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Influence of hydrogels, calcium ammonium nitrate (CAN), and sodium nitroprusside (SNP) on growth parameters of marigold (*Tagetes erecta* L.) cv. 'Bidhan-2' during hot summer conditions

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Abstract
Marigold (*Tagetes erecta* L.) is a popular ornamental flower known for its vibrant colors and pleasant fragrance. To enhance its growth and productivity, various agricultural inputs like hydrogels, calcium ammonium nitrate (CAN), and sodium nitroprusside (SNP) have been employed in this study. The present research investigates the impact of these treatments on growth parameters such as plant height, plant spread, number of leaves and branches, main stem diameter, total dry matter, and total leaf area in marigold cv. 'Bidhan-2' over a two-year experimentation period (2019-2021) at College of Horticulture, Dr. Y.S.R Horticultural University, Anantharajupeta, Annamayya district of Andhra Pradesh. The experiment consisted of 12 treatments, laid out in factorial randomized block design with three replications under open field condition. Significant variations were observed among different treatments with respect to vegetative growth. Among the results, number of leaves per plant (2380.1, 2618.1 and 2499.1), number of branches per plant (103.67, 98.33 and 101.00), total dry matter (123.67, 128.67 and 126.17 g plant^{-1}) and leaf area (27750.5, 30524.6 and 29137.5 cm^2) recorded were significantly maximum with $H_1N_2S_1$ treatment during the two years and pooled data respectively. While maximum plant height (76.53, 77.37 and 76.95 cm) and plant spread (3884.3, 3962.0 and 3923.2 cm^2) was observed with $H_1N_1S_1$ treatment during the two years and pooled data respectively. However maximum diameter of main stem (2.17, 2.19 and 2.18 cm) was registered with $H_1N_1S_2$ treatment during the two years and pooled data respectively.

Keywords: Marigold, calcium ammonium nitrate, sodium nitroprusside, hydrogels, growth parameters

Introduction
Marigold (*Tagetes erecta* L.) is a widely cultivated ornamental and medicinal plant known for its vibrant colors and potential health benefits. Its popularity in horticulture is attributed to its aesthetic appeal, ease of cultivation, and various uses in traditional medicine. The plant's numerous bioactive compounds, including flavonoids, carotenoids, and essential oils, have been reported to possess antimicrobial, anti-inflammatory, and antioxidant properties, making it a valuable resource in traditional medicine practices across different cultures.

As marigold gains prominence for its versatile applications, there is a growing demand to enhance its growth and development to maximize its horticultural potential. Achieving optimal growth parameters, such as plant height, spread, leaf number, and biomass accumulation, is crucial for producing visually appealing and commercially valuable marigold plants. Moreover, promoting the growth of marigold can lead to increased flower yield, extending its usage in the ornamental industry and medicinal preparations. The total area dedicated to marigold cultivation in India covers approximately 73.15 thousand hectares, resulting in a substantial production of 728.53 thousand metric tons. In the state of Andhra Pradesh, marigold is cultivated over an area of around 6,370 hectares, yielding a total production of 76,420 metric tons. (NHB, 2021-22 advance estimates).

One promising approach to improve plant growth and development is the use of hydrogels. Hydrogels are three-dimensional, hydrophilic, polymeric materials capable of absorbing and retaining large amounts of water and nutrients. They have been widely utilized in agriculture and horticulture to enhance water availability and nutrient uptake for plants. By effectively storing water and releasing it gradually to the roots, hydrogels can mitigate the adverse effects of water scarcity and improve plant resilience to drought conditions.

Furthermore, hydrogels can create a favorable microenvironment around the root zone, promoting root growth and overall plant development.

In addition to hydrogel application, the use of specific plant growth promoters can further enhance the growth and performance of marigold. Calcium ammonium nitrate (CAN) is a nitrogenous fertilizer that not only provides essential nutrients but also plays a vital role in signaling pathways and physiological processes in plants. The application of CAN can stimulate root and shoot growth, improve nutrient assimilation, and increase the plant's ability to withstand environmental stresses.

Another plant growth promoter, sodium nitroprusside (SNP), has been recognized for its positive effects on plant growth and development. SNP acts as a nitric oxide donor, a signaling molecule that regulates various physiological processes, including seed germination, root development, flowering, and stress responses. By facilitating nitric oxide production, SNP can enhance nutrient uptake efficiency and modulate plant metabolism, leading to improved growth and stress tolerance.

