Irrigation and tillage practices for fodder maize (*Zea mays* L.)in rice fallows

By

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(2011-11-172)

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Irrigation and tillage practices for fodder maize (*Zea mays* L.) in rice fallows"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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Subba Reddy, B.

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ABBREVIATIONS

AAS	: Atomic Absorption Spectrophotometer
ASMD	: Available Soil Moisture Depletetion
CF	: Crude Fibre
CP	: Crude Protein
CPE	: Cumulative Pan Evaporation
CGR	: Crop Growth Rate
CU	: Consumptive Use
CWUE	: Crop Water Use Efficiency
DAS	: Days After Sowing
EEL	: Evans Electroselenium Limited
Ep	: Pan Evaporation
ET	: Evapotranspiration
ET_0	: Reference Evapotranspiration
FWUE	: Field Water Use Efficiency
FYM	: Farm Yard Manure
GOK	: Government of Kerala
ICAR	: Indian Council of Agricultural Research
IW	: Irrigation Water
KAU	: Kerala Agricultural University
Kc	: Crop Coefficient
LAI	: Leaf Area Index
LSD	: Least Significant Difference
MOP	: Muriate of Potash
NS	: Non significant

PET	: Potential Evapo Transpiration
RBD	: Randomised Block Design
RDF	: Recommended Dose of Fertilizer
RGR	: Relative Growth Rate
RNA	: Ribonucleic Acid
Rs	: Rupees
SSP	: Single Super Phosphate
TNAU	: Tamil Nadu Agricultural University
USWB	: United State Weather Bureau
WUE	: Water Use Efficiency

Introduction

1. INTRODUCTION

Agricultural production systems in India are generally based upon mixed farming in which crops and livestock are integrated. Farmers mix these two enterprises to diversify the use of their resources for maximizing family income. However, in Kerala, livestock husbandry as a whole is on the decline. Livestock population in Kerala is decreasing at an alarming rate; it was 34.2 lakhs in 1987, but in 2007, it was just 17.4 lakhs (GOK, 2010). The decline in cattle population affects many other facets of farming besides affecting the supply and availability of milk and dairy products. Although several reasons can be attributed to the drastic decline in livestock population, a major reason is decreased availability of paddy straw because of the dwindling paddy area year after year. Availability of alternative feed resources is also limited as cultivation of fodder crops is not popular among farmers. It is estimated that the present fodder availability from all sources in Kerala is only 5.1 million tonnes when the total requirement is 23.2 million tonnes (Anita *et al.,* 2011).

In the present land use pattern of Kerala, it is very difficult to find new areas for fodder cultivation. However, introduction of short duration fodder crops in the existing cropping systems is a practical solution to this problem. Food-forage based systems provide support to the farmers by adjusting a part of their land or season exclusively for fodder production. Food-fodder based crop rotations have been evaluated for their profitability and were found more remunerative than others in many agro-climatic and management situations (Suneethadevi *et al*., 2004).

The rice fallows, especially during the third crop season, can be utilized in a big way for cultivating short duration fodder crops such as fodder maize. In the third crop season, however, water availability might be a major problem. Farmers would be interested in fodder production system which requires low inputs. Fodder maize is found to be an ideal short duration fodder crop for the rice fallows with irrigation (George, 2011). She compared fodder sorghum, fodder maize and fodder bajra, and came to the conclusion that fodder maize with irrigation under herbicide based zero tillage was the best.

Fodder maize is a cheaper source of nutrients as compared to concentrates and is useful in bringing down the cost of feeding. It provides all the critical elements in animal nutrition such as digestible protein, carbohydrates, minerals and also a very good source of β-carotene. It can also produce reasonably good herbage yield within a short growing period of 60-65 days. The present investigation involving fodder maize in summer rice fallows was planned with the main objectives, (1) To determine the most profitable irrigation schedule for fodder maize in rice fallows under different tillage practices and (2) To study the soil moisture extraction pattern and water use efficiency under different treatments.

Review of Literature

2. REVIEW OF LITERATURE

The present study was undertaken to determine the most profitable irrigation schedule for fodder maize in summer rice fallows under different tillage practices. In this chapter, review of literature on various aspects included in the present study such as growth, growth parameters, fodder production, weed growth, nutritive value and quality, nutrient uptake, consumptive use, water use efficiency, moisture extraction pattern and B: C ratio is presented. Similar works on grain maize are also included in this review wherever the literature on fodder maize is insufficient.

2.1. Growth and growth parameters

Maize is considered as an ideal forage crop and can be raised throughout the year in areas where irrigation facilities are available.

Balaswamy *et al*. (1978) observed that increased soil moisture depletion decreased the number of functional leaves per plant. A decrease in leaf number per plant was reported with increasing soil moisture depletion (EL-Sharif *et al*., 1986). Water stress conditions during vegetative growth (30 to 48 DAS) affected leaf area (Sabrado, 1990). More frequent irrigation at IW/CPE= 0.8 and 1.0 caused increase in leaf are index and grain yield (Prasad and Prasad, 1989). Moisture deficit reduced leaf longevity, green leaf area and turgor from anthesis to harvest (Wolfe *et al*., 1988). In general frequent irrigations increased plant height (Shalaby and Mikhail, 1979; Prasad and Prasad, 1992).

Singh *et al.* (1989) noticed on sandy loam soil at Hissar during summer that the plant height and other growth attributes like number of leaves, leaf area and leaf area index increased with irrigation at IW/CPE ratio 0.75 over 0.5.

Prasad *et al*. (1985) noted significantly higher maize plant height (135.0 cm) at IW/CPE ratio 1.0 than ratios at 0.8 (127.6 cm) and 0.6 (116.2 cm).

Sridhar and Singh (1989) reported increased leaf area per plant, leaf area index, dry weight of leaves and stem because of increased frequency of irrigation from IW/CPE ratio 0.6 to 0.8 with 6 cm depth of water for maize grown at Varanasi during winter season.

Mansfield *et al.* (1990) at Belvatagi during rainy season in clay loam soils recorded significantly higher plant height in fodder maize due to irrigation at IW/CPE ratio 0.9 (220.1 cm to 225.9 cm) over 0.7 and 0.5 ratios and un irrigated control.

According to Palled *et al*. (1991) plant height of maize increased with increase in irrigation level from IW/CPE ratio 0.5 to 0.9.

Jadhav *et al.* (1993) observed that irrigations scheduled at IW/CPE ratio 0.8 and 1.0 produced significantly more stover maize yield (775.1 and 791.0 q/ha) at 0.4 and 0.6 ratio owing to increase in plant height, number of functional leaves and dry matter accumulation in clay loam soil during *Rabi* season at Kolhapur. A similar result was also reported by Bajwa *et al.* (1988) on clay loam soil at Kolhapur.

Hussaini *et al.* (2001) in Nigeria recorded maximum total dry matter, plant height, CGR and RGR (96.3 g/plant, 171.0 cm, 85.1 g/m^2/week and 610 mg/g/week, respectively) with scheduling of irrigation at IW/CPE ratio 1.0 over ratios 0.6 and 0.8 in sandy soil during *Rabi* season in maize crop.

Singh (2001) observed that scheduling of water at IW/CPE ratio 1.0 recorded higher plant height (23.0 cm), dry matter production (13500 kg/ ha) over 0.5 and 0.75 ratios in baby corn.

In clay loam soil of Akola during *Rabi* season, Jiotode *et al.* (2002) observed that scheduling of irrigation at 40 mm CPE recorded higher plant height (173.48 cm) number of leaves per plant (11.38) leaf area per plant (35.22

dm^2/plant), LAI (5.66) and dry matter per plant (103.66 g) over 60 and 80 mm CPE due to better water use.

Kumar (2005) from a study in Bihar reported higher plant height , number of leaves per plant, leaf length and LAI in rotavator tilled maize at all growth stages over zero tilled maize, while crops receiving five to six irrigations were significantly superior over those receiving lower frequencies of irrigation.

Nagaraju (2006) in Dharwad observed that scheduling irrigation at IW/CPE ratio 1.2 produced higher plant height and LAI over 0.9 and 0.6 ratios at 30, 60, 90 DAS and at physiological maturity in maize.

George (2011) compared different systems of tillage in Kerala and recorded higher plant height, LAI, leaf-stem ratio and total plant dry matter production in fodder maize with herbicide based zero tillage. However, shoot to root ratio was higher with normal tillage.

2.2. Effect of tillage and irrigation levels on fodder yield

The dry matter production of maize increased with increase in IW/CPE ratio from 0.6 to 1.2 (Khera *et al*., 1976). Prasad *et al*. (1985) found that dry matter production per plant increased significantly (from 39.21 to 52.20 g/plant) when IW/CPE ratio was increased from 0.6 to 1.0. Increasing irrigation frequency (Bajwa, *et al*., 1988) and level of irrigation (Kasele *et al*., 1994) increased dry matter yield.

Singh *et al.* (1989) from a study during summer season observed significantly higher green fodder and dry matter yield at IW/CPE ratio of 0.5 and 0.75 over 0.25 ratios. Dry matter production in stem and leaves showed slow growth up to 56 days and increased rapidly and almost linearly thereafter (Galbiatti *et al*., 1989). Similar results were reported by Rana and Malik (1981).

Mansfield *et al.* (1990) at Belvatagi during rainy season in clay loam soils recorded maximum dry matter and fresh forage yield of maize at IW/CPE ratio 0.7 (445.0 q/ha).

Manhi and Shukla (1992) observed that green forage yield was more with the application of irrigation at 75 per cent available soil moisture over 50 per cent available soil moisture and no irrigation during rainy season at Jhansi.

Abu-Awwad (1994) recorded higher dry matter production of sweet corn (144.0 q/ha) due to irrigation at E_{pan} 1.0 over E_{pan} 0.25 and 0.5 (70.0 and 104.0 q/ha) respectively in clay soils.

Sathyamurthi *et al.* (2001) reported that higher maize grain yield with better economic returns could be achieved by land preparation with tractor drawn disc plough followed by cultivator tillage combined with integrated weed management (pre-emergence application of atrazine @ 0.25 kg/ha followed by one hand weeding).

Nagaraju (2006) observed that scheduling of irrigation at IW/CPE ratio of 1.2 recorded higher dry matter per plant and total biomass yield over 0.9 and 0.6 ratios in maize. Yield attributing characters and grain yield of maize did not differ significantly among various tillage and crop establishment practices (Ram *et al*., 2010). Kaputsa *et al.* (1996) reported similar effects of tillage methods on maize.

Ramulu *et al.* (2010) reported significantly higher grain yield (7.46 Mg/ha) and straw yield (12.89 Mg/ha) in fertigation scheduled at E_{pan} 1.0 supplied with 100 per cent RDF (Recommended dose of fertilizers) through water soluble fertilizers compared to fertigation at E_{pan} 1.0 with 100 per cent RDF through conventional fertilizers (N & K fertigation and P as basal soil application).

Sarma and Gautam (2010) reported that conventional tillage gave higher grain yield of maize (0.11 – 0.17 Mg/ha) than minimum tillage. Chemical weeding with herbicide (Alachlor) resulted in 7.8 per cent higher yield of maize over mechanical weeding. There was significant increase in grain yield with conventional tillage (23.5%) due to reduced population and dry weight of weeds when compared with zero till (3.69 Mg/ha). According to them, conventional tillage, higher seed rate (24 kg/ha) and hand weeding at 25 and 45 DAS was the best in reducing weed growth and for maximum yield and net return in maize.

George (2011) reported significant variation between tillage methods in fodder yield of maize. The highest yield was recorded in zero tillage with herbicide followed by minimum tillage and normal tillage.

2.3. Effect of tillage and irrigation levels on weed growth and crop yield

Weed control measures include physical, cultural, biological and chemical methods. Tillage practices come under physical methods of weed control. Presently zero tillage and minimum tillage practices are gaining significance in conservation agriculture due to their role in soil and moisture conservation and reduced cost of cultivation. According to Vargessel *et al.* (1994) weed distribution in corn fields was not a critical consideration in determining yield loss. Amador Ramirez (2002) registered higher grain yield with an increase in the weed free period.

It is widely recognised that primary tillage influences distribution of weed seed in different soil layers (Fray and Olson, 1978). They also observed that inversion tillage such as mouldboard ploughing caused burial of large proportion of weed seeds. Non-inversion tillage methods such as chisel ploughing left a greater proportion of weed seeds near the surface. According to Tiwari *et al.* (1987), maize grain yield was reduced by 100 per cent due to uncontrolled weed competition under maize-cowpea intercropping system.

The depressing effect of weeds on crop yields varies with types of weeds, intensity and duration of weed infestation. Young *et al.* (1984) noted that

Agropyron repens at a density of 745 shoots/m^2 reduced maize grain yield by 37 per cent. Another major reported weed is *Echinochloa crusgalli* which at a density of 100 plants/m^2 reduced yield of maize by 18 per cent (Kropft *et al*., 1984). Maize yield was reduced by 80 per cent when the fields were infested with *Rottoboellia exaltata* (Sharma and Zelaya, 1986). Rola and Rola (1992) reported that the presence of *Amaranthus retroflexus* in maize fields reduced grain yield by 20 and 30 per cent with 20 and 30 weeds/m^2.

Ball and Miller (1990) reported that secondary tillage practices such as hand hoeing and harrowing had less influence on the seed bank than primary tillage.

From a 20 year tillage experiment, Cardina *et al.* (1991) found that the greatest weed seed density was in no tillage plots and the lowest in conventional tillage plots.

Sathyamurthi *et al.* (2001) reported that primary tillage with country plough resulted in lower densities of grasses and sedges, whereas broad leaved weed population was reduced by tractor drawn disc or mould board plough followed by cultivator tillage in maize fields raised in black clay and red sandy loam soils.

Chopra and Angirasto (2008) studied the influence of various tillage methods on the productivity and weed control in maize. Among tillage methods, raised seed bed resulted in significantly lower density and dry matter of weeds at 60 days after sowing (DAS) and at harvest of the crop followed by conventional tillage.

Chauhan and Johnson (2009) reported that agronomic practices such as tillage have implications for weed competition and weed management strategies. The effect of different tillage systems, including conventional tillage, minimum tillage and zero-tillage, on the emergence pattern of different weed species was evaluated in a field experiment in the *Kharif* seasons of 2007 and 2008. In both years, seedling emergence of *Digitaria ciliaris, Echinochloa colona, Eleusine* *indica, Ageratum conyzoides, Eclipta prostrata* and *Portulaca oleracea* were greater in zero-tillage compared with either conventional or minimum tillage where the seedling emergence was similar.

Mishra and Singh (2009) observed that rotational tillage systems significantly reduced the seed density of *E. colona* as compared to continuous zero or conventional tillage systems. The number of weed seeds decreased considerably in plots receiving effective weed control (herbicide + one hand weeding).

According to George (2011), major variation was noticed among tillage methods with respect to weed dry matter production at 30 DAS and at harvest. Weed dry matter was the highest in zero tillage at both stages. The lowest weed dry matter was recorded in normal tillage followed by zero tillage with herbicide at both stages.

Weed population shifts towards annual weeds were observed when conventional tillage systems were changed to zero-tillage systems in maize (Ball and Miller, 1993).

The crop rotation that included one to three year of forage production showed higher densities of annual broad leaf and perennial weeds in the succeeding potato crop (Liebman *et al.,* 1996). Similarly, Stevenson *et al.* (1997) reported that the total weed density in the barley-forage rotation was about three times as that in the barley monoculture. Pandey *et al.* (1999) recorded reduced density of broad leaved and grassy weeds with repeated weedings or herbicidal management with atrazine and pendimethalin in maize-wheat rotation.

Tuesca *et al.* (2001) reported that the weed spectrum changed rapidly in no-tillage systems with increase of annual grassy weed population in maize-soybean as against wind dispersed weeds in wheat-soybean cropping system and inconsistent behaviour of perennial weeds in relation to tillage systems.

Zero tillage with effective weed control was found more remunerative in soybean-wheat system (Mishra and Singh, 2009).

2.4. Effect of irrigation on nutrient absorption

Nutrient uptake and moisture use are closely related. Brown *et al.* (1960) observed that cotton and soybeans increased their absorption of nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) linearly in response to increase in soil moisture level from wilting point to field capacity.

Singh (1975) studied the effect of different soil moisture regimes along with graded doses of fertilizers on berseem fodder and found that the percentage of N, P and K decreased with increase in moisture availability from 25 per cent to 50 per cent and 75 per cent available soil moisture in the soil. An increase in soil moisture increased the total uptake of nitrogen significantly. The uptake of P and K also increased with wetter regimes but did not reach the level of significance.

While evaluating the effects of the soil moisture regimes of 25, 50, 75 and 100 per cent available soil moisture on green gram, Varma and Subba Rao (1975) observed a moisture regime of 50 per cent to be optimum for maximum nitrogen content in plant parts.

Cocueci *et al*. (1976) followed the growth of squash fruit in the field under normal and drought conditions and found a decrease of RNA and protein content in fruit tissues of water stressed plants. They further observed that under drought conditions, fruit growth is controlled by water availability through protein synthesis.

Crop yield response to P and other nutrients varies depending on water availability. The lower the rainfall, the greater the response to P. The same relationship is commonly observed with K. Crop response to K in wet soils can be related to the effect of reduced aeration on respiration. Plant roots respire to obtain energy to absorb nutrients and respiration requires O_2 (adequate K enhances respiration). Nutrient and water interactions under irrigated systems are similar to dry land systems, except the interactions operate at higher yield levels. Fertility is one of the important controllable factors influencing water use in irrigated soils. When N is deficient, increasing N fertilization will increase yield, total water use, and WUE. Generally, the crop response to N is much greater under irrigation, where water is non limiting (Thorne *et al*., 1979).

2. 5. Effect of tillage on nutrient absorption and uptake

Soil tillage and fertility management influence both nutrient and soil moisture dynamics in the soil– plant system, which in turn affect nutrient use efficiency in cropping systems. Tillage practices are helpful to incorporate fertilizer and crop residues in the soil, improve soil aeration, and subsequently promote organic N and P mineralization (Carter and Rennie, 1987, Groffman *et al*., 1987, House *et al*., 1984, Huntington *et al*., 1985, McCarthy *et al*., 1995, Rice *et al*., 1987, Varco *et al*., 1993 and Yoong *et al*., 2001, Dinnes *et al.,* 2002).

Nitrogen uptake of maize increased significantly with chemical weeding and legume mulching and it was lower under minimum tillage (Sharp *et al*., 1986). However, P uptake of maize was more efficient under no tillage than under conventional tillage. Tillage treatments affected the distribution of roots and extractable P in the top soil layer (Anderson *et al*., 1987).

Phosphorus absorption and dry matter production in conventional tillage were less than that in a hand planted no till plot but greater than that with severe soil disturbance (Mc Gonigle *et al*., 1990).

As the N availability is affected by the tillage system, P availability can equally be affected, leading to P deficiency in many cropping systems. Plant P uptake varies with soil P and moisture availability, and the concentration of P in plant tissue decreases with plant age and water stress (Payne *et al*., 1995). It was found that banded P (deep or shallow) increased early corn growth and P uptake compared with broadcast placement under no tillage (Mallarino *et al*., 1999).

Plant N use can be altered by different management practices and interactions between tillage system, N rate, and N application timing. The interactive effects of different tillage systems such as zero tillage, conventional tillage, or minimum tillage and N rate on grain N uptake was significant in increasing N removal with increasing N rate (Halvorson *et al*., 2001).

