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Efficacy of Different Levels of Hydrogel and Crop Geometric Strategies in Overcoming the Pessimistic Effect of Abiotic Stress on Growth and Yield Attributes of Spring Maize (*Zea mays* L.)

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ABSTRACT

Background: Climate change is a major issue across the globe. The erratic weather conditions fluctuate to create uncertain and stressful abiotic conditions. With escalating abiotic stress analogous to the decline in freshwater accessibility and soil properties, global food security is at stake.

Methods: The experiment was implemented in the spring seasons of 2022 and 2023 to assess the impact of different levels of hydrogel and crop geometric strategies on the growth and yield attributes of spring maize. The field trial was executed in split-plot design with three levels of hydrogel *i.e.*, 0 (@ 0 kg/ha), 50% (@ 1.5 kg/ha) and 100% (@ 3 kg/ha); four crop geometric strategies *i.e.*, normal spacing (70 × 25 cm); paired-row spacing (55-85 × 25 cm); normal spacing with seed capsule (70 × 25 cm) and paired-row spacing with seed capsule (55-85 × 25 cm). Here we correlate the outcomes with the factors in incapacitating the pessimistic effects of abiotic stress on spring maize.

Result: The results revealed that the attributes were significantly affected by the employment of the combination hydrogel @ 3 kg/ha + paired-row spacing with seed capsule at (55-85 × 25 cm) which was also found effective in overcoming the abiotic stress. There was a significant enhancement of growth attributes as well as grain yield by 28.1% and 29.3%; stover yield by 24.4% and 19.9% compared to control in 2022 and 2023 respectively.

Key words: Abiotic stress, Crop geometry, Growth, Hydrogel, Seed capsule.

INTRODUCTION

Maize is a multifaceted crop that is under cultivation globally with a high range of adaptability to climatic conditions which accounts for 40% of worldwide grain production (Anonymous, 2022). Currently, the world is transforming at a rapid pace with an upsurge in the population and urbanization analogous to climate change. Global agriculture is impacted by climate change raising the hunger threat, water paucity with diminishing freshwater resources to the arable lands [Intergovernmental Panel on Climate Change (IPCC, 2007)]. Food production need to be raised by 70% without creating a burden on the ecosystem with the estimated escalation of the population of 9 billion by 2050 (Hunter *et al.,* 2017).

Plants live in intrinsically severe environmental conditions right from their emergence. Many factors including low to high temperatures, uncertainty in rainfall, ultraviolet (UV) radiation and salinity issues are denoted as abiotic stresses posing a menace to agriculture. With abiotic stress as the foremost yield-constraining aspect, the crop productivity increase should be achievable with inconsistent erratic situations. Globally, 90% of the cultivable land is prone to more than one of the aforesaid stresses. The amalgamation of the climate change and crop yield models has projected a further decline in crop productivity of the major food grain crops (Tigchelaar *et al.,* 2018). Due to their static nature, plants must resist stress to survive and thrive with potent versatile tactics to tolerate or prevent the pessimistic effects of stress. Spring season is followed by the summer with peak temperature in majority of the regions worldwide which makes the spring season crops more vulnerable to abiotic stress mainly drought (Joshi, 2023). The adaptation by plants to stress is not an instant solution but a process that is progressive with time. The employment of agronomic measures like the hydrogel and crop geometric strategies can be effective in drought stress prevention.

Hydrogel is a synthetic, hydrophilic and biodegradable polymer. It absorbs large quantity of water from the soil when water is available in the form of rainfall or irrigation (Schacht, 2004). Hydrogel is made of cellulose and cation-charged potassium polyacrylate-based super-absorbent polymer. During the water discharging stage, these hydrogel forms a

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free pore volume in the soil which enables proper root growth. Water remains in the root zone, ceasing nutrient leaching and deep percolation (Kishor *et al.,* 2023). To ensure proper crop production in arid regions, maintaining adequate soil moisture at the vital growth stages is very crucial. Adequate soil moisture fortifies the crop during dry spells, thereby enhancing the production (Ramulu and Reddy, 2023). The water stress impacts the crop irrespective of its developmental stage and is furthermore dreadful in the critical growth stages of the crop (Nivethitha *et al.,* 2024). The upsurge of the water use efficiency to effective water resources utilization and increasing the morphology and yield attributes of various crops. The yield potential of a crop can be appropriately achieved with the effective employment of agronomic practices, nutrient management and by adopting appropriate crop geometry.

