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Studies on the effect of irrigation management and other agronomic practices on growth and yield characters of hybrid maize (*Zea mays* L.)

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Abstract
One of the most critical inputs in crop production is water. Water for irrigation is currently getting more expensive for crop production due to the depletion of surface and subsurface water supplies caused by unpredictable and unequal distribution of rainfall. To overcome this crisis, farmers carefully monitor the weather forecast and adjust their irrigation schedule according to the current situation. The objective of this study was to evaluate the irrigation management and other agronomic practices in growth and yield of hybrid maize (*Zea mays* L). The study was conducted under field conditions in Chinnakandiyankuppam village, Vriddhachalam Taluk, in the North-Eastern region of Tamil Nadu state, India between December 2020 to March 2021. Three irrigation practices in main plot (M_1 - Irrigation during critical stages of crop growth, M_2 - Tensiometer based irrigation and M_3 - Normal irrigation (Farmer's practice) were combined with four treatments in sub-plots (S_1 - Seed hardening with 1% KH_2PO_4, S_2 - Soil application of hydrogel @ 2.5 kg ha^{-1} before sowing, S_3 - Foliar application of triacontanol @ 10 ppm on 20 and 35 DAS, S_4 - Foliar application of humic acid @ 450 ppm on 30 and 45 DAS) and was set up in a split plot layout and replicated thrice. Tensiometer based irrigation along with soil application of hydrogel @ 2.5 kg ha^{-1} (M_2S_2) was the most efficient irrigation and other agronomic practices for growth attributes, yield and yield attributes and nutrient uptake for the hybrid maize under irrigated condition of North - Eastern zone of Tamil Nadu State, India.

Keywords: irrigation management, tensiometer, hydrogel, humic acid, triacontanol, seed hardening

Introduction

In comparison to other cereal crops, maize (*Zea mays* L.) is a versatile crop that can provide food, feed, and fuel in relatively large numbers. Maize is cultivated all year round. Because of its great genetic production potential, it is known as the "Queen of Cereals." Maize is one of the world's most important cereal crops, with a total area of 193.29 million hectares and a production of 570 million tonnes. Maize is cultivated in an area of 9.72 million hectares in India, with a production of 28.63 million tonnes and a productivity of 3.07 tonnes per hectare (source: USDA 2019-2020). It is grown on 0.38 million hectares in Tamil Nadu, with a production of 2.51 million tonnes.

Many countries of the world are currently experiencing an increasing scarcity of agricultural water. Drought and desertification are among the causes, as are climate change and fluctuation, water pollution, excessive water consumption and inadequate water management practices are all issues that need to be addressed. As the amount of water accessible for agriculture decreases, it will be important to raise water productivity in order to improve agricultural output. Due to severe water limitations, the goal of boosting food production with less water will be a major issue in the future decade, particularly in areas with restricted water resources (FAO, 2002) [12]. Maize as a C4 crop, is a water-efficient crop that flourishes in a range of 500 to 600 mm of water, but can grow with as little as 300 mm of irrigation (Boateng, 2011).

Irrigation scheduling is essential for meeting crop-specific water requirements and obtaining the desired output without wasting water (Leib *et al*., 2002) [18]. Irrigation scheduling can be accomplished using either a tensiometer or other indices. Because of its prompt and precise reaction, irrigation scheduling to crops based on tensiometer is gaining popularity these days. Irrigation scheduling based on tensiometers would greatly improve water productivity by applying irrigation just when it is required. Moisture stress causes a significant loss in grain yield during some critical growth phases of maize for irrigation. Irrigation was provided throughout important stages such as seedling, knee high, tasseling, silking and grain filling stage.

During the critical growth stages of the crop, proper irrigation leads in a significant boost in production (Sharma *et al*., 2018) [26, 28]. Maize is cultivated with a guaranteed irrigation of 500 mm (Shankar *et al*., 2012), and irrigation is typically delivered at a 10-days interval. The successful cultivation of maize necessitated a total of ten irrigations. It is referred as normal irrigation.