The tillage system can influence soil N availability due to its impact on soil organic C and N mineralization and subsequent plant N use or accumulation (Dinnes *et al*., 2002; Al-Kaisi and Licht, 2004; Licht and Al-Kaisi, 2005; Sanju and Singh, 2001). Compared to zero tillage, the conventional tillage system significantly changed the mineralizable C and N pools (Woods and Schuman, 1988). However, a long-term zero-till system has potentially greater mineralizable C and N pools compared with conventional tillage (Doran, 1980).

Tillage along with N fertilizer application had a significant effect on plant uptake of N and P, especially at early growth stages of maize. However, the N rate and seasonal variability have more influence on plant N and P uptake than do the tillage system (Al-Kaisi and Kwaw-Mensah, 2007).

George (2011) reported that there was significant difference between tillage treatments with respect to nitrogen content in leaf and uptake. The nitrogen content in leaf was found significantly higher in normal tillage plots whereas it was comparable in all other treatments. There was no significant difference between tillage methods with respect to nitrogen content in stem. However, phosphorus, potassium, calcium and magnesium content in leaf, stem and uptake by maize was high in herbicide based zero tillage when compared with normal tillage, minimum tillage and zero tillage.

2.6. Forage quality

Fodder maize can be fed safely at any stage of growth and there is no risk of prussic or oxalic acid or ergot disease poisoning (Chatterji and Das, 1989).

Kumar *et al*. (2001) noticed that scheduling of irrigation at IW/CPE ratio 1.0 recorded the lowest protein content in grain (9.87%) over one irrigation at tasseling at IW/CPE ratio 0.7 (10.41%) in sandy loam soil of Raipur.

Singh (2001) obtained higher crude protein (%) and vitamin C (100 mg/g) due to irrigation at IW/CPE ratio 1.0 (13.23 and 12.65, respectively) over IW/CPE ratios 0.75 and 0.5 (12.78 and 12.57, and 12.11 and 12.44) in sandy clay loam during summer 1997 at TNAU.

2.7. Water use efficiency

Prasad *et al.* (1985) reported increased water use efficiency (from 135.6 to 150.2 kg/ha-cm), with increasing IW: CPE ratio (from 0.5 to 0.9). Similarly, Cheema and Uppal (1987) recorded increased water use efficiency from 48.5 to 53.3 kg/ha-cm with increased number of irrigations.

Balaswamy *et al.* (1986) noticed that the water use efficiency of maize crop in sandy clay to sandy loam soil at Hyderabad was 38.8 kg/ha- mm at 40 per cent ASMD over 60 and 80 per cent ASMD (37.9 and 35.8 kg/ha- mm respectively) during summer in sandy clay loam soil.

Roy and Tripathi (1987) reported inverse relationship between irrigation and water use efficiency. Aujla *et al*. (1987) reported that mean WUE decreased (from 51 to 44 kg/ha-cm) with increasing application of irrigation water (from 25.0 to 49.5 cm).

Pillai *et al*. (1990) found that mean water use efficiency decreased with increasing irrigation levels (from 25 to 75 per cent available moisture). Palled *et al*. (1991) reported that water use efficiency decreased with irrigation applied beyond 0.7 IW: CPE ratio. Prasad and Prasad (1992) found highest water use efficiency (351 kg/ha-cm) under IW: CPE ratio 0.4 followed by IW: CPE ratios 0.6 and 0.8. Jadhav *et al*. (1992) found that water use efficiency increased (from 12.1 to 17.0 kg/ha-cm) with decreased IW: CPE ratio from 1.0 to 0.4.

Narang *et al.* (1989) observed that higher water use efficiency was recorded at 50 mm CPE over 100 mm and 75 mm CPE during wet year whereas 80 mm CPE during dry year in red sandy loam soils of Punjab.

Varughese and Iruthayaraj (1996) observed higher water use efficiency for maize at IW: CPE ratio of 0.75. Similarly, Bandyopadhyay and Mallick (1996) reported WUE of 7.25, 6.41 and 6.32 kg/ha- mm for IW: CPE ratio of 1.2, 0.9 and 0.6 respectively in winter maize. Kumar and Bangarwa (1997) found that water stress created at early stage caused more extraction of water from deeper soil layers. Moisture stress at silking and dough stages decreased water use efficiency of maize. According to them silking is the most sensitive to water stress.

Tulu *et al.* (1998) noticed that irrigation scheduled at IW/CPE ratio 0.6 continuously during reproductive and grain filling stages recorded the highest WUE of 142.24 kg/ ha/cm.

Vishwanathan *et al.* (2000) reported that water use efficiency was significantly higher in drip irrigation at E_{pan} 0.4 (40.04 kg/ha-mm) over E_{pan} of 0.6 and 0.8 (33.27 and 32.69 kg/ha-mm), which were significantly better than weekly surface irrigation at E_{pan} 0.8 (27.19 kg/ha-mm) during summer 1998 in red sandy loam soil of Bangalore.

According to Singh (2001) scheduling irrigation at IW/CPE ratio 0.5 recorded maximum water use efficiency in summer and *Kharif* (20.7 and 17.4 kg/ha-cm) over 0.75 and 1.0 ratio (summer 18.6, 144 and *Kharif* 11.8 and 11.2 kg/ha-cm respectively) in sandy clay loam soil of Tamilnadu.

Hussaini *et al.* (2002) at Samaru, Nigeria recorded higher WUE with irrigations scheduling at IW/CPE ratio 0.6 (6.96 kg/ha-mm) over ratios of 0.8 and 1.0 (6.37 and 6.33 kg/ha- mm respectively) in sandy soil during *Rabi* season.

Jiotode *et al.* (2002) observed that water use efficiency was more in irrigations scheduled as per critical growth stages (5.86 kg/ha-mm) over 40 mm, 60 mm and 80 mm CPE (3.29, 3.86 and 4.19 kg/ha- mm respectively) in clay loam soil of Akola in Maharastra.

2.8. Consumptive use

Bowman *et al*. (1991) stated that the water requirement of maize was generally in accordance with evaporative demand and rainfall. The water requirement of sweet corn ranged from 311 mm to 604 mm under silt clay loam (Braunworth, 1987). In another study, the water used was 481 mm as estimated by soil water balance equation (Braunworth and Mack, 1987).

Jadhav *et al*. (1994) found that the water consumption of maize varying from 436.33 to 414.41 mm at IW: CPE 0.4 to 0.6 ratios in Maharashtra under clay loam soil. In another study, maize water need was 304 mm during summer season in silty clay loam soil at IW/CPE ratio 0.75 with higher yield (Khan *et al*., 1996).

Mallikarjunaswamy (1997) reported 519.8 mm water use at IW: CPE ratio 0.8 irrigation scheduling as compared to 469.8 mm at IW: CPE ratio 0.6. Leta Tulu *et al*. (1998) reported that total water requirement of maize ranged from 451mm to 601mm depending on irrigation scheduling at Bangalore during summer. Irrigation at IW: CPE ratio of 1.0 throughout the crop growth period gave the higher yield with a water use of 601mm and WUE of 126.89 kg/ha-mm.

2.9. Soil moisture extraction pattern

Chandrasekharaiah *et al*. (1985) reported that the moisture extraction pattern in deep black soil of Dharwad (Karnataka) was influenced by irrigation levels. Crop extracted more soil moisture from the upper 0-15 cm (37.73 to 42.20 per cent) than 15-30 cm (25.36 to 29.13 per cent) soil layers. Moisture extraction at IW/CPE ratio 0.9 was higher from upper soil layers compared to IW/CPE ratios 0.6 and 0.3. Sinha *et al*. (1989) conducted an irrigation experiment on sandy loam soil at New Delhi and they reported increased moisture extraction pattern with increase in the level of moisture regimes. The amount of soil moisture extracted by plant roots decreased substantially with increasing depth of soil profile.

The higher soil moisture extraction (73 per cent) in wheat was observed from 0-40 cm soil layer followed by the deeper soil layer (27 per cent) in IW/CPE ratio 0.8 (Yadhav, 1991).

Mishra *et al*. (1994) reported that the wheat crop extracted more (77 per cent) moisture from top 60 cm than 60-120 cm depth of profile in IW/CPE ratio1.0 irrigation schedule compared to IW/CPE ratio of 0.5 and 0.75. It was noticed that the top 0-15 cm soil layer contributed 46.8, 41.7 and 31.0 per cent soil moisture in eight, six and four irrigations, respectively.

On the black soil of Dharwad (Karnataka) Angadi (1999) observed that treatment receiving frequent irrigations (IW/CPE ratio 0.9) extracted higher per cent of soil moisture from 0-30 cm soil layer, than treatment receiving less frequent irrigation (IW/CPE ratio 0.5). On the contrary, the lower depth (30-60 cm) contributed more moisture in IW/CPE ratio 0.5 irrigation schedules.

Jana *et al*. (2001) conducted an experiment in Nadia (West Bengal) to study the response of wheat to irrigation regimes. The results indicated that wheat crop extracted more moisture from the top layer of soil (0-15 cm) under irrigated condition.

In a field experiment conducted on the black soil of Dharwad (Karnataka), Ahmad (2002) observed that treatment receiving frequent irrigation (*i.e.,* six irrigations) extracted higher per cent of soil moisture from 0-30 cm soil layer than other treatments (*viz.*, two, three, four and five irrigations). On the contrary, the lower depth (30-60 cm) contributed more moisture with two irrigations.

Kibe and Singh (2003) reported that the crop extracted more moisture of 59.4 to 65.8 per cent from the top 30 cm soil layer and the minimum (7.10 to

5.32%) from the 90 to 120 cm soil layer on the deep sandy loam soil of New Delhi.

2.10. Benefit: cost ratio

Balaswamy *et al.* (1986) noticed that net return was higher in paired row planting (Rs. 71000/ha) over normal planting (Rs. 58000/ha) in sandy clay to clay loam soil. Further the net return was maximum in scheduling of irrigation at 40 per cent (Rs. 56000/ha) over 60 and 80 per cent (Rs. 38000 and Rs. 22000/ha, respectively) ASMD in sandy loam soil of Hyderabad.

Jadhav *et al.* (1993) noticed that scheduling of irrigation at IW/CPE ratio 1.0 recorded higher B: C ratio (0.83) over 0.4, 0.6 and 0.8 ratios (0.58, 0.74 and 0.80, respectively) during *Rabi* season of 1986-87 in clay loam soil of Kolhapur (Maharashtra).

Kumar *et al.* (1996) reported that higher net return of maize (Rs. 7459/ha) was with water stress at dough (84 DAS) over knee high, tasseling, silking stages (Rs. 4038, Rs. 5919 and Rs. 3854/ha, respectively). Silking stage was most critical for moisture, which recorded lowest returns (Rs. 3524/ha) due to stress in loamy soil of Karnal during summer 1991.

Vishwanathan *et al.* (2000) observed that scheduling of irrigation by weekly surface irrigation at E_{pan} 1.0 recorded higher B: C ratio (5.8) which was on par with drip at E_{pan} 0.8 (5.2) over other 0.4 and 0.6 E_{pan} by drip (3.9 and 4.3, respectively) in sweet corn in red sandy loam soil during summer 1998 at Bangalore.

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled "Irrigation and tillage practices for fodder maize (*Zea mays* L.) in rice fallows" was undertaken at the Department of Agronomy, College of Horticulture, Kerala Agricultural University during 2012-2013. The details of materials used and methods adopted for the study are explained in this chapter.

3.1. General details

Experiment site

The experiment was conducted in the Kotteppadam rice fields attached to the Department of Agronomy, College of Horticulture, Vellanikkara. Geographically, the area is situated at 10^{0}31'N latitude and 76^{0}13'E longitude at an altitude of 40.3 m above mean sea level.

Soil characteristics

The soil of the experimental site is sandy loam (Order: Oxisol), and acidic in reaction with a pH of 5.7. The field capacity of the soil was 15.10 per cent and permanent wilting point was 7.69 per cent. Basic physico-chemical properties of the soil are given in Table 1.

Season and weather conditions

The experiment was conducted in rice fallows after the harvest of first season rice crop (date of harvest: 04-11-2012) during the period November 2012 to February 2013. The details of meteorological data recorded at Vellanikkara during the crop period are given in Appendix I and graphically presented in Fig.1, Fig.2 and Fig.3.

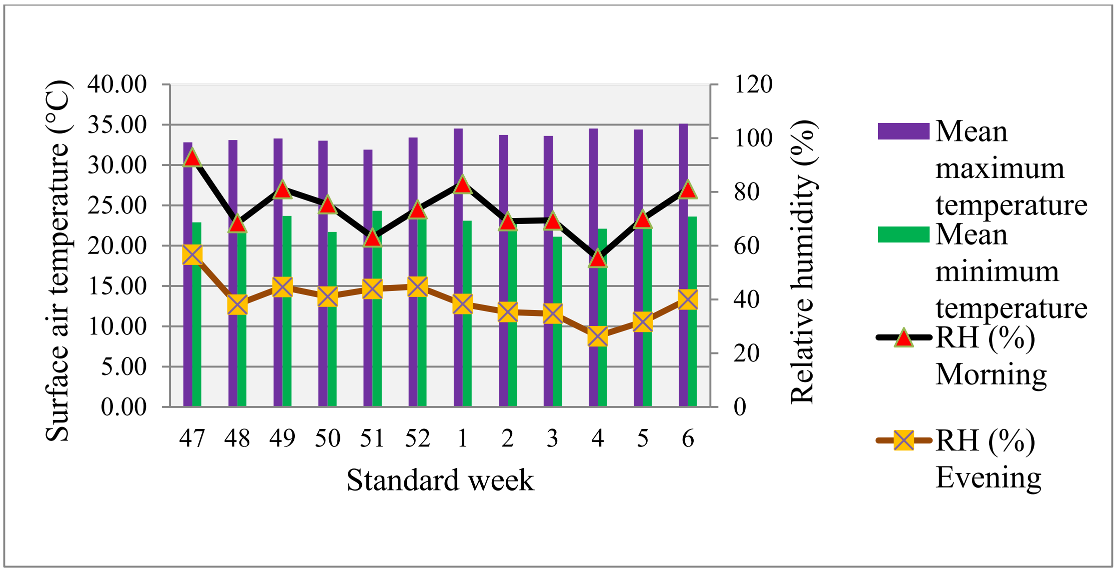


Fig. 1. Temperature and relative humidity during the crop period (Nov 2012 to Feb 2013) at Vellanikkara, Thrissur

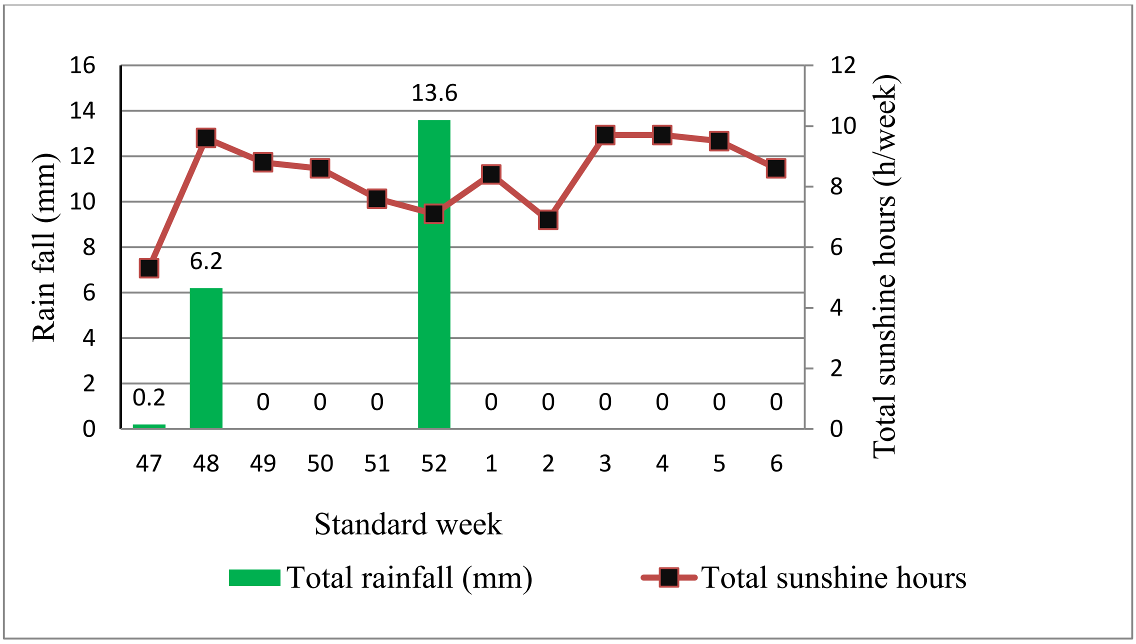


Fig. 2. Rainfall and Sunshine hours during the crop period (Nov 2012 to Feb 2013) at Vellanikkara, Thrissur

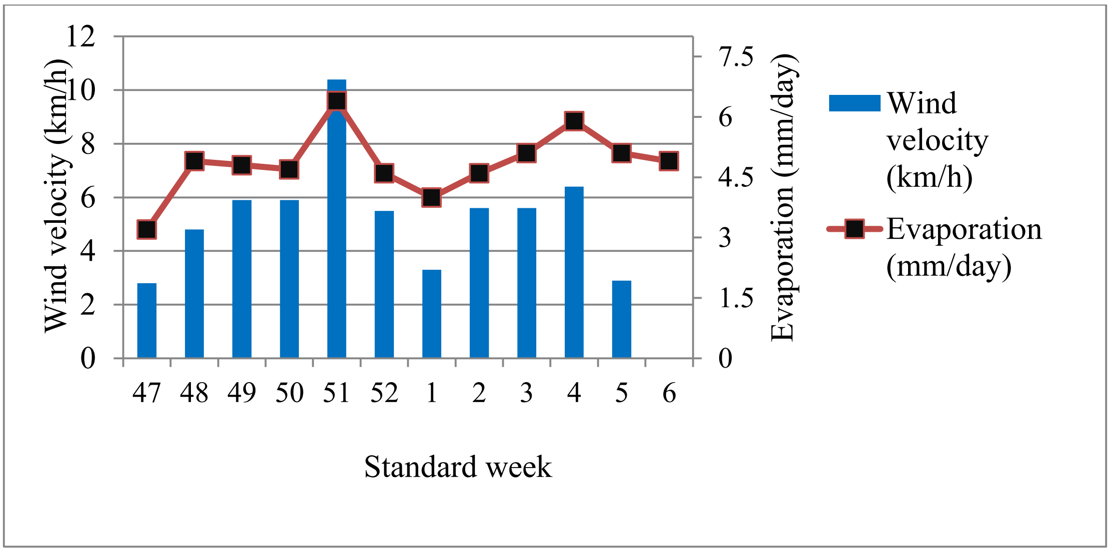


Fig. 3.Wind velocity and evaporation during the crop period (Nov 2012 to Feb 2013) at Vellanikkara, Thrissur

3.2. Crop husbandry

Field operations

The selected field was laid out as per the lay out plan (Fig.4).The field was kept undisturbed for S_1 and glyphosate was applied @ 0.8 kg ai/ha. For S_2, soil was dug in strips (width about 15cm) at a spacing of 30 cm. In the case of S_3, the land was ploughed thoroughly twice and then levelled.

Seeds and sowing

The cultivar "African tall", a high yielding fodder maize was used for the study. The seed material for the experiment was obtained from the Department of Agronomy, College of Agriculture, Dharwad. African Tall is a high yielding composite of seven genotypes released in 1983 for year round cultivation throughout the country. Average plant height is 260 cm with yield potential of 40 Mg/ha. One week after herbicide application all the seeds were dibbled at a spacing of 30 cm X 15 cm on 29-11-2012. The seed rate used was 50 kg/ha.

