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EFFECT OF DEFICIT IRRIGATION AND DRIP EMITTER SPACING ON SOIL MOISTURE, YIELD AND WATER USE EFFICIENCY OF MAIZE (*ZEA MAYS*) UNDER SEMI-ARID CONDITION

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ABSTRACT

An experiment was conducted at the Entomology block (E8) of the Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS), Raichur during the late Rabi season of 2019-20 to standardize micro irrigation techniques for maize cultivation. The study encompassed three replications with main treatments focusing on emitter spacing (0.3, 0.4, and 0.5 m) and sub-treatments involving different Evapotranspiration (ET) levels (0.6, 0.8, and 1.0). Maize sowing commenced on January 8, 2020, and soil moisture readings were recorded at 60 days after sowing (DAS). Results indicated that the 0.3 m emitter spacing recorded the highest soil moisture content at 60 DAS. Furthermore, the 1.0 ET level treatment exhibited the highest soil moisture levels across all locations. Regarding grain yield, the 0.4 m emitter spacing significantly outperformed both 0.3 and 0.5 m spacings, while the 1.0 ET level recorded the highest yield. Interaction effects revealed that the combination of 0.4 m emitter spacing with 1.0 ET level yielded the highest grain output. Additionally, water use efficiency (WUE) was highest at the 0.4 m emitter spacing and 0.6 ET level, emphasizing the importance of optimal irrigation practices for enhancing maize productivity.
***Keywords* :** Maize, Soil moisture, Grain yield, Water use efficiency.

Introduction

Water is one of the most critical inputs for agriculture (Hans, 2016) which consumes more than 80 % of the water resources of the country (Venkateswarlu, 1996). Availability of adequate quantity and quality of water is, therefore, key factors for achieving higher productivity levels. Investments in conservation of water, improved techniques to ensure its timely supply, and improve its efficient use are some of the imperatives which the country needs to enhance. Poor irrigation efficiency (Howell, 2003) of conventional irrigation system has not only reduced the anticipated outcome of investments made towards water resource development, but has also resulted in environmental problems like water logging and soil salinity thereby affecting crop yields. This, therefore, calls for massive investments in adoption of improved methods of irrigation such as drip and sprinkler, including fertigation (Bar Yosef, 1999; Incrocci *et al.*, 2017).

The micro-irrigation (MI) technologies such as drip and sprinkler are the key interventions in water saving and improving crop productivity (English and Raja, 1996; Abdelraouf *et al.*, 2020). Evidence shows that up to 40 % to 80 % of water can be saved and water use efficiency (WUE) can be enhanced up to 100

% in a properly designed and managed MI system compared to 30- 40 % under conventional practice (Kumar *et al*., 2008; Narayanamoorthy, 2009).

Globally, it is cultivated in more than 160 m ha area across 166 countries having wider diversity of soil, climate, biodiversity and management practices. Maize contributes maximum among the food cereal crops i.e. 40 % annually (> 800 mt.) in the global food production. Among the world maize growing countries, USA is the largest producer of contributes nearly 35 % of the total maize produced, followed by China with more than 20 % production with same acreage as of USA (Kresović *et al*., 2016). Maize is the driver of US with highest productivity (> 10 t ha^{-1}) which is double than the global (5.3 t ha^{-1}). Whereas, Productivity of India is just half than the world productivity.

In India, maize is the third important food crop after rice and wheat. According to latest data (2010-11), it is being cultivated on 8.6 m ha with 80 % area during Kharif season. The current maize production is 21.7 mt, with an average productivity of 2.5 t ha^{-1} . Despite maize being predominantly rain fed crop its productivity is more than rice which is mainly grown under assured irrigated/ rain fed conditions. Maize contributes nearly 9 % in the national food basket and more than 400 billion to the agricultural GDP at current prices. In addition, it generates employment to over 1000 million man-days at the farm and downstream agricultural and industrial sectors. Maize is primarily used for feed (60 %) followed by human food (24 %), industrial (starch) products (14 %) beverages and seed (1 % each). Thus, maize has attained an important position as industrial crop because 75 % of its produce disused in starch and feed industries (Cirilo and Andrade, 1996). In India, maize is predominantly cultivated as rain fed crop but due to focused research on single cross hybrids. Ten states in India represents around 80 % of the total area of maize grown. Karnataka (15 %) is the largest state for maize cultivation followed by Rajasthan (13 %) and Madhya Pradesh (10 %) (Parihar *et al*., 2011).

