Enhancement of Growth and Physiological Parameters of Marigold (cv. 'Bidhan-2') through Hydrogels, Calcium Ammonium Nitrate (CAN), and Sodium Nitroprusside (SNP) During Hot Summer Conditions in Rayalaseema Region of Andhra Pradesh

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 analysis parameters such as Crop growth rate, Relative growth rate, Net assimilation rate and Specific leaf weight 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 growth analysis parameters. The results highlight the positive influence of Pusa hydrogel on Crop Growth Rate (CGR) and the benefits of applying 50% nitrogen in the form of calcium ammonium nitrate (CAN) to stimulate Net Assimilation Rate (NAR). The complex interplay among moisturizing agents, the concentration of CAN and the timing of sodium nitroprusside (SNP) application, offering insights into the intricate mechanisms that influence Specific Leaf Weight (SLW).

Key words: Marigold, calcium ammonium nitrate, sodium nitroprusside, hydrogels, growth analysis parameters, climate change.

INTRODUCTION

Marigold (*Tagetes erecta* L.) is a widely cultivated and admired plant known for its vibrant colors, aesthetic charm, and versatile medicinal properties. It holds a special place in horticulture due to its visual appeal, ease of cultivation, and its historical role in traditional medicine across diverse cultures. Marigold is rich in bioactive compounds, including flavonoids, carotenoids, and essential oils, which are valued for their antimicrobial, anti-inflammatory, and antioxidant properties, making it a valuable asset in traditional healing practices.

As the importance of marigold continues to grow, there is an increasing demand to optimize its growth and development to fully realize its horticultural potential. Achieving ideal growth analysis parameters such as Crop growth rate, Relative growth rate, Net assimilation rate and Specific leaf weight becomes crucial for producing captivating marigold specimens with commercial value. Moreover, fostering marigold's growth has the potential to enhance flower yield, expanding its applications in both ornamental and medicinal domains.

To boost marigold's growth and development under summer conditions, the use of hydrogels, which are hydrophilic polymeric materials capable of absorbing and retaining water and nutrients, holds great promise. These hydrogels are valuable in agriculture and horticulture as they enhance water availability, nutrient absorption, and plant resilience to drought conditions. They also create a favorable microenvironment around the roots, promoting root growth and overall plant vigor. Additionally, the incorporation of specific growth promoters such as calcium ammonium nitrate (CAN), a nitrogenous fertilizer, aids in essential nutrient provision, stimulates root and shoot growth, and strengthens the plant's ability to cope with environmental stresses. Sodium nitroprusside (SNP), another growth promoter, functions as a nitric oxide donor, influencing various physiological processes like seed germination, root development, flowering, and stress responses. By enhancing nitric oxide production, SNP improves nutrient uptake efficiency and modulates plant metabolism, leading to enhanced growth and increased stress tolerance.

With the potential benefits of hydrogels and plant growth promoters in mind, this study is designed to comprehensively assess their effects on various growth analysis parameters of marigold cv. 'Bidhan-2'. The specific objectives include evaluating the influence of hydrogel application, calcium ammonium nitrate (CAN) treatment, and sodium nitroprusside (SNP) treatment on Crop growth rate, Relative growth rate, Net assimilation rate and Specific leaf weight of marigold cv. 'Bidhan-2'. The findings of this research endeavor hold the promise of shedding light on optimal cultivation practices, thereby unlocking the full horticultural and medicinal potential of marigold, and consequently augmenting its commercial and therapeutic 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). The experiment was laid-out in f-Randomized Block Design with three replications. 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

Five plants were selected per 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). The treatment means were compared by using the least significant difference values calculated at 5 per cent level of significance during March to July 2020 and March to July.

RESULTS AND DISCUSSION

The data pertaining to growth analysis parameters was recorded in tables 1-4 and discussed in detail by using earlier reports published by various research workers on different crops.