The paired-row spacing is a spacing pattern devoid of plant population loss, in which two adjacent rows are brought nearer to make a pair further increasing the distance between two pairs by maintaining the same plant-plant spacing. The concept of the seed capsule is in the early stage of research with negligible execution by farmers. The seed capsule is prepared by filling the gelatin capsule of size- 00 with the seed of a crop, humic acid, neem powder and IFFCO NPK biofertilizer consortia comprised of Azotobacter, Rhizobium, Phosphate solubilizing bacteria (PSB) and Potash solubilizing bacteria (KSB) at 2 kg/ha with every ingredient having their independent role for the betterment of the crop. Capsules are made from plant-based gelatin, they are easily soluble and act as a biostimulant to the crop. Neem powder acts as a bioprotectant. Biofertilizers enhance the harvesting of nutrients by mobilizing them in the soil (Ammar *et al.,* 2023). Humic acid enhances soil nutrient mobilization and accessibility to the plant. There are no such studies that have comprehensively assessed the combination of the hydrogel, crop geometry and seed capsule in mitigating the abiotic stress. Considering the aforementioned facts the current study was executed with an objective to know the comprehensive impact of irrigation and crop geometric strategies in overcoming the pessimistic effect of abiotic stress on the growth and yield attributes of spring maize (*Zea mays* L.).

MATERIALS AND METHODS

Experimental site and factor description

The experimental field trial was executed at research farm, Lovely Professional University, Punjab, India during the spring season of the year 2022 and 2023. The experimental soil was sandy loam in texture. The soil was slightly alkaline (7.95 pH), with a normal range of electrical conductivity (0.135 d/Sm), low in available nitrogen (207.98 kg/ha), high in phosphorus (23.80 kg/ha) and moderate in potassium (166.37 kg/ha). The research trial was carried out in a split plot design with three main plots and four sub-plots replicated thrice. The treatment combinations formulated are mentioned in the Table 1.

Experimental trial implementation

The field was thoroughly ploughed with a cultivator followed by planking. Firstly, the field was divided into three replications. Each replication was divided into 3 main plots which were further divided into four sub-plots with a net plot size of 25 m^2. Variety PMH-10 was selected for the experiment. The recommended dose of N: P: K (120: 60: 40 kg/ha) was applied during the trial in the form of urea, single super phosphate (SSP) and muriate of potash (MOP). Half of the recommended dose of N and the full dose of P and K were applied as the basal dose. Whereas, the rest

Table 1: Description of the experimental factors and treatment combination.

		Experimental factors
Main plots		Sub-plots
H1:	Control (@ 0 kg/ha)	C1: Normal spacing (70 × 25 cm)
H2:	50% hydrogel (@ 1.5 kg/ha)	C2: Paired-row spacing (55-85 × 25 cm)
H3:	100 % hydrogel (@ 3 kg/ha)	C3: Normal spacing with the seed capsule (70 × 25 cm)
		C4: Paired-row spacing with the seed capsule (55-85 × 25 cm)
		Treatment combination
H1C1	T_1	Hydrogel @ 0 kg/ha + Normal spacing (70 × 25 cm)
H1C2	T_2	Hydrogel @ 0 kg/ha + Paired row spacing (55-85 × 25 cm)
H1C3	T_3	Hydrogel @ 0 kg/ha + Normal spacing (70 × 25 cm) with the seed capsule
H1C4	T_4	Hydrogel @ 0 kg/ha + Paired row spacing (55-85 × 25 cm) with the seed capsule
H2C1	T_5	Hydrogel @ 1.5 kg/ha + Normal spacing (70 × 25 cm)
H2C2	T_6	Hydrogel @ 1.5 kg/ha + Paired row spacing (55-85 × 25 cm)
H2C3	T_7	Hydrogel @ 1.5 kg/ha + Normal spacing (70 × 25 cm) with the seed capsule
H2C4	T_8	Hydrogel @ 1.5 kg/ha + Paired row spacing (55-85 × 25 cm) with the seed capsule
H3C1	T_9	Hydrogel @ 3 kg/ha + Normal spacing (70 × 25 cm)
H3C2	T_{10}	Hydrogel @ 3 kg/ha + Paired row spacing (55-85 × 25 cm)
H3C3	T_{11}	Hydrogel @ 3 kg/ha + Normal spacing (70 × 25 cm) with the seed capsule
H3C4	T_{12}	Hydrogel @ 3 kg/ha + Paired row spacing (55-85 × 25 cm) with the seed capsule

half of N was applied in 3 split doses at 45, 60 and 75 DAS respectively. The recommended doses of hydrogel 0, 1.5 and 3 kg/ha were mixed with the dry soil at the (1:10) ratio before the sowing. Subsequently broadcasted in the required plots and was thoroughly raked for uniform distribution in the plots. The sowing was done as per the crop geometric strategies.