Considering the potential benefits of hydrogels and plant growth promoters on plant growth, this study aims to evaluate their effects on various growth parameters of marigold cv. 'Bidhan-2.' The specific objectives are to assess the impact of hydrogel application, calcium ammonium nitrate (CAN) treatment, and sodium nitroprusside (SNP) treatment on plant height, spread, leaf and branch numbers, main stem diameter, total dry matter accumulation, and total leaf area of marigold plants. The results of this research will provide valuable insights into optimizing cultivation practices and promoting the horticultural potential of marigold, contributing to its commercial and medicinal significance.

Material and Methods

The present investigation was carried out at college of horticulture, Anantharajupeta, Annamayya district of Andhra Pradesh during the two year period 2019-21. The experimental area had red soil and loam in texture with moderate fertility. In the experimentation, there were about 12 treatments consisting of 2 levels of hydrogels *viz*., H_1 (Pusa Hydrogel (1.25 g m^{-2})), H_2 (Zeba (1.25 g m^{-2})), 3 levels of Calcium Ammonium Nitrate *viz.*, N_1 (100% of RDN through CAN), N_2 (75% of RDN through CAN), N_3 (50% of RDN through CAN), 2 levels of Sodium Nitro Prusside spray intervals *viz.*, S_1 (SNP @ 100µM sprayed at 7 days interval), S_2 (SNP @ 100 µM sprayed at 14 days interval). A recommended dose of FYM and vermicompost were also applied to all the treatments uniformly along with 200 kg single super phosphate and 100 kg murate of potash. The experiment was laid-out in f-Randomized Block Design with three replications. The plot size is 1 x 7.5 m^2. Spacing adopted was 45 cm between the rows and 30 cm in plants within a row. The treatment details are as follows

The treatment details are as follows

T_1 - $H_1N_1S_1$	:	Pusa Hydrogel + 100% RDN + SNP spray at 7 days interval
T_2 - $H_1N_2S_1$	:	Pusa Hydrogel + 75% RDN + SNP spray at 7 days interval
T_3 - $H_1N_3S_1$	:	Pusa Hydrogel + 50% RDN + SNP spray at 7 days interval
T_4 - $H_2N_1S_1$	:	Zeba + 100% RDN + SNP spray at 7 days interval
T_5 - $H_2N_2S_1$	:	Zeba + 75% RDN + SNP spray at 7 days interval
T_6 - $H_2N_3S_1$	:	Zeba + 50% RDN + SNP spray at 7 days interval
T_7 - $H_1N_1S_2$	:	Pusa Hydrogel + 100% RDN + SNP spray at 14 days interval
T_8 - $H_1N_2S_2$	:	Pusa Hydrogel + 75% RDN + SNP spray at 14 days interval
T_9 - $H_1N_3S_2$	:	Pusa Hydrogel + 50% RDN + SNP spray at 14 days interval
T_{10} - $H_2N_1S_2$	:	Zeba + 100% RDN + SNP spray at 14 days interval
T_{11} - $H_2N_2S_2$	:	Zeba + 75% RDN + SNP spray at 14 days interval
T_{12} - $H_2N_3S_2$	:	Zeba + 50% RDN + SNP spray at 14 days interval

*RDN (Recommended dose of nitrogen) is applied through Calcium Ammonium Nitrate

The straight fertilizers *viz*., Calcium Ammonium Nitrate, Single Super Phosphate and Muriate of Potash were used as the source of N, P_2O_5 and K_2O respectively. Just before planting, half the dose of nitrogenous fertilizer in the form of calcium ammonium nitrate (CAN) was applied for all the spots of planting as per treatment details. Half the dose of potassium in the form of muriate of potash @ 100 kg ha^{-1} was commonly applied to all the treatments. Remaining half the dose of nitrogenous fertilizer in the form of calcium ammonium nitrate as per the treatment details and remaining half the dose of potassium, common to all the treatments in the form of muriate of potash @ 100 kg ha^{-1} were applied after 35 days of transplantation of marigold. Five plants were selected per each plot at random and were labeled properly for recording observations. The results of growth parameters were recorded as per the standard procedures outlined by different research workers. The data collected on each character was subjected to statistical analysis by ANOVA technique as described by Panse and Sukhatme (1985) [1]. The treatment means were compared by using the least significant difference values calculated at 5 per cent level of significance.