Manures and fertilizers

At the time of land preparation, farm yard manure @ 10 Mg/ha was applied uniformly to the plots and incorporated in S_3 plots but in S_1 and S_2 plots, it was only broadcast uniformly. The fertilizer recommendation followed was 120:60:40 kg N, P_2O_5 and K_2O/ha as per the package of practices recommendations, Kerala Agricultural University (KAU, 2007). The entire quantity of P and half N and half K were applied basally as urea (46% N), mussorie rock phosphate (20% P_2O_5) and muriate of potash (60% K_2O) respectively. The remaining quantity of N and K were applied as top dressing at 30 days after sowing.

Gap filling and thinning

Gap filling and thinning were done one week after sowing to maintain the required plant population.

Irrigation

Differential irrigations according to treatments were started immediately after sowing. A pre sowing irrigation of 40 mm with check basin method through hose pipe (after calibration) was given uniformly to all the plots on 28-11-2012. Afterwards, 40 mm irrigation water was applied as and when the respective cumulative pan evaporation values were attained in various treatment plots. Accordingly, 40 mm irrigation was scheduled when evaporation values from a class A open pan evaporimeter readings reached to 100 mm, 57.1 mm and 40 mm to M_4, M_3 and M_2 plots respectively. During the crop period a total of 20 mm rainfall was received on these days, on 1-12-2012 (0.2 mm); on 2-12-2012 (6.2 mm) and on 29-12-2012 (13.6 mm). This rainfall was accounted in calculating CPE for scheduling irrigation. The details of irrigation given are presented in Table 2.

Harvesting

Harvesting was done at 50 per cent flowering to milky stage. Two border rows all around the plots were separated first and kept aside to reduce border effect. The remaining plants were harvested and weight recorded. Five plants were uprooted at random from each plot for observations on dry matter production and chemical analysis.

3.3. Experiment details

The layout of the experimental field is given in Fig.4. The details of the experiment are as follows:

Cultivar	:	African tall
Design	:	Split plot
Plot size	:	5 m x 4 m (sub plots)
Replications	:	3
Spacing	:	30 cm x 15 cm
Method of irrigation	:	Check basin (Hose irrigation)
Date of sowing	:	29-11-2012
Date of harvest	:	02-02-2013

3.4. Biometric observations

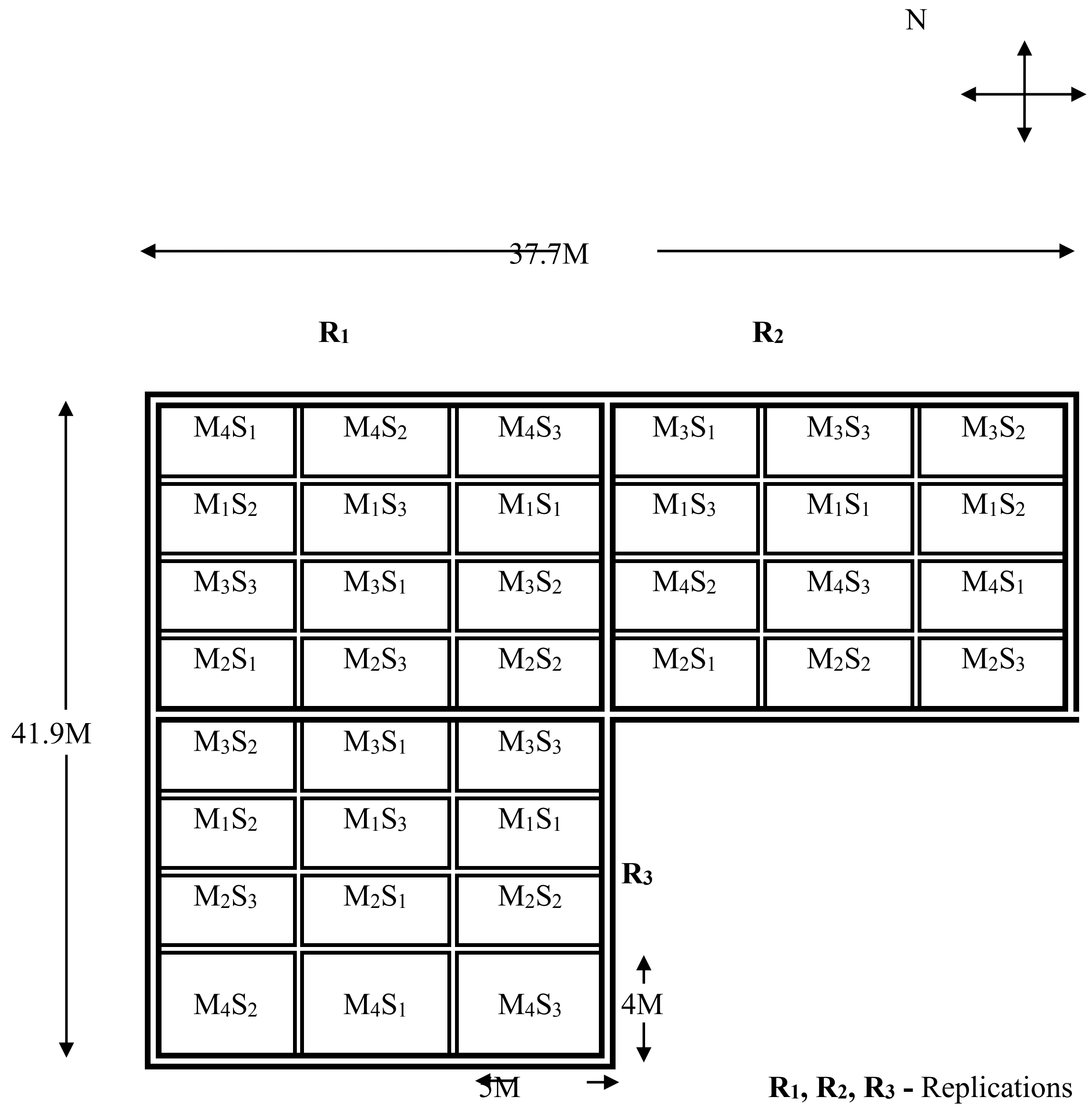
Five plants were selected from each plot and tagged for recording observations on plant height, number of leaves, leaf blade length, leaf blade width, Leaf area, and days to 50 percent flowering. Similarly, five plants were randomly selected for recording leaf to stem ratio, shoot to root ratio and dry matter production. The mean values were worked out. The following observations were recorded at 30 DAS and at harvest.

Plant height

Plant height in cm was measured from base of the plant to the tip of the top most leaf.

Table 1. Physico-chemical properties of soil

SI.No.	Particulars				Value	Method adopted
I.	A. Particle size composition					
	Sand (%)				68.83	International pipette method (Piper,1942)
	Silt (%)				16.25	
	Clay (%)				14.90	
	Soil texture				Sandy loam	
	B. Field capacity (%)					
		0-15 cm	15-30 cm	30-60 cm	60-90 cm	Pressure membrane apparatus (Richards,1947)
		14.60	14.78	15.62	15.43	
	C. Permanent wilting point (%)					
		0-15 cm	15-30 cm	30-60 cm	60-90 cm	
		7.85	8.43	6.57	7.94	
	D. Bulk density (g/cm^3)					Core Sampler method (Dastane, 1972)
		0-15 cm	15-30 cm	30-60 cm	60-90 cm	
		1.27	1.41	1.55	1.60	
	E. Particle density (g/cm^3)				2.63	Pycno meter method
II.	**Chemical properties**					
	Organic carbon (%)				0.69	Walkley and Black method (Jackson,1958)
	Available nitrogen (kg /ha)				305.00	Alkaline permanganate method (Subbaiah and Asijah,1956)
	Available phosphorus (kg/ha)				20.25	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen,1965)
	Available potassium (kg /ha)				112.50	Neutral normal ammonium acetate extractant flame photometry (Jackson,1958)
	Soil pH				5.70	pH meter (Jackson,1958)



Main plots : Irrigation

M_1: No irrigation
(with residual moisture)
M_2: Irrigation at IW/CPE: 0.4
M_3: Irrigation at IW/CPE: 0.7
M_4: Irrigation at IW/CPE: 1.0

Sub plots: Tillage

S_1: Zero tillage
(with herbicide)
S_2: Minimum tillage
S_3: Conventional tillage

Fig. 4. Lay out of field experiment

Table 2. Details of irrigation given

Serial number of irrigation	M_4	M_3	M_2	M_1
1	28/11/2012*	28/11/2012*	28/11/2012*	28/11/2012*
2	8/12/2012	12/12/2012	22/12/2012	
3	18/12/2012	25/12/2012	17/1/2013	
4	28/12/2012	11/1/2013		
5	7/1/2013	23/1/2013		
6	15/1/2013			
7	24/1/2013			
8	31/1/2013			
Total number of irrigations	8	5	3	1
Total quantity applied (mm)	320	200	120	40

*- Pre –sowing irrigation (common)

Number of leaves

Number of leaves per plant was counted from five tagged plants and the mean was worked out.

Length of leaf blade

Five tagged plants were selected for measuring the length of leaf blade. For measuring length of leaf blade, fully opened and completely matured fourth leaf from top was fixed as the index leaf. Length of leaf lamina in cm was measured from the base to the tip. The average leaf length per plant was worked out.

Width of leaf blade

Five tagged plants were selected for measuring the width of leaf blade. Leaf width in cm was taken at the widest point of the index leaf. The average leaf width per plant was worked out.

Days to 50 percent flowering

Five tagged plants were used for the determination of days to 50 percent flowering, when flowering was noticed on 50 percent of plants.

Plant dry matter production

Five plants from each plot were collected randomly by cutting from ground level at 30 DAS and at harvest. The samples were sun-dried and then oven dried at 80 ± 5^0C temperature for 24 to 48 hours till constant weight was obtained and averaged to get data in gram per plant.

Leaf area

The length of index leaf of each plant was measured from the base to the tip of the leaf. The width was taken at the widest point of the index leaf lamina. The products of leaf length and width were multiplied by a factor 0.75, which will give the leaf area per plant in cm^2 (Saxena and Singh, 1965). The average leaf area per plant in cm^2 was worked out.

Leaf area index (LAI)

Leaf area index is defined as the ratio of total leaf area to ground area. The leaf area index was measured using LI-COR: LAI-2000 plant canopy analyzer (Welles and Norman, 1990).

Leaf:stem ratio

Leaf to stem ratio was determined using five randomly selected plants per plot at 30 DAS and at harvest. The plants were cut at the base and then the leaves and stems were separated carefully and dried. The ratio was calculated on dry weight basis.

$$\text{Leaf: stem ratio} = \frac{\text{Dry weight of leaf}}{\text{Dry weight of stem}}$$

Shoot: root ratio

Five plants from each plot were randomly pulled out and their root and shoot portions were separated and dried. The shoot to root ratio was calculated on dry weight basis at 30 DAS and at harvest.

$$\text{Shoot: root ratio} = \frac{\text{Dry weight of shoot}}{\text{Dry weight of root}}$$

3.5. Fodder yield

Green fodder yield

Green fodder yield from each plot was recorded immediately after cutting and the yield of green fodder in Mg/ha was calculated for each plot.

3.6. Observations on weed growth

Observations on weed count and weed dry matter production was taken at 30 DAS and at harvest.

Weed count

Species wise weed count randomly chosen from 1m^2 area in each plot was taken and recorded as number/m^2.

Weed dry matter production

The weeds from the sampling area from each plot were uprooted, dried initially in shade and then in a hot air oven at 80 $\pm$ 5^0C and the weed dry weight in g/$m^2$was recorded.

3.7. Nutrient content and uptake

Nitrogen

The nitrogen content in the plant was estimated by Microkjeldal digestion and distillation method (Jackson, 1958).

Phosphorus

The plant samples were digested using diacid mixture (HNO_3: $HClO_4$ at 2:1 ratio) and the phosphorus content was determined by vanado molybdo phosphoric yellow colour method (Jackson, 1958). The intensity of colour was read using spectrophotometer at 420 nm.

Potassium

Potassium content in the digested plant sample was estimated by using EEL Flame photometer (Jackson, 1958).

Calcium and Magnesium

Calcium and magnesium contents in the plant samples were estimated using Atomic Absorption Spectrophotometer (AAS) (Jackson, 1958).

Nutrient uptake

Total nitrogen, phosphorus, potassium, calcium and magnesium uptake was calculated for each treatment separately using the following formula and expressed in kg/ha.

Nutrient uptake = Percentage nutrient concentration/100 x total dry matter (kg/ha)

3.8. Quality of forage

Plant samples from all the treatments were collected at harvest; leaves and stems were initially separated, chopped, air dried and oven dried at 80 $\pm$ 5^0C temperature for 24 to 48 hours till constant weight was obtained. The samples after grinding were used to find out two fractions of proximate analysis, crude protein and crude fibre of leaves and stems.

Crude protein

Nitrogen content in the plant was estimated by Microkjeldal digestion and distillation method (Jackson, 1958). The nitrogen content thus obtained was multiplied by 6.25 to get crude protein content of the sample.

Crude fibre

The crude fibre content was estimated using the acid – alkali digestion method (Sadasivam and Manickam, 1992).

3.9. Soil analysis for nutrients

Representative soil samples from each experimental plot were drawn after the harvest of the crop. Samples thus collected were air dried; ground to pass through two mm sieve and chemical analysis for N, P, K, Ca and Mg was carried out.

Available nitrogen

Available nitrogen was determined by Alkaline Permanganate method as per the procedure given by Subbaiah and Asijah (1956) and expressed in kg/ha.

Available phosphorus

Available phosphorus content in the soil was extracted with Bray's reagent No.1. The extracted phosphorus was then estimated by molybdopohospheric blue colour method, using spectrophotometer at a wave length of 660 nm (Watnabe and Olsen, 1965) and expressed as kg/ha.

Available potassium

Available potassium was estimated by extracting the soil with neutral normal ammonium acetate solutions and by atomizing the aliquot using Flame Photometer
(Jackson, 1958) and expressed as kg/ha.

Available calcium and magnesium

Available calcium and magnesium contents were estimated using Atomic absorption spectrophotometer (AAS) (Jackson, 1958) and expressed as kg/ha.

3.10. Moisture studies

Soil moisture determination was done using thermo-gravimetric method. Soil samples were drawn with the help of a tube auger from 0-15, 15-30, 30-60 and 60-90 cm soil depth. In all the treatments soil samples were collected before sowing and before and after each irrigation. Soil samples for moisture determination were also collected after the harvest of the crop.

Moisture percentage from different soil depths were used to calculate consumptive use of water and soil moisture extraction pattern of the crop for irrigation treatments.

Consumptive use (CU)

Consumptive use was calculated based on the soil moisture depletion from each soil layer in the effective root zone. The consumptive use of the crop was calculated as detailed by Dastane (1972)

Consumptive use of water (mm) = Total moisture depleted from each layer + soil moisture contribution + (E_0 X 0.7)

$$\text{Moisture depleted from i}^{\text{th}}\text{ layer (cm)} = \frac{\text{Mai} - \text{Mbi}}{100} \times \text{Bd} \times \text{Di}$$

Where,

Mai = Moisture percentage after irrigation in ith layer

Mbi = Moisture percentage before irrigation in ith layer

Bd = Bulk density of ith layer (g/cm^3)

Di = Depth of ith layer in cm

ER = Effective rainfall (mm)

E_0 = USWB Open pan evaporimeter reading (mm)

$$\text{Soil moisture contribution} = \sum_{i=1}^{n} \frac{\begin{pmatrix} \text{Moisture} \\ \text{percentage} \\ \text{before sowing} \\ - \\ \text{Moisture} \\ \text{percentage} \\ \text{after harvest} \end{pmatrix}}{100} \times \text{Bd} \times \text{Di}$$

Soil moisture extraction pattern

Soil moisture extraction pattern from four layers *viz*., 0-15, 15-30, 30-60 and 60-90 cm depths was calculated by using the formula given below. Moisture extracted from each layer was calculated by adding all the short period depletion from all the respective depths till the harvest of the crop and percentage depletion at various depths to the total was worked out.

$$\text{Moisture depleted from i}^{\text{th}}\text{ layer (cm)} = \frac{\text{Mai} - \text{Mbi}}{100} \times \text{Bd} \times \text{Di}$$

Where,

Mai = Moisture percentage after irrigation in ith layer

Mbi = Moisture percentage before irrigation in ith layer

Bd = Bulk density of ith layer (g/cm^3)

Di = Depth of ith layer in cm

Field water use efficiency (FWUE)

The yield of marketable crop produced per unit of water used is referred to as field water use efficiency and calculated by using the formula given by Viets (1962).

$$\text{FWUE (kg/ha} - \text{mm)} = \frac{\text{Y}}{\text{WR}}$$

Y = Fodder yield (kg/ha)

WR = Water applied (mm)

Crop water use efficiency (CWUE)

The yield of marketable crop produced per unit of consumptive use of water is referred to as crop water use efficiency and calculated by using the formula.

$$\text{CWUE (kg/ha} - \text{mm)} = \frac{\text{Y}}{\text{Cu}}$$

Y = Fodder yield (kg/ha)

Cu = Consumptive use (mm)

3.11. Economics

Cost of production of fodder maize under various levels of irrigation and tillage practices were calculated on the basis of labour charges of the locality, cost of inputs and treatment costs. The net returns per hectare and benefit cost ratio was worked out by dividing the gross return with total expenditure per hectare.

3.12. Data analysis

Data generated on the various parameters of the experiment was analyzed statistically. Analysis of variance was performed on all the data collected using the statistical package, 'MSTAT' (Freed, 1986). Where the F-test was significant (at 5 percent level of significance), the least significant difference (LSD) was used to compare means at P=0.05.

Plate 1. General view of experimental field

Plate 2. Measuring LAI using plant canopy analyser

Results

4. RESULTS

A field experiment was carried out to compare various aspects of growth, fodder production potential and nutritive value of fodder maize under different irrigation and tillage practices in rice fallows at the Department of Agronomy, College of Horticulture, Kerala Agricultural University during 2012-2013. Various parameters recorded were statistically analysed and the results are presented in this chapter.

4.1. Biometric observations

4.1.1. Plant height

Plant height differed significantly among irrigation schedules both at 30 DAS and at harvest (Table 3). At both stages, the tallest plants were in irrigated plots with IW/CPE = 1.0 (M_4) followed by IW/CPE =0.7 (M_3) and the lowest height was recorded in control plots (M_1) with no irrigation.

Among the three tillage methods, zero tillage with herbicide (S_1) recorded the highest plant height at 30 DAS and at harvest, but it was on par with conventional tillage (S_3) at 30 DAS. The lowest height was recorded in minimum tillage plots (S_2) at both stages of observation.

Significant interaction was noticed between irrigation schedules and tillage methods at both the stages of observation. Fodder maize recorded the highest plant height in irrigated plots at IW/CPE ratio 1.0 (M_4) with herbicide based zero tillage (S_1) followed by conventional tillage (S_3) at both stages of observation. In other irrigated plots too, herbicide based zero tillage (S_1) and conventional tillage (S_3) recorded higher values when compared with minimum tillage (S_2). The lowest plant height was recorded in plots with minimum tillage (S_2) both at 30 DAS and at harvest.