1. **Crop growth rate (g m^{-2} day^{-1})**

Crop growth rate (CGR) in marigold cv. 'Bidhan-2' was influenced by different treatments, as shown in Table 1a&b. Significant differences in CGR were observed with individual treatments of hydrating agents and graded levels of calcium ammonium nitrate (CAN) throughout the study period, but not with sodium nitroprusside (SNP) or combination treatments. Between the two hydrating agents used, there were non-significant differences in CGR from 30-60 days after transplanting (DAT) in both years, but significant differences were noted from 60-90 DAT. Pusa hydrogel application showed the highest CGR (1.372, 1.411, and 1.392 g m^{-2} day^{-1}) in 2020, 2021 and the pooled data, while Zeba application had the lowest CGR (0.959, 0.981, and 0.970 g m^{-2} day^{-1}). Soil application of Pusa hydrogel mitigated heat stress by retaining moisture and providing a better root microenvironment, consistent with earlier research.

Among graded levels of CAN, non-significant differences in CGR were observed from 30-60 DAT in 2021 and the pooled data, but significant differences were seen in 2020. Soil application of 100% nitrogen in the form of CAN had the highest CGR (1.292 g m^{-2} day^{-1}) in 2020 and was on par with 75% nitrogen in the form of CAN, while 50% nitrogen in the form of CAN had the lowest CGR (0.961 g m^{-2} day^{-1}). Soil application of 75% nitrogen in the form of CAN was optimal, resulting in the highest CGR (1.394, 1.431 and 1.413 g m^{-2} day^{-1}) from 60-90 DAT in both years and the pooled data, on par with 100% nitrogen in the form of CAN.

Sodium nitroprusside and interaction effects did not yield significant differences in CGR during both study years and in the pooled data. The present result was found in line with the earlier findings of Danmaigoro *et al.* (2017), who reported increased CGR in rice by application of herbicide for weed (biotic) control.

2. **Relative growth rate (g g^{-1} day^{-1})**

The influence of hydrating agents, graded CAN levels, SNP sprays, and their interactions on the relative growth rate (RGR) of marigold cv. 'Bidhan-2' was examined (Table 2a&b). No significant differences were observed in RGR among different treatments, except for three combination treatments during the first year (2020) from 30-60 days after transplanting (DAT).

Among the interactions of hydrogels, CAN levels, and SNP spray intervals, significant differences in RGR were noted during 2020 from 30-60 DAT. The treatment combining Zeba soil application, 50% CAN, and SNP spraying at 7-day intervals had the highest RGR (0.0410 g g^{-1} day^{-1}), while Zeba soil application, 50% CAN, and SNP spraying at 14-day intervals had the lowest RGR (0.0394 g g^{-1} day^{-1}).

In summary, the overall data showed no significant differences among treatments in RGR. However, the combination of Zeba soil application, 50% CAN, and SNP spraying at 7-day intervals resulted in superior RGR during early vegetative growth, likely due to improved nutrient supply, stress alleviation, and enhanced moisture retention. On the other hand, the combination of Zeba soil application, 50% CAN, and SNP spraying at 14-day intervals had the lowest RGR, possibly due to Sub-optimal growth conditions during a critical vegetative growth phase. The interplay of hydrogel, nitrogen content, and SNP spray intervals played a complex role in affecting plant growth and development.

3. **Net assimilation rate (g m^{-2} day^{-1})**

The data concerning the impact of various hydrating agents, graded levels of calcium ammonium nitrate (CAN), sodium nitroprusside (SNP) sprays, and their interactions on the net assimilation rate (NAR) in marigold cv. 'Bidhan-2' is summarized in Table 3a&b. Notable variation in NAR was observed due to the application of different CAN levels during both study years and in the pooled data mean. Soil application of Zeba hydrogel exhibited significantly higher NAR at 0.00057 g m^{-2} day^{-1} in 2020 and 0.00056 g m^{-2} day^{-1} in the pooled data, particularly during the early stages of plant growth, primarily in the first year. In contrast, Pusa hydrogel showed a significantly lower NAR at 0.00044 g m^{-2} day^{-1} in 2020 and 0.00043 g m^{-2} day^{-1} in the pooled data within the 30-60 DAT period.

This indicates that Pusa hydrogel had a positive impact on the physiological processes responsible for assimilation and growth, leading to more efficient photosynthesis and carbon assimilation. In contrast, Zeba hydrogel had a lower NAR, suggesting less support for photosynthesis and carbon assimilation during the 30-60 DAT period, potentially resulting in reduced plant growth. The observed differences between the two hydrating agents may be attributed to their varying capabilities in terms of water retention, aeration, and nutrient holding in the root zone. However, these differences are relatively minor, contributing to non-significant variations in NAR, which aligns with previous research in rice by Danmaigoro et al. (2017).