Results and Discussion

The data pertaining to total plant height and total plant spread was presented in table 1 & 2 respectively. The data were found significant with respect to the individual effects but no significant effects were found with respect to interaction effects of hydrogels, CAN levels and SNP intervals. Significantly lowest plant height (67.98, 68.59 and 68.29 cm respectively during 2020, 2021 and pooled data mean) and plant spread (3176.3, 3239.8 and 3208.1 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the application of Zeba granules, whereas, application of Pusa hydrogel has recorded significantly highest plant height (69.79, 70.53 and 70.16 cm respectively during 2020, 2021 and pooled data mean) and plant spread (3277.7, 3343.3 and 3310.5 cm^2 respectively during 2020, 2021 and pooled data mean). Significantly lowest plant height (65.03, 65.79 and 65.41 cm respectively during 2020, 2021 and pooled data mean) and plant spread (2855.2, 2912.3 and 2883.8 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the application of 50% RDN through CAN, whereas, application of 100% RDN through CAN has

recorded significantly highest plant height (72.31, 72.97 and 72.64 cm respectively during 2020, 2021 and pooled data mean) and plant spread (3604.4, 3676.5 and 3640.5 cm^2 respectively during 2020, 2021 and pooled data mean). Significantly lowest plant height (67.40, 68.11 and 67.76 cm respectively during 2020, 2021 and pooled data mean) and plant spread (3103.6, 3165.6 and 3134.6 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the spraying of SNP @ 14 days interval, whereas, spraying of SNP @ 7 days interval has recorded significantly highest plant height (70.37, 72.97 and 72.64 cm respectively during 2020, 2021 and pooled data mean) and plant spread (3350.5, 3417.5 and 3384.0 cm^2 respectively during 2020, 2021 and pooled data mean). Among the combination of doses, spraying of SNP @ 14 days interval and application of 50% RDN through CAN recorded significantly lowest plant spread (2767.2, 2822.6 and 2794.9 cm^2 respectively during 2020, 2021 and pooled data mean), whereas, spraying of SNP @ 7 days interval and application of 100% RDN through CAN recorded significantly highest plant spread (3839.1, 3915.9 and 3877.5 cm^2 respectively during 2020, 2021 and pooled data mean).

Pusa hydrogel's superior performance can be attributed to its efficient water retention and gradual release, ensuring a consistent moisture supply that enhances nutrient absorption and metabolic activities. This leads to increased cell division, expansion, and greater plant height and spread. Similar observations were reported in various crops, including cucumber (Al-Harbi *et al*., 1999) [2], tomato (Sendur *et al*., 2001) [3], soybean (Sivalapan, 2006; Sharma *et al*., 2014; Sureshrao *et al*., 2016) [4, 5, 6], maize (Brar *et al*., 2001) [7], and castor (Naik *et al*., 2020) [8]. The optimal nitrogen dose (100% CAN) supports vegetative growth by aiding protein synthesis and cell development. The addition of calcium from $Ca(NO_3)_2$ further promotes plant growth, similar to findings in African marigold (Shinde *et al*., 2014; Kumar *et al*., 2015) [9, 10] and annual chrysanthemum (Chopde *et al*., 2015) [11]. Frequent Sodium Nitroprusside (SNP) spraying enhances heat stress resistance through proline accumulation and improved photosynthesis, leading to increased lateral branching and overall plant spread. Similar results were observed in tomato (Siddiqui *et al*., 2017) [12], chickpea (Chohan *et al*., 2012) [13], oriental lily (Meng-Wang *et al*., 2015) [14], groundnut (Kong *et al*., 2014) [15], and rubber (Nayanakantha *et al*., 2014) [16]. In conclusion, Pusa hydrogel, 100% CAN, and weekly SNP spraying promote greater plant height and spread in marigold under hot summer conditions.

The data pertaining to total number of leaves per plant, branches per plant, total dry matter content and total leaf area were presented in table 3 to 6 respectively. The data were found significant with respect to the individual effects and interaction effects of hydrogels, CAN levels and SNP intervals. Significantly lowest number of leaves per plant (966.1, 1062.7 and 1014.4 respectively during 2020, 2021 and pooled data mean), number of branches per plant (67.11, 62.94 and 65.03 respectively during 2020, 2021 and pooled data mean), total dry matter content (76.28, 79.33 and 77.81 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (7193.5, 7913.1 and 7553.3 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the application of Zeba granules, whereas, application of Pusa hydrogel has recorded significantly highest number of leaves per plant (1359.6, 1495.5 and 1427.5 respectively during 2020, 2021 and pooled data mean), number of branches per plant (80.00, 75.94 and 77.97 respectively during 2020, 2021 and pooled data mean), total dry matter content (93.00, 96.78 and 94.89 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (13233.0, 14556.5 and 13894.8 cm^2 respectively during 2020, 2021 and pooled data mean).