Weather

It is an important aspect that influences the crop during the cropping season. The weather variables like maximum and minimum temperature (°C), total weekly rainfall (mm) and rainy days per week were recorded. The fluctuating and varied weather conditions were observed throughout the cropping seasons of both years. The prevailing weather conditions during cropping seasons of the experiment in the years 2022 and 2023 are depicted in Fig 1.

Data collection

Three plants were selected from the centre of each plot and tagged with labels for recording the various observations on the growth attributes like plant height (cm), no. of leaves and stem girth (cm) periodically at 25, 50 and 75 days after sowing (DAS). The yield attributes like grain yield (t/ha), stover yield (t/ha) and harvest index (%) was recorded at harvest as per the standard protocols and represented for both years separately.

Statistical analysis

The recorded data was subjected to analysis of variance (ANOVA) as per the standard procedures by using R studio statistical computing software. The treatments were equated by Duncan's multiple range test (DMRT) at a 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth attributes

Growth attributes at 25 DAS

The effect of hydrogel levels and crop geometric strategies were varied in both years. 100% hydrogel (@ 3 kg/ha) and paired-row spacing with the seed capsule (55-85 × 25 cm) have obtained superior growth attributes. There has been a positive significant influence on the plant height and stem girth, whereas a non-significant impact on the leaf counts with the integration of the hydrogel and crop geometric strategies in 2022. Significantly higher plant height of 15.43 and 22.61 cm was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2022 and 2023 respectively. Maximum no. of leaves of 7.88 and 8.56 were obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2022 and 2023 respectively. Whereas in 2022, the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) has shared the parity with the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule. A wider stem girth of 3.39 and 3.69 cm was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2022 and 2023 respectively. However, the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule shared the statistical parity with the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule (Fig 2).

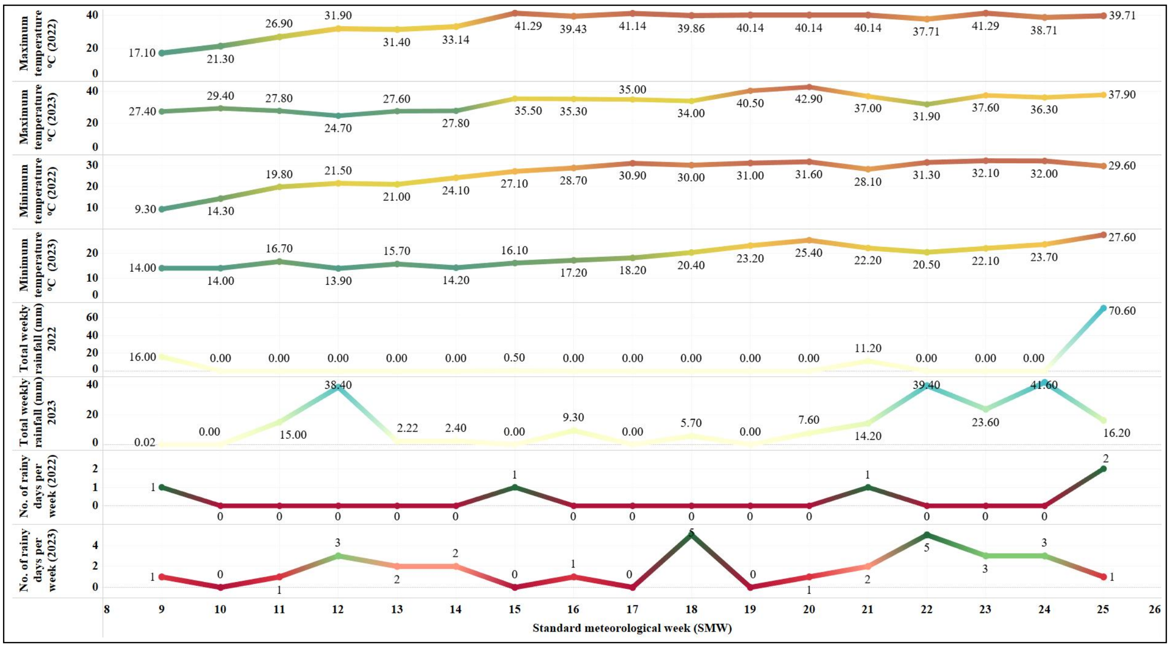

Fig 1: Prevailed weather conditions during the cropping seasons of 2022 and 2023.