Regarding the different levels of CAN, significant differences in NAR were noticed during both study years and in the pooled data. Soil application of 50% nitrogen in the form of CAN resulted in a significantly higher NAR in both the 30-60 DAT and 60-90 DAT intervals, with values of 0.00073 g m^{-2} day^{-1} and 0.00069 g m^{-2} day^{-1} in 2020 and 2021, and 0.00071 g m^{-2} day^{-1} in the pooled data. In contrast, soil application of 75% nitrogen in the form of CAN recorded the lowest NAR in both the 30-60 DAT and 60-90 DAT intervals, with values of 0.00037 g m^{-2} day^{-1} and 0.00035 g m^{-2} day^{-1} in 2020 and 2021, and 0.00036 g m^{-2} day^{-1} in the pooled data, and was on par with 100% nitrogen applied in the form of CAN during both study years and in the pooled data.

In conclusion, soil application of 50% nitrogen in the form of CAN was sufficient to stimulate physiological activities that increased NAR compared to higher doses of CAN. Higher doses of CAN did not have a positive influence on NAR and may have led to imbalanced physiological processes, reducing photosynthesis and growth rates. This highlights the importance of employing a balanced nutrient management approach in marigold cultivation, emphasizing the selection of the appropriate type and dose of nitrogen fertilizer to optimize growth, development, and overall productivity. Present result was found in line with the earlier findings of Danmaigoro *et al.* (2017) in rice and Noorjahan *et al*. (2018) in marigold.

4. **Specific leaf weight (g dry matter m^{-2} leaf)**

The data regarding the impact of hydrating agents, graded levels of calcium ammonium nitrate (CAN), and sodium nitroprusside (SNP) spray intervals on specific leaf weight (SLW) in marigold cv. 'Bidhan-2' is presented in Table 4a&b. Significant differences were observed due to the application of different hydrating agents, graded levels of CAN, and SNP spray intervals.

Among the two hydrating agents used, Zeba hydrogel resulted in significantly higher SLW. It recorded 42.86, 42.79 and 42.83 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. During 60-90 DAT, Zeba hydrogel showed 44.99, 45.91 and 45.45 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. In contrast, Pusa hydrogel displayed significantly lower SLW, with 35.35, 35.16 and 35.25 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In the 60-90 DAT period, it had 36.61, 36.94 and 36.80 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. This difference in SLW may be due to the mitigating effect of Zeba hydrogel on temperature stress in plants. These findings align with previous studies, such as Kolozsvari et al. (2020) and Karwa *et al*. (2020) which reported higher SLW in plants exposed to high-temperature stress but contradicts with Huang *et al*. (2020). However, it's worth noting that the relationship between SLW and temperature stress may vary among different plant species and genetic traits.

Significant differences were observed in SLW due to the graded levels of CAN. The application of 50% nitrogen in the form of CAN resulted in significantly higher SLW. It showed 55.62, 55.76 and 55.69 g dry matter m^{-2} leaf in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it recorded 58.46, 59.86 and 59.16 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. On the other hand, the application of 75% nitrogen in the form of CAN resulted in significantly lower SLW, with 30.40, 30.37 and 30.38 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it had 27.98, 28.27, and 28.13 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. Here, it's clear that lower doses of nitrogen (50% CAN) enhanced the accumulation of dry matter in leaves, resulting in higher SLW values. These findings support earlier research, like Posada et al. (2012), which indicated that SLW could be influenced by environmental factors such as solar radiation and temperature.

Significant differences in SLW were found between the two spray intervals of sodium nitroprusside (SNP). Foliar application of SNP at a 14-day interval led to significantly higher SLW, registering 42.34, 41.77 and 42.06 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it showed 41.74 g dry matter m^{-2} leaf in 2020 and 41.89 g dry matter m^{-2} leaf in the pooled data. In contrast, foliar application of SNP at a 7-day interval resulted in significantly lower SLW, with values of 35.87, 36.18 and 36.02 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it recorded 39.91 g dry matter m^{-2} leaf in 2020 and 40.36 g dry matter m^{-2} leaf in the pooled data. This demonstrates that the spray interval of SNP has a significant impact on SLW. A 14-day interval promoted better accumulation of carbohydrates and metabolites during leaf growth and development.