Irrigation, in this sense, besides supplying this deficiency, may favor the cultivation of other crops during the dry season. However, the improper use of water resources in irrigated agriculture, due to the search for higher yields has contributed to the high waste of water, resulting in undesirable consequences for the environment (Valipour and Singh, 2016). Thus, to use it economically in irrigation projects, it is necessary to know the water consumption by the crop and its response in productivity, the atmospheric demand and the physical-water characteristics of the soil to determine the economic irrigation level (Koushal *et al*., 2024; Ritchie, 1983; Dobriyal *et al*., 2012). In addition, it is convenient to make use of localized irrigation systems (Navalawala, 1991), which present better efficiency and uniformity of water application, low energy consumption and keep soil moisture always close to field capacity. However still there is no evidence for using exact emitter spacing with different levels of irrigation under inline drip irrigation for better moisture distribution in maize cultivation (Stanhill, 1986; Zwart, and Bastiaanssen, 2004). Therefore, to overcome the above problems and to suggest the emitter spacing and levels of irrigation, the experiment was carried out with following specific objects.

- To determine the effect of different inline emitter spacing and deficit irrigation on soil moisture
- To determine the effect of different inline emitter spacing and different irrigation level on yield and water use efficiency of maize.

Materials and Methods

Study Area

The field experiment was conducted at Entomology block of Main Agriculture Research Station (MARS), UAS, Raichur from December to April which is having located at 16^{0}11 40.56 N latitude and 77^{0}18 43.39 E longitude with an elevation of 394 m above mean sea level (MSL). Irrigation water was pumped from an irrigation tank which was 3.0 m deep and water being collected from the canal. The total area under the drip irrigation was 8.0 acres and area of the experimental block is 1354 m^2 area.

Fig. 1 : Google earth map showing study block area

Weather and climatic conditions

Raichur belongs to North Eastern Dry zone of Karnataka under state agro-climatological classification. The weather data pertaining to the study area was collected from Meteorological observatory, located at a distance of 500 m away in Main Agricultural Research Station, University of Agricultural Sciences, Raichur. The 35 years normal weather data values are summarized as follows; annual maximum and minimum temperature of Raichur is 34.2 and 21.1 ℃, respectively. The station receives 625.9 mm rainfall annually with 33 rainy days. Average wind speed was 5.98 kmph and with 7 hours of sunshine a day and relative humidity of 76.7and 41.08% in morning and evening respectively. The seven year's (2014-2020) average evaporation was 6.55 mm day^{-1} data are presented in appendix-I. The highest and lowest evaporation was during 24 April - 2016 and 13 December 2014 month respectively.

Methodology

Characterization of soil

Soil samples were collected from 0-20 cm and 20-40 cm depths using core samplers, which were then subjected to characterization of physico-chemical properties of the soil.

The physico-chemical properties of the soil and the methodologies adopted for the determination are illustrated in Table 1. The soil samples were collected before sowing of the maize crop from two different depths (0-20 cm and 20-40 cm) using core cutter. The methodologies are briefly given below.

Soil texture

Soil texture was determined with international pipette method (Piper, 1966).

Bulk density

Core cutters of 10 cm internal diameter and 14 cm heights were used for bulk density determination of the soil samples of different depths (0-20 cm and 20-40 cm). It was estimated with eq. (1).

Table 1 : Important physicochemical characteristics of soil estimated from the experiment field with the methodology.

Sl. No.	Parameters	Methodology/ Instrument	References
1	Soil Texture	International pipette method	Piper, 1966
2	Bulk density	Core cutter method	Jackson, 1973
3	Field capacity	Pressure plate apparatus (1/3 bar)	Richards and Weaver, 1964
4	Permanent wilting point	Pressure plate apparatus (15 bar)	Richards and Weaver, 1964
5	Maximum water holding capacity	Keen's cup method	Keen and Reckzowaski, 1921
6	Basic infiltration rate	Double ring infiltration test	Annonymous, 2009
7	pH	pH meter	Jackson, 1973
8	Electrical conductivity	Conductivity bridge	Jackson, 1973
9	Volumetric moisture content	Gravimetric method	Jackson, 1973

$$\text{Bulk density} = \frac{M}{V} \qquad \text{Eq. (1)}$$

Where, M=mass of the soil sample collected by the core cutter, g;

V=volume of the soil sample in the core cutter (measured with the internal diameter and height of the core), cm^3.