Table 3. Plant height (cm) of maize as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	45.02	94.89
M_2	67.41	163.34
M_3	83.22	201.40
M_4	102.65	237.53
SEm±	1.58	0.62
LSD (0.05)	5.47	2.15
Tillage method		
S_1	78.04	186.91
S_2	69.08	165.92
S_3	76.61	170.03
SEm±	0.62	1.21
LSD (0.05)	1.86	3.63
Irrigation X Tillage method		
M_1S_1	53.15	109.90
M_1S_2	35.77	81.20
M_1S_3	46.14	93.48
M_2S_1	72.10	178.48
M_2S_2	64.50	145.00
M_2S_3	65.67	166.39
M_3S_1	83.03	197.86
M_3S_2	75.33	185.71
M_3S_3	91.31	220.62
M_4S_1	111.48	261.31
M_4S_2	93.14	218.12
M_4S_3	103.34	233.14
SEm±	2.74	1.08
LSD (0.05)	4.11	7.26

4.1.2. Number of leaves

Irrigation scheduling has significant influence on number of leaves per plant at both the stages (Table 4). The highest number of leaves per plant was recorded in IW/CPE = 1.0 (M_1) followed by IW/CPE = 0.7 (M_3) which was on par with IW/CPE= 0.4 (M_2) at harvest. The number of leaves per plant was the least in control plot (M_1).

There was significant difference between tillage methods with respect to number of leaves per plant both at 30 DAS and at harvest. The highest number of leaves per plant was recorded in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) which was on par with minimum tillage (S_2).

There was no significant interaction between levels of irrigation and tillage methods on number of leaves.

Table 4. Number of leaves as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	6.95	9.97
M_2	8.73	13.27
M_3	9.02	13.96
M_4	10.26	15.54
SEm±	0.10	0.31
LSD (0.05)	0.35	1.08
Tillage method		
S_1	9.31	13.90
S_2	8.26	12.80
S_3	8.65	12.83
SEm±	0.07	0.15
LSD (0.05)	0.22	0.45
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.1.3. Length of leaves

Irrigation schedules affected the length of leaves significantly at all the growth stages of crop (Table 5). The highest leaf length was noticed in M_4 plot followed by M_3, M_2 and M_1 plots at both stages of observation. The lowest leaf length was recorded in M_1 (control) plot.

Table 5. Leaf length (cm) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	33.12	59.05
M_2	41.89	62.93
M_3	53.60	78.89
M_4	60.42	83.16
SEm±	1.35	1.21
LSD (0.05)	4.69	4.25
Tillage method		
S_1	44.42	70.58
S_2	46.62	71.19
S_3	50.74	71.25
SEm±	0.97	1.46
LSD (0.05)	2.90	NS
Irrigation X Tillage method		
M_1S_1	34.26	60.06
M_1S_2	28.54	61.86
M_1S_3	36.56	55.23
M_2S_1	38.79	57.46
M_2S_2	43.48	71.66
M_2S_3	43.42	59.66
M_3S_1	42.05	77.92
M_3S_2	58.17	73.97
M_3S_3	60.59	84.76
M_4S_1	62.58	86.87
M_4S_2	56.30	77.28
M_4S_3	62.39	85.34
SEm±	2.34	2.10
LSD (0.05)	6.2	NS

Tillage methods influenced the leaf length significantly at 30 DAS but not significant at harvest. The highest leaf length was noticed in conventional tillage (S_3) followed by minimum tillage (S_2) which was on par with herbicide based zero tillage (S_1).

The interaction effect of the two factors was significant at 30 DAS but it was not significant at harvest. Fodder maize recorded the highest leaf length in IW/CPE = 1.0 (M_4) with herbicide based zero tillage (S_1) followed by conventional tillage (M_4S_3). The lowest leaf length was noticed in control plots with minimum tillage (M_1S_2).

4.1.4. Width of leaves

Width of leaf blades differed significantly among irrigation schedules (Table 6) both at 30 DAS and at harvest. Width of leaf blades increased from M_1 to M_4. The highest leaf blade width was noticed in M_4 plot followed by M_3 plot at both stages of observation and the lowest leaf blade width was noticed in control plot (M_1) at both stages of observations. Tillage methods had no significant effects on width of leaves.

The interaction between irrigation schedules and tillage methods was not significant at both stages of observation.

Table 6. Leaf width (cm) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	3.32	6.34
M_2	4.21	7.23
M_3	5.37	7.59
M_4	6.00	8.65
SEm±	0.07	0.07
LSD (0.05)	0.57	0.26
Tillage method		
S_1	4.63	7.56
S_2	4.61	7.38
S_3	4.94	7.45
SEm±	0.03	0.05
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.1.5. Days to 50 per cent flowering

Levels of irrigation or tillage methods or their interaction did not influence significantly the days to 50 per cent flowering (Table 7). In the experiment, the number of days taken from planting to 50 per cent flowering ranged from 53 to 58 days.

Table 7. Number of days taken for 50 per cent flowering as affected by irrigation and tillage

Treatment	Days
Irrigation	
M_1	57.71
M_2	52.68
M_3	56.08
M_4	53.44
SEm±	1.33
LSD (0.05)	NS
Tillage method	
S_1	54.56
S_2	55.32
S_3	55.07
SEm±	0.49
LSD (0.05)	NS
Irrigation X Tillage	
LSD (0.05)	NS

4.1.6. Leaf area

Leaf area differed significantly among different irrigation schedules at both the stages (Table 8). Leaf area increased significantly with increasing levels of irrigation from M_1 to M_4. The highest leaf area was noticed in IW/CPE= 1.0 followed by IW/CPE= 0.7 and same trend was noticed at both the stages of observation. Lowest leaf area was noticed in control plot.

Leaf area differed significantly among tillage methods at both the stages of observation. The highest leaf area was noticed in herbicide based zero tillage followed by conventional tillage and lowest leaf area was noticed in minimum tillage.

Table 8. Leaf area (cm^2 / plant) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	679.03	3198.39
M_2	1164.45	4995.40
M_3	1803.65	7731.38
M_4	2564.45	9674.69
SEm±	18.45	22.85
LSD (0.05)	63.67	78.86
Tillage method		
S_1	1773.76	7010.42
S_2	1248.56	5835.56
S_3	1636.37	6353.93
SEm±	13.83	31.90
LSD (0.05)	41.47	95.65
Irrigation X Tillage method		
M_1S_1	833.21	3714.81
M_1S_2	532.87	2802.75
M_1S_3	670.03	3077.63
M_2S_1	1342.01	5916.36
M_2S_2	892.29	4225.39
M_2S_3	1259.05	4844.45
M_3S_1	2058.57	8226.12
M_3S_2	1419.81	7168.71
M_3S_3	1932.58	7799.31
M_4S_1	2861.24	10184.39
M_4S_2	2148.28	9145.39
M_4S_3	2683.84	9694.30
SEm±	31.95	39.57
LSD (0.05)	87.96	195.97

There was significant interaction between levels of irrigation and tillage methods with respect to leaf area both at 30 DAS and at harvest. Fodder maize recorded highest leaf area in M_4 with herbicide based zero tillage followed by conventional tillage at both the stages of observation. Whereas in M_3, M_2 and M_1 also same trend was noticed, herbicide based zero tillage and conventional tillage recorded higher values when compare with minimum tillage. Lowest leaf area recorded in all plots with minimum tillage both at 30 DAS and at harvest.

4.1.7. Leaf area index (LAI)

Leaf area index differed significantly among levels of irrigation both at 30 DAS and at harvest (Table 9). Fodder maize plants in IW/CPE= 1.0 (M_4) recorded higher LAI of 1.75 and 4.80 at 30 DAS and at harvest respectively than other treatments. The next best treatment was irrigation at IW/CPE= 0.7 (M_3) followed by IW/CPE = 0.4 (M_2). The lowest LAI was observed in control plots (M_1) in both stages of observation.

LAI differed significantly among tillage methods at 30 DAS and at harvest. The maximum LAI was noticed in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and the lowest LAI was recorded in minimum tillage (S_2) at both stages of observation.

There was significant interaction between levels of irrigation and tillage at both stages of observation. The maximum LAI was noticed in M_4 plot with herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and the lowest in minimum tillage (S_2) at both stages of observation. The same trend was noticed in other irrigation treatments with the herbicide based zero tillage (S_1) and conventional tillage (S_3) recording higher values.

Table 9. Leaf area index (LAI) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	0.56	0.85
M_2	0.64	2.35
M_3	1.59	3.29
M_4	1.75	4.80
SEm±	0.03	0.05
LSD (0.05)	0.09	0.17
Tillage method		
S_1	1.29	3.13
S_2	1.05	2.58
S_3	1.14	2.76
SEm±	0.01	0.02
LSD (0.05)	0.03	0.05
Irrigation X Tillage method		
M_1S_I	0.69	0.95
M_1S_2	0.45	0.77
M_1S_3	0.54	0.84
M_2S_1	0.85	2.60
M_2S_2	0.47	2.19
M_2S_3	0.67	2.28
M_3S_1	1.75	3.98
M_3S_2	1.43	2.91
M_3S_3	1.58	2.99
M_4S_1	1.87	5.01
M_4S_2	1.62	4.46
M_4S_3	1.78	4.94
SEm±	0.04	0.08
LSD (0.05)	0.07	0.11

4.1.8. Leaf dry matter

Significant variation was noticed among irrigation schedules on leaf dry matter at 30 DAS and at harvest (Table 10). At 30 DAS, leaf dry matter was higher in irrigation scheduled at IW/CPE= 1.0 (M_4) followed by IW/CPE= 0.7

(M_3) whereas at harvest, leaf dry matter decreased with increased levels of irrigation from M_2 to M_4. Lower values were recorded in control plots (M_1) at both stages of observation.

Among the tillage methods, herbicide based zero tillage (S_1) recorded the highest leaf dry matter followed by conventional tillage (S_3) at both stages of observation. The lowest leaf dry matter was in minimum tillage (S_2).

The interaction between irrigation schedules and tillage methods was not significant on leaf dry matter at both stages of observation.

Table 10. Leaf dry matter (g/plant) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	1.59	10.62
M_2	3.31	33.65
M_3	4.82	30.10
M_4	9.20	18.41
SEm±	0.15	0.85
LSD (0.05)	0.52	2.95
Tillage method		
S_1	5.49	25.74
S_2	4.17	21.00
S_3	4.52	22.85
SEm±	0.17	0.69
LSD (0.05)	0.53	2.09
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.1.9. Stem dry matter

Significant variation was noticed among irrigation schedules on stem dry matter at 30 DAS and at harvest (Table 11). At both stages, stem dry matter was the highest in irrigated plots scheduled with IW/CPE= 1.0 (M_4) followed by

IW/CPE= 0.7 (M_3). Lower values were recorded in control plots (M_1) at both stages of observation.

Among the tillage methods, herbicide based zero tillage (S_1) recorded the highest stem dry matter followed by conventional tillage (S_3) at both stages of observation. The lowest plant dry matter production was in minimum tillage (S_2).

Table 11. Stem dry matter (g/plant) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	0.10	4.38
M_2	0.31	19.02
M_3	0.54	36.32
M_4	1.41	81.67
SEm±	0.02	0.65
LSD (0.05)	0.08	2.24
Tillage method		
S_1	0.65	38.76
S_2	0.55	32.59
S_3	0.56	34.68
SEm±	0.02	0.87
LSD (0.05)	0.07	2.65
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.1.10. Total dry matter production

Significant variation was noticed among irrigation schedules on plant dry matter production at 30 DAS and at harvest (Table 12). At both stages, plant dry matter production was the highest in irrigated plots scheduled at IW/CPE= 1.0 (M_4) followed by IW/CPE= 0.7 (M_3). Lower values were recorded in control plots (M_1) at both stages of observation.

Table 12. Dry matter production (g/plant) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	1.60	14.24
M_2	3.43	47.57
M_3	5.21	67.53
M_4	10.07	96.09
SEm±	0.07	0.62
LSD (0.05)	0.27	2.15
Tillage method		
S_1	5.57	64.17
S_2	4.78	49.04
S_3	4.89	55.87
SEm±	0.05	0.78
LSD (0.05)	0.16	2.36
Irrigation X Tillage method		
M_1S_1	1.99	16.28
M_1S_2	1.12	12.03
M_1S_3	1.70	14.39
M_2S_1	2.65	51.65
M_2S_2	3.32	40.98
M_2S_3	4.31	50.09
M_3S_1	5.20	80.76
M_3S_2	6.00	55.78
M_3S_3	4.47	66.05
M_4S_1	12.41	108.00
M_4S_2	8.71	87.35
M_4S_3	9.09	92.93
SEm±	0.13	1.07
LSD (0.05)	0.35	4.86

Among the tillage methods, herbicide based zero tillage (S_1) recorded the highest plant dry matter production followed by conventional tillage (S_3) at both stages of observation. The lowest plant dry matter production was in minimum tillage (S_2).

Interaction was significant between irrigation and tillage both at 30 DAS and at harvest. In M_4 plot, the highest dry matter production was noticed in herbicide based zero tillage (S_1) followed by conventional tillage (M_4S_3). The lowest dry matter production was noticed in control plots with minimum tillage (M_1S_2).

4.1.9. Leaf-stem ratio

Leaf stem ratio was calculated based on the dry weight of leaves and stems of five sample plants. There was significant variation between levels of irrigation with respect to leaf stem ratio at both the stages (Table 13). Leaf stem ratio decreased with increasing levels of irrigation. The highest leaf stem ratio was recorded in control plots (M_1) at both the stages of observation and the lowest leaf stem ratio was recorded by IW/CPE= 1.0 (M_4) followed by IW/CPE= 0.7 (M_3). There was no significant difference among tillage methods on leaf to stem ratio.

Table 13. Leaf-stem ratio as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	15.73	2.43
M_2	10.65	1.59
M_3	8.97	0.93
M_4	6.56	0.22
SEm±	0.70	0.03
LSD (0.05)	2.43	0.14
Tillage method		
S_1	10.75	1.28
S_2	9.67	1.30
S_3	11.01	1.29
SEm±	0.58	0.05
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

The interaction between irrigation schedules and tillage methods was not significant on leaf stem ratio.

4.1.10. Shoot-root ratio

There was significant difference between levels of irrigation on shoot root ratio at both the stages of observation (Table 14). The highest shoot root ratio was observed in M_4 plot followed by M_3 plot and the lowest shoot root ratio was observed in M_1 plot both at 30 DAS and at harvest.

There were no significant differences between tillage methods on shoot root ratio and also no interaction was noticed between main plots and sub plots.

Table 14. Shoot –root ratio as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	4.52	7.45
M_2	5.25	8.37
M_3	6.51	9.41
M_4	8.60	10.65
SEm±	0.07	0.13
LSD (0.05)	0.24	0.46
Tillage method		
S_1	6.23	9.05
S_2	6.20	9.01
S_3	6.23	8.89
SEm±	0.08	0.09
LSD (0.05)	NS	NS
Irrigation X Tillage		
SEm±	0.12	0.23
LSD (0.05)	NS	NS

4.2. Observations on weed growth

4.2.1. Weed count

Between levels of irrigation no significant variation was noticed in the population of grass weeds at both stages of observation (Table 15).

There was no significant variation between tillage methods with respect to population of grassy weeds at 30 DAS and at harvest. The interaction between tillage methods and levels of irrigation was also found to be non significant.

Among the weeds present in the cropped field, the population of sedges was the lowest and the variation between irrigation levels and tillage as well as their interaction was found to be non significant at both the stages of observation.

The dominant weeds in the experimental field were dicot weeds; however, there was no significant difference in the number of dicot weeds according to levels of irrigation, tillage methods and their interaction.

Table 15. Species wise weed count as affected by irrigation and tillage

Treatment	30 DAS			At harvest		
	Grasses	Sedges	Dicots	Grasses	Sedges	Dicots
Irrigation						
M_1	3.22 (1.73)	0.22(0.82)	15.67(3.82)	3.34 (1.69)	0.00(0.71)	9.89(3.19)
M_2	3.56(1.64)	0.22(0.80)	13.44(3.61)	6.89(2.42)	0.20(0.82)	14.36(3.77)
M_3	2.45(1.57)	0.23(0.82)	14.56(3.69)	5.67(2.22)	0.40(0.92)	11.89(3.42)
M_4	7.00(2.27)	0.33(0.88)	10.23(3.09)	7.56(2.69)	0.40(0.92)	10.00(3.22)
SEm±	0.99(0.16)	0.19(0.07)	3.85(0.36)	1.38(0.27)	0.17(0.06)	0.59(0.09)
LSD (0.05)	NS	NS	NS	NS	NS	NS
Tillage method						
S_1	3.42(1.80)	0.00(0.71)	10.67(3.25)	5.25(2.32)	0.08(0.75)	9.30 (3.08)
S_2	7.75(2.50)	0.50(0.95)	17.00(3.86)	10.17(3.03)	0.70(1.03)	13.92(3.74)
S_3	1.00(1.16)	0.25(0.84)	12.75(3.55)	2.17(1.43)	0.08(0.75)	11.33(3.39)
SEm±	1.40(0.23)	0.14(0.05)	2.31(0.31)	1.25(0.23)	0.11(0.04)	1.09(0.15)
LSD (0.05)	NS	NS	NS	NS	NS	NS
Irrigation X Tillage						
LSD (0.05)	NS	NS	NS	NS	NS	NS

*$\sqrt{x+0.5}$ transformed values within parentheses

4.2.2. Weed dry matter production

Table 16. Weed dry matter production (g/m^2) as affected by irrigation and tillage

Treatment	30 DAS	At harvest
Irrigation		
M_1	13.50	36.73
M_2	57.32	88.31
M_3	23.77	69.22
M_4	13.76	45.02
SEm±	0.54	1.45
LSD (0.05)	1.87	5.02
Tillage method		
S_1	12.58	26.62
S_2	56.01	108.20
S_3	12.67	44.64
SEm±	0.45	1.00
LSD (0.05)	1.35	3.00
Irrigation X Tillage method		
M_1S_1	13.22	15.27
M_1S_2	16.39	74.53
M_1S_3	10.88	20.40
M_2S_1	20.67	37.10
M_2S_2	125.87	183.60
M_2S_3	25.43	44.23
M_3S_1	6.80	18.40
M_3S_2	56.43	119.00
M_3S_3	8.09	70.26
M_4S_1	9.63	35.72
M_4S_2	25.37	55.67
M_4S_3	6.27	43.67
SEm±	0.94	2.51
LSD (0.05)	2.84	6.00

Weed dry matter production varied significantly among levels of irrigation (Table 16). The highest weed dry matter production was noticed in M_2 plot followed by M_3 plot in both stages of observation. The lowest dry matter production was noticed in M_1 plot at both stages of observation.

Significant variation was noticed among tillage methods with respect to weed dry matter production. The highest weed dry matter production was noticed in minimum tillage (S_2) followed by conventional tillage (S_3) and the lowest dry matter production was noticed in herbicide based zero tillage (S_1) at both the stages of observation.

Significant interaction was noticed among irrigation levels and tillage at both the stages of observation. The highest weed dry matter production was noticed in M_2 plot with minimum tillage (S_2) followed by M_3 plot with minimum tillage (S_2) at both the stages of observation and the lowest weed dry weight was observed in M_4 plot with conventional tillage (S_3) at 30 DAS and M_1 plot with herbicide based zero tillage (S_1) at harvest.

4.3. Fodder yield

4.3.1. Green forage yield

Levels of irrigation had significant influence on fresh forage yield of fodder maize (Table 17). The highest green herbage yield (31.84 Mg/ha) was recorded in IW/CPE= 1.0 (M_4) which was statistically superior to others. The next best treatments were IW/CPE= 0.7 (M_3) followed by IW/CPE= 0.4. The control plots recorded the lowest green herbage yield (3.43 Mg/ha).