The interaction effects of different hydrating agents, graded levels of CAN, and spray intervals of SNP also played a significant role in SLW. Soil application of Zeba hydrogel, combined with 50% nitrogen in the form of CAN, resulted in the highest SLW, with 57.34, 58.08 and 57.71 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively in the pooled data during 30-60 DAT. In 60-90 DAT, it displayed 60.24, 62.37 and 61.30 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. Conversely, soil application of Pusa hydrogel with 75% nitrogen in the form of CAN led to significantly lower SLW, recording 23.18, 23.61 and 23.39 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it showed 16.49, 16.71 and 16.60 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. Soil application of 50% nitrogen in the form of CAN combined with a 14-day interval of SNP demonstrated significantly higher SLW. These results are consistent with the earlier findings of Posada et al. (2012) regarding the significant impact of different factors on SLW. Huang *et al.* (2020) noticed an increase in the SLW of rice with a reduction in the daily temperature/increase in daily solar radiation *i.e.*, under heat and temperature stress conditions.

The interaction effects between graded levels of CAN and SNP spray intervals showed that soil application of 50% nitrogen in the form of CAN combined with a 14-day interval of SNP resulted in significantly higher SLW. It registered 59.54, 58.53 and 59.03 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it displayed 62.54, 62.83 and 62.68 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. Conversely, soil application of 75% nitrogen in the form of CAN combined with a 7-day interval of SNP led to significantly lower SLW, with values of 26.20, 26.34 and 26.27 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively during 30-60 DAT. In 60-90 DAT, it recorded 27.74, 27.99 and 27.87 g dry matter m^{-2} leaf in 2020, 2021 in the pooled data mean respectively. Soil application of 50% nitrogen in the form of CAN combined with a 14-day interval of SNP exhibited the highest SLW, emphasizing the significance of these interactions in influencing SLW. These results underscore the importance of selecting the right combination of factors to optimize SLW during marigold cultivation.

Among the treatments, soil application of 50% nitrogen in the form of CAN and foliar application of SNP at 14 days interval in combination with either of the hydrogel recorded higher SLW in between 30-60 DAT as well as 60-90 DAT during both the years of study as well as in the pooled data mean, whereas soil application of 75% nitrogen in the form of CAN and foliar application of SNP at 7 days interval in combination with Pusa hydrogel recorded significantly lowest SLW (14.55, 15.27 and 14.91 g dry matter m^{-2} leaf respectively during 2020, 2021 and the pooled data mean) in between 30-60 DAT as well as 60-90 DAT, which was found at par with the soil application of 75% nitrogen in the form of CAN and foliar application of SNP at 14 days interval in combination with Pusa hydrogel. Based on the critical analysis of these results, it may be concluded that soil application of 50% nitrogen in the form of CAN and foliar application of SNP at 14 days interval in combination with either of the hydrogel recorded higher

SLW during both the years of study as well as in the pooled data mean. Soil application of 50% nitrogen in the form of CAN and foliar application of SNP at 14 days interval in combination with either of the hydrogel applied in soil might have created better microclimate around the plant cultivated during summer thus consistently recorded increased SLW of marigold during both the years of study as well as in the pooled data mean.

CONCLUSION

Based on these findings, a treatment that combines Pusa hydrogel for better flowering and Zeba hydrogel for enhanced early vegetative growth, with 50% nitrogen in the form of CAN, and a 7-day interval for SNP spraying, could be considered as a balanced choice for overall growth and performance during the increasing hot summer conditions year by year under Rayalaseema conditions in Andhra Pradesh.

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Table 1(a): Influence of hydrogels, CAN and SNP on crop growth rate (g m^{-2} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

CGR (g m^{-2} day^{-1}) from 30-60 DAT

Treatments	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	1.306	1.333	0.989	1.209	1.339	1.367	1.022	1.243	1.322	1.350	1.006	1.226
H_2	1.278	1.111	0.933	1.107	1.306	1.144	0.961	1.137	1.292	1.128	0.947	1.122
Mean	1.292	1.222	0.961		1.322	1.256	0.992		1.307	1.239	0.976	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	1.241	1.178	1.209	1.274	1.211	1.243	1.257	1.194	1.226
H_2	1.141	1.074	1.107	1.170	1.104	1.137	1.156	1.089	1.122
Mean	1.191	1.126		1.222	1.157		1.206	1.142	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	1.294	1.272	1.006	1.191	1.322	1.306	1.039	1.222	1.308	1.289	1.022	1.206
S_2	1.289	1.172	0.917	1.126	1.322	1.206	0.944	1.157	1.306	1.189	0.931	1.142
Mean	1.292	1.222	0.961		1.322	1.256	0.992		1.307	1.239	0.976	