Treatment details

The three different emitters spacing and three different irrigation levels were kept as main and sub treatments respectively to fulfill the objectives of the study. The details are given below

Main treatments

M_0– 0.3 m emitter spacing
M_1– 0.4 m emitter spacing
M_2– 0.5 m emitter spacing

Sub-treatments

S_0 – 0.6 ET level
S_1– 0.8 ET level
S_2 – 1.0 ET level

Replications: 3 No

Experimental Layout

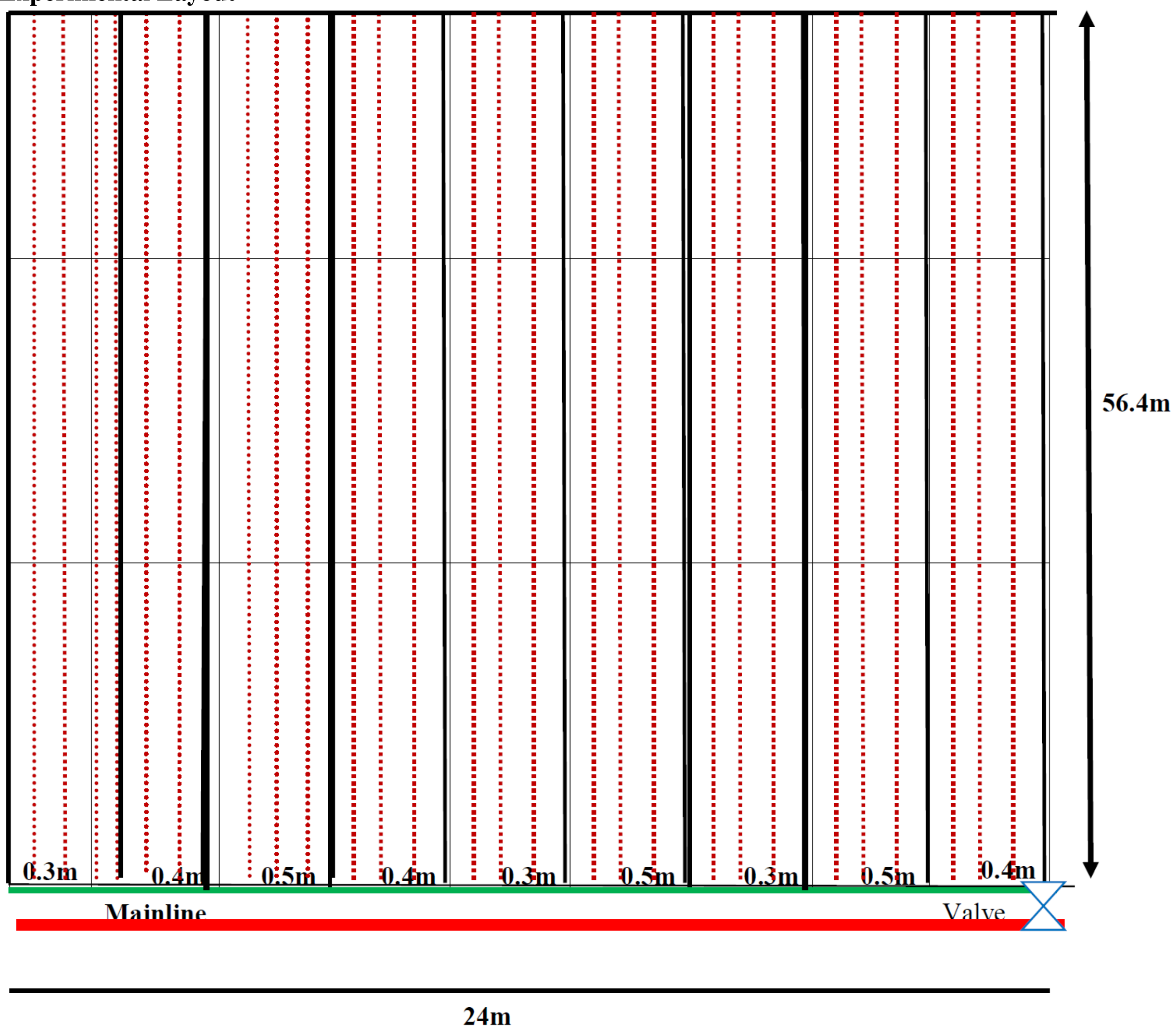

Fig. 2 : Experimental Layout

Main line
Lateral
Sub main line

Design of Drip Irrigation system

- Pressure required at end of the lateral was considered as 10 m and the pressure at emitter point was 1 kg cm^{-2}
- Computing the frictional head loss of drip line with the help of Hazen-William flow chart.
- Computing the frictional head loss of sub-main line with the help of Hazen-William flow chart and total flow (Shift flows).
- Computing the frictional head loss of main line with the help of Hazen-William flow chart.
- Computing the total head loss
- Computing the horse power of a motor.

For computing the horse power of a motor the following formula is under

$$HP = (Q*H) / (2.244*n)$$

Where,

HP - Horse power of motor.

Q - Total flow (m^3/hr).

H - Total head loss (m).

n - Efficiency (55-60%).

Components Used in Drip Irrigation

Plate (a) and (b) shows the different components used for installation of drip head unit. The following different components were used for drip system.

1. Motor – 10HP motor is used.
2. Filtration unit
   Primary Filter- Sand Filter (4" -40 m^3)
   Secondary Filter – Disc Filter (3" -40 m^3)
3. Pressure gauge 8 Bar.
4. Venturi (2")
5. Air vacuum release valve (1"-AV10)
6. Vacuum breaker valve (0.5")
7. Pressure relief valve (2")
8. Main line (110, 90, 75 mm (4", 3" and 2.5") - 4 Kg cm^{-2})
9. PP Ball Valve (75 and 63 mm (2.5' and 2"))
10. Sub main (75 and 63 mm (2.5' and 2") – 4 Kg cm^{-2})
11. 16 mm Plane lateral (2.5kg cm^{-2})