The weather varied a lot during the initial cropping period in both years. In 2022, the maximum AWT of 17°C was recorded. The unfavourable conditions have delayed maize germination. The low-temperature extremes weaken the seedling and growth by affecting the photosynthetic activity and also make the plant deficient in macronutrients by restrictive metabolite transport (Liu *et al.,* 2016). The cooler temperature during the early vegetative stage might have antagonistically influenced the growth initially (Sindhu *et al.,* 2024). The sudden rise in the temperature in 12th SMW in 2022 and null rainfall resulted in heat stress that might have affected the growth attributes. In contrast, the 2023 weather was much more favourable for germination and an optimal temperature with a good amount of rainfall might have helped the crop in stress prevention and ample growth at 25 DAS. The growth attributes increased with the increase in the hydrogel dose. The humic acid and hydrogel could have properly maintained the soil moisture for the crop at the seedling stage and perhaps safeguarded the crop from abiotic stress (Albalasmeh *et al.,* 2022). The properties of neem powder might have shielded the seedlings at the early stages by repelling insects and averting their development by providing natural fumigation (Adusei and Azupio, 2022).

Growth attributes at 50 DAS

The hydrogel and crop geometric strategies have differed significantly. The superior growth attributes were obtained by 100% hydrogel (@ 3 kg/ha) and paired-row spacing with the seed capsule (55-85 × 25 cm) The interaction of both factors was significant on the plant height and stem girth in both years, whereas non-significant on the no. of leaves in 2022. In 2022 and 2023, significantly higher plant height of 67.56 and 82.94 cm; no. of leaves 10.44 and 11.22 respectively were obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule. In 2022, a significantly wider stem girth of 5.93 cm was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule and in 2023 the same treatment resulted in a wider stem girth of 6.94 cm while the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule was found statistically at par with the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule. However, hydrogel @ 0 kg/ha + normal spacing (70 × 25 cm) obtained the lowest growth attributes (Fig 3).

This is one of the crucial growth stages as maize has a slow growth habit in the early stages. In 2022, the maximum AWT was more than 40°C and at least 5°C of temperature difference was recorded during 2022-23. As the optimal temperature requirement for the maize growth is 25-33°C, further temperature increase affects growth. In both years, there has been a sudden upsurge in maximum AWT up to 8°C between the 14th and 15th SMW. In 2022, there was an increase of 8°C than the optimal requirement but in 2023 there was only a 2°C increase, thus heat stress affecting the growth was more in 2022 than in 2023. Similarly, more rainy days (5) in 2023 with only one between 25-50 DAS in 2022 might be one of the reasons for the growth difference in the two years. Maize leaf growth rises at temperatures ranging from 10-35°C, with an increase above 35°C causing a decline in leaf growth (Hussain *et al.,* 2006). This might have resulted in less leaf count in 2022 and also in the case of control. Growth attributes have shown substantial betterment with the hydrogel application, this might be due to the continuous supply of moisture and nutrients to plants

Fig 2: Impact of different hydrogel levels and crop geometric strategies on growth attributes of spring maize at 25 DAS in years 2022 and 2023.

during peak heat stress (Salem *et al.,* 2023). Enhanced accessibility of macronutrients and production of growth-promoting phytohormones with the application of biofertilizers perhaps enhanced growth attributes (Singh *et al.,* 2023). The various rhizosphere microbes have been reported to produce auxin, a plant growth-promoting hormone that might have enhanced root growth. Subsequently, better moisture availability and nutrient uptake by plants perhaps positively influenced the auxin production in plants which could have enhanced cell division and elongation eventually the growth attributes (Bradacova *et al.,* 2020; Park *et al.,* 2021). The co-adjuvant integration of both factors might have prevented stress, competition, enhanced macro nutrient accessibility, attributed to rapid cell division and enlargement. Thus, a progressive repercussion of growth attributes (Kumar *et al.,* 2022).

