The study conducted on African marigold cv. 'Bidhan Marigold -2' demonstrated that plant growth, vegetative parameters, and floral characteristics are significantly influenced by the interaction of plant spacing, sodium nitroprusside (SNP) concentration, and the source of nitrogen fertilizer.

1. **Plant Growth**: The highest plant height was observed in the treatment with closer spacing (45 x 30 cm), 200 µM SNP, and calcium nitrate as the nitrogen source (T8). This suggests that the combination of closer spacing, higher SNP concentration, and calcium nitrate promotes vertical growth due to reduced light penetration and enhanced auxin activity.
2. **Vegetative Parameters**: Wider spacing (60 x 30 cm) with 200 µM SNP and calcium nitrate (T26) significantly improved most vegetative parameters, including the number of primary and secondary branches, plant spread, leaf area, stem diameter, specific leaf weight, total fresh biomass, and total dry matter. The wider spacing reduced plant competition, allowing for better nutrient uptake, light exposure, and overall vegetative growth.
3. **Floral Parameters**: Maximum flowering duration, as well as delayed flowering, was observed with the wider spacing (60 x 30 cm) and 200 µM SNP with calcium nitrate (T26). In contrast, closer spacing (45 x 30 cm) with 0 µM SNP and urea (T1) induced earlier flowering and a shorter flowering

duration. The delay in flowering at wider spacing is attributed to prolonged vegetative growth due to reduced competition.

4. **Nitrogen Source**: Calcium nitrate was more effective than urea and ammonium sulfate in enhancing vegetative growth and flowering parameters, likely due to its efficient uptake and utilization by plants, especially under stress conditions.
5. **SNP Concentration**: The higher concentration of SNP (200 µM) consistently showed better results in improving plant growth and stress tolerance, highlighting its role in mitigating heat stress and enhancing antioxidant defense mechanisms.

Overall, the interaction of wider spacing, higher SNP concentration, and calcium nitrate as a nitrogen source proved to be the most effective combination for achieving optimal growth, biomass, and extended flowering duration in African marigold cv. 'Bidhan Marigold -2'. This suggests that for maximizing yield and quality in marigold cultivation, careful consideration of spacing, SNP application, and nitrogen source is crucial.

References

1. DOH Data Base. Published by Department of Horticulture Government of Andhra Pradesh; c2017-18.
2. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons Inc. UK; c1984. p. 7-240.
3. Simontacchi M, García-Mata C, Bartoli CG, Santa-María GE, Lamattina L. Nitric oxide as a key component in hormone-regulated processes. Plant Cell Rep. 2013;32:853-866.
4. Rajanna PH. Effect of spacing and levels of N and P on growth, flower and seed yield of china aster [M.Sc. (Agri.) Thesis]. Dharwad: University of Agricultural Sciences; c2001.
5. Mirza H, Kamrun N, Alam MM, Fujita M. Exogenous nitric oxide alleviates high temperature induced oxidative stress in wheat (*Triticum aestivum* L.) seedlings by modulating the antioxidant defence and glyoxalase system. Aust J Crop Sci. 2012;6(8):1314-1323.
6. Ahmad P, Bhardwaj R, Tuteja N. Plant signalling under abiotic stress environment. In: Ahmad P, Prasad MNV, editors. Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change. Springer; c2012. p. 297-324.
7. Liu J, Shono M. Characterization of mitochondria-located small heat shock protein from tomato (*Lycopersicon esculentum*). Plant Cell Physiol. 1999;40:1297-304.
8. Lee BH, Won SH, Lee HS, Miyao M, Chung WI, Kim IJ, *et al*. Expression of the chloroplast-localized small heat shock protein by oxidative stress in rice. Gene. 2000;245:283-290.
9. Seyedi N, Mohammadi N, Torkashvand A, Allahyari MS. Investigating the effects of calcium concentration under hydroponic conditions on quantitative and qualitative growth of Lilium 'Tresor.' J Ornamental Hortic Plants. 2013;3:19-24.
10. Fernández-Marcos M, Sanz L, Lorenzo Ó. Nitric oxide: An emerging regulator of cell elongation during primary root growth. Plant Signal Behav. 2012;7:196-200.
11. Waraich EA, Ahmad R, Ashraf MY, Saifullah, Ahmad M. Improving agricultural water use efficiency by nutrient management in crop plants. Acta Agric Scand B Soil Plant Sci. 2011;61(4):291-304.
12. Song J, Shi GW, Xing S, Chen M, Wang BS. Effects of nitric oxide and nitrogen on seedling emergence, ion accumulation, and seedling growth under salinity in the euhalophyte Suaeda salsa. J Plant Nutr Soil Sci. 2009;172:544-549.
13. Nigel MC, Guo FQ. New insights into nitric oxide metabolism and regulatory functions. Trends Plant Sci. 2005;10(4):195-200.
14. He Y. Nitric oxide represses the Arabidopsis floral transition. Science. 2004;305:1968-1971.
15. Neill SJ, Desikan R, Hancock JT. Nitric oxide signaling in plants. New Phytol. 2003;159:11-35.
16. Unsal NP, Arisan D. Nitric oxide signaling in plants. Bot Rev. 2009;75:203-229.
17. Gabaldon C, Gomez RLV, Pedreno MA, Ros Barcelo AR. Nitric oxide production by differentiating xylem of Zinnia elegans. New Phytol. 2005;163:121-130.
18. Wang M, Li B, Zhu YC, Niu LJ, Jin X, Xu QQ, *et al*. Effect of exogenous nitric oxide on vegetative and reproductive growth of oriental lily 'Siberia.' Hortic Environ Biotechnol. 2015;56(5):677-686.
19. Kaur JP, Singh, Parmar U. Response of mungbean (*Vigna radiata* L.) to exogenous application of sodium nitroprusside (SNP- NO releasing compound). Environ Ecol. 2006;24S:187-189.
20. Garcia-Mata C, Lamattina G. Nitric and abscisic acid cross talk in guard cells. Plant Physiol. 2002;128:790-792.