12. 16 mm Drip line (with Emitter spacing of 0.3, 0.4 and 0.5 m)
13. Drip accessories with end cap 16 mm

(a) (b)

Plate 1 : Front (a) and side (b) view of installed drip head unit used for experimental block

Determination of Crop Water Requirement

1. Collection daily evaporation (E) data (From Meteorology Department)
2. Collecting K_p and K_c values

$$ET_c = ET * K_p * K_c$$

Where,

ET_c = Crop Evapotranspiration (mm/day)

ET = Daily Evaptranspiration (mm/day)

K_p = Pan co-efficient (0.7 constant)

K_c = Crop co-efficient (values taken from FAO)

Soil Moisture

Soil moisture readings were collected at three times during, at the time of sowing, growth and harvesting stage. Soil samples were collected at depth of 0-20 cm at the point of emitter, along and across 10 cm apart from the emitter drip line. These samples were collected and analyzed by gravimetric method using following formula

$$MC = \{(W_2-W_3) / (W_3-W_1)\}*100$$

Where,

MC = Soil moisture content (%)
W_1 = Container weight (gram)
W_2 = Container weigh + Soil sample (gram)
W_3 = Container weight + Dry soil (gram)

Procedure

- Weigh an Aluminum tine and record the weight (W_1)
- Weigh the soil sample along with the tin (W_2)
- Place the sample in the oven at 105°C for 24 hrs
- Weigh the sample and record it(W_3)

Daily crop water requirement

Daily crop water requirement for maize crop was worked out with following formula

$$ET_c = ET_o * k_c$$

Where,

ET_c = Crop evapotranspiration

ET_o = Reference crop evapotranspiration

$ET_o = ET * kp$

kc = Crop factor for maize crop at initial stage, mid (growth) stage and at harvesting stage were considered as 0.3, 1.2 and 0.3 respectively.

- The water applied to individual treatments were recorded and indicated in m^3.

Maize Growth Parameter

Maize plant height

Height of the maize plants at different treatments were recorded during 30, 60 and 90 DAS (Days after Sowing).