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	1.322	1.289	1.378	1.289	1.022	0.956	1.356	1.322	1.411	1.322	1.056	0.989	1.339	1.306	1.394	1.306	1.039	0.972
H_2	1.267	1.289	1.167	1.056	0.989	0.878	1.289	1.322	1.200	1.089	1.022	0.900	1.278	1.306	1.183	1.072	1.006	0.889

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.060	NS	0.109	NS	0.084	NS
N	0.074	0.216	0.133	NS	0.103	NS
S	0.104	NS	0.109	NS	0.084	NS
H x N	0.060	NS	0.189	NS	0.145	NS
H x S	0.085	NS	0.154	NS	0.119	NS
S x N	0.104	NS	0.189	NS	0.145	NS
H x N x S	0.147	NS	0.267	NS	0.205	NS

Table 1(b): Influence of hydrogels, CAN and SNP on crop growth rate (g m^{-2} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	CGR (g m^{-2} day^{-1}) from 60-90 DAT											
	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	1.439	1.800	0.878	1.372	1.478	1.850	0.906	1.411	1.458	1.825	0.892	1.392
H_2	1.133	0.989	0.756	0.959	1.161	1.011	0.772	0.981	1.147	1.000	0.764	0.970
Mean	1.286	1.394	0.817		1.319	1.431	0.839		1.303	1.413	0.828	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	1.526	1.219	1.372	1.570	1.252	1.411	1.548	1.235	1.392
H_2	1.022	0.896	0.959	1.044	0.919	0.981	1.033	0.907	0.970
Mean	1.274	1.057		1.307	1.085		1.291	1.071	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	1.350	1.589	0.883	1.274	1.383	1.633	0.906	1.307	1.367	1.611	0.894	1.291
S_2	1.222	1.200	0.750	1.057	1.256	1.228	0.772	1.085	1.239	1.214	0.761	1.071
Mean	1.286	1.394	0.817		1.319	1.431	0.839		1.303	1.413	0.828	

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	1.478	1.400	2.156	1.444	0.944	0.811	1.511	1.444	2.222	1.478	0.978	0.833	1.494	1.422	2.189	1.461	0.961	0.822
H_2	1.222	1.044	1.022	0.956	0.822	0.689	1.256	1.067	1.044	0.978	0.833	0.711	1.239	1.056	1.033	0.967	0.828	0.700

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.090	0.263	0.094	0.274	0.092	0.268
N	0.110	0.322	0.115	0.336	0.112	0.329
S	0.155	NS	0.094	NS	0.092	NS
H x N	0.090	NS	0.162	NS	0.159	NS
H x S	0.127	NS	0.132	NS	0.129	NS
S x N	0.155	NS	0.162	NS	0.159	NS
H x N x S	0.219	NS	0.229	NS	0.224	NS

Table 2(a): Influence of hydrogels, CAN and SNP on relative growth rate (g g^{-1} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

RGR (g g^{-1} day^{-1}) from 30-60 DAT

Treatments	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	0.0403	0.0401	0.0400	0.0401	0.0385	0.0382	0.0390	0.0386	0.0394	0.0392	0.0395	0.0394
H_2	0.0398	0.0404	0.0402	0.0401	0.0379	0.0388	0.0386	0.0384	0.0389	0.0396	0.0394	0.0393
Mean	0.0401	0.0402	0.0401		0.0382	0.0385	0.0388		0.0392	0.0394	0.0394	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	0.0402	0.0401	0.0401	0.0386	0.0385	0.0386	0.0394	0.0393	0.0394
H_2	0.0402	0.0400	0.0401	0.0384	0.0385	0.0384	0.0393	0.0393	0.0393
Mean	0.0402	0.0400		0.0385	0.0385		0.0394	0.0393	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	0.0401	0.0402	0.0404	0.0402	0.0380	0.0384	0.0392	0.0385	0.0390	0.0393	0.0398	0.0394
S_2	0.0401	0.0403	0.0398	0.0400	0.0385	0.0386	0.0385	0.0385	0.0393	0.0394	0.0391	0.0393
Mean	0.0401	0.0402	0.0401		0.0382	0.0385	0.0388		0.0392	0.0394	0.0394	