Due to scarce and unevenly distributed water supplies, water conservation is critical in the agricultural sector. As a result, effective agronomic measures are required to limit evaporation and provide water when and where it is needed (Sharma *et al*, 2018) [26, 28]. The use of appropriate techniques and technologies such as hydrogels, seed hardening, triacontanol, and humic acid, farmers will be able to efficiently manage water resources and raise crops in a sustainable manner.

Seed hardening is a seed management technique in which seeds are soaked in water and then dried to their original moisture content to assist them resist field stress. Seed priming is one of the most important advancements in helping seeds germinate quickly and uniformly. It improves the vitality, root development and yield of seedlings (Sathish *et al*., 2011) [24].

Hydrogel is a polymer that absorbs 20 times more water than its own weight. When water is available, hydrogels have a great capacity to absorb water and make that absorbed water available to plants over time (Montesano *et al*., 2015) [20]. The addition of super absorbent to the soil increased the physical qualities of the soil, boosted seed germination and helped seedlings emerge, crop growth and output were improved and reduced agricultural irrigation requirements. It also reduces the frequency with which crops are irrigated (Yazdani *et al.*, 2007) [32].

Triacontanol is a photosynthesis enhancer and a naturally occurring plant growth stimulator. Triacontanol has been shown to affect a variety of physio-chemical processes, including water and mineral nutrient intake, photosynthesis, essential oil yield and secondary metabolites, when applied topically (Khanam and Mohammed, 2018) [15].

Humic acid is a water soluble, organically charged bio-stimulant that has a considerable impact on plant growth and development while also increasing crop output. It stimulates microbiological activity, which improves mineral absorption. Increased humic acid rate improved growth characteristics, yield characteristics and protein percentage (Aisha *et al*., 2014) [2]. As a result, the current study was designed to investigate the impact of irrigation management and other agronomic methods on hybrid maize (*Zea mays* L.) growth and yield characteristics in Tamil Nadu's North-Eastern agro-climatic zone.

Materials and Methods

Experimental site description

The experiment was carried out in December 2020 at Chinnakandiyankuppam village, Vriddhachalam Taluk, Tamil Nadu state to study the effect of irrigation management and other agronomic practices on growth and yield of hybrid maize. The experiment site was geographically located in North-Eastern agro climatic zone of Tamil Nadu. It lies between11º52'N latitude and 79º33'E longitude and at an altitude of 45 metres above mean sea level. The mean annual rainfall received at chinnakandiyankuppam was 1204.1 mm. The mean maximum and minimum temperature ranges from 32.2 ºC to 39.5 ºC and 21 ºC to 26 ºC respectively. The highest relative humidity is 89% during March and lowest is 77% during May with a mean of 83%.

The pre-sowing soil samples collected from each treatment plots of the experimental field in three replicates were analyzed for the initial physico-chemical properties. The texture of the soil in the experimental field was sandy clay loam. Maize hybrid S 6668 was used as a test crop for the experiment during December 2020-March 2021.

Field experiment details

The field experiment was laid out in split-plot design and sampling was done in three replicates with 36 plots in total, each covering 21.6 m^2 (5.4 m X 4 m). The experiment was conducted during December 2020-March 2021 with maize hybrid S 6668. Three irrigation practices in main plot (M_1- Irrigation during critical stages of crop growth, M_2- Tensiometer based irrigation and M_3- Normal irrigation (Farmer's practice) were combined with four other agronomic practices in sub-plots (S_1- Seed hardening with 1% KH_2PO_4, S_2- Soil application of hydrogel @ 2.5 kg ha^{-1} before sowing, S_3- Foliar application of triacontanol @ 10 ppm on 20 and 35 DAS, S_4- Foliar application of humic acid @ 450 ppm on 30 and 45 DAS). The soil samples were collected from thirty six plots. The experimental field was ploughed twice with tractor mounted mould board plough at the optimum moisture content of the soil. The field was then levelled and harrowed. The ridges and furrows were formed at 60 cm apart using tractor drawn ridger and rectification was done manually.