Yield

The maize grain yield was recorded from different treatments and indicated in Kg.

Water Use Efficiency

The water use efficiency is determined after knowing the total water applied and the yield and it is calculated by using below formula.

WUE (Water Use Efficiency) = Yield (kg) / Water applied (m^3)

Result and Discussion

Design of drip irrigation

The various design parameters such as irrigation data, pump duty calculation and irrigation scheduling were calculated and present under this sub heading.

Irrigation data

The different irrigation parameters need to know in order to design the drip irrigation at different emitter spacing *viz.* 0.3, 0.4 and 0.5 m and the suitable emitter spacing is suggested based on the moisture and growth parameters of maize. Table.2 shows the different irrigation parameters for maize cultivation.

Pump duty calculation for drip

Pump duty calculation for drip irrigation is very much needed in order to compute the total head requirement by calculating the frictional head losses under filters, venture, PVC pipes, valves, drip accessories and in drip laterals. As per the design criteria the operating pressure required at the end of the lateral was kept as 10 m i.e. 1.0 kg cm^2. Table 3 shows pump duty calculation of drip irrigation unit.

Irrigation scheduling

In order to operate the drip irrigation system efficiently and provide the required amount of water to the plant at root zone and at required time, the irrigation scheduling is very much important. The Table 4 represents the irrigation scheduling for maize crop. The valve number V10 represent the experimental block and the total flow under this valve is 11.8 m^3 hr^{-1} and the peak maximum operating time required is 0.825 hr day^{-1}. The irrigation was given at every two days interval and the time of operation of this was 1.65 hr day^{-1}.

Table 2 : Different irrigation parameters for maize cultivation

Irrigation data	Emitter spacing, 0.3m	Emitter spacing, 0.4m	Emitter spacing, 0.6m
Crop	**MAIZE**		
Emitter type	Aries	Aries	Aries
Irrigation system	Drip	Drip	Drip
Distance between rows (m)	0.6m	0.6m	0.6m
Distance between plants(m)	0.3m	0.3m	0.3m
Emitter spacing(m)	0.3	0.4	0.5
Number of laterals per row	1	1	1
Lateral spacing(m)	0.6	0.6	0.6

Emitter discharge(l/hr)	1	2	2
Application rate(mm/hr)	1.11	8.33	6.66
Evaporation equivalent (mm/hr)	5.5	5.5	5.5
Number of shifts	1	1	1
Duration of one shift (hr)	0.49	0.66	8.25
Total operational time(hr)			
Maximum dish variation (%)			
Net area (Ac)	0.114	0.114	0.114
Area (m^2)	451.2	451.2	451.2
Water source	Tank	Tank	Tank
Total area(ac)	0.111	0.111	0.111
Total Q	0.376	0.376	0.376
Flow per shift (m^3 /hr)			
Area per shift(Ac)			
Total amount of water required at peak period (m^3)			

Table 3 : Pump duty calculation of drip irrigation unit

Pump duty calculation for drip (m)	
Emitter minimum operating pressure(m)	10
Lateral drip line head loss(m)	3.4
Sub main head loss(m)	0.228
Elevation(m)	
Pressure required at sub main inlet(m)	13.62
Valve head loss(m)	2
Field fitting head loss(m)	2
Minimum head loss(m)	
Main line head loss(m)	1.44
Elevation (m)	2
Pressure at outlet of HV(m)	21.068
Secondary filtration head loss(m)	4
Fertigation head loss (m)	4
Primary filtration head loss(m)	4
Pressure at the inlet of HV(m)	33.068
Water source depth(m)	4
Vertical pipe head loss(m)	1
Safety factor(m)	
Total head required(m)	**38.068**
Shift flow rate (m^3 /hr)	**11.76 m^3/ hr**