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	0.0406	0.0401	0.0403	0.0400	0.0398	0.0401	0.0386	0.0385	0.0385	0.0380	0.0389	0.0391	0.0396	0.0393	0.0394	0.0391	0.0393	0.0396
H_2	0.0396	0.0401	0.0401	0.0406	0.0410	0.0394	0.0374	0.0385	0.0384	0.0391	0.0394	0.0378	0.0385	0.0393	0.0393	0.0399	0.0402	0.0386

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.0001	NS	0.0031	NS	0.0015	NS
N	0.0002	NS	0.0038	NS	0.0019	NS
S	0.0001	NS	0.0031	NS	0.0015	NS
H x N	0.0002	NS	0.0054	NS	0.0027	NS
H x S	0.0002	NS	0.0044	NS	0.0022	NS
S x N	0.0002	NS	0.0054	NS	0.0027	NS
H x N x S	0.0003	0.00099	0.0077	NS	0.0038	NS

Table 2(b): Influence of hydrogels, CAN and SNP on relative growth rate (g g^{-1} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	RGR (g g^{-1} day^{-1}) from 60-90 DAT											
	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	0.0193	0.0228	0.0160	0.0194	0.0190	0.0224	0.0158	0.0191	0.0192	0.0226	0.0159	0.0192
H_2	0.0163	0.0163	0.0162	0.0163	0.0160	0.0160	0.0158	0.0159	0.0161	0.0162	0.0160	0.0161
Mean	0.0178	0.0196	0.0161		0.0175	0.0192	0.0158		0.0177	0.0194	0.0160	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	0.0208	0.0180	0.0194	0.0205	0.0177	0.0191	0.0206	0.0178	0.0192
H_2	0.0166	0.0159	0.0163	0.0162	0.0157	0.0159	0.0164	0.0158	0.0161
Mean	0.0187	0.0170		0.0183	0.0167		0.0185	0.0168	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	0.0182	0.0213	0.0165	0.0187	0.0179	0.0209	0.0162	0.0183	0.0181	0.0211	0.0163	0.0185
S_2	0.0174	0.0178	0.0157	0.0167	0.0171	0.0174	0.0155	0.0167	0.0172	0.0176	0.0156	0.0168
Mean	0.0178	0.0196	0.0161		0.0175	0.0192	0.0158		0.0177	0.0194	0.0160	

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	0.0193	0.0193	0.0264	0.0192	0.0166	0.0155	0.0189	0.0191	0.0260	0.0188	0.0165	0.0152	0.0191	0.0192	0.0262	0.0190	0.0165	0.0154
H_2	0.0172	0.0154	0.0162	0.0165	0.0164	0.0160	0.0169	0.0151	0.0158	0.0161	0.0159	0.0158	0.0170	0.0153	0.0160	0.0163	0.0161	0.0159

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.0018	NS	0.0018	NS	0.0018	NS
N	0.0022	NS	0.0022	NS	0.0022	NS
S	0.0018	NS	0.0018	NS	0.0018	NS
H x N	0.0031	NS	0.0031	NS	0.0031	NS
H x S	0.0026	NS	0.0026	NS	0.0026	NS
S x N	0.0031	NS	0.0031	NS	0.0031	NS
H x N x S	0.0044	NS	0.0044	NS	0.0044	NS