Growth attributes at 75 DAS

The levels of the hydrogel as well as crop geometric strategies, have varied effects. In both factors, better attributes were recorded with 100% hydrogel (@ 3 kg/ha) and paired-row spacing with the seed capsule (55-85 × 25 cm). The interaction of the hydrogel and crop geometric strategies has shown pragmatic efficacy in the amplification of the growth attributes. Significantly higher plant height of 134.04 and 163.73 cm; wider stem girth of 8.12 and 8.87 cm was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2022 and 2023 respectively. The highest leaf number of 16.10 and 16.56 was recorded in 2022 and 2023 by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule respectively. In 2022, the treatments hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) and hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule shared parity whereas hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule was found statistically at par with the hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2023. The lowest growth attributes were recorded with the treatment hydrogel @ 0 kg/ha + normal spacing (70 × 25 cm) (Fig 4).

The 75 DAS is a critical stage where the crop transforms from the vegetative to the reproductive stage. In 2022, the constant maximum and minimum AWT of more than 40°C and 30°C were recorded from the 15th SMW. Whereas in 2023, a sharp rise in temperature from 34°C to 40.5°C was observed between the 18th and 19th SMW. The maximum AWT of 42.9°C was recorded in the 20th SMW, which was the highest in both years but the temperature has dropped down to below 40°C from the 21st SMW. However, the minimum AWT was constantly less than 25°C. With more heat wave effect in 2022, the crop has confronted severe stressful situations when compared to 2023. Despite inconsistent rainfall in 2023 during 50-75 DAS, the rainfall received was adequate for the crop needs. But in the case of 2022, the absence of rainfall has created far more stressful conditions for the crop by impacting the plant-water relations. Application of hydrogel and seed capsule with humic acid and biofertilizer could have ascribed to an uninterrupted supply of moisture and nutrients might have ascribed to enhanced cell division and elongation which resulted in superior growth attributes (Thejesh *et al.,* 2020; Balasubramanian *et al.,* 2023). With 75 DAS, more prone

Fig 3: Impact of different hydrogel levels and crop geometric strategies on growth attributes of spring maize at 50 DAS in years 2022 and 2023.

to water as well as nutrient stresses and the active growing stages of the crop the wider crop geometry perhaps enabled better light interception, photosynthetic activity, nutrient uptake, moisture availability and reduction of competition and stress thereby promoting the growth attributes (Salem *et al.,* 2023).

Yield attributes

Grain yield (t/ha)

The application of hydrogel was effective in the improvement of the grain yield. In both years, the hydrogel levels differed significantly and higher grain yield was recorded by 100% hydrogel (@ 3 kg/ha). An increase in grain yield of 19.6% and 12.10% over control was recorded in 2022 and 2023 respectively. In crop geometric strategies, a higher grain yield was obtained by paired-row spacing with the seed capsule (55-85 × 25 cm). An increase in grain yield of 12.1% and 9.2% was recorded over normal spacing (70 × 25 cm) in 2022 and 2023 respectively. However, in 2022 normal spacing with the seed capsule (70 × 25 cm) and paired-row spacing (55-85 × 25 cm) were found statistically at par with each other. There was a pragmatic interactive effect of both factors in the augmentation of grain yield as shown in Fig 5. An increase in the grain yield of 28.1% and 29.3% in 2022 and 2023 respectively were obtained. In the year 2022, the maximum grain yield of 9.35 t/ha was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule and the minimum of 6.72 t/ha was obtained by hydrogel @ 0 kg/ha + normal spacing (70 × 25 cm). However, the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule shared statistical parity with the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule. In 2023, a significantly higher grain yield of 10.46 t/ha was recorded by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule and a lower grain yield of 7.39 t/ha was recorded by hydrogel @ 0 kg/ha + normal spacing (70 × 25 cm).

Grain yield is a vital attribute as it defines the potential of a crop. In 2022, the abiotic stress due to high temperatures and rainfall scarcity drastically affected the grain yield under control. The persistent temperature of more than 36°C has shown its stressful impact on the reproductive stages. The control treatment resulted in a loss of grain yield by 28% over the best treatment. The forfeiture of grain yield in the case of control and inferiorly performed treatments when compared best treatment perhaps triggered pollen and ovule dysfunction as well as flower abortion which failed in fertilization, impacted grain filling and eventually grain yield (Pavithra *et al.,* 2024). The hydrogel application and crop geometric strategies helped in overcoming the abiotic stress in 2023. The application of hydrogel in the soil might have helped in stress mitigation and perhaps increased the moisture availability, nutrient holding capacity, uptake and transfer of photosynthates from source to sink in the plants (Jamwal *et al.,* 2023). The biofertilizer consortia might have enhanced nutrient fixation and mobilization (Reddy *et al.,* 2023). Competition among plants is an additional problem for the crop besides the abiotic stress. The paired-row spacing might have helped in better exploitation of the resources. Thus, is attributed to better grain yield compared to the control (Liu *et al.,* 2020).