Soil application (Manure and fertilizer)

Farmyard manure @ 12.5 t ha^{-1} was incorporated in the soil before sowing. The recommended fertilizer dose of 250:75:75 Kg N, P_2O_5 and K_2O ha^{-1} was followed. Nitrogen was applied as urea, phosphorous as single super phosphate and potassium as Muriate of potash. Urea was applied in 3 splits *viz*., 1/3rd at basal, 1/3rd at 25 DAS (knee high stage) and 1/3rd at 45 DAS (Tasseling stage). Entire quantity of phosphorus and potassium were applied as basal dressing.

Seeds and sowing

A seed rate of 20 kg ha^{-1} was used. A spacing of 60 cm between rows and 25 cm between plants (60 x 25 cm) was followed. Before sowing, the seeds are treated with seed hardening chemical such as KH_2PO_4 @ 1%. Soaking of 1 kg of seed in 350 ml of solution for 6 hours was done. After priming, seeds were removed from the solution, rinsed in water and shade dried at room temperature.

Irrigation

Irrigation was given to each plot as per the treatment schedule. As a general water requirement maize requires 500mm of water, irrigation at 10 days interval is usually followed by the farmers and it is referred as normal irrigation. Totally 10 irrigations were required for successful completion of maize production as farmer's practice (M_3). Under tensiometer based irrigation, irrigation was scheduled based on the value of 0.5. Accordingly 8 irrigations were given (M_2). For the irrigation during critical stages of crop growth such as seedling stage, knee high stage, tasseling stage, silking stage and grain filling stage, irrigation was given to the crop. Irrigation to the crop after sowing is necessary for uniform germination, so life irrigation was given 3 days after sowing. So totally 6 irrigations were given (M_1).

Other agronomic practices

Agronomic practices are an important practice for sustainability of agriculture and environment. It improves the availability of water for plant use. The various agronomic practices tried with experiment are seed hardening, hydrogel application, triacontanol and humic acid application.

Sampling procedures and measurements

The collected soil samples were analyzed for pH, EC and available macro nutrients. In the laboratory, standard protocols for nutritional analysis were used. Five plants from each net plot area were tagged and used for recording all biometric observations for growth attributes (plant height, leaf area Index, dry matter production), yield and yield attributes (cob length, cob diameter, number of grains per cob, hundred grain weight, grain yield and stover yield) and nutrient uptake (N, P and K) were recorded at harvest.

Statistical analysis

According to Gomez and Gomez (1984) [13], the data collected from numerous observations was statistically evaluated using the split plot design approach and standard analysis of variance (ANOVA) procedures. Wherever the 'F' test was significant, the critical difference was calculated at a 5% level of probability to examine the significance of the difference between any two means. The difference between the treatments was significant whenever the calculated 'F-value' exceeded the tabulated value.

Results and Discussion

Growth and attributes

The effect of irrigation management and other agronomic practices in hybrid maize on plant height, leaf area index and dry matter production is presented in Table 1.

The growth components differed significantly ($P \leq 0.05$) due to irrigation management and other agronomic practices in hybrid maize. Among the different water management practices, tensiometer based irrigation (M_2) recorded the maximum plant height of 176.31 cm, LAI (7.15), DMP (12357 kg ha^{-1}). Improved plant growth was due to proper and timely irrigation scheduling of maize based on soil water tension, which might have increased the irrigation water productivity by avoiding water stress and over-irrigation and resulted in increased plant height, leaf area index and dry matter production. A similar findings was reported by Bhatt *et al.* (2016) [3] and Durga *et al.* (2018) [8].

Among the agronomic practices, the effect of hydrogel was prominent. Plant height (183.80 cm), LAI (7.50) and DMP (13319 kg ha^{-1}) were higher with soil application of hydrogel @ 2.5 kg ha^{-1} before sowing. Hydrogel enhance the plant growth at the early stages of production. Application of hydrogel decreases the frequency of irrigation in crops. After incorporating with soil, hydrogel retain large quantities of water and nutrients, which are released as required by the crop. The effect of hydrogel on plant growth are evidenced by prolonged survival time, increased plant height, wider leaves, greater leaf area and a higher concentration of chloroplast. Similar results was revealed by Lawrence *et al.* (2013) [17]. Hydrogel improves nutrition availability to crop roots, resulting in increased photosynthetic activity and, as a result, increased vegetative development, as measured by the number of leaves per plant, plant height and root growth. Suresh rao *et al.* (2016) [27] reported on similar findings.