Table 4 : Irrigation scheduling for maize crop

Operational Schedule							
Shift number	**Valve number**	**Area (m2)**	**Valve area (acres)**	**Valve flow (m^3/hr)**	**Shift Area (Ac)**	**Shift Flow (m^3/hr)**	**Operating Time (hr day^{-1})**
1	V1	2849	0.7	15.7	1.4	31.4	1.46
	V2	2849	0.7	15.7			
2	V3	3254	0.8	17.9	1.6	35.8	1.46
	V4	3254	0.8	17.9			
3	V5	3254	0.8	17.9	1.6	35.8	1.46
	V6	3254	0.8	17.9			
4	V7	2507	0.62	13.8	1.57	34.9	1.46
	V8	2507	0.62	13.8			
	V9	1325	0.33	7.3			
5	V10	1325	0.33	11.8	0.33	11.8	0.825
6	V11	2462	0.61	13.6	1.22	27.2	1.46
	V12	2462	0.61	13.6			
Total		31302	7.72	176.9	7.72	176.9	8.12

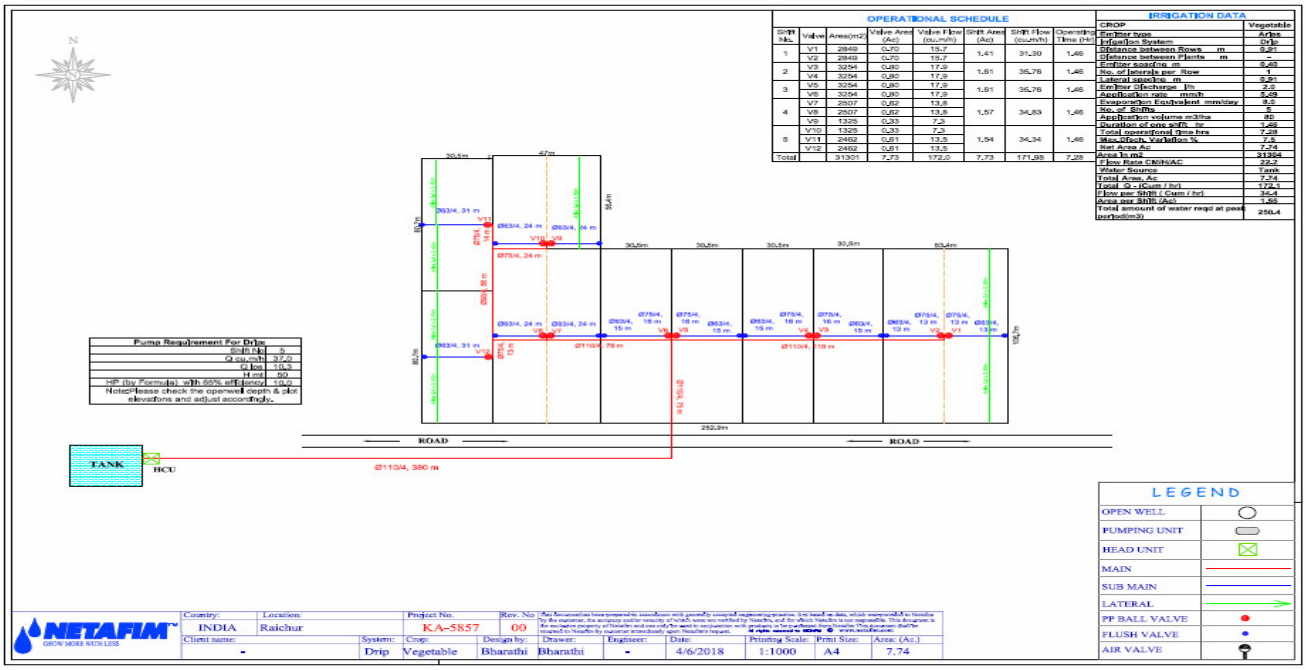

Fig. 3 : Auto CAD design of the drip irrigation experiment plot

Determination of crop water requirement for maize crop

The daily crop water requirement for maize was calculated for whole season on daily basis for different emitter spacing and under different irrigation levels.

Collection of daily evaporation (E) data and calculation of daily water requirement

The daily evaporation (E, mm) data's were collected from the Meteorological department, Main Agricultural Research Station, University of Agricultural Sciences Raichur from December to May month, 2021. The daily crop water requirement was calculated for the whole season based on the method mentioned in the material methods chapter and represented in tables. The pan factor (k_p) was considered as 0.7 (FAO, 2000) and crop factor (kc) values.