Table 3(a): Influence of hydrogels, CAN and SNP on net assimilation rate (g m^{-2} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	NAR (g m^{-2} day^{-1}) from 30-60 DAT											
	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	0.00037	0.00025	0.00069	0.00044	0.00035	0.00024	0.00066	0.00042	0.00036	0.00025	0.00068	0.00043
H_2	0.00046	0.00049	0.00076	0.00057	0.00044	0.00047	0.00073	0.00055	0.00045	0.00048	0.00075	0.00056
Mean	0.00042	0.00037	0.00073		0.00040	0.00035	0.00069		0.00041	0.00036	0.00071	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	0.00038	0.00050	0.00044	0.00036	0.00047	0.00042	0.00037	0.00048	0.00043
H_2	0.00055	0.00060	0.00057	0.00052	0.00057	0.00055	0.00053	0.00058	0.00056
Mean	0.00047	0.00055		0.00044	0.00052		0.00045	0.00053	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	0.00038	0.00033	0.00069	0.00047	0.00036	0.00031	0.00066	0.00044	0.00037	0.00032	0.00067	0.00045
S_2	0.00046	0.00042	0.00077	0.00055	0.00044	0.00040	0.00073	0.00052	0.00045	0.00041	0.00075	0.00053
Mean	0.00042	0.00037	0.00073		0.00040	0.00035	0.00069		0.00041	0.00036	0.00071	

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	0.00034	0.00040	0.00017	0.00034	0.00064	0.00074	0.00032	0.00038	0.00016	0.00032	0.00061	0.00071	0.00033	0.00039	0.00016	0.00033	0.00063	0.00073
H_2	0.00042	0.00051	0.00049	0.00049	0.00073	0.00080	0.00040	0.00049	0.00047	0.00047	0.00070	0.00075	0.00041	0.00050	0.00048	0.00048	0.00072	0.00077

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.00003	0.00008	0.00005	NS	0.00004	0.00011
N	0.00004	0.00010	0.00006	0.00017	0.00005	0.00014
S	0.00003	NS	0.00005	NS	0.00004	NS
H x N	0.00005	NS	0.00008	NS	0.00007	NS
H x S	0.00004	NS	0.00007	NS	0.00005	NS
S x N	0.00005	NS	0.00008	NS	0.00007	NS
H x N x S	0.00007	NS	0.00012	NS	0.00009	NS

Table 3(b): Influence of hydrogels, CAN and SNP on net assimilation rate (g m^{-2} day^{-1}) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

NAR (g m^{-2} day^{-1}) from 60-90 DAT

Treatments	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	0.00017	0.00012	0.00025	0.00018	0.00016	0.00011	0.00023	0.00017	0.00017	0.00011	0.00024	0.00017
H_2	0.00016	0.00018	0.00025	0.00020	0.00015	0.00016	0.00023	0.00018	0.00016	0.00017	0.00024	0.00019
Mean	0.00017	0.00015	0.00025		0.00016	0.00014	0.00023		0.00016	0.00014	0.00024	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	0.00017	0.00018	0.00018	0.00016	0.00017	0.00017	0.00017	0.00018	0.00017
H_2	0.00019	0.00020	0.00020	0.00018	0.00019	0.00018	0.00019	0.00019	0.00019
Mean	0.00018	0.00019		0.00017	0.00018		0.00018	0.00019	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	0.00017	0.00014	0.00024	0.00018	0.00016	0.00013	0.00022	0.00017	0.00016	0.00014	0.00023	0.00018
S_2	0.00017	0.00015	0.00026	0.00019	0.00016	0.00014	0.00024	0.00018	0.00016	0.00015	0.00025	0.00019
Mean	0.00017	0.00015	0.00025		0.00016	0.00014	0.00023		0.00016	0.00014	0.00024	

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	0.00017	0.00017	0.00011	0.00012	0.00024	0.00026	0.00016	0.00016	0.00010	0.00011	0.00022	0.00024	0.00016	0.00017	0.00011	0.00012	0.00023	0.00025
H_2	0.00016	0.00016	0.00018	0.00018	0.00024	0.00026	0.00015	0.00015	0.00016	0.00017	0.00022	0.00024	0.00016	0.00016	0.00017	0.00017	0.00023	0.00025

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.00002	NS	0.00002	NS	0.00002	NS
N	0.00002	0.00007	0.00002	0.00006	0.00002	0.00007
S	0.00002	NS	0.00002	NS	0.00002	NS
H x N	0.00003	NS	0.00003	NS	0.00003	NS
H x S	0.00003	NS	0.00003	NS	0.00003	NS
S x N	0.00003	NS	0.00003	NS	0.00003	NS
H x N x S	0.00005	NS	0.00004	NS	0.00005	NS