Table 1: Effect of irrigation management and other agronomic practices on growth attributes of hybrid maize

Treatments	Plant height (cm) at harvest	Leaf are index at 60 DAS	Dry matter production (kg ha^{-1}) at harvest
Irrigation management practices			
M_1 – Irrigation during critical stages of crop growth	160.46	6.55	10737
M_2 – Tensiometer based irrigation	176.31	7.15	12357
M_3 – Normal irrigation (Farmers's practice)	174.14	7.10	12629
SEm(±)	0.56	0.03	54.97
CD (P=0.05)	2.19	0.08	220.91
Other agronomic practices			
S_1 – Seed hardening with 1% KH_2PO_4	164.44	6.74	11146
S_2 – Soil application of hydrogel @ 2.5 kg ha^{-1} before sowing	183.80	7.50	13319
S_3 – Foliar application of triacontanol @ 10 ppm on 20 and 35 DAS	156.29	6.37	10379
S_4 – Foliar application of humic acid @ 450 ppm on 30 and 45 DAS	176.00	7.13	12277
SEm(±)	1.25	0.06	134.09
CD (P=0.05)	3.71	0.16	400.92
Interaction			
$M_1 \times S_1$	152.62	6.28	9866
$M_1 \times S_2$	175.25	7.10	12286
$M_1 \times S_3$	149.37	6.09	9588
$M_1 \times S_4$	164.58	6.73	11210
$M_2 \times S_1$	172.79	7.02	11927
$M_2 \times S_2$	189.80	7.75	13894
$M_2 \times S_3$	158.98	6.46	10615
$M_2 \times S_4$	183.67	7.38	12992
$M_3 \times S_1$	169.92	6.91	11645
$M_3 \times S_2$	186.34	7.66	13778
$M_3 \times S_3$	160.53	6.55	10935
$M_3 \times S_4$	179.76	7.27	12629
M×S			
SEm(±)	1.17	0.07	114.53

CD (P=0.05)	4.63	0.17	460.23
S×M			
SEm(±)	2.20	0.11	235.26
CD (P=0.05)	6.51	0.28	703.37

Yield Components

The effect of irrigation management and other agronomic practices on yield attributes of cob length, cob diameter, number of grain cob^{-1} and hundred grain weight recorded are presented in Table 2.

The yield components differed significantly ($p \leq 0.05$) due to irrigation management and other agronomic practices in hybrid maize. Among the main treatments, tensiometer based irrigation (M_2) recorded the higher cob length (20.21 cm), cob diameter (5.09 cm) and number of grain cob^{-1} (455). Availability of adequate water to the crops as well as good aeration certainly increase the yield components. This findings were reported by Sah *et al.* (2020) [23]. The optimum availability of nutrients and irrigation resulted in better translocation of assimilates from source to sink. Better crop growth and higher nutrient uptake increased the leaf gas exchange parameters like photosynthetic rate, stomatal conductance and better transpiration rate might have influenced the yield attributes favourably. Hammad *et al.* (2011) [14] and Ramachandiran and Pazhanivelan (2016) [22] have made similar observations. The least cob length (15.94 cm), cob diameter (3.90 cm) and number of grain cob^{-1} (379) was recorded in treatment M_1 (irrigation during critical stages of crop growth). Water stress and insufficient nitrogen status resulted in lesser LAI, DMP, nutrient uptake and photosynthetic rate, resulting in inefficient conversion of the source to sink and hence reduced maize yield attributes. Ramachandiran and Pazhanivelan (2016) [22] both made similar observations.

The effect of hydrogel was prominent among the agronomic practices. The highest cob length (22.93 cm), cob diameter (5.79 cm) and number of grain cob^{-1} (501) were recorded in treatment S_2 (soil application of hydrogel). Hydrogel application helpful in ameliorating the stress, controlling erosion as well as increases the yield components. An increase in yield-related qualities could be owing to adequate water availability, which is indirectly supplied by the SAP to plants under water stress, resulting in improved water, nutrient and photosynthate translocation and eventually improved plant stand. It could be due to the hydrogel's super-absorbent characteristics, which absorb water and slowly release it to the growing plants as per the crop needs. It increase the number of grains cob^{-1}, number of rows and test weight in maize El Hardy *et al.* (2009) [10] and Kumari *et al.* (2017) [16] were reported on similar findings.