Crop water requirement for maize in different emitter spacing under 0.6 ET level

Crop water requirement for maize in different emitter spacing *viz.* 0.3, 0.4 and 0.5 m under 0.6 ET level was calculated and presented in table 4.2-4.7 from sowing (December) to harvesting time (May). The maximum water required (Crop evapotranspiration, ET_c) for the maize crop was recorded on 31.03.2021 and minimum was on 28.12.2020. This was mainly due to higher evaporation during May month and lower evaporation during December month.

Crop water requirement for maize in different emitter spacing under 0.8 ET level

Crop water requirement for maize in different emitter spacing *viz.* 0.3, 0.4 and 0.5 m under 0.6 ET level was calculated and presented in table 4.8-13from sowing (December) to harvesting time (May). The maximum water required (Crop evapotranspiration, ET_c) for the maize crop was recorded on 31.03.2021 and minimum on 28.12.2020. This was mainly due to higher evaporation during May month and lower evaporation during December month.

Crop water requirement for maize in different emitter spacing under 1.0 ET level

Crop water requirement for maize in different emitter spacing *viz.* 0.3, 0.4 and 0.5 m under 0.6 ET level was calculated and presented in table 4.13-4.19 from sowing (December) to harvesting time (May). The maximum water required (Crop evapotranspiration, ET_c) for the maize crop was recorded on 31.03.2021 and minimum on 28.12.2020. This was mainly due to higher evaporation during May month and lower evaporation during December month.

Soil moisture content

Soil moisture readings were collected at three different times i.e. during after sowing, growth and harvesting stage. The data on soil moisture content during after sowing were presented in Table 5.

Table 5 : Effect of emitter spacing and irrigation levels on soil moisture content after sowing

	Moisture content (%) recorded during 60 DAS		
	0.6 ET level	**0.8 ET level**	**1.0 ET level**
0.3 m Emitter spacing			
At emitter point	37.39	44.19	46.63
20 cm apart from emitter (Along)	35.98	41.52	42.79
20 cm apart from emitter (Across)	35.00	37.29	40.50
0.4 m Emitter spacing			
At emitter point	**36.00**	**42.10**	44.33
20 cm apart from emitter (Along)	35.77	40.68	41.96
20 cm apart from emitter (Across)	34.98	37.72	40.08
0.5 m Emitter spacing			
At emitter point	33.41	39.57	42.67
20 cm apart from emitter (Along)	31.95	38.58	41.70
20 cm apart from emitter (Across)	31.57	35.85	40.16

The soil moisture content reading was collected at the emitter point, 20 cm apart from the emitter (along the lateral) and 20 cm apart from the emitter (across the lateral) at different emitter spacing and irrigation level treatments during 60 DAS (mid stage) and presented in table 5. It was recorded that, among different emitter spacing treatments, 0.3 m and 0.4 m emitter spacing showed higher moisture content as compared to 0.5 m emitter spacing at the point of emitter, at 20 cm apart from the emitter (along lateral) and at 20 cm apart from the emitter (across lateral). Least moisture content was recorded in 0.5 m emitter spacing in all the three points. Therefore, the inline emitter spacing of 0.4 m could be suggested for maize crop under clay soils. It was observed that, in case of sub treatments i.e. irrigation level treatments, the highest moisture content was observed in 1.0 ET followed by 0.8 and least in case of 0.6 ET level (Table 5). The 1.0 ET level treatment recorded highest moisture in all the three locations i.e. at the point of emitter, 20 cm away from the dripper (along) and 20 cm away from the dripper (across). This was mainly because of deficit irrigation. Therefore, 0.8 ET irrigation level could be suggested for the maize crop under semi-arid region. Plate 2 shows the soil wetting pattern before sowing.

Plate 2 : Soil wetting pattern before sowing

Maize grain yield

The maize grain yield was recorded and is presented in Table 6. Among the different emitter spacing, significantly higher grain yield (53.34 t ha^{-1}) was recorded at 0.4 m emitter spacing as compared to 0.3 and 0.5 m emitter spacing. In sub treatments, significantly higher grain yield (53.85 t ha^{-1}) was recorded at 1.0 ET level as compared to 0.6 ET (46.76 t ha^{-1}) but observed on par grain yield (52.72 t ha^{-1}) at 0.8 ET level (Table 4.21). In interaction effect, significantly higher grain yield of maize was recorded in emitter spacing of 0.4 m with 1.0 ET level i.e. M_1S_2 followed by M_1S_1 and least in case of emitter spacing of 0.3 m with 0.6 ET level (M_0S_0). Plate 3 and 4 shows the maize plant height during 60 DAS and maize plant and cobs size influenced by 0.4 m emitter spacing with 0.8 ET level of irrigation level respectively. Plate 5 shows general view of the experimental plot.