There was significant difference between tillage methods with respect to forage yield. The highest herbage yield was recorded by herbicide based zero tillage (S_1) (18.07 Mg/ha) followed by conventional tillage (S_3) (14.74 Mg/ha) and the lowest in minimum tillage (S_2) (12.99 Mg/ha).

The interaction between irrigation schedules and tillage methods was not significant on green forage yield.

Table 17. Green forage yield (Mg/ha) as affected by irrigation and tillage

Treatment	Yield (Mg/ha)
Irrigation	
M_1	3.43
M_2	9.56
M_3	16.23
M_4	31.84
SEm±	0.72
LSD (0.05)	2.47
Tillage method	
S_1	18.07
S_2	12.99
S_3	14.74
SEm±	0.65
LSD (0.05)	1.94
Irrigation X Tillage	
LSD (0.05)	NS

4.4. Nutrient composition

Percentage content of nitrogen, phosphorus, potassium, calcium and magnesium of both leaves and stems was noted at the time of harvest.

4.4.1. Nitrogen

There was significant difference between levels of irrigation with respect to nitrogen content and uptake. The control plots showed the highest nitrogen content with 2.64 per cent followed by IW/CPE= 0.4 (M_2) with 2.51 per cent (Table 18). The nitrogen content was lower in irrigation at IW/CPE= 1.0 (M_4) (2.16%).

Table 18. Effect of irrigation and tillage on the content of nitrogen (%) in leaves and stems

Treatment	Leaf N (%)	Stem N (%)
Irrigation		
M_1	2.64	0.82
M_2	2.51	0.77
M_3	2.42	0.76
M_4	2.16	0.56
SEm±	0.02	0.01
LSD (0.05)	0.08	0.04
Tillage method		
S_1	2.49	0.77
S_2	2.36	0.70
S_3	2.41	0.71
SEm±	0.01	0.01
LSD (0.05)	0.03	0.02
Irrigation X Tillage method		
M_1S_1	2.73	0.89
M_1S_2	2.54	0.76
M_1S_3	2.65	0.80
M_2S_1	2.52	0.86
M_2S_2	2.57	0.64
M_2S_3	2.45	0.80
M_3S_1	2.48	0.84
M_3S_2	2.29	0.70
M_3S_3	2.47	0.76
M_4S_1	2.29	0.64
M_4S_2	1.83	0.45
M_4S_3	2.17	0.55
SEm±	0.04	0.02
LSD (0.05)	0.07	0.04

With respect to nitrogen content in stem M_1 plot recorded statistically superior values. The uptake of nitrogen was found to be significantly higher in IW/CPE= 1.0 (M_4) (240.57 kg/ha) followed by IW/CPE= 0.7 (M_3) (110.72 kg/ha). Uptake of nitrogen was very poor in control (M_1) plots (20.52 kg/ha) (Table 21).

Significant variation was noticed among tillage methods with respect to nitrogen content both in leaf and stem. Nitrogen content was high in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and then minimum tillage (S_2) both in leaf and stem. Uptake of nitrogen was also significantly influenced by different tillage methods. Uptake of nitrogen was high in herbicide based zero tillage (S_1) (122.31 kg/ha) followed by conventional tillage (S_3) (115.89 kg/ha) and lowest in minimum tillage (S_2) (102.24 kg/ha).

Significant interaction was noticed between irrigation and tillage with respect to nitrogen per cent in both leaf and stem. Nitrogen content was high in control with herbicide based tillage (M_1S_1) followed by control with conventional tillage (M_1S_3) and the lowest nitrogen content was recorded in irrigation at IW/CPE ratio 1.0 with minimum tillage (M_4S_2) followed by conventional tillage in control plot (M_4S_3). No interaction was noticed among main plot and sub plot with respect to uptake nitrogen.

4.4.2. Phosphorus

It is observed that the content of phosphorus both in leaf and stem was unaffected neither by irrigation and tillage nor by their interactions (Table 19).

However, there were significant differences between levels of irrigation on phosphorus uptake (Table 21). There was a progressive increase in the uptake of phosphorus with increase in levels of irrigation. The uptake of phosphorus was found to be significantly higher in IW/CPE= 1.0 (M_4) (31.39 kg/ha) followed by IW/CPE= 0.7 (M_3) (17.97 kg/ha) and uptake of phosphorus was very low in control plots (M_1) (4.34 kg/ha).

There was significant difference between tillage methods with respect to phosphorus uptake. Same as nitrogen uptake here also the highest uptake was noticed in herbicide based zero tillage (S_1) (19.21kg/ha) followed by conventional tillage (S_3) (16.10 kg/ha) and the lowest in minimum tillage (S_2) (13.35 kg/ha). There was no interaction between main and sub plots on phosphorus uptake.

Table 19. Effect of irrigation and tillage on the content of phosphorus (%) in leaves and stems

Treatment	Leaf P (%)	Stem P (%)
Irrigation		
M_1	0.240	0.117
M_2	0.249	0.113
M_3	0.254	0.119
M_4	0.250	0.143
SEm±	0.008	0.011
LSD (0.05)	NS	NS
Tillage method		
S_1	0.262	0.125
S_2	0.241	0.123
S_3	0.243	0.121
SEm±	0.006	0.009
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.4.3. Potassium

Levels of irrigation or tillage methods or their interaction did not influence significantly the content of potassium both in leaf and stem (Table 20).

Table 20. Effect of irrigation and tillage on the content of potassium (%) in leaves and stems

Treatment	Leaf K (%)	Stem K (%)
Irrigation		
M_1	1.03	0.69
M_2	0.90	0.61
M_3	1.14	0.67
M_4	1.17	0.71
SEm±	0.13	0.07
LSD (0.05)	NS	NS
Tillage method		
S_1	1.18	0.71
S_2	0.92	0.69
S_3	1.08	0.71
SEm±	0.07	0.05
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

There were significant differences between the levels of irrigation on potassium uptake (Table 21). The uptake of potassium was found to be significantly higher in IW/CPE= 1.0 (M_4) (152.36 kg/ha) followed by IW/CPE= 0.7 (M_3) (98.64 kg/ha) and low phosphorus uptake was noticed in control plots (M_1) (24.67 kg/ha).

Significant interaction was noticed among tillage methods with respect to uptake of potassium. As like other nutrients here also the highest potassium uptake noticed in herbicide based zero tillage (S_1) (94.83 kg/ha) followed by conventional tillage (S_3) (82.84 kg/ha) and the lowest in minimum tillage (S_2) (72.87 kg/ha).

There was no significant interaction between levels of irrigation and tillage methods on potassium uptake.

Table 21. Uptake of major nutrients (kg/ha) as affected by irrigation and tillage

Treatment	Uptake N (kg/ha)	Uptake P (kg/ha)	Uptake K (kg/ha)
Irrigation			
M_1	20.52	4.34	24.67
M_2	82.09	11.43	58.38
M_3	110.72	17.97	98.64
M_4	240.57	31.39	152.36
SEm±	3.62	0.87	5.84
LSD (0.05)	12.71	3.02	20.23
Tillage method			
S_1	122.31	19.12	94.83
S_2	102.24	13.35	72.87
S_3	115.89	16.10	82.84
SEm±	2.93	0.69	5.64
LSD (0.05)	8.80	2.01	16.92
Irrigation X Tillage			
LSD (0.05)	NS	NS	NS

4.4.4. Calcium

The levels of irrigation or tillage methods or their interaction did not influence significantly the content of calcium in both leaf and stem (Table 22).

There was significant difference between levels of irrigation with respect to calcium uptake (Table 24). The uptake of calcium was found to be significantly higher in IW/CPE= 1.0 (M_4) (32.51 kg/ha) which was on par with IW/CPE= 0.7 (M_3) (18.74 kg/ha) and IW/CPE= 0.4 (M_2) (16.52 kg/ha). Low calcium uptake was noticed in control plot (7.13 kg/ha).

It is seen that the uptake of calcium was unaffected neither by tillage methods nor by irrigation and tillage interactions.

Table 22. Effect of irrigation and tillage on the content of calcium (%) in leaves and stems

Treatment	Leaf Ca (%)	Stem Ca (%)
Irrigation		
M_1	0.231	0.136
M_2	0.229	0.182
M_3	0.238	0.140
M_4	0.242	0.118
SEm±	0.027	0.015
LSD (0.05)	NS	NS
Tillage method		
S_1	0.225	0.172
S_2	0.223	0.115
S_3	0.257	0.139
SEm±	0.021	0.023
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.4.5. Magnesium

Levels of irrigation or tillage methods or their interaction did not influence significantly the content of magnesium both in leaf and stem (Table 23).

There was significant difference between levels of irrigation with respect to magnesium uptake (Table 24). There was a progressive increase in the uptake of magnesium with increase in levels of irrigation from M_1 to M_4. The uptake of magnesium was found to be significantly higher in IW/CPE= 1.0 (M_4) (39.05 kg/ha) followed by IW/CPE= 0.7 (M_3) (27.73 kg/ha) and uptake was poor in control plot (M_1) (5.53 kg/ha).

There was no significant difference between tillage methods on magnesium uptake. The interaction between irrigation and tillage failed to produce any significant influence on magnesium uptake.

Table 23. Effect of irrigation and tillage on the content of magnesium (%) in leaves and stems

Treatment	Leaf Mg (%)	Stem Mg (%)
Irrigation		
M_1	0.327	0.176
M_2	0.298	0.178
M_3	0.309	0.189
M_4	0.337	0.181
SEm±	0.032	0.004
LSD (0.05)	NS	NS
Tillage method		
S_1	0.315	0.181
S_2	0.309	0.174
S_3	0.328	0.188
SEm±	0.026	0.005
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.5. Forage quality

4.5.1. Crude protein

Significant variation was noticed between levels of irrigation with respect to crude protein in both leaves and stems at harvest (Table 25). The highest leaf and stem crude protein was noticed in control plot followed by IW/CPE= 0.4 (M_2). However, the lowest leaf and stem crude protein was noticed in irrigation at IW/CPE= 1.0 (M_4).

The tillage methods significantly affected leaf and stem crude protein. The highest leaf and stem crude protein was noticed in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and the lowest in minimum tillage (S_2) at harvest.

Significant interaction was noticed between irrigation and tillage with respect to leaf and stem crude protein. The highest leaf and stem crude protein was noticed in control plot with herbicide based zero tillage (M_1S_1). The lowest crude protein was noticed in irrigation at IW/CPE= 1.0 with minimum tillage (M_4S_2).

Table 24. Uptake of secondary nutrients (kg/ha) as affected by irrigation and tillage

Treatment	Uptake Ca (kg/ha)	Uptake Mg (kg/ha)
Irrigation		
M_1	7.13	5.53
M_2	16.52	16.26
M_3	18.74	27.73
M_4	32.51	39.05
SEm±	4.13	0.31
LSD (0.05)	14.26	1.08
Tillage method		
S_1	25.34	22.04
S_2	15.37	21.96
S_3	15.46	22.42
SEm±	3.81	0.23
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

Table 25. Effect of irrigation and tillage on crude protein (%) in leaves and stems

Treatment	Leaf crude protein (%)	Stem crude protein (%)
Irrigation		
M_1	16.50	5.15
M_2	15.70	4.87
M_3	15.12	4.76
M_4	13.10	3.43
SEm±	0.15	0.05
LSD (0.05)	0.51	0.18
Tillage method		
S_1	15.53	4.86
S_2	14.73	4.41
S_3	15.06	4.42
SEm±	0.06	0.04
LSD (0.05)	0.19	0.13
Irrigation X Tillage method		
M_1S_1	17.06	5.6
M_1S_2	15.89	4.7
M_1S_3	16.55	5.0
M_2S_1	15.75	5.1
M_2S_2	16.04	5.4
M_2S_3	15.31	3.9
M_3S_1	15.53	4.8
M_3S_2	14.36	4.4
M_3S_3	15.45	5.3
M_4S_1	14.29	3.9
M_4S_2	11.45	2.9
M_4S_3	13.56	5.3
SEm±	0.25	0.09
LSD (0.05)	0.44	0.29

4.5.2. Crude fibre

Leaves and stems of fodder maize were analysed separately for contents of crude fibre at harvest (Table 26).

Significant variation was noticed between levels of irrigation with respect to crude fibre in leaves and but not significant in stems. The highest leaf crude fibre was noticed in IW/CPE= 1.0 (M_4) followed by IW/CPE= 0.7 (M_3), whereas the lowest leaf crude fibre was in control plot (M_1) with residual soil moisture.

There was no significant difference between tillage methods and also no interaction was noticed between main and sub plots with respect to crude fibre in both leaf and stem.

Table 26. Effect of irrigation and tillage on the content of crude fibre (%) in leaves and stems.

Treatment	Leaf crude fibre (%)	Stem crude fibre (%)
Irrigation		
M_1	15.53	28.42
M_2	17.40	27.35
M_3	21.72	27.68
M_4	22.02	27.78
SEm±	0.12	0.34
LSD (0.05)	0.41	NS
Tillage method		
S_1	19.23	28.23
S_2	19.25	27.39
S_3	19.03	27.82
SEm±	0.09	0.46
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.6. Soil analysis

4.6.1. Available NPK

Levels of irrigation or tillage methods or their interaction did not influence significantly the available nitrogen, available P_2O_5 and available K_2O in the soil (Table 27).

Table 27. Available NPK (kg/ha) as affected by irrigation and tillage

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Irrigation			
M_1	261.89	23.44	461.86
M_2	247.82	22.34	436.67
M_3	253.07	23.56	441.92
M_4	241.36	18.81	441.31
SEm±	9.12	1.22	5.53
LSD (0.05)	NS	NS	NS
Tillage method			
S_1	260.57	23.16	443.88
S_2	239.75	22.39	439.70
S_3	252.79	20.54	452.73
SEm±	7.76	1.95	5.39
LSD (0.05)	NS	NS	NS
Irrigation X Tillage			
LSD (0.05)	NS	NS	NS

4.6.2. Available calcium and magnesium

Levels of irrigation or tillage methods or their interaction did not influence significantly available calcium and magnesium in the soil (Table 28).

4.7. Moisture studies

4.7.1. Consumptive use (CU)

The irrigation treatments were started immediately after sowing. The data on total consumptive use was presented in Table 29. Total consumptive use was maximum in M_4 (365.45 mm) followed by M_3 (313.97 mm). Total consumptive use was the least in M_1 (62.95 mm).

There was significant difference among tillage methods on total consumptive use. The interaction between levels of irrigation and tillage methods failed to produce any significant influence on total consumptive use of water.

Table 28. Available calcium and magnesium (kg/ha) as affected by irrigation and tillage.

Treatment	Available calcium (kg/ha)	Available magnesium (kg/ha)
Irrigation		
M_1	130.46	94.24
M_2	126.52	82.88
M_3	138.41	85.27
M_4	133.53	91.48
SEm±	5.15	2.47
LSD (0.05)	NS	NS
Tillage methods		
S_1	129.17	88.42
S_2	129.39	91.37
S_3	138.14	85.62
SEm±	3.15	1.79
LSD (0.05)	NS	NS
Irrigation X Tillage		
LSD (0.05)	NS	NS

4.7.2. Field water use efficiency (FWUE)

Field water use efficiency calculated in kilogram fodder per hectare millimetre water applied is given in Table 30. Irrigation schedules influenced the field water use efficiency of fodder maize significantly. The treatment M_4 was significantly superior to the remaining treatments and recorded 88.44 kg/ha-mm followed by M_1 (85.92 kg/ha-mm) and lowest M_2 (67.63 kg/ha-mm).

There was significant difference between tillage methods with respect to field water use efficiency. Highest field water use efficiency was noticed in herbicide based zero tillage (92.95 kg/ha-mm) followed by conventional tillage (73.67 kg/ha-mm) and lowest in minimum tillage (59.69 kg/ha-mm).

There was no significant interaction due to levels of irrigation and tillage methods on field water use efficiency.

Table 29. Mean consumptive use of fodder maize as affected by irrigation schedules and tillage

Treatment	CU (mm)
Irrigation	
M_1	62.95
M_2	274.17
M_3	313.97
M_4	365.35
SEm±	0.96
LSD (0.05)	3.33
Tillage method	
S_1	254.55
S_2	250.80
S_3	257.06
SEm±	0.93
LSD (0.05)	2.79
Irrigation X Tillage	
LSD (0.05)	NS

4.7.3. Crop water use efficiency (CWUE)

There was significant difference between levels of irrigation with respect to crop water use efficiency. Crop water use efficiency calculated in kilogram fodder per hectare millimetre water consumed is given in Table 30. The highest crop water use efficiency (87.15 kg/ha-mm) was noticed in M_4 followed by M_3 plot (51.72 kg/ha-mm) and the lowest in M_1 (32.80 kg/ha-mm) plot.

Crop water use efficiency was affected by tillage methods. Highest CWUE was noticed in herbicide based zero tillage (S_1) (61.98 kg/ha-mm) followed by conventional tillage (S_3) (49.40 kg/ha-mm) and lowest in minimum tillage (S_2) (43.54 kg/ha-mm).

There was no significant interaction due to levels of irrigation and tillage methods on crop water use efficiency.

Table 30. Field water use efficiency and crop water use efficiency as affected by irrigation and tillage

Treatment	CU (mm)	CWUE (kg/ha-mm)	Total water applied (mm)	FWUE (kg/ha-mm)
Irrigation				
M_1	62.95	32.80	40	85.92
M_2	274.15	34.89	160	59.76
M_3	313.97	51.72	240	67.63
M_4	365.45	87.15	360	88.44
SEm±	0.96	2.42	-	3.51
LSD (0.05)	3.33	8.34	-	12.13
Tillage method				
S_1	254.54	61.98	200	92.95
S_2	250.79	43.54	200	59.69
S_3	257.05	49.40	200	73.67
SEm±	0.93	2.34	-	4.43
LSD (0.05)	2.79	7.01	-	13.30
Irrigation X Tillage				
LSD (0.05)	NS	NS	NS	Ns

4.7.4. Soil moisture depletion pattern

The soil moisture depletion pattern of fodder maize as influenced by irrigation schedules and tillage methods is presented in Table 31.

The average relative soil moisture depletion from different soil layers in the root zone (up to 90 cm depth) was worked out for each drying cycle following irrigation. The highest soil moisture was extracted from the surface layer (0-15 cm) in all irrigation schedules and extraction from this layer decreased progressively in no irrigation i.e. M_1. The top 15 cm accounted for on an average 34 to 44 per cent of the total moisture depleted. The moisture use from the 15-30 cm layer was as high as that from the next 30 cm soil layer below. The top 30 cm layer contributed about 61-80 per cent of total water use. Moisture depletion decreased rapidly with soil depth. In comparison with wet regimes, dry regimes extracted more soil water from the lower soil layers.

The soil moisture extraction pattern did not vary appreciably due to different tillage methods.

4.8. Economics

Economics (Rs./ha) of different treatments are presented in table 32. The data indicated that total cost, gross returns, net returns and B: C ratios were significantly influenced by different treatments in the experiment.

Costs of production as well as the net returns (negative) were lower in plots with no irrigation (M_1). The highest gross return of Rs. 72,920 per hectare was obtained for fodder maize in the treatment IW/CPE ratio 1.0 (M_4) with herbicide based zero tillage (S_1) and it gave the highest B: C ratio of 2.67. Irrigation at IW/CPE ratio 1.0 with conventional tillage (M_4S_3) and minimum tillage resulted in a B: C ratios of 2.08 and 2.01. The B: C ratios calculated for irrigation at IW/CPE ratio 0.7 with herbicide based zero tillage, conventional tillage and minimum tillage were 1.68, 1.16 and 1.03 respectively. However, B: C ratios were less than 1.0 in the case of treatments, IW/CPE 0.4 (M_2) and no irrigation (M_1).