Significantly lowest number of leaves per plant (715.7, 787.2 and 751.5 respectively during 2020, 2021 and pooled data mean), number of branches per plant (62.92, 59.17 and 61.04 respectively during 2020, 2021 and pooled data mean), total dry matter content (65.75, 68.42 and 67.08 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (4597.3, 5057.1 and 4827.2 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the application of 50% RDN through CAN, whereas, application of 75% RDN through CAN has recorded significantly highest number of leaves per plant (1577.3, 1735.1 and 1656.2 respectively during 2020, 2021 and pooled data mean), number of branches per plant (82.25, 77.42 and 79.83 respectively during 2020, 2021 and pooled data mean), total dry matter content (94.17, 98.00 and 96.08 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (15666.4, 17233.3 and 16449.9 cm^2 respectively during 2020, 2021 and pooled data mean).

Significantly lowest number of leaves per plant (1085.2, 1193.7 and 1139.4 respectively during 2020, 2021 and pooled data mean), number of branches per plant (71.11, 66.89 and 69.00 respectively during 2020, 2021 and pooled data mean), total dry matter content (80.06, 83.28 and 81.67 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (9135.6, 10049.4 and 9592.5 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the spraying of SNP @ 14 days interval, whereas, spraying of SNP @ 7 days interval has recorded significantly highest number of leaves per plant (1240.5, 1364.5 and 1302.5 respectively during 2020, 2021 and pooled data mean), number of branches per plant (76.00, 72.00 and 74.00 respectively during 2020, 2021 and pooled data mean), total dry matter content (89.22, 92.83 and 91.03 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (11291.0, 12420.1 and 11855.6 cm^2 respectively during 2020, 2021 and pooled data mean).

Among the combination of doses, significantly lowest number of leaves per plant (680.2, 748.2 and 714.3 respectively during 2020, 2021 and pooled data mean), number of branches per plant (62.00, 57.67 and 59.83 respectively during 2020, 2021 and pooled data mean), total dry matter content (62.67, 65.17 and 63.92 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (4226.0, 4648.7 and 4437.3 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the combination application of Zeba granules and application of 50% RDN, whereas, application of Pusa hydrogel and application of 100% RDN has recorded significantly highest number of leaves per plant (2102.7, 2312.9 and 2207.8 respectively during 2020, 2021 and pooled data mean), number of branches per plant (96.67, 91.50 and 94.08 respectively during 2020, 2021 and pooled data mean), total dry matter content (111.17, 115.67 and 101.00 g $plant^{-1}$ respectively during 2020, 2021 and pooled data mean) and total leaf area (23558.5, 25914.2 and 24736.4 cm^2 respectively during 2020, 2021 and pooled data mean).

Significantly highest number of leaves per plant (1478.1, 1625.9 and 1552.0 respectively during 2020, 2021 and pooled data mean), number of branches per plant (84.22, 80.22 and 82.22 respectively during 2020, 2021 and pooled data mean), total dry matter content (98.89, 102.89 and 100.89 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (14844.5, 16328.8 and 15586.6 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the combination application of pusa hydrogel and spraying of SNP @ 7 days interval, whereas, application of zeba and spraying of SNP @ 14 days interval has recorded significantly lowest number of leaves per plant (929.3, 1022.3 and 975.8 respectively during 2020, 2021 and pooled data mean), number of branches per plant (66.44, 62.11 and 64.28 respectively during 2020, 2021 and pooled data mean), total dry matter content (73.00, 75.89 and 74.44 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (6649.6, 7314.7 and 6982.1 cm^2 respectively during 2020, 2021 and pooled data mean).

Significantly highest number of leaves per plant (1737.1, 1910.8 and 1824.0 respectively during 2020, 2021 and pooled data mean), number of branches per plant (86.00, 81.33 and 83.67 respectively during 2020, 2021 and pooled data mean), total dry matter content (102.17, 106.33 and 104.25 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (17954.9, 19750.1 and 18852.5 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the combination spraying of SNP @ 7 days interval and application of 75% RDN through CAN, whereas, the combination spraying of SNP @ 14 days interval and application of 50% RDN through CAN has recorded significantly lowest number of leaves per plant (669.1, 736.0 and 702.5 respectively during 2020, 2021 and pooled data mean), number of branches per plant (62.17, 58.17 and 60.17 respectively during 2020, 2021 and pooled data mean), total dry matter content (62.00, 64.50 and 63.25 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (4098.1, 4507.9 and 4303.0 cm^2 respectively during 2020, 2021 and pooled data mean).