Table 2: Effect of irrigation management and other agronomic practices on yield attributes of hybrid maize

Treatments	Cob length (cm)	Cob diameter (cm)	Number of grain cob^{-1}	Hundred grain weight (g)
Irrigation management practices				
M_1 – Irrigation during critical stages of crop growth	15.94	3.90	379	29.57
M_2 – Tensiometer based irrigation	20.21	5.09	455	29.74
M_3 – Normal irrigation (Farmers's practice)	19.66	4.94	445	29.68
SEm(±)	0.16	0.05	2.59	0.01
CD (P=0.05)	0.59	0.19	10.38	NS
Other agronomic practices				
S_1 – Seed hardening with 1% KH_2PO_4	16.90	4.18	395	29.61
S_2 – Soil application of hydrogel @ 2.5 kg ha^{-1} before sowing	23.93	5.79	501	29.85
S_3 – Foliar application of triacontanol @ 10 ppm on 20 and 35 DAS	14.48	3.51	356	29.51
S_4 – Foliar application of humic acid @ 450 ppm on 30 and 45 DAS	20.09	5.08	453	29.75
SEm(±)	0.41	0.12	6.68	0.02
CD (P=0.05)	1.16	0.34	19.87	NS
Interaction				
$M_1 \times S_1$	13.52	3.32	345	29.48
$M_1 \times S_2$	20.25	4.91	448	29.74
$M_1 \times S_3$	13.01	3.24	329	29.45
$M_1 \times S_4$	16.97	4.13	394	29.61
$M_2 \times S_1$	19.13	4.67	427	29.69
$M_2 \times S_2$	24.96	6.43	536	29.92
$M_2 \times S_3$	14.69	3.58	364	29.53
$M_2 \times S_4$	22.04	5.69	491	29.83
$M_3 \times S_1$	18.05	4.56	413	29.65
$M_3 \times S_2$	23.58	6.04	518	29.88
$M_3 \times S_3$	15.74	3.72	376	29.56
$M_3 \times S_4$	21.27	5.43	473	29.80
M×S				
SEm(±)	0.34	0.11	5.42	0.03
CD (P=0.05)	1.23	0.40	21.63	NS
S×M				
SEm(±)	0.72	0.21	11.72	0.04
CD (P=0.05)	2.05	0.61	34.86	NS

Yield

The effect of irrigation management and other agronomic practices on grain yield and stover yield recorded are presented in Fig. 1.

The yield differed significantly ($p \leq 0.05$) due to irrigation management and other agronomic practices in hybrid maize. Tensiometer based irrigation (M_2) recorded the maximum grain yield (5156 kg ha^{-1}) and stover yield (8411 kg ha^{-1}). The tensiometer guarantees that irrigation is scheduled on time. The biological yield of maize was greatly increased when appropriate water was available. It is possible that the greater yield is attributable to better water management throughout the crop's life cycle. Mamdouh Eissa and Osama Negim (2019) also found comparable findings. The minimum grain yield (4382 kg ha^{-1}) and stover yield (7351 kg ha^{-1}) were recorded in irrigation during critical stages of crop growth (M_1).

Among the agronomic practices, soil application of hydrogel @ 2.5 kg ha^{-1} (S_2) recorded the maximum grain yield (5623 kg ha^{-1}) and stover yield (9043 kg ha^{-1}). The increased growth and growth properties of hybrid maize may account for the increase in yield. Hydrogel provides a solution to the fresh water shortage, increasing soil and water productivity and yielding the best crop yields. Ekebafe *et al.* (2011) [8] and Yang *et al.* (2017) [31] reported similar results. The higher stover yield might be due to higher dry matter accumulation in vegetative parts. Super absorbent polymers are known to increase the total size of the plant and dry weight by increasing the growth of cells by reducing the moisture stress effects. Similar results were reported by Chaithra and Sridhara (2018) [5].