Table 6 : Effect of different irrigation levels and emitter spacing on grain yield of maize

Maize grain yield (t/ha)					
Irrigation level		**Emitter spacing 0.3 m**	**Emitter spacing 0.4 m**	**Emitter spacing 0.5 m**	**Mean**
		M_0	**M_1**	**M_2**	
0.6 ET	S_0	45.37	47.92	46.99	**46.76**
0.8 ET	S_1	51.17	55.81	51.18	**52.72**
1.0 ET	S_2	53.95	56.30	51.30	**53.85**
Mean		**50.16**	**53.34**	**49.82**	
		SE m +/-	CD (0.05)		
M		0.73	2.85		
S		0.4	1.21		
Interaction (M x S)		0.68	2.1		

Plate 3 : Maize plant height during 60 DAS


Plate 4 : Maize plant and cobs size influenced by 0.4 m emitter spacing with 0.8 ET level of irrigation level.

Plate 5 : General view of the experimental plot

Maize water use efficiency

Among the different emitter spacing, higher use efficiency (WUE) 171.01 kg ha^{-1} mm^{-1} was recorded at 0.4 m emitter spacing as compared to 0.3 and 0.5 m emitter spacing but it is observed that WUE is non-significant among main treatments. In sub treatments, significantly higher WUE (194.19 kg ha^{-1} mm^{-1}) was recorded at 0.6 ET level as compared to 0.8 ET (164.13 kg ha^{-1} mm^{-1}) but observed least in 1.0 ET (134.18 kg ha^{-1} mm^{-1}) treatment (Table 7). This is mainly because of deficit irrigation where; lesser amount of water was applied in 0.6 ET. The interaction effect also observed non-significant.

Table 7 : Effect of different irrigation levels and emitter spacing on Water use efficiency of maize

Maize water use efficiency (kg ha^{-1} mm^{-1})					
Irrigation level		**Emitter spacing 0.3 m**	**Emitter spacing 0.4 m**	**Emitter spacing 0.5 m**	**Mean**
		M1	**M2**	**M3**	
0.6 ET	S1	188.41	199.01	195.14	**194.19**
0.8 ET	S2	159.30	173.74	159.35	**164.13**
1.0 ET	S3	134.44	140.28	127.83	**134.18**
Mean		**160.72**	**171.01**	**160.78**	
		SE m +/-	CD (0.05)		
M		2.60	NS		
S		1.40	4.32		
M x S		2.43	NS		

Conclusions

It can be concluded that among the different emitter spacing treatments, a spacing of 0.4 m exhibited superior moisture retention compared to 0.3 m and 0.5 m emitter spacing configurations, particularly beneficial for maize cultivation in clay soils. Additionally, the 0.8 ET irrigation level proved to be optimal for maize crops in semi-arid regions, ensuring adequate moisture without excessive water application.

Furthermore, the 0.4 m emitter spacing significantly enhanced grain yield, recording 53.34 t ha^{-1}, showcasing its potential for maximizing productivity. Similarly, the 1.0 ET irrigation level resulted in the highest grain yield, albeit with a lower water use efficiency (WUE), indicating the importance of balancing irrigation intensity to optimize both yield and resource utilization.

In terms of WUE, the 0.4 m emitter spacing also exhibited superior performance, emphasizing its efficiency in water utilization for crop production. Conversely, deficit irrigation strategies, such as the 0.6 ET level, though promoting higher WUE, resulted in reduced grain yield compared to the optimal 0.8 ET level.

Authorship

All authors have made substantial contributions to the conception, design, data collection, analysis, and interpretation of the study. All authors have read and approved the final manuscript.

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Data Availability

The data supporting the findings of this study are available within the article and its supplementary materials.

Conflicts of Interest

The authors declare that they have no conflicts of interest

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