Effect of land configuration technique and moisture regime on water productivity of maize (*Zea mays* L.) in summer season

ABSTRACT

To investigate the effect of maize on water use efficiency, water productivity, protein content, and economics in semiarid regions, it is necessary to evaluate the effects of land configuration and moisture regimes. In the summer of 2018-19, a field experiment was carried out at the Agronomy Research Farm, ANDUA &T, Kumarganj, Ayodhya (U.P.) to investigate the effects of moisture regime and land layout approach on the water productivity of maize in the summer months. Four moisture regimes—0.5, 0.7, 0.9, and 1.1 IW/CPE ratios—were assigned to subplots in the experiment, while three land configurations—ridge planting, paired row planting, and flat bed planting—were maintained in the main plots. The experiment consisted of 12 treatment combinations and was conducted in SPD and replicated four times. The results revealed that crop sown on paired row planting on a raised bed showed higher water use efficiency and water productivity when computed under paired row planting on a raised bed with 0.5 irrigation water/cumulative pan evaporation moisture regimes. Further, it was observed that among the moisture regimes, 0.9 and 1.2 Irrigation Water/Cumulative Pan Evaporation ratios, and assessing the economics, that is, gross return, net return, and benefit cost (B:C) ratios, were observed in the combination of paired row planting on a raised bed with a 0.9 Irrigation Water/Cumulative Pan Evaporation ratio, and a minimum was observed in the combination of flat bed planting with a 0.5 Irrigation Water/Cumulative Pan Evaporation ratio.

Keywords-*Land configuration, Maize, Moisture regimes, Protein Water productivity.*

Introduction

Maize is one of the most important cereal crops next to wheat and rice in terms of total production in the world. It is grown under diverse environmental condition and has varied uses as food, feed and fodder, Devendra *et al*. (2022). In India maize accounts for an area of 11.03 million ha with a production of 28.64 m tonnes and a productivity of 25.68 q ha-1 (Anonymous, 2021). Currently, more than 85% of India's maize crop is consumed by people, especially in the country's poorer regions, where hunger and protein malnutrition are prevalent. It is among the most important grain crops in the world. The grain of maize has about 3.6 percent protein, 4% oil, and 70% carbohydrates. It has a high zein percentage, which is low in tryptophan and virtually free of lysine. After rice and wheat, maize is the third most important food crop in India. Which is cultivated in both *Kharif* (7.7 Mha) and *Rabi* (1.6 Mha) seasons and produces 19.5 and 7.6 MT, respectively (Anonymous 2017). Approximately 2% of the world's total maize production is produced in India, with Karnataka accounting for the majority of production at 16%, followed by Telangana and Bihar together at 20%. India produces about 71% of its maize crop during the kharif season. It is generally grown in Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh, Uttar Pradesh, Telangana, Rajasthan, etc. The three main states that produced maize during the Rabi season were Andhra Pradesh, Bihar, and Tamil Nadu, with Tamil Nadu leading the pack with 40% of the crop.

Maize may be produced in both seasons, although it is mainly a *Kharif* crop. In *Kharif*, the first week of February is the ideal time to sow summer maize, and it should be completed by the last week of February. The highest yield of baby corn was obtained through scheduling irrigation at an IW/CPE ratio of 1.0 during the whole season, which was significantly better than the 0.75 IW/CPE ratio, Reddy, K.J. *et al*. (2021). The bed sowing method produced the highest crop growth rate (17.39 g/m2/day) and net assimilation rate (6.27 g/m2/day), while the ridge sowing and flat sowing methods produced lower values.

The configuration of the land is crucial for reducing soil erosion and increasing field crops' ability to use water and nutrients efficiently. It is a useful technology for in-situ moisture conservation. Making ridges by opening furrows may benefit from the conservation of more rainwater on the bed, which enriches soil moisture content. Manipulation of sowing techniques facilitates easy and uniform germination, plant growth and development, and boosts crop nutrient availability Halli, *et al.* (2021). The ridges and furrow system's superiority may be due to its superior ability to drain surplus water and provide sufficient aeration during irrigation or periods of heavy rainfall. According to Parihar *et al*. (2009), the flat bed method of planting maize produced less grain and stover than the ridges and furrows approach. The growth, development, and physiological processes of maize plants can be impacted by water stress, which lowers biomass production.Nagdeote*et al*., (2016), Hanamant and Angadi (2017).