Table 31. Soil moisture extraction pattern (%) from different soil layers of fodder maize as influenced by irrigation schedules and tillage

Treatments	Soil moisture extraction (percentage)															
	Tillage methods												Mean			
	Herbicide based zero tillage(S_1) Soil layer (cm)				Minimum tillage(S_2) Soil layer (cm)				Conventional tillage(S_3) Soil layer (cm)				Soil layer(cm)			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Irrigation schedule																
M_1	31.80	27.60	26.98	13.70	36.02	25.62	26.78	11.40	34.90	28.82	22.37	13.86	34.30	27.34	25.38	13.00
M_2	37.50	24.80	21.47	16.30	33.18	23.93	22.30	20.60	34.90	29.91	19.83	15.38	35.20	26.20	21.19	17.40
M_3	45.20	31.10	18.11	5.61	40.04	36.06	14.68	9.20	47.50	38.27	9.84	4.36	44.24	35.14	14.21	6.39
M_4	40.20	21.10	20.47	18.20	38.09	25.31	20.86	15.70	40.20	25.45	18.83	15.49	39.49	23.95	20.05	16.46
Mean	38.70	26.10	21.75	13.40	36.83	27.73	21.16	14.20	39.40	30.61	17.72	12.27	38.30	28.17	20.21	13.30

Table 32. Economics of fodder maize in various irrigation schedules and tillage

Irrigation schedules	Herbicide based zero tillage				Minimum tillage				Conventional tillage			
	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
No irrigation	25086	11680	-13406	0.46	25716	4800	-20916	0.18	27516	9460	-18056	0.34
Irrigation at IW/CPE=0.4	25566	24180	-1386	0.94	26196	19640	-6556	0.75	27996	20720	-7276	0.74
Irrigation at IW/CPE=0.7	26286	44260	17974	1.68	26916	27800	884	1.03	28716	33480	4764	1.16
Irrigation at IW/CPE=1.0	27246	72920	45674	2.67	27876	56000	28124	2.01	29676	61740	32064	2.08

Discussion

5. DISCUSSION

A field experiment was conducted to determine the most profitable irrigation schedule for fodder maize in summer rice fallows under different tillage practices at the Department of Agronomy, College of Horticulture, Kerala Agricultural University during 2012-2013. The results obtained from the experiment, reported in the previous chapter, are discussed below based on available literature.

5.1. Crop growth

Plant height is considered as a varietal character which is genetically controlled, but modified by a lesser extent due to environment. Plant height of fodder maize differed significantly because of different irrigation regimes during both stages of observation that is, at 30 DAS and harvest at 64 days. Irrigation at IW/CPE=1.0 recorded significantly higher plant height compared to others at both the stages of observation (Table 3 and Fig. 5). Increasing the frequency of irrigation from no irrigation to IW/CPE =1.0 markedly influenced plant height in all the irrigation treatments. In general, increasing the frequency of irrigation increases plant height in maize (Singh, 2001). Water deficit is likely to affect the two vital processes of growth viz. cell division and cell enlargement and according to Begg and Turnor (1976) cell enlargement is more affected, resulting in poor growth. The general belief is that growth is suspensed during moisture stress and resumed upon its elimination (Arnon, 1975).

It was found that plant height was significantly lower in minimum tillage (S_2) and higher in herbicide based zero tillage (S_1) at 30 DAS and at harvest. Agbede *et al*. (2008) reported that growth parameters like plant height, leaf area and dry matter production were higher in herbicide based zero tillage compared to other tillage practices. In the case of minimum tillage (S_2), weed growth is very high causing higher competition with crop plants for nutrients and moisture thus reducing plant height. In herbicide based zero tillage (S_1), crops were grown in relatively weed free condition compared to other tillage methods. Significant

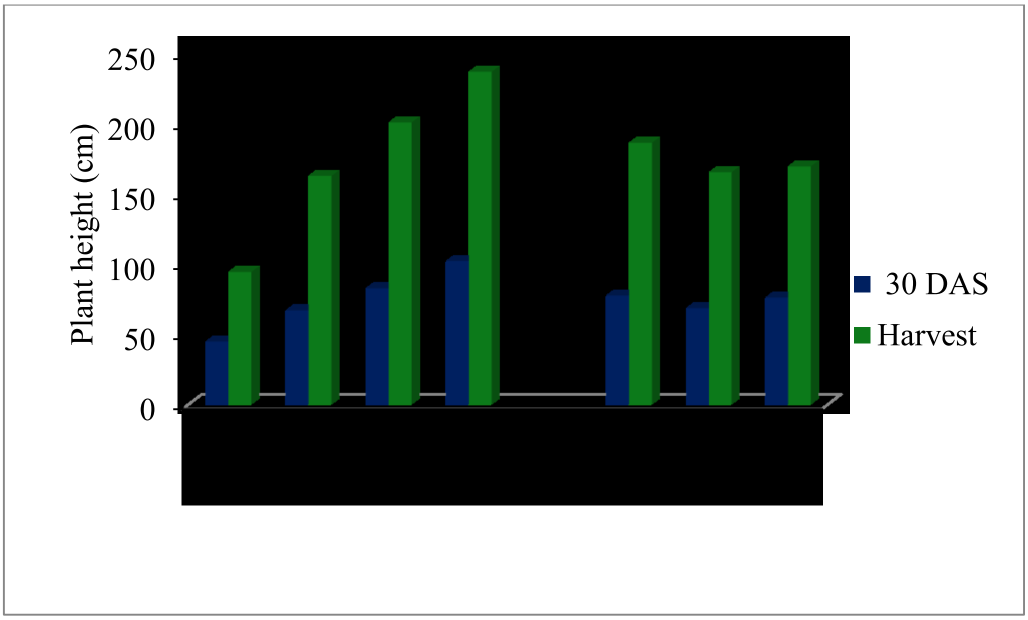


Fig. 5. Plant height (cm) of fodder maize at different growth stages as influenced by irrigation schedules and tillage

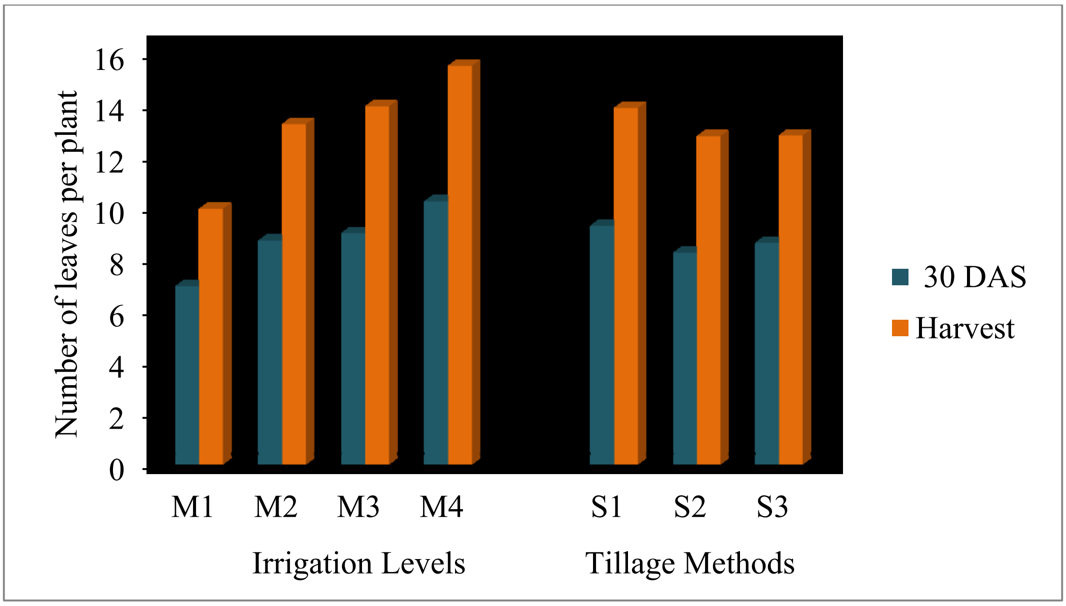


Fig. 6. Number of leaves per plant at different growth stages as influenced by irrigation schedules and tillage

interaction was noticed between irrigation schedules and tillage methods with respect to plant height at both stages of observation. Fodder maize recorded the highest plant height at IW/CPE ratio 1.0 with the herbicide based zero tillage (M_4S_1) followed by conventional tillage (M_4S_3) and the lowest in control plot with minimum tillage (M_1S_2) at both stages of observation.

As reported by Singh *et al*. (1995), leafiness can be used as an indicator of biomass yield and nutritive value. Leaf number and leaf area per plant and per tiller are indications of leafiness, and this feature is closely correlated with yield and digestibility. In this experiment, plants showed an increase in the number of leaves with increasing levels of irrigation from M_1 to M_4 (Table 4 and Fig. 6). Leaf number depends on the number of growing points, the length of time during which the leaves are produced, the rate of leaf production during the period and the length of life of leaves. Frequent irrigations markedly increased the number of leaves.

Numbers of leaves were the highest in M_4 plot both at 30 DAS and at harvest. However, M_3 and M_2 were on par with respect to leaf number both at 30 DAS and at harvest. As suggested by Humpheries and Wheeler (1963), leaf number and size in plants are characters, which are affected by genotype and environment. In the case of leaf number, plants in the herbicide based zero tillage (S_1) recorded the highest value both at 30DAS (9.31) and at harvest (13.90) which was superior to other tillage methods. This indicated that plants experienced favourable growth conditions in this treatment. However, there were no apparent differences between minimum tillage (S_2) and conventional tillage (S_3) with respect to leaf number at both stages of observation.

Leaf length is a morphological characteristic highly correlated with yield (Malaviya, 1999). In the present experiment, Leaf length and width also showed a similar trend as that of leaf number. Bade *et al.* (1985) reported that water stress retarded cell enlargement and stem elongation and reduced leaf area. The mean leaf length and width was found to be the highest in M_4 plot and the lowest in M_1 plot at both stages of observation (Table 5 and 6). Similarly, the tillage methods influenced leaf blade length significantly at 30 DAS but the differences were not significant at harvest. The highest leaf blade length was noticed in conventional tillage (S_3) followed by minimum tillage (S_2) which was on par with herbicide based zero tillage (S_1) at 30 DAS. Significant interaction was noticed among levels of irrigation and tillage methods with respect to leaf blade length at 30 DAS but there was no interaction at harvest. The highest leaf blade length was noticed in M_4S_1 combination. The width of leaf blade was unaffected due to tillage treatments.

Leaf area is one of the factors which contribute to fodder production (Thomas *et al*., 2007). Leaf area and LAI differed significantly among different irrigation schedules at both stages (Table 8, 9 and Fig. 7). Leaf area and LAI increased significantly with increasing the levels of irrigation from M_1 to M_4. The highest leaf area and LAI was noticed in IW/CPE=1.0 and the lowest values in M_1 with no irrigation. In the present study, leaf area index values varied from 0.45 to 5.01 and leaf area values varies from 532.87 cm^2 to 10184.39 cm^2 depending on the stages of observation. Generally, plants show low LAI and leaf area because of less leaf length, leaf width and number of leaves. Increase in leaf area and LAI, which can be attributed to rapid increase in number of leaves, leaf length and leaf width. As reported by Soltani *et al.* (2013) leaf area and LAI decreased with increased water stress in the present experiment. Also a steep decline in LAI was reported by several workers in crops when leaf water potential decreased. This indicates that modest changes in evaporative condition or the soil water supply will have a considerable influence on leaf growth. Low leaf water potential also causes the loss of existing leaf area (Arnon, 1975; Begg and Turner, 1976).

In the case of LAI and leaf area, plants in the herbicide based zero tillage (S_1) recorded higher values both at 30 DAS and at harvest which was significantly superior to other tillage methods. This indicates that the plants experienced favourable growth conditions in this treatment. The least LAI and leaf area values recorded in minimum tillage (S_2) might be due to severe weed competition and

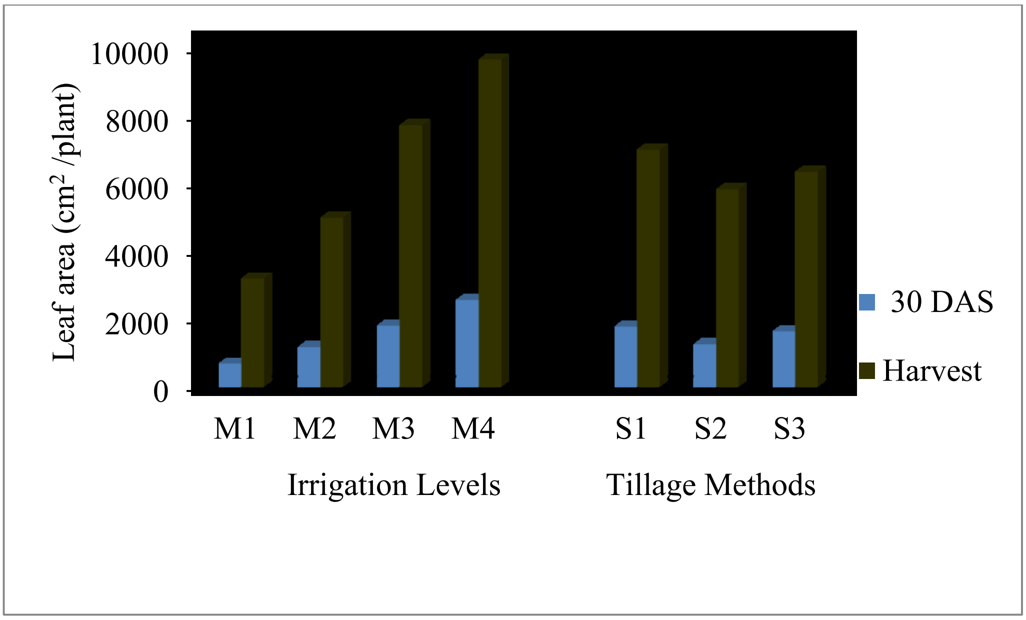


Fig. 7. Leaf area (cm^2/ plant) at different growth stages as influenced by irrigation schedules and tillage

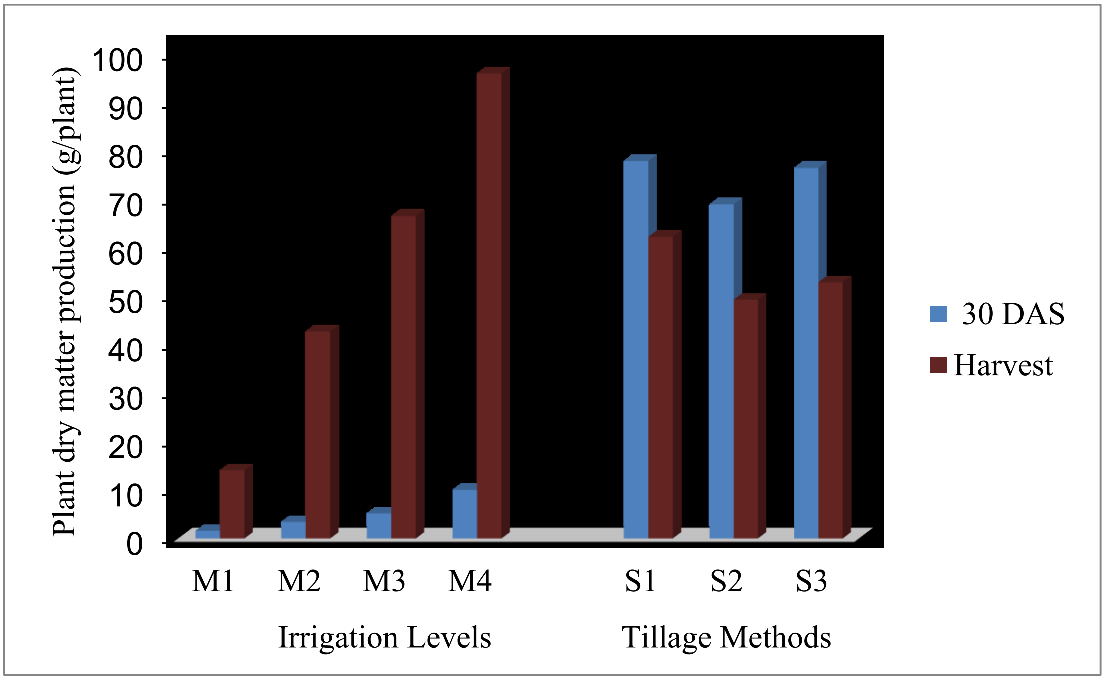


Fig. 8. Plant dry matter production (g/plant) at different growth stages as influenced by irrigation schedules and tillage

resultant poor growth. George (2011) reported similar results from a tillage study involving fodder maize, fodder sorghum and fodder bajra.

As evident from Table 10 and 11, mean leaf and stem dry matter at both the stages increased with increase in soil wetness from M_1 to M_4. Yegappan *et al.* (1996) stated that drought stress causes premature aging of leaves and reduces the leaf number. Hajibabaee *et al.* (2012) reported that leaf and stem dry weight decreased with increased water stress.

As evident from Table 12 and Fig. 8, mean dry matter production at both the stages increased with increase in soil wetness from M_1 to M_4. Photosynthesis is the basic process for the build up of organic substances by the plants, whereby sunlight provides the energy required for reducing CO_2 to sugar as the building material for all the other organic components of the plant. The amount of dry matter production will, therefore, depend on the effectiveness of photosynthesis of the crop, and further more on plants whose vital activities are functioning effectively (Arnon, 1975). The leaves of a plant are the main organ of photosynthesis and LAI is the best measure of the capacity of a crop for producing dry matter. Lower photosynthetic efficiency which was evident from low LAI in less frequently irrigated plots (Table 9) might be a major reason for the poor growth and low dry matter production in these treatments. The increase in total dry matter was mainly due to greater plant height, number of leaves and LAI (Ayub *et al*., 2009). The low total dry matter in water stress conditions can be attributed to more reduction in stem dry matter than leaf dry matter (Kholova *et al*., 2010). In the present study low total dry matter production was noticed in M_1 plot (1.60 g/plant and 14.24 g/plant respectively) both at 30 DAS and at harvest. Jahanzad *et al*. (2013) reported that shorter interval irrigation yielded 25 to 35 per cent higher forage dry matter compared to the longer interval irrigations. Increased dry matter yield of forage associated with higher irrigation have been reported in several studies (Vasilakoglou *et al*., 2011; Marsalis *et al*., 2010 and Singh 2001).

The variation in dry matter production with respect to tillage practices can be explained in terms of plant growth parameters recorded in herbicide based zero tillage (S_1) and conventional tillage (S_3). It could be seen that plant height and LAI were higher in herbicide based zero tillage (S_1) followed by conventional tillage (S_3). Variation in dry matter with tillage practices has also been reported by Agbede *et al*. (2008). Higher dry matter production in herbicide based zero tillage (S_1) and conventional tillage (S_3) could also be due to less weed competition and mulching effect in herbicide based zero tillage (S_1). Sharma and Acharya (2000) reported that crop residues of previous crop can favourably influence the succeeding crop due to their mulching effect.