Fig 4: Impact of different hydrogel levels and crop geometric strategies on growth attributes of spring maize at 75 DAS in years 2022 and 2023.

Stover yield (t/ha)

The hydrogel levels have differed significantly in both years. Maximum stover yield was obtained by 100 % hydrogel (@ 3 kg/ha). In the crop geometric strategies, the effect varied in 2023. However, a significantly higher stover yield was obtained by paired-row spacing with the seed capsule (55-85 × 25 cm). In 2022, normal spacing with the seed capsule (70 × 25 cm) and paired-row spacing (55-85 × 25 cm) were found statistically at par with each other. A maximum stover yield of 16.09 t/ha and 17.18 t/ha was obtained by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule with 24.4% and 19.9% increase over control in 2022 and 2023 respectively (Fig 5). The treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule is statistically at par with the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in both years. The second higher stover yield of 15.9 t/ha was recorded by the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule, an increase of 24.01% and 19.16% over control in 2022 and 2023 respectively. The third higher stover yield of 15.60 t/ha was recorded by the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with an increase of 22.11% and 17.41% compared to the control in 2022 and 2023 respectively. The minimum stover yield of 12.15 t/ha and 13.75 t/ha was obtained by hydrogel @ 0 kg/ha + normal spacing (70 × 25 cm) in 2022 and 2023 respectively.

The abiotic stress has affected the stover yield of spring maize particularly in the plots under control. Both factors were effective in disabling the negative impact of stress and also helped in improving the stover yield. The hydrogel might have enhanced the growth and dry matter accumulation. The water and nutrient-holding capability of hydrogel might have seized the moisture stress. Thereby, enhancing the cell growth and eventually increasing the weight of the plant (Chikarango *et al.,* 2021). The biofertilizer consortia made macronutrients more available to plants (Reddy *et al.,* 2023). The paired-row spacing improved the photosynthetic activity and enhanced the photo-assimilates in the straw ultimately increasing the straw yield (Thamatam and Mehera, 2022). The progressive hydro-thermal regime due to the integration of both the factors and good weather conditions might have reduced the losses due to transpiration, evaporation and runoff. Thereby, improved the mitigation, nutrient mineralization and availability (Salem *et al.,* 2023).

Harvest index (%)

In both years, the effect of hydrogel levels varied and 100 % hydrogel (@ 3 kg/ha) resulted in the highest harvest index. Among crop geometric strategies, the highest harvest index was obtained under paired-row spacing with the seed capsule (55-85 × 25 cm) in both years. The non-significant interactive effect of both factors was observed and the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule recorded a maximum harvest index of 36.11% in 2022. A significant interaction of both factors was observed and the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule recorded a maximum harvest index of 37.2% and the treatment hydrogel @ 3 kg/ha + normal spacing (70 × 25 cm) with the seed capsule shared statistical parity with the treatment

Fig 5: Impact of different hydrogel levels and crop geometric strategies on yield attributes of spring maize in years 2022 and 2023.

hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule in 2023.

The harvest index was affected due to the prevalence of stress in 2022 and plots under control in 2023. The enhanced harvest index was perhaps due to the superior plant-water relations and translocation of photo-assimilates from source to sink by the aforementioned roles of both factors (Reddy *et al*., 2023; Jamwal *et al*., 2023).

CONCLUSION

The results obtained from the current assessment showed that the application of different levels of hydrogel and crop geometric strategies has shown a progressive impact on the enhancement of growth and yield attributes. The integration of hydrogel levels 100% (3 kg/ha) and paired row spacing (55-85 × 25 cm) with seed capsule has shown improvement over the control. The outcomes signify that the higher dose of hydrogel application and paired-row spacing with the seed capsule helped in preservation of moisture, plant-water relation, stress resistance, nutrient mineralization and resource management. The seed capsule has demonstrated a positive influence over control. Hence, it is concluded that the treatment hydrogel @ 3 kg/ha + paired row spacing (55-85 × 25 cm) with the seed capsule was effective in gaining better productivity in a resource-conservative and stress-preventive way in the spring maize. Further studies are required to comprehend the effectiveness of the treatments in increasing the pertinence in the real world.

Conflict of interest

The authors state that there is no conflict of interest associated with the paper publication.

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