Crop irrigation requirements are primarily driven by evapotranspiration. The loss of water due to evapotranspiration is calculated using climatological data, and irrigation is scheduled when ET reaches a certain threshold.

The amount of irrigation that is applied in proportion to ET or ET. Using the IW/CPE technique, a predetermined level of cumulative pan evaporation is reached before applying a given amount of irrigation water. There is a strong relationship between evaporation from an open pan and ET produced by a complete crop cover. Kaur *et al*. (2021). Proposed a more feasible meteorological strategy based on the provision of a predetermined quantity of water required for irrigation to CPE as the basis for scheduling irrigation. It was observed that maize crop irrigation at an IW/CPE ratio of 1.0 was significantly superior to 0.6 but at par with 0.8 regarding plant dry weight (g) at harvest, kernel weight (g)/cob, kernel yield (kg ha^{-1}), number of kernels/cob, and stover yield (kg ha-1). Nagarajan *et al*., (2018). Presently, few studies and investigations have attempted to explore the additive influence of land configuration and moisture regimes on the productivity, grain yield, and water productivity of hybrid maize. Although tremendous work has been done on the maize crop for yield enhancement, the effect of irrigation scheduling based on the IW/CPE ratio on maize is very limited, particularly in the eastern part of Uttar Pradesh.Brar *et al*. (2012).

2.0 Material and methods

2.1. Study Location Details

At the Acharya Narendra Deva University of Agriculture & Technology's Agronomy Research Farm in Ayodhya, Uttar Pradesh (located 113 meters above mean sea level and 26 degrees 47 degrees N and 82 degrees 12 degrees E), a field experiment was carried out in the summer of 2019. The farm is located 42 kilometers from the district headquarters of Ayodhya on the Raibareily Road. Geographically speaking, the Indo-Gangatic Plains, with their alluvial plains, have a semi-arid subtropical climate (IGP). There is 1002 mm of rain on average every year. About 80% to 85% of the total rainfall takes place during the monsoon, June to September. There is an abundance of surface water that can percolate deeply into the groundwater.

The temperature rises rapidly. From March to May and early June, the temperature sometimes reaches 47°C. After the onset of the monsoon in June, there is an appreciable drop in temperature. The average monthly minimum is 16.5°C, while the average monthly maximum is 32°C. April recorded the lowest recorded temperature (21.44 °C), and May recorded the average maximum temperature (40.35 °C). The study site's soil has a silty loam texture, with 16.3% clay and 28.9% silt. Its bulk density is 1.56 g cm^{-3} (0–30 cm), pH is 8.3, electrical conductivity is 0.25 dSm^{-1}, organic carbon is 0.32%, and its available nitrogen content is low (180 kg ha^{-1}) and medium (25.25 kg ha^{-1}) in terms of phosphorus and potassium (270.0 kg ha^{-1}).

2. 2. Experimental Details

The experiment was conducted at Three land configurations—flat bed planting, ridge planting, and paired row planting on raised beds-were maintained in the main plots, and four moisture regimes—0.5, 0.7, 0.9, and 1.1 Irrigation Water/Cumulative Pan Evaporation ratios—were allocated to the subplots. Four replications of each treatment were included in the split-plot design. On April 7, 2019, the hybrid maize variety known as "Kanchan (K-25)" (1982 GBPU & AT, India) was sown at a rate of 25 kg ha-1, with a spacing of 60 × 20 cm. Irrigation was done in accordance with treatments determined by the IW/CPE ratio, which ranged from 0.5 to 1.1. The pre-emergence herbicide was used to control weeds, and one manual weeding operation was performed 30 days later.

2.3. Water use Efficiency and Water Productivity

Water use efficiency (WUE) is defined as the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop (Jerry L. Hatfield *et al.*, 2019). It is estimated by taking the ratio of grain yield to total water used.