Nutrient Uptake

The effect of irrigation management and other agronomic practices on nitrogen (N), phosphorous (P) and potassium (K) uptake recorded are presented in Fig. 2.

The nutrient uptake differed significantly ($p \leq 0.05$) due to irrigation management and other agronomic practices in hybrid maize. Tensiometer based irrigation (M_2) recorded the higher NPK uptake N (211.15 kg ha^{-1}), P (49.54 kg ha^{-1}) and K (143.53 kg ha^{-1}). This might be due to appropriate level of water supply. By increasing irrigation level in maize, plant growth increased which resulted increased nutrient uptake. Ercoli *et al.* (2008) and Mamdouh Eissa and Osama Negim (2019) were made similar reports. Irrigation during critical stages of crop growth (M_1) recorded the lower NPK uptake. Nitrogen uptake is reduced under limited soil moisture conditions. Reducing the irrigation level in maize minimized the plant growth and reduced the nutrient uptake. Similar results were reported by Moser *et al.* (2006) [21].

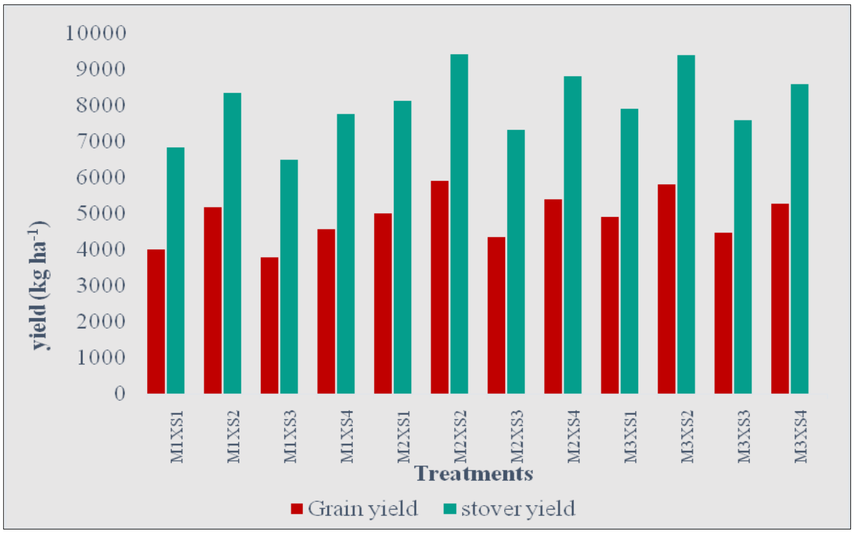

Fig 1: Effect of irrigation management and other agronomic practices on yield (kg ha^{-1}) of hydrid maize

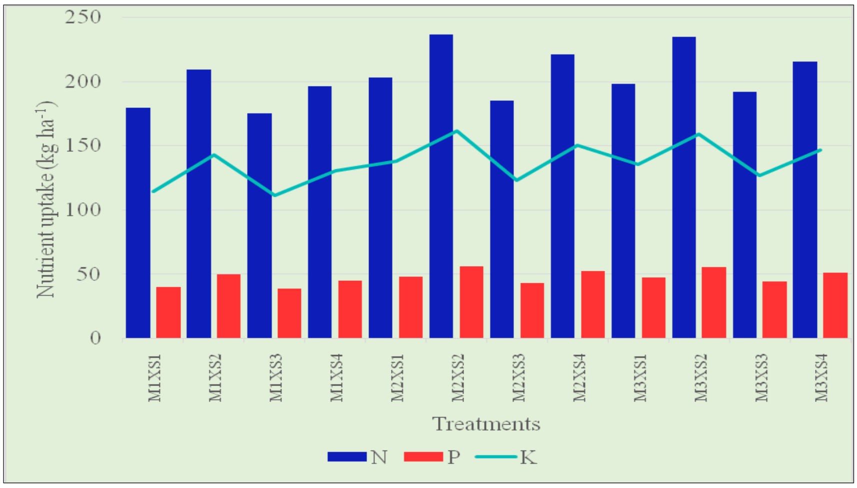

Fig 2: Effect of irrigation management and other agronomic practices on nutrient uptake (kg ha^{-1}) of hydrid maize