Significantly highest number of leaves per plant (2380.1, 2618.1 and 2499.1 respectively during 2020, 2021 and pooled data mean), number of branches per plant (103.67, 98.33 and 101.0 respectively during 2020, 2021 and pooled data mean), total dry matter content (123.67, 128.67 and 126.17 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (27750.5, 30524.6 and 29137.5 cm^2 respectively during 2020, 2021 and pooled data mean) was observed with the application of 75% RDN through CAN, application of pusa hydrogel and spraying of SNP @ 7 days interval, whereas, the application of 50% RDN through CAN, application of zeba and spraying of SNP @ 14 days interval has recorded significantly lowest number of leaves per plant (656.1, 721.7 and 688.9 respectively during 2020, 2021 and pooled data mean), number of branches per plant (61.33, 56.67 and 59.00 respectively during 2020, 2021 and pooled data mean), total dry matter content (58.67, 61.00 and 59.83 g plant^{-1} respectively during 2020, 2021 and pooled data mean) and total leaf area (3774.5, 4151.8 and 3963.2 cm^2 respectively during 2020, 2021 and pooled data mean).

A combination of Pusa hydrogel applied to the soil, 75% nitrogen as Calcium Ammonium Nitrate (CAN), and foliar Sodium Nitroprusside (SNP) spraying at either 7-day or weekly intervals proves effective in enhancing marigold growth, development, and stress tolerance. Pusa hydrogel enhances root moisture, stimulating cell division, expansion, and branching, resulting in more leaves and branches. The 75% CAN with Pusa hydrogel meets the plant's nitrogen and calcium needs. SNP foliar application bolsters the plant's defense against summer heat, boosting leaf area and overall dry matter content. These findings align with previous studies in various crops, including pine (Huttermann *et al*., 1999[17]), soybean (Yazdani *et al*., 2007) [18], coleus (Dawlatzai *et al*., 2017) [19], strawberry (Singh *et al*., 2020) [20], rose (Mehdi *et al*., 2015) [21], African marigold (Aparna, 2019) [22], mungbean (Kaur *et al*., 2006) [23], hot pepper (Ghaname *et al*., 2009) [24], potato (Palta, 1996) [25], sunflower (Nejadalimoradi *et al*., 2014) [26].

Table 1: Influence of hydrogels, CAN and SNP on total plant height (cm) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total plant height (cm)											
	First year (2019-20)				Second year (2020-21)				Pooled data mean			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	73.62	69.80	65.95	69.79	74.33	70.48	66.78	70.53	73.98	70.14	66.37	70.16
H_2	71.00	68.83	64.12	67.98	71.60	69.38	64.80	68.59	71.30	69.11	64.46	68.29
Mean	72.31	69.32	65.03		72.97	69.93	65.79		72.64	69.63	65.41	
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean	
H_1	71.50	68.08	69.79		72.23	68.83	70.53		71.87	68.46	70.16	
H_2	69.24	66.72	67.98		69.80	67.39	68.59		69.52	67.06	68.29	
Mean	70.37	67.40			71.02	68.11			70.69	67.76		
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	73.92	69.95	67.25	70.37	74.65	70.50	67.90	71.02	74.28	70.23	67.58	70.69
S_2	70.70	68.68	68.82	67.40	71.28	69.37	63.68	68.11	70.99	69.03	63.25	67.76
Mean	72.31	69.32	65.03		72.97	69.93	65.79		72.64	69.63	65.41	

Treatments	N_1		N_2		N_3		N_1		N_2		N_3		N_1		N_2		N_3	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
H_1	76.53	70.70	70.10	69.50	67.87	64.03	77.37	71.30	70.70	70.27	68.63	64.93	76.95	71.00	70.40	69.88	68.25	64.48
H_2	71.30	70.70	69.80	67.87	66.63	61.60	71.93	71.27	70.30	68.47	67.17	62.43	71.62	70.98	70.05	68.17	66.90	62.02