Water use efficiency (kg ha^{-1} cm^{-1})

$$\text{WUE (Kg ha}^{-1}\text{ cm}^{-1}\text{)} = Grainyield\ \text{(Kg ha}^{-1}\text{)}\ Totalwaterused\ (cm)$$

Agricultural water productivity, or crop water productivity (CWP), is defined as the production of physical mass (e.g., biomass, grain yield) or the economic value of mass produced relative to the amount of water used for the production of that mass. It is estimated by taking the ratio of grain yield and total water applied in a season. The generic equation for water productivity (WP) is as follows:

$$WP\left(\frac{kg}{m^3}\ or\ \frac{\$}{m^3}\right) = \frac{out\ put\ derived\ from\ water\ use\ \left(\frac{kg}{m^2}\ or\ \frac{\$}{m^2}\right)}{water\ applied\ \left(\frac{m^3}{m^2}\right)}$$

2.4 Protein content (%)

Using a modified Micro-Kjeldal method, the protein content in maize grains was determined by the total N content of all types of maize (hybrid and composite) in each treatment (Piper, 1966). The following formula was used to determine the percentage of protein in the maize: The protein percentage from the maize was calculated using the following formula:.

Percent protein = N% × 6.25 (factor)

2.5 Economics

The cost of cultivation for each treatment was calculated by adding the variable costs due to the treatment to all of the costs associated with growing the experimental crop. The gross return was calculated. By multiplying gain and stover yield individually under different conditions at their exiting market price to obtain the gross income of Rs. ha^{-1}, the money values of the stover production and the grain were combined. The calculated net income by cost of cultivation was subtracted from the gross income of each individual treatment. Bennefit The cost ratio, or net income invested, was worked out by dividing the net income by the cost of cultivating individual treatments.

3.0 Results and Discussion

3.1 Water use efficiency and water productivity

Water use efficiency and water productivity were both were significantly affected by land configuration and moisture regimes. In row planting on a raised bed (L1), both water use efficiency and water productivity were recorded at higher values, followed by ridge planting as presented in Table 1. This might be due to the efficient use of water by crops and the minimum loss of water. A similar result was observed by Aggarwal and Goswami (2002). The maximum water use efficiency was observed with irrigation at 0.5 Irrigation Water/Cumulative Pan Evaporation ratio (I_1) (86.19 kg ha^{-1} cm^{-1}), followed by 0.9 Irrigation Water/Cumulative Pan

Evaporation ratio (I_3) (80.74 kg ha^{-1} cm^{-1}), 0.7 Irrigation Water/Cumulative Pan Evaporation ratio (I_2) (74.88 kg ha^{-1} cm-1), and 1.1 Irrigation Water/Cumulative Pan Evaporation ratio (I_4) (64.72 kg ha^{-1} cm^{-1}). The decline in water use efficiency under an increasing level of irrigation (1.1 irrigation water/cumulative pan evaporation ratio) might be due to the fact that grain yield has not increased proportionally to the consumptive use of water. The highest water productivity was noticed with irrigation at 0.5 Irrigation Water/Cumulative Pan Evaporation ratio (I_1) (2.20 kg m-3), followed by 0.9 Irrigation Water/Cumulative Pan Evaporation ratio (I_3) (2.02 kg m^{-3}), 0.7 Irrigation Water/Cumulative Pan Evaporation ratio (I_2) (1.90kg m-3), and 1.1 Irrigation Water/Cumulative Pan Evaporation ratio (I_4) (1.60 kg m^{-3}). Similar results were observed by Manal *et al*. (2007) and Kumar *et al.* (2011), Chao *et al*. (2022)

Table 1Water use efficiency and water productivity of summer maize as influenced by land configuration, and moisture regimes.

Treatments	**Water use efficiency (kg ha^{-1}cm^{-1})**	**Water productivity (kg m-3)**
A-Land configuration		
Flat bed planting	66.21	1.60
Ridge planting	73.12	1.80
Paired row planting on raised bed	85.37	2.14
B- Moisture regimes		
0.5 IW/CPE ratio	86.19	2.20
0.7 IW/CPE ratio	74.88	1.90
0.9 IW/CPE ratio	80.74	2.02
1.1 IW/ CPE ratio	64.72	1.60

3.2 Quality Analysis

3.2.1 Protein content (%)

Data represented in Table 2 revealed that the land configuration were found non-significant on Nitrogen content in grain. The maximum protein content in grain (10.25%) was found in paired row planting on raised bed (L_3) followed by ridge planting (L_2) and flat bed planting (L_1). The effect moisture regimes also found non-significant on protein content in grain. However the higher protein content in grain (10.31%) was recorded under 0.9 IW/CPE ratio (I_3) and minimum protein content (10.06%) in 0.5 IW/CPE ratio (I_1). Similar finding was given by Monreal *et al*. 2007, Halli, *et al*. (2021), Babu *et al.*(2020).