Among the different agronomic practices, the higher uptake of NPK, N (226.49 kg ha^{-1}), P (53.43 kg ha^{-1}) and K (154.65 kg ha^{-1}) was observed with soil application of hydrogel @ 2.5 kg ha^{-1} applied before sowing. Hydrogel enables nutrient retention at the exchange site and their timely release for plant uptake, this process reduces NH_3 volatilization and nutrient leaching. This process increased the nutrient uptake and nutrient use efficiency. Similar findings were revealed by Xu *et al.* (2015) [30] and El-Asmar *et al.* (2017) [9]. Hydrogel application minimizes micronutrients from washing out to water tables and increase water consumption efficiency, nutrient leaching is prohibited by decreasing nutrient losses. Dehkordi (2017) [6] and Abobatta (2018) [1] have made similar observations.

Conclusion

The results of the present study showed that maize grown under irrigated condition in North Eastern zone was highly responsive to tensiometer based irrigation along with soil application of hydrogel @ 2.5 kg ha^{-1}. They had a remarkable effect on growth attributes, yield attributes, grain yield, stover yield and nutrient uptake. It holds promise as an agronomically efficient and economically viable practice for achieving higher yields in hybrid maize.

References

1. Abobatta W. Impact of hydrogel polymer in agricultural sector. Advances in Agricultural and Environmental Science. 2018;1:59-64.
2. Aisha HA, Shafeek MR, Mahmoud RA, El-Desuki M. Effect of various levels of organic fertilizer and humic acid on the growth and roots quality of turnip plants (*Brassica rapa*). Current Science International. 2014;3(1):7-14.
3. Bhatt R, Arora S, Chew CC. Improving irrigation water productivity using Tensiometers. Journal of Soil and Water Conservations. 2016;15(2):120-124.
4. Boateng EO. Estimation of genetic improvement of maize in Ghana under three levels of nitrogen application (Doctoral dissertation), 2013.
5. Chaithra GM, Sridhara S. Growth and yield of rainfed maize as influenced by application of super absorbent polymer and pongamia leaf mulching. International Journal of Chemical Studies. 2018;6(5):426-430.
6. Dehkordi DK. Effect of superabsorbent polymer on salt and drought resistance of Eucalyptus globulus. Applied Ecology and Environmental Research. 2017;15(4):1791-1802.
7. Durga C, Ramalu V, Suresh K, Umadevi M. Evaluation of soil moisture sensors and irrigation scheduling in rabi maize. International Journal of Chemical Studies. 2018;6(5):1789-1792.
8. Ekebafe LO, Ogbeifun DE, Okieimen FE. Polymer applications in agriculture. Biokemistri, 2011, 23(2).
9. El-Asmar J, Jaafar H, Bashour I, Farran MT, Saoud IP. Hydrogel banding improves plant growth, survival and water use efficiency in two calcareous soils. Clean- Soil, Air, Water. 2017;45(7):1700251. https://doi.org/10.1002/clen.201700251.
10. El-Hardy OA, El-Kader AAA, Shafi AM. Physico-bio-chemical properties of sandy soil conditioned with acrylamide hydrogels after cucumber plantations. Australian Journal of Basic and applied Science. 2009;3(4):3145-3151.
11. Ercoli L, Lulli L, Mariotti M, Masoni A, Arduini I. Post-anthesis dry matter and nitrogen dynamics in durum wheat as affected by nitrogen supply and soil water availability. European Journal of Agronomy. 2008;28:138–147.
12. FAO, World Agriculture: Towards 2015/2030. 2002. Summary Report, FAO, Rome, Italy.
13. Gomez KA, Gomez AA. Statistical procedure for agricultural research. IIedition John Wiley and Sons, New York, 1984, 680p.
14. Hammad HM, Ahmad A, Azhar F, Khaliq T, Wajid A, Nasim W, *et al*. Optimizing water and nitrogen requirement in maize (*Zea mays* L.) under semi-arid conditions of Pakistan. Pakistan Journal of Botany. 2011;43(6):2919-2923.
15. Khanam EA, Mohammad F. Plant growth regulators ameliorate the ill effect of salt stress through improved growth, photosynthesis, antioxidant system, yield and quality attributes in *Menthapiperita* L. Acta Physiologiae Plantarum. 2018;40(11):1-13.
16. Kumari S, Solanki NS, Dashora LN, Upadhyay B. Effect of superabsorbent polymer and plant geometry on growth and productivity of maize (*Zea mays* L.). Journal of Pharmacognosy Phytochemistry. 2017;6(4):179-181.
17. Lawrence JBO, Hillary A, Gerald E, Martin DK, Aloys H. Effects of hydrogels on tree seedling performance in temperate soils before and after water stress. Journal of Environmental Protection. 2013;93(3):1360-1371.
18. Leib BG, Jabro J, Mattews RG. Field evaluation and Performance Comparison of Soil Moisture Sensors. Journal of Soil science. 2002;168(6):396-408.
19. Mamdouh Eissa MA, Osama Negim OE. Nutrients uptake and water use efficiency of drip irrigated maize under deficit irrigation. Journal of Plant Nutrition. 2019;42(1):79-88.
20. Montesano FF, Parente A, Santamaria P. Biodegradable superabsorbent hydrogel increases water retention properties of growing media and plant growth. Agriculture and Agricultural Science Procedia. 2015;4:451-458.
21. Moser SB, Feil B, Jampatong S, Stamp P. Effects of pre-anthesis drought, nitrogen fertilizer rate, and variety on grain yield, yield components, and harvest index of tropical maize. Agricultural Water Management. 2006;81(1-2):41-58.
22. Ramachandiran K, Pazhanivelan S. Influence of irrigation and nitrogen levels on growth, yield attributes and yield of maize (*Zea mays*). Indian Journal of Agronomy. 2016;61(3):360-365.
23. Sah RP, Chakraborty M, Prasad K, Pandit M, Tudu VK, Chakravarty MK, Impact of water deficit stress in maize: Phenology and yield components. Scientific reports. 2020;10(1):1-15.
24. Sathish S, Sundareswaran S, Ganesan N. Influence of seed priming on physiological performance of fresh and ages seeds of maize hybrid [COH (M) 5] and it's parental lines. ARPN Journal of Agricultural and Biological Science. 2011;6(3):12-17.
25. Shankar V, Ojha CSP, Prasad KS. Irrigation scheduling for maize and Indian-mustard based on daily crop water requirement in a semi-arid region. International Journal of Civil and Environmental Engineering. 2012;6:476-