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.43	1.25	0.43	1.26	0.43	1.25
N	0.52	1.53	0.53	1.55	0.53	1.54
S	0.43	1.25	0.43	1.26	0.43	1.25
H x N	0.74	NS	0.75	NS	0.74	NS
H x S	0.60	NS	0.61	NS	0.61	NS
S x N	0.74	NS	0.75	NS	0.74	NS
H x N x S	1.05	NS	1.06	NS	1.05	NS

Table 2: Influence of hydrogels, CAN and SNP on total plant spread (cm^2) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total plant spread (cm^2)											
	First year (2019-20)				Second year (2020-21)				Pooled data mean			
	N_1	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**
H_1	3,640.0	3,254.8	2,938.5	3,277.7	3,712.8	3,319.8	2,997.2	3,343.3	3,676.4	3,287.3	2,967.8	3,310.5
H_2	3,568.8	3,188.1	2,772.0	3,176.3	3,640.2	3,251.9	2,827.4	3,239.8	3,604.5	3,220.0	2,799.7	3,208.1
Mean	3,604.4	3,221.4	2,855.2		3,676.5	3,285.9	2,912.3		3,640.5	3,253.6	2,883.8	
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean	
H_1	3,395.4	3,160.1	3,277.7		3,463.3	3,223.3	3,343.3		3,429.3	3,191.7	3,310.5	
H_2	3,305.6	3,047.0	3,176.3		3,371.7	3,107.9	3,239.8		3,338.7	3,077.4	3,208.1	
Mean	3,350.5	3,103.6			3,417.5	3,165.6			3,384.0	3,134.6		
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	3839.1	3269.2	2943.2	3350.5	3915.9	3334.5	3002.1	3417.5	3877.5	3301.8	2972.6	3384.0
S_2	3369.7	3173.7	2767.2	3103.6	3437.1	3237.2	2822.6	3165.6	3403.4	3205.5	2794.9	3134.6
Mean	3604.4	3221.4	2855.2		3676.5	3285.9	2912.3		3640.5	3253.6	2883.8	

Treatments	**N_1**		**N_2**		**N_3**		**N_1**		**N_2**		**N_3**		**N_1**		**N_2**		**N_3**	
	S_1	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
H_1	3884.3	3395.7	3320.4	3189.1	2981.3	2895.6	3962.0	3463.6	3386.8	3252.9	3041.0	2953.5	3923.2	3429.6	3353.6	3221.0	3011.2	2924.5
H_2	3793.9	3343.7	3217.9	3158.3	2905.0	2638.9	3869.8	3410.6	3282.3	3221.5	2963.1	2691.7	3831.9	3377.2	3250.1	3189.9	2934.1	2665.3

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	23.2	67.8	23.7	69.1	23.4	68.5
N	28.4	83.0	29.0	84.7	28.7	83.8
S	23.2	67.8	23.7	69.1	23.4	68.5
H x N	40.2	NS	41.0	NS	40.6	NS
H x S	32.8	NS	33.5	NS	33.2	NS
S x N	40.2	117.4	41.0	119.7	40.6	118.6
H x N x S	56.9	NS	58.0	NS	57.4	NS

Table 3: Influence of hydrogels, CAN and SNP on total number of leaves per plant in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total number of leaves per plant											
	First year (2019-20)				Second year (2020-21)				Pooled data mean			
	N_1	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**	**N_1**	**N_2**	**N_3**	**Mean**
H_1	1224.9	2102.7	751.1	1359.6	1347.4	2312.9	826.2	1495.5	1286.1	2207.8	788.7	1427.5
H_2	1166.0	1052.0	680.2	966.1	1282.6	1157.3	748.2	1062.7	1224.3	1104.6	714.3	1014.4
Mean	1195.4	1577.3	715.7		1315.0	1735.1	787.2		1255.3	1656.2	751.5	
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean	
H_1	1478.1	1241.0	1359.6		1625.9	1365.1	1495.5		1552.0	1303.0	1427.5	
H_2	1002.8	929.3	966.1		1103.1	1022.3	1062.7		1053.0	975.8	1014.4	
Mean	1240.5	1085.2			1364.5	1193.7			1302.5	1139.4		
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	1222.0	1737.1	762.3	1240.5	1344.2	1910.8	838.5	1364.5	1283.1	1824.0	800.4	1302.5
S_2	1168.9	1417.5	669.1	1085.2	1285.8	1559.4	736.0	1193.7	1227.3	1488.5	702.5	1139.4
Mean	1195.4	1577.3	715.7		1315.0	1735.1	787.2		1255.2	1656.2	751.5	