Table 4(a): Influence of hydrogels, CAN and SNP on SLW (g dry matter m^{-2} leaf) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Treatments	Specific leaf weight (g dry matter m^{-2} leaf) from 30-60 DAT											
	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	28.98	23.18	53.89	35.35	28.43	23.61	53.44	35.16	28.70	23.39	53.67	35.25
H_2	33.61	37.63	57.34	42.86	33.16	37.13	58.08	42.79	33.39	37.38	57.71	42.83
Mean	31.30	30.40	55.62		30.80	30.37	55.76		31.05	30.38	55.69	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	30.57	40.13	35.35	30.94	39.37	35.16	30.76	39.75	35.25
H_2	41.17	44.55	42.86	41.41	44.18	42.79	41.29	44.37	42.83
Mean	35.87	42.34		36.18	41.77		36.02	42.06	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	29.72	26.20	51.69	35.87	29.19	26.34	52.99	36.18	29.46	26.27	52.34	36.02
S_2	32.87	34.61	59.54	42.34	32.40	34.39	58.53	41.77	32.64	34.50	59.03	42.06
Mean	31.30	30.40	55.62		30.80	30.37	55.76		31.05	30.38	55.69	

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	28.03	29.92	14.55	31.80	49.13	58.66	27.34	29.52	15.27	31.95	50.22	56.65	27.69	29.72	14.91	31.87	49.68	57.65
H_2	31.41	35.82	37.84	37.42	54.26	60.43	31.04	35.29	37.42	36.84	55.77	60.40	31.22	35.55	37.63	37.13	55.01	60.41

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.405	1.188	0.475	1.392	0.404	1.184
N	0.496	1.455	0.581	1.705	0.494	1.450
S	0.405	1.188	0.475	1.392	0.404	1.184
H x N	0.701	2.057	0.822	2.411	0.699	2.051
H x S	0.573	1.680	0.671	1.969	0.571	1.674
S x N	0.701	2.057	0.822	2.411	0.699	2.051
H x N x S	0.992	2.909	1.163	3.410	0.989	2.900

Table 4(b): Influence of hydrogels, CAN and SNP on SLW (g dry matter m^{-2} leaf) in marigold (*Tagetus erecta* L.) cv. 'Bidhan-2'

Specific leaf weight (g dry matter m^{-2} leaf) from 60-90 DAT

Treatments	First year (2019-20)				Second year (2020-21)				Pooled data analysis			
	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
H_1	36.82	16.49	56.68	36.61	36.76	16.71	57.36	36.94	36.79	16.60	57.02	36.80
H_2	35.26	39.47	60.24	44.99	35.53	39.83	62.37	45.91	35.39	39.65	61.30	45.45
Mean	36.04	27.98	58.46		36.14	28.27	59.86		36.09	28.13	59.16	

Treatments	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
H_1	36.53	36.80	36.66	37.26	36.62	36.94	36.89	36.71	36.80
H_2	43.29	46.69	44.99	44.39	47.43	45.91	43.84	47.06	45.45
Mean	39.91	41.74		40.82	42.03		40.36	41.89	

Treatments	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean	N_1	N_2	N_3	Mean
S_1	37.60	27.74	54.38	39.91	37.58	27.99	56.90	40.82	37.59	27.87	55.64	40.36
S_2	34.48	28.22	62.54	41.74	34.71	28.55	62.83	42.03	34.59	28.38	62.68	41.89
Mean	36.04	27.98	58.46		36.14	28.27	59.86		36.09	28.13	59.16	

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	42.25	31.38	15.79	17.19	51.54	61.82	41.96	31.56	15.87	17.55	53.94	60.77	42.11	31.47	15.83	17.37	52.74	61.29
H_2	32.95	37.57	39.70	39.24	57.22	63.26	33.19	37.86	40.11	39.55	59.86	64.88	33.07	37.72	39.91	39.40	58.54	64.07

Source	SEm±	CD @ 5%	SEm±	CD @ 5%	SEm±	CD @ 5%
H	0.350	1.026	0.523	1.535	0.398	1.168
N	0.429	1.257	0.641	1.880	0.488	1.430
S	0.350	1.026	0.523	NS	0.398	1.168
H x N	0.606	1.778	0.907	2.659	0.690	2.023
H x S	0.495	1.451	0.740	2.171	0.563	1.651
S x N	0.606	1.778	0.907	2.659	0.690	2.023
H x N x S	0.857	2.514	1.282	3.760	0.975	2.860

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