Table 2 Protein, content (%) in grain of summer maize as influenced by land configuration and moisture regimes.

Treatments	**Protein content (%)**
A- Land configuration	

Flat bed planting	10.06
Ridge planting	10.23
Paired row planting on raised bed	10.25
Sem+	**0.23**
CD at 5%	**NS**
B- Moisture regimes	
0.5 IW/CPE ratio	10.06
0.7 IW/CPE ratio	10.13
0.9 IW/CPE ratio	10.31
1.1 IW/ CPE ratio	10.18
Sem+	**0.19**
CD at 5%	**NS**

3.3 Economics

The main objective of any experiment is to find the highest profit with the minimum cost of cultivation. With this aim, the treatments that recorded higher profits are worth adopting. As such, to work out the economics of each treatment combination separately, the prevailing market prices were used. The data presented in Table 3. The maximum cost of cultivation (Rs. 42125 ha^{-1}) was calculated with L_1I_4, L_2I_4, and L_3I_4 treatment combinations. The gross income of different treatment combinations increased with an increase in grain and stover yields of maize. Maximum gross income of maize (Rs. 104113 ha^{-1}) was recorded under paired row planting on a raised bed along with irrigation applied at a 0.9 IW/CPE ratio, while maximum net income (Rs. 63988 ha^{-1}) was noticed under paired row planting on a raised bed long with irrigation at a 0.9 IW/CPE ratio, and the highest B:C ratio (1.59) was calculated under paired row planting on a raised bed with irrigation applied at a 0.9 IW/CPE ratio. A similar finding was given by Meena *et al.* (2015), Sonpure*et al.* (2017), and Joshi *et al*. (2018).

Table 3Cost of cultivation, gross income, net income and B:C ratio as influenced by various treatment combinations.

Treatments combinations	Cost of Cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio (Rs. Re^{-1} invested)
L_1I_1	36125	50162	14037	0.38
L_1I_2	38125	59418	21293	0.55
L_1I_3	40125	80987	40862	1.01
L_1I_4	42125	78649	36524	0.86

L_2I_1	36125	55357	19232	0.53
L_2I_2	38125	65595	27470	0.72
L_2I_3	40125	89191	49066	1.22
L_2I_4	42125	86625	44500	1.05
L_3I_1	36125	64473	28348	0.78
L_3I_2	38125	76341	38216	1.002
L_3I_3	40125	104113	63988	1.59
L_3I_4	42125	101091	58966	1.39

Conclusion:

To summarize, this study is one of the few that has assessed the impact of land configuration and moisture regime on water use efficiency, water productivity, protein content, and the economics of maize in semi-arid environments. The study indicated In the case of moisture regimes, irrigation at a 0.9 IW/CPE ratio proved to be the most beneficial with respect to growth parameters, yield attributes, and yield of maize. Thus, technologies of establishment of summer maize on paired row planting on raised beds and moisture regimes at a 0.9 IW/CPE ratio based on the availability of water can be adopted to enhance the productivity of summer maize and the profitability of farmers under limited availability of moisture regimes. And the maximum net income was assumed under the treatment combination of paired row planting on a raised bed along with 6 cm of irrigation at a 0.9 IW/CPE ratio.

Conference disclaimer:

Some part of this manuscript was previously presented in the conference: “International Conference on Emerging Trends in Agriculture & Allied Sector for Sustainable Developments” organized by Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur Nagar, U.P., India on 8th and 9th December, 2023. Web Link of the proceeding: https://www.ramauniversity.ac.in/news-rama-university-hosts-successful-international-conference-on-emerging-trends-in-agriculture-12-49-5706

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