Treatments	**N_1**		**N_2**		**N_3**		**N_1**		**N_2**		**N_3**		**N_1**		**N_2**		**N_3**	
	S_1	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
H_1	1234.0	1215.7	2380.1	1825.2	820.3	682.0	1357.5	1337.3	2618.1	2007.8	902.3	750.2	1295.7	1276.5	2499.1	1916.5	861.3	716.1
H_2	1210.0	1122.0	1094.1	1009.9	704.3	656.1	1331.0	1234.2	1203.6	1110.9	774.7	721.7	1270.5	1178.1	1148.9	1060.4	739.5	688.9

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	8.82	25.86	9.70	28.44	9.26	27.15
N	10.80	31.67	11.87	34.83	11.34	33.25
S	8.82	25.86	9.70	28.44	9.26	27.15
H x N	15.27	44.79	16.79	49.25	16.03	47.02
H x S	12.47	36.57	13.71	40.21	13.09	38.39
S x N	15.27	44.79	16.79	49.25	16.03	47.02
H x N x S	21.60	63.34	23.75	69.65	22.67	66.50

Table 4: Influence of hydrogels, CAN and SNP on total number of branches per plant in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total number of branches per plant											
	First year (2019-20)				Second year (2020-21)				Pooled data mean			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	79.50	96.67	63.83	80.00	75.67	91.50	60.67	75.94	77.58	94.08	62.25	77.97
H_2	71.50	67.83	62.00	67.11	67.83	63.33	57.67	62.94	69.67	65.58	59.83	65.03
Mean	75.50	82.25	62.92		71.75	77.42	59.17		73.63	79.83	61.04	
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean	
H_1	84.22	75.78	80.00		80.22	71.67	75.94		82.22	73.72	77.97	
H_2	67.78	66.44	67.11		63.78	62.11	62.94		65.78	64.28	65.03	
Mean	76.00	71.11			72.00	66.89			74.00	69.00		
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	78.33	86.00	63.67	76.00	74.50	81.33	60.17	72.00	76.42	83.67	61.92	74.00
S_2	72.67	78.50	62.17	71.11	69.00	73.50	58.17	66.89	70.83	76.00	60.17	69.00
Mean	75.50	82.25	62.92		71.75	77.42	59.17		73.63	79.83	61.04	

Treatments	N_1		N_2		N_3		N_1		N_2		N_3		N_1		N_2		N_3	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
H_1	84.33	74.67	103.67	89.67	64.67	63.00	80.67	70.67	98.33	84.67	61.67	59.67	82.50	72.67	101.0	87.17	63.17	61.33
H_2	72.33	70.67	68.33	67.33	62.67	61.33	68.33	67.33	64.33	62.33	58.67	56.67	70.33	69.00	66.33	64.83	60.67	59.00

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.19	0.55	0.21	0.62	0.143	0.418
N	0.23	0.67	0.26	0.76	0.175	0.512
S	0.19	0.55	0.21	0.62	0.143	0.418
H x N	0.33	0.95	0.37	1.08	0.247	0.724
H x S	0.27	0.78	0.30	0.88	0.202	0.591
S x N	0.33	0.95	0.37	1.08	0.247	0.724
H x N x S	0.46	1.35	0.52	1.53	0.349	1.024

Table 5: Influence of hydrogels, CAN and SNP on total dry matter (g plant^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total dry matter content (g plant^{-1})											
	First year (2019-20)				Second year (2020-21)				Pooled data mean			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	99.00	111.17	68.83	93.00	103.00	115.67	71.67	96.78	101.00	113.42	70.25	94.89
H_2	89.00	77.17	62.67	76.28	92.50	80.33	65.17	79.33	90.75	78.75	63.92	77.81
Mean	94.00	94.17	65.75		97.75	98.00	68.42		95.88	96.08	67.08	
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean	
H_1	98.89	87.11	93.00		102.89	90.67	96.78		100.89	88.89	94.89	
H_2	79.56	73.00	76.28		82.78	75.89	79.33		81.17	74.44	77.81	
Mean	89.22	80.06			92.83	83.28			91.03	81.67		
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	96.00	102.17	69.50	89.22	99.83	106.33	72.33	92.83	97.92	104.25	70.92	91.03
S_2	92.00	86.17	62.00	80.06	95.67	89.67	64.50	83.28	93.83	87.92	63.25	81.67
Mean	94.00	94.17	65.75		97.75	98.00	68.42		95.88	96.08	67.08	