Leaf to stem ratio is a qualitative character affecting the palatability and consequently animal intake. If the harvested produce contains more of stems, it will be more fibrous, difficult to chew and herbage will be wasted by the livestock. Hence leafiness of the crop or high leaf stem ratio is a desirable character in cut and carry system of livestock feeding. Often, it is a genetic character. However, sometimes other management factors may also influence leaf to stem ratio. In the present experiment leaf to stem ratio varied considerably between levels of irrigation as evident from Table 13 and Fig. 9. Leaf to stem ratio decreased with increasing levels of irrigation from M_1 to M_4. Jahanzad *et al.* (2013) reported that as the intervals between irrigations was increased the leaf to stem ratio increased because of high accumulation of biomass in rapidly growing leaves than stems in water stress conditions. The highest leaf to stem ratio was recorded at 30 DAS compared to that at harvest in almost all treatments. This can be attributed to less stem portions compared to leaf portion during the early growth stages of observation and the lowest leaf stem ratio was recorded in IW/CPE=1.0. In maize, Gheysari *et al*. (2009) observed that stem dry matter reduced (19%) more than leaf dry matter (11%) in droughted maize compared to frequently well watered ones.

Shoot to root ratio is also a genetic character and fodder maize differed substantially with different levels of irrigation (Table 14 and Fig. 10). In the

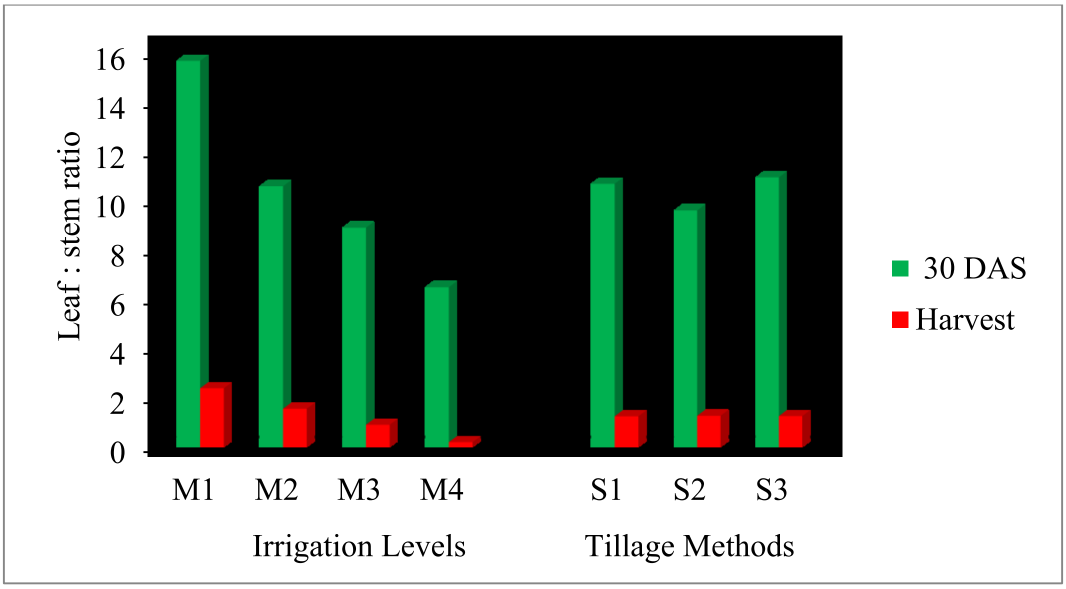


Fig. 9. Leaf to stem ratio of fodder maize at different growth stages as influenced by irrigation schedules and tillage

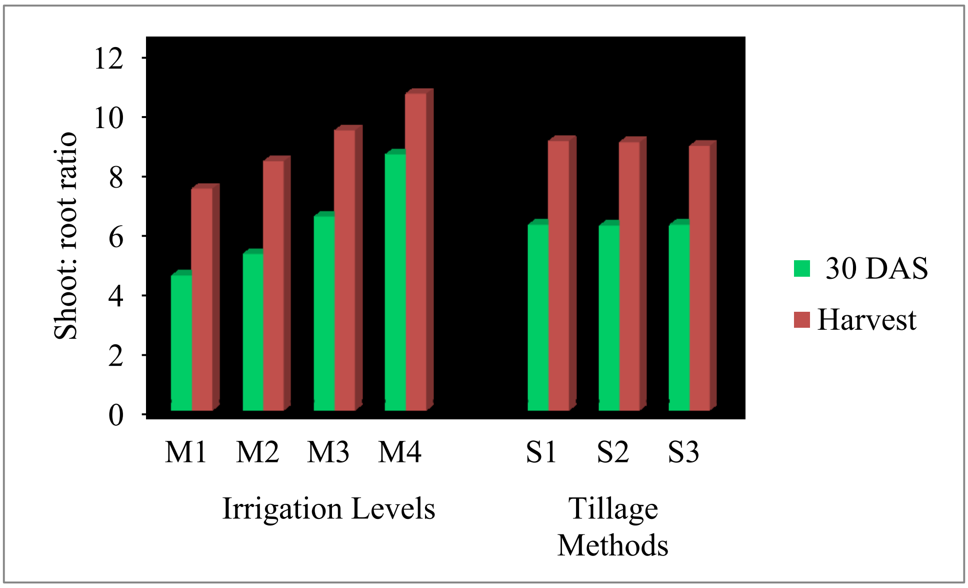


Fig. 10. Shoot root ratio of fodder maize at different growth stages as influenced by irrigation schedules and tillage

present study, shoot-root ratio increased with increasing levels of irrigation from M_1 to M_4. Shoot to root (S-R) ratio has physiological significance as it can reflect tolerance to drought. Pandey *et al*. (2000) reported that maize plants under vegetative water stress utilized an adaptive strategy by extended rooting depth and water extraction from the deeper soil profile. As Gardner *et al.* (1985) stated although S-R ratio is under genetic control, it is strongly influenced by environment. They also suggested that moisture stress during the vegetative stage causes development of smaller leaves, which reduce LAI and finally less light interception by the crop. Root elongation and dry weight were not affected as much as leaf area, stem elongation and dry weight. In other words, water deficiency has a relatively greater effect on shoot growth than root growth. According to Bade *et al.* (1985), water stress in tropical grasses slows cell enlargement and stem elongation, and reduces leaf area and shoot: root ratio and finally yield. There was no significant difference between tillage methods and no interaction was also noticed among main plot and sub plot with respect to leaf stem ratio or shoot root ratio. George (2011) could not observe any difference in leaf stem ratio and shoot to root ratio due to tillage methods.

5.2. Weed growth

Broad leaved weeds were the major weed flora of the experimental field followed by grasses and sedges. Major dicot weeds were *Melochia corchorifolia, Mollugo trifolia, Coldenia procumbens, Oldenlandia corymbosa, Ageratum conyzoides* and *Glinus oppositifolius*. The major grassy weeds observed were included *Digitaria ciliaris, Cynodon dactylon, Ischaemum indicum, Isachne miliacea* and *Echinochloa* sp. Important sedges were *Fimbristylis miliacea* and *Cyperus haspan*. In general weed population was more at 30 DAS compared to that at harvest, probably due to smothering of weeds by crop and also due to drying up of some weeds.

Compared to weed population, the dry matter production of weeds per unit area can give better indication about the weed competition. Weed dry matter production varied significantly among levels of irrigation (Table 16). The highest weed dry matter production was noticed in M_2 plot followed by M_3 plot in both stages of observation. The lowest dry matter production was noticed in M_1 plot at both the stages of observation. In M_1, the crop was raised with residual soil moisture, hence weeds also faced severe water stress like crop plants and growth was very less. However, in M_4 and M_3, crops received adequate moisture and grown luxuriously and inhibited weed growth through shading effect and in case of M_2, crop growth was comparatively less than M_3 and M_4, indicating that shading effect was less and weed growth was high.

Significant variation was noticed among tillage methods with respect to weed dry matter production. The highest weed dry matter production was noticed in minimum tillage (S_2) followed by conventional tillage (S_3) and the lowest dry matter production was noticed in herbicide based zero tillage (S_1) at both the stages of observation. In herbicide based zero tillage (S_1), due to application of the broad spectrum herbicide glyphosate, complete weed control was achieved at the time of sowing, and therefore, less weed growth was observed in this plots. In minimum tillage (S_2), as strip sowing was practiced some weeds present in inter row spaces were left undisturbed, leading to higher values of weed dry matter compared to normal tillage or herbicide based zero tillage. George (2011) observed the weed dry matter was higher in zero tillage followed by minimum tillage and the lowest in zero tillage with herbicide.

5.3. Fodder production

The data on fresh forage yields under different levels of irrigation and tillage conditions are given in Table 17 and Fig. 11. Levels of irrigation had significant influence on fresh forage yield of fodder maize. The highest green herbage yield (31.84 Mg/ha) was recorded in IW/CPE=1.0 (M_4) which was statistically superior to others and control plot (M_1) recorded the lowest green herbage yield (3.43 Mg/ha).

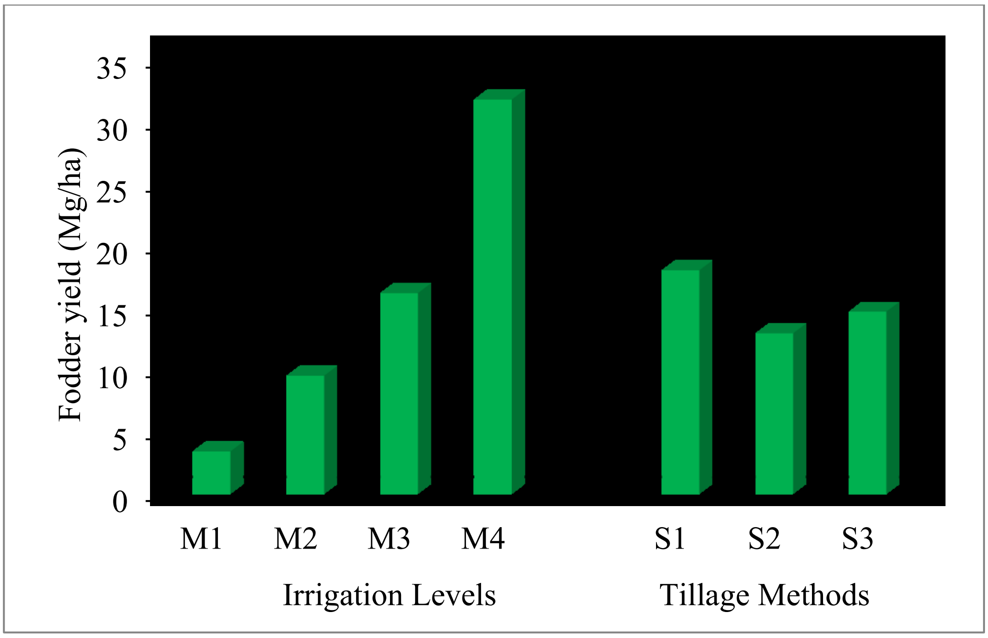


Fig. 11. Fodder yield (Mg/ha) as influenced by irrigation schedules and tillage

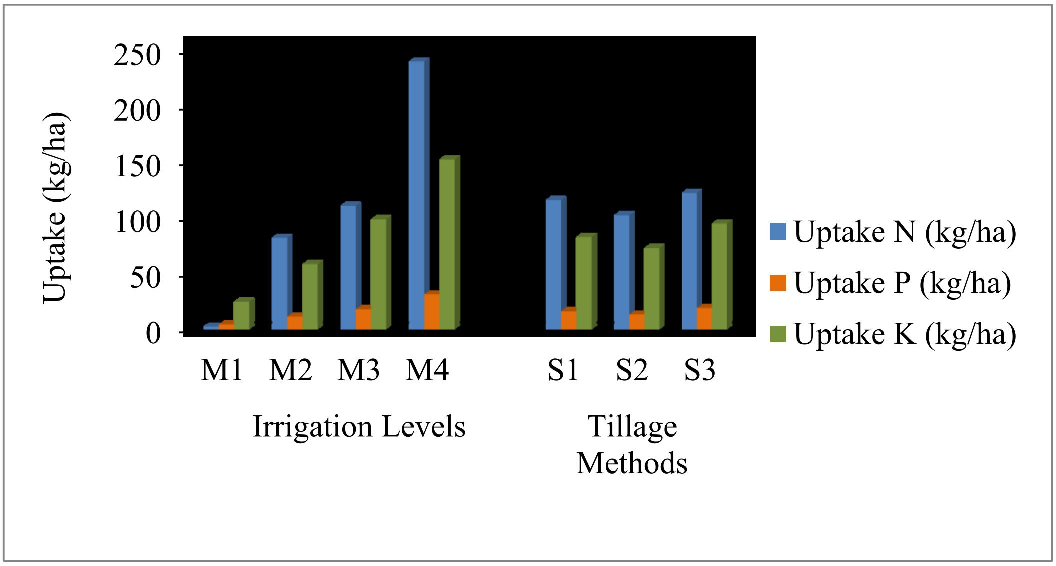


Fig. 12. Nutrient uptake of NPK (kg/ha) as influenced by irrigation schedules and tillage

The observed increase in forage yield with increase in soil wetness can be attributed to more or less similar trend in yield attributes like plant height, leaf number, leaf length, leaf width and leaf area. Rostamza *et al.* (2011) reported that a significant decrease in fresh forage yield was observed at each level of water supply reduction. As Ghildyal (1971) suggested, uptake of major nutrients and plant growth as evidenced by dry matter production are closely related to the amount of water transpired particularly under high evaporative demand conditions. Increased transpiration under high evaporative demand and favourable moist conditions of the soil increases the rate of uptake of nutrients as a result of mass transfer of ions through the transpirational stream. Moreover, reduced transpiration derived from dry soil might disrupt nutrient uptake by roots and ion transportation from roots to shoots (Kramer and Boyer, 1995). An increase in the rate of uptake of N, P and K with increased soil wetness was observed in the present study (Table 22) might have contributed to better growth and fodder yield. Here emphasis should also be given to the availability and uptake of various other nutrients from the moist surface soil due to frequent shallow irrigations as well as the favourable microclimate inside the crop canopy. In short, the reduction in yield at lower levels of irrigation is due to the adverse effect of stress on the physiology of growth and development. Several studies revealed that fodder production increased with increase in IW/CPE from 0.6 to 1.2 (Khera *et al.*, 1976; Palled *et al.*, 1991; Sathyamoorthi *et al.*, 2001; Nagaraju, 2006; Ramulu *et al.*, 2010 and Jahanzad *et al.*, 2013).

There is significant difference between tillage methods with respect to fresh forage yield. The highest fresh forage yield was recorded in herbicide based zero tillage (S_1) (18.07 Mg/ha) followed by conventional tillage (S_3) (14.74 Mg/ha) and the lowest in minimum tillage (S_2) (12.99 Mg/ha). The reduction in yield in minimum tillage (S_2) can be attributed to competition from weeds which resulted in poor plant growth. It could be seen that the weed dry matter production in minimum tillage (S_2) plots was significantly higher (108.20 g/m^2) compared to other treatments. The growth parameters recorded at various growth stages also showed poor plant growth in this treatment. The plant height at 30 DAS and at harvest was significantly lower in minimum tillage (S_2) plots compared to other tillage methods. Normal tillage may not be required for getting good crop yield (Carter *et al*., 2002). Lal (1989) noted that no till farming systems are successful for production of row crops in the tropics.

Shenk and Saunders (1981) observed that no till and reduced tillage systems produced more maize grain yield than ploughed treatments. Sharma *et al*., (2010) reported that chemical weeding with herbicides resulted in 7.8 per cent higher yield of maize over mechanical weeding.

Although herbicide application is not advocated in the context of environmental safety and residual toxicity, in the present case, it seems to be safe. Glyphosate is a post emergence broad spectrum herbicide which normally enters the plants through the green aerial parts, mainly the foliage. It is usually sprayed prior to sowing of the crop on the emerged weeds and the crop is harvested about 60 days after sowing. A characteristic of glyphosate is that its herbicidal activity through soil is low. This has been attributed to its easy adsorption to soil constituents. It has also been reported to be fairly immobile in soil, and in soil its degradation is brought about by microflora (Grossbard and Atkinson, 1985). Hence, the chance of herbicide residue problem and the resultant toxicity in livestock fed with fodder raised in a field treated with glyphosate is minimal.

5.4. Chemical composition of plant parts

Soil moisture controls the concentration and availability of various elements in soil for plant growth. Therefore, availability of water is of great significance to the plants to absorb nutrients and soil to supply them (Havlin *et al*., 2007; Agarwala and Sharma, 1976). Phosphorus, potassium, calcium and magnesium contents of plant parts viz., leaves and stems were not affected by water management practices (Table 19, 20, 22 and 23). However, there was significant difference between levels of irrigation, tillage methods and their interaction with respect to nitrogen content in both leaves and stems (Table 18).

Nitrogen content in leaves and stems decreased with increase in the level of irrigation. Leaf nitrogen content varied between 1.83 to 2.73 per cent whereas stem nitrogen content varied between 0.45 to 0.89 per cent. In general, there is a tendency to show a higher content of nitrogen in plant due to accumulation of this element in leaves and stems with water stress. High nitrogen content and associated problems are commonly reported in drought stressed maize. As Bolan and Kemp (2003) stated, although plant roots take up nitrogen both as ammonium and nitrate ions, under most soil conditions, uptake of nitrate dominates. Under normal growing condition, nitrate nitrogen taken up by plants is readily converted into ammonia, which is subsequently assimilated into amino acids and proteins. Hence, the level of nitrate is not high enough to be toxic. However, when the rate of uptake exceeds the rate of NO_3^- reduction, accumulation of NO_3^- in plants occurs. A common cause of high NO_3^- content in forage tissue is drought conditions (Bolan and Kemp, 2003). Rafiee *et al*. (2011) noted that as the drought progressed, the amount of nitrate and proline followed an increasing trend, but soluble protein decreased in shoot and root.

Maize plant can store the highest concentration of nitrogen in the stalk compared to leaf or other parts (Hicks and Peterson, 2006). The highest concentrations of nitrates in drought-stressed corn are normally found in the stalks and other conductive tissues. According to Hicks and Peterson, (2006), higher excessive rates of nitrogen fertilizer and drought conditions are the most important factors contributing to nitrate buildup in maize plants. The highest levels of nitrate accumulation occur where drought occurs during heavy nitrate uptake by the plant.

It has often been reported that NO_3^- concentration in herbage is high after a short period of drought. Two reasons have been attributed to this phenomenon (Wright and Davison 1964; Denium and Sibma 1980). During the drought period, the $NO3^-$ concentration builds up in the soil and therefore, most of the N is taken up in this form. A second reason is that the moisture stress during the drought period causes dry matter yield depression, thereby resulting in less reduction of

NO_3^- to organic N. Wright and Davison (1964) reported that drought during the heading and ripening period increases the NO_3^- concentration in oats. In New Zealand, the accumulation of NO_3^- in pasture has been noticed under cool and cloudy weather conditions, especially after a dry spell (Goh and Haynes 1986). When a plant experiences moisture shortage, there is a general disturbance of assimilatory process. The rate of reduction of NO_3^- is slowed, due to drop in NO_3 reductase enzyme. Nitrate accumulates in plants during periods of moderate drought because the roots continue to absorb NO_3^-, but high day time temperature is likely to inhibit its conversion to amino acids. In the present experiment although nitrate content was not determined, it is reasonable to assume that high nitrogen content in stem and leaf portions in less frequently irrigated plots is due to accumulation of nitrate.

Significant variation was noticed among tillage methods with respect to nitrogen content both in leaf and stem. Nitrogen content was high in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and low in minimum tillage (S_2) both in leaf and stem. This is probably due to less weed competition which resulted in better nutrient availability. Pandey *et al.* (2001) and Jat *et al.* (2004) also reported less nutrient removal by weeds in herbicidal treatments leading to more nutrients uptake by crop. George (2011) reported that nutrient removal by weeds was less in herbicide based zero tillage and uptake of nutrients by crop was high.