485.
26. Sharma BR, Gulati A, Mohan G, Manchanda S, Ray I, Amarasinghe U. Water productivity mapping of major Indian crops, 2018.
27. Sureshrao KS, Pradeeprao KT, Dyanobarao GS, Agarwal T, Kotasthane AS. Root growth stimulation in rice (*Oryza sativa* L.) by seed biopriming with *Trichoderma sp*. Applied Biological Research. 2016;18(1):30-38.
28. Sharma V, Sharma BL, Sharma GD, Porte SS, Dubey A. Studies on Impact of Sulphur with and without FYM on Yield, Uptake and Methionine Content in Mustard. Indian Journal of Agronomy. 2018;62(2):141-146.
29. USDA. World Agricultural Supply and Demand Estimates Report US: USDA, 2019.
30. Xu S, Zhang L, McLaughlin NB, Mi J, Chen Q, Liu J. Effect of synthetic and natural water absorbing soil amendment soil physical properties under potato production in a semi-arid region. Soil and Tillage Research. 2015;148:31-39.
31. Yang W, Li P, Guo S, Fan B, Song R, Zhang J, Yu J. Compensating effect of fulvic acid and super-absorbent polymer on leaf gas exchange and water use efficiency of maize under moderate water deficit conditions. Plant Growth Regulation. 2017;83(3):351-360.
32. Yazdani F, Allahdadi I, Akbari GAB. Impact of super absorbent polymer on yield and growth of Soybean under drought stress condition. Pakistan Journal of Biological Science. 2007;10(23):4190-4196.