Treatments	N_1		N_2		N_3		N_1		N_2		N_3		N_1		N_2		N_3	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
H_1	100.67	97.33	123.67	98.67	72.33	65.33	104.67	101.33	128.67	102.67	75.33	68.00	102.67	99.33	126.17	100.67	73.83	66.67
H_2	91.33	86.67	80.67	73.67	66.67	58.67	95.00	90.00	84.00	76.67	69.33	61.00	93.17	88.33	82.33	75.17	68.00	59.83

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.40	1.19	0.38	1.12	0.39	1.15
N	0.50	1.45	0.47	1.37	0.48	1.40
S	0.40	1.19	0.38	1.12	0.39	1.15
H x N	0.70	2.05	0.66	1.93	0.68	1.98
H x S	0.57	1.68	0.54	1.58	0.55	1.62
S x N	0.70	2.05	0.66	1.93	0.68	1.98
H x N x S	0.99	2.90	0.93	2.73	0.96	2.80

Table 6: Influence of hydrogels, CAN and SNP on total leaf area (cm^2) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Total leaf area (cm^2)															
	First year (2019-20)				Second year (2020-21)				Pooled data mean							
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean				
H_1	11172.1	23558.5	4968.7	13233.0	12289.7	25914.2	5465.4	14556.5	11730.9	24736.4	5217.1	13894.8				
H_2	9580.2	7774.4	4226.0	7193.5	10538.3	8552.3	4648.7	7913.1	10059.2	8163.4	4437.3	7553.3				
Mean	10376.2	15666.4	4597.3		11414.0	17233.3	5057.1		10895.1	16449.9	4827.2					
Treatments	S_1	S_2	Mean		S_1	S_2	Mean		S_1	S_2	Mean					
H_1	14844.5	11621.7	13233.1		16328.8	12784.2	14556.5		15586.6	12202.9	13894.8					
H_2	7737.5	6649.6	7193.5		8511.5	7314.7	7913.1		8124.5	6982.1	7553.3					
Mean	11291.0	9135.6			12420.1	10049.4			11855.6	9592.5						
Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean				
S_1	10821.6	17954.9	5096.6	11291.0	11904.0	19750.1	5606.3	12420.1	11362.8	18852.5	5351.4	11855.6				
S_2	9930.7	13378.0	4098.1	9135.6	10923.9	14716.5	4507.9	10049.4	10427.3	14047.3	4303.0	9592.5				
Mean	10376.2	15666.4	4597.3		11414.0	17233.3	5057.1		10895.1	16449.9	4827.2					
Treatments	N_1		N_2		N_3		N_1		N_2		N_3		N_1		N_2		N_3	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
H_1	11267.4	11076.8	27750.5	19366.5	5515.6	4421.7	12394.8	12184.7	30524.6	21304.0	6067.0	4863.9	11831.1	11630.8	29137.5	20335.2	5791.3	4642.8
H_2	10375.8	8784.7	8159.3	7389.5	4677.5	3774.5	11413.3	9663.2	8975.7	8129.1	5145.5	4151.8	10894.5	9223.9	8567.5	7759.3	4911.5	3963.2
Source	SEm±		CD @ 5%				SEm±		CD @ 5%				SEm±		CD @ 5%			
H	106.81		313.27				117.44		344.44				112.13		328.86			
N	130.82		383.68				143.83		421.85				137.33		402.77			
S	106.81		313.27				117.44		344.44				112.13		328.86			
H x N	185.01		542.61				203.41		596.59				194.21		569.60			
H x S	151.06		443.04				166.09		487.11				158.57		465.07			
S x N	185.01		542.61				203.41		596.59				194.21		569.60			
H x N x S	261.64		767.36				287.67		843.70				274.65		805.53			

Conclusion

The combination of Pusa hydrogel, 75% nitrogen as CAN and foliar SNP spraying at regular weekly intervals proves highly effective in enhancing marigold growth, development, and stress tolerance. Pusa hydrogel's water retention and gradual release improve nutrient uptake and metabolic processes, boosting cell division, expansion, and overall plant height and spread. This approach aligns with similar findings in various crops. Additionally, 100% CAN ensures optimal vegetative growth, and calcium from $Ca(NO_3)_2$ promotes plant development. Frequent SNP spraying enhances heat stress resistance, leading to increased lateral branching and overall plant spread. This study offers valuable insights for enhancing marigold growth under hot summer conditions in horticulture.

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