5.5. Uptake of nutrients

Higher levels of irrigation resulted in a marked increase in nitrogen, phosphorus, potassium, calcium and magnesium uptake by plants (Table 21and 24 and Fig.12 and 13). Nutrient uptake decreased as irrigation deficits are imposed. Similar results have been reported for pearl millet (Maman *et al*., 2006; Rostamza *et al*., 2011) and corn (Di Paolo and Rinaldi, 2008). In the present study, in less frequently irrigated plots biomass production was less and hence less nutrient demand by plants (Table 21). Moreover, the absorption of nutrients by roots requires the presence of water in the soil as it is the agent that transports solutes to

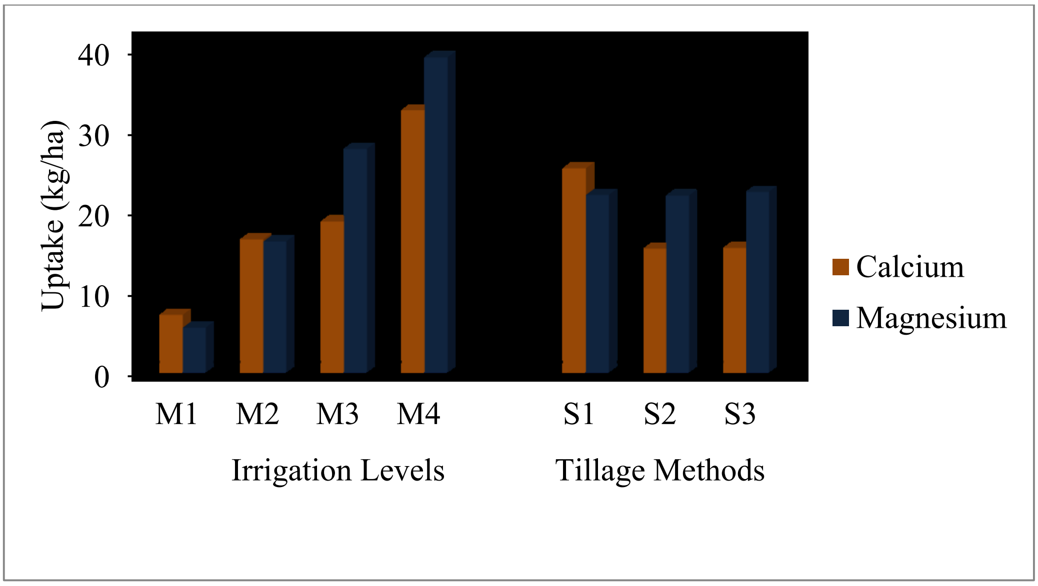


Fig. 13. Nutrient uptake of calcium and magnesium (kg/ha) as influenced by irrigation schedules and tillage

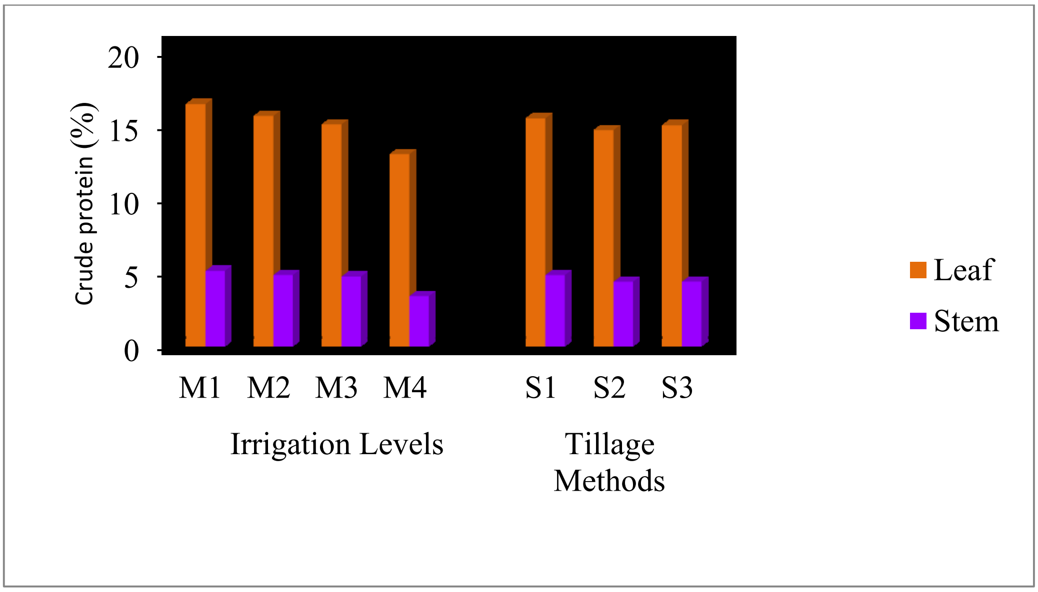


Fig. 14. Crude protein content (%) of leaves and stems of fodder maize at harvest as influenced by irrigation schedules and tillage

the soil-root interface (Garwood and Williams, 1967). Increased dry matter production under higher levels of irrigation may be due to better proliferation of root system and due to increased uptake of nutrients by the plants. Increased availability of plant nutrients due to irrigation and consequent increase in growth and mineral absorption also have to be considered in explaining the present trend. These results are in agreement with that of Brown *et al*. (1960), Singh (1975) and Balakumaran (1981) in different crops.

Significant interaction was noticed among tillage methods with respect to uptake of major nutrients like nitrogen, phosphorus and potassium. The highest N, P and K uptake was in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and the lowest in minimum tillage (S_2). However, there is no effect of tillage on the uptake of calcium and magnesium. The N uptake varied from 102.24 kg/ha in minimum tillage to 122.31 kg/ha in herbicide based zero tillage. Sharma *et al*. (2010) reported that the N uptake of maize increased significantly with chemical weeding and legume mulching and it was lower under minimum tillage. Verma *et al*. (2007) reported that herbicide application brought about significant reduction in N, P, and K uptake by weeds and enhanced nutrient uptake by wheat crop. Similar results were reported by George (2011) in cereal fodder crops.

The P and K uptake was high and comparable in conventional tillage (S_3) and herbicide based zero tillage (S_1). Sharp *et al*. (1986) reported that the plant uptake of P was more efficient under no tillage than under conventional tillage. Anderson *et al.* (1987) reported that tillage treatments affected the distribution of roots and extractable P in the top soil layer.

The P uptake varied from 13.35 kg/ha in minimum tillage (S_2) to 19.12 kg/ha in herbicide based zero tillage (S_1) whereas K uptake was in the range of 72.87 kg/ha (minimum tillage) to 94.83 kg/ha (herbicide based zero tillage). The drastic decline in uptake values in minimum tillage (S_2) plots can be attributed to the least dry matter production in this treatment together with lesser content of nutrients. Singh *et al*. (2009) reported that the nutrient uptake (N, P and K) in conventional, reduced and rotary tillage practices were significantly higher than that in zero tillage.

5.6. Nutritive value and quality

Plant samples from all the treatments were collected and analysed to find out percentage content of crude protein, crude fibre, nitrogen, phosphorus, potassium, calcium and magnesium of both leaves and stems at harvest.

Crude protein content gives an approximate value of protein content in the forages. Significant differences were noticed between levels of irrigation with respect to crude protein content. In general, the percentage content of crude protein was higher in leaves than stems. In the present study, in leaves, the content ranged from 11.45 to 17.06 per cent whereas in stems it ranged from 2.90 to 5.60 per cent. In both leaves and stems, the content increased with decreased levels of irrigation from M_4 to M_1 as the nitrogen content of leaves and stems in these treatments also decreased with increased levels of irrigation. In this experiment, less irrigation led to a progressive rise in crude protein content (Table 25 and Fig.14). In wheat, protein content is significantly increased under water deficit (Guttieri *et al*., 2000; Ozturk and Aydin, 2004) mainly due to higher rates of accumulation of grain N and lower rates of accumulation of carbohydrates.

In the present experiment, crude protein content was estimated from total nitrogen content. As discussed earlier in section 5.4 in this chapter, the high nitrogen content in stem and leaves may not be a reflection of actual protein content, but due to accumulation of high nitrate content under drought like situation. Normally, ruminant animals with high NO_3^- levels in their diets accumulate highly toxic nitrite (NO_2^-), which in turn is reduced, to ammonia and then incorporated into bacterial protein (Hicks and Peterson, 2006). However, when nitrate consumption is excessive, the reduction of nitrite to ammonia becomes overloaded, and toxic levels of nitrites accumulate in the rumen. Nitrite is absorbed into the blood and combines with hemoglobin to form methemoglobin. This condition is known as nitrate poisoning

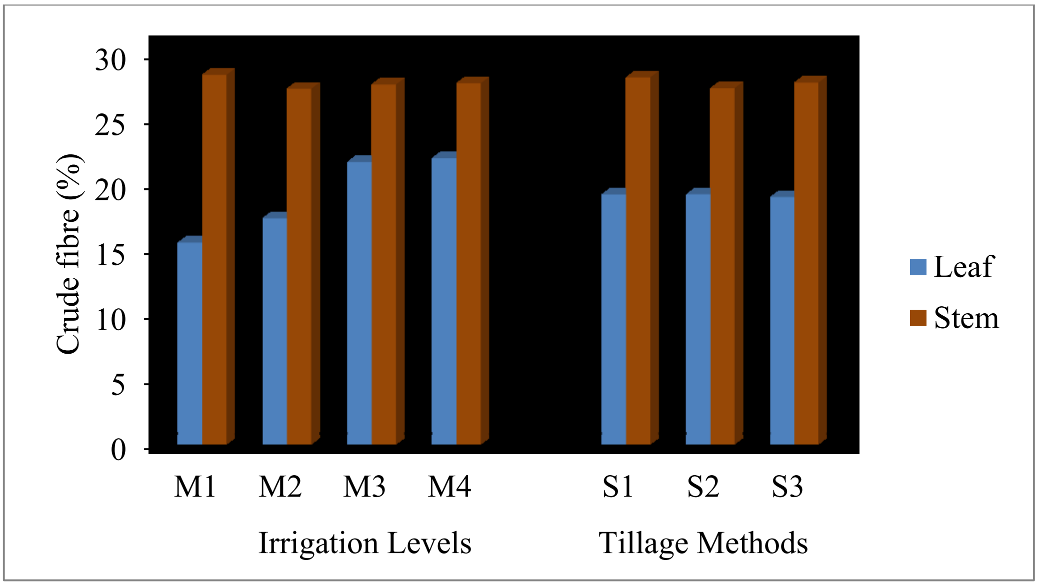


Fig. 15. Crude fibre content (%) of leaves and stems of fodder maize at harvest as influenced by irrigation schedules and tillage.

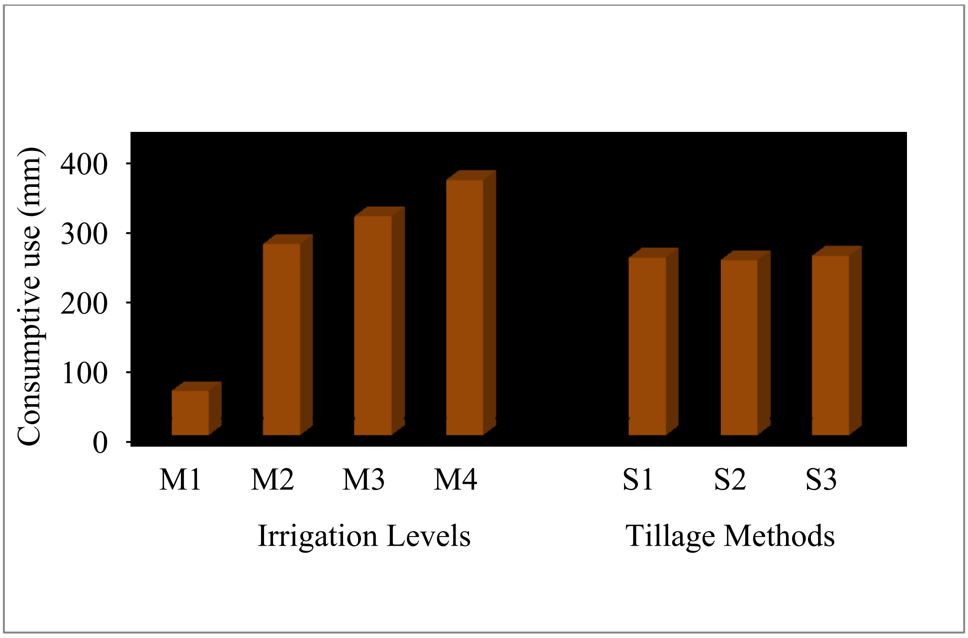


Fig. 16. Consumptive use (mm) as influenced by irrigation schedules and tillage methods.

(methemoglobinaemea). Nitrate poisoning occurs when animals eat forage material with high NO_3^- content. It has been reported in several studies that when water deficit intensifies, forage crude protein (CP) content enhances as a result of nitrogen accumulation (Jahanzad *et al*., 2013; Haberle *et al*., 2008; Pessarakli *et al*., 2005 and Abreu *et al*., 2004).

Among the three tillage methods, significant variation was noticed with respect to leaf and stem crude protein. The highest leaf and stem crude protein was noticed in herbicide based zero tillage (S_1) followed by conventional tillage (S_3) and lowest in minimum tillage (S_2). George (2011) obtained higher crude protein content in leaves and stems in herbicide based zero tillage followed by conventional tillage.

In general, crude fibre content of stems was more than leaves and showed significant differences between levels of irrigation. Significant variation was noticed among levels of irrigation with respect to crude fibre in leaves but not significant in stems (Table 26 and Fig.15). Leaf crude fibre content increased with increased levels of irrigation from M_1 to M_4. The highest leaf crude fibre was noticed in IW/CPE=1.0 and the lowest crude fibre in control plot with residual soil moisture. Leaf crude fibre content increased with increased levels of irrigation (Rostamza *et al*. 2011).

5.7. Soil fertility status

Levels of irrigation or tillage methods or their interaction did not influence significantly the available nitrogen, available P_2O_5, available K_2O, available calcium and available magnesium in the soil (Table 27 and 28). This can be explained as all the treatments received the same dose of fertilizers.

5.8. Moisture studies

The consumptive use increased with increase in the level of irrigation from M_1 to M_4 (Table 29 and Fig. 16). Consumptive use of water is higher in M_4 due to more frequent irrigations resulting in more moisture availability to the crop and soil and increased evapotranspiration. Many workers have reported similar results in different crops (Prasad and Singh (1979), Sharma and Parashar (1979), Singh *et al*. (1971), Nayak and Sengupta (1981) and Rathore and Patel (1991)).

Among the tillage methods, the highest consumptive use noticed in conventional tillage (S_3) followed by herbicide based zero tillage (S_1) but the lowest was in minimum tillage (S_2). Increased growth of roots and foliage due to less weed infestation in conventional tillage and herbicide based zero tillage plots might have contributed to these results.

The results revealed that the field water use efficiency increased with increased levels of irrigation from M_2 to M_4 (Table 30). Higher field water use efficiency was recorded in M_4 followed by M_1 and least in M_2. In general water use efficiency is likely to increase with decrease in soil moisture supply until it reaches the minimum critical level because plants may actively try to economise water loss in the range from minimum critical to optimum moisture level. However, in the present study, water use efficiency increased with increasing levels of irrigation, which may be due to fresh forage yield increased with increased levels irrigation. Similar results have been reported by Palled *et al*. (1991).

There was significant difference between tillage methods with respect to field water use efficiency. The highest field water use efficiency was noticed in herbicide based zero tillage (92.95 kg/ha-mm) followed by conventional tillage (73.67 kg/ha-mm) and the lowest in minimum tillage (59.69 kg/ha-mm). High herbage yield in herbicide based zero tillage might have played a role in increasing field water use efficiency.

Irrigation levels played a role in increasing crop water use efficiency (Table 30). The highest crop water use efficiency (87.15 kg/ha-mm) was in M_4 followed by M_3 plot (51.72 kg/ha-mm) and the lowest in M_1 (32.80 kg/ha-mm). These differences are obvious because of huge differences in herbage yield.

Mahdi *et al.* (2003) observed that in sandy loam soil of Yuma, scheduling of irrigation at IW/CPE= 1.00 recorded high CWUE over IW/CPE=0.6 and 0.8.

Crop water use efficiency was significantly affected by tillage methods too. The highest CWUE was noticed in herbicide based zero tillage (S_1) (61.98 kg/ha-mm) followed by conventional tillage (S_3) (49.40 kg/ha-mm) and the lowest in minimum tillage (S_2) (43.54 kg/ha-mm). High herbage yield in herbicide based zero tillage with the same quantity of consumptive use is the major reason behind this trend.

Maximum depletion of soil water was observed from the top 0-15 cm soil layer irrespective of the treatment and then gradually decreased with the increase in soil depth (Table 31 and Fig. 17). The high soil moisture depletion observed from the upper 15 cm layer might be due to the fact that, besides transpiration, lossess due to evaporation from soil surface was considerable. The moisture use from 15-30 cm layer was as high as that from the next 30 cm layer below. Moisture depletion decreased rapidly with the soil depth. It clearly suggests that the activity of fodder maize roots is high in the 0-60 cm soil layer. According to Gardner (1968), root mass and their activity are important for soil moisture extraction. Similar observations were reported by Thomas and Pillai (1990) in bitter gourd.

Compared to maize plants with irrigation at IW/CPE 1.0, maize plants with irrigation at 0.7 and 0.4 extracted more water from deeper layers that is 15-90 cm. As drought like situation prevailed in M_1 (no irrigation), its roots may not have penetrated to deeper layers and hence low moisture extraction from deeper layers. In frequently irrigated plots (IW/CPE=1.0), water extraction was low from 30-90 cm layer probably because of higher availability of water in the top 0-30 cm layer. Pandey *et al*. (2000) reported that maize plants under vegetative water stress utilized an adaptive strategy by extended rooting depth and water extraction from the deeper soil profile.

5.9. Economics

The feasibility of a crop production or management practice can be judged only by cost benefit analysis. In the case of rice fallow cultivation, this is very important as most often the land is left fallow due to economic constraints. In dairying, in order to reduce the cost of production, the cost of fresh fodder production has to be minimised. Hence cost benefit analysis was carried out.

The analysis indicated that fodder maize cultivation at IW/CPE ratio 1.0 with herbicide based zero tillage (M_4S_1) was the best option as it yielded the highest B: C ratio of 2.67 (Table 32). This happened because of high gross and net returns. If farmers want to have herbicide free production system with irrigation, they can do it with conventional tillage (M_4S_3) as the B: C ratio for this treatment was found to be the next best (2.08). Rostamza *et al.* (2011) reported that the profit and revenue were decreased as water stress increased. According to Ranjita (2005), gross income, net return and B: C ratios were higher due to frequent irrigations.

5.10. Future line of work

Only one year data could be taken in the present experiment. As the experiment generated useful findings, it may be repeated for one or two years for confirmation.

In the present experiment, 'African Tall', a composite maize cultivar was used. As several promising forage maize cultivars- both hybrids and composits are recommended for cultivation in India, these may also be evaluated in summer rice fallows with irrigation. Nutritional dynamics, especially nitrogen, in the soil and plant and their residual effects on the succeeding crop need further investigation. Similarly, its adaptability for further processing as silage or hay may also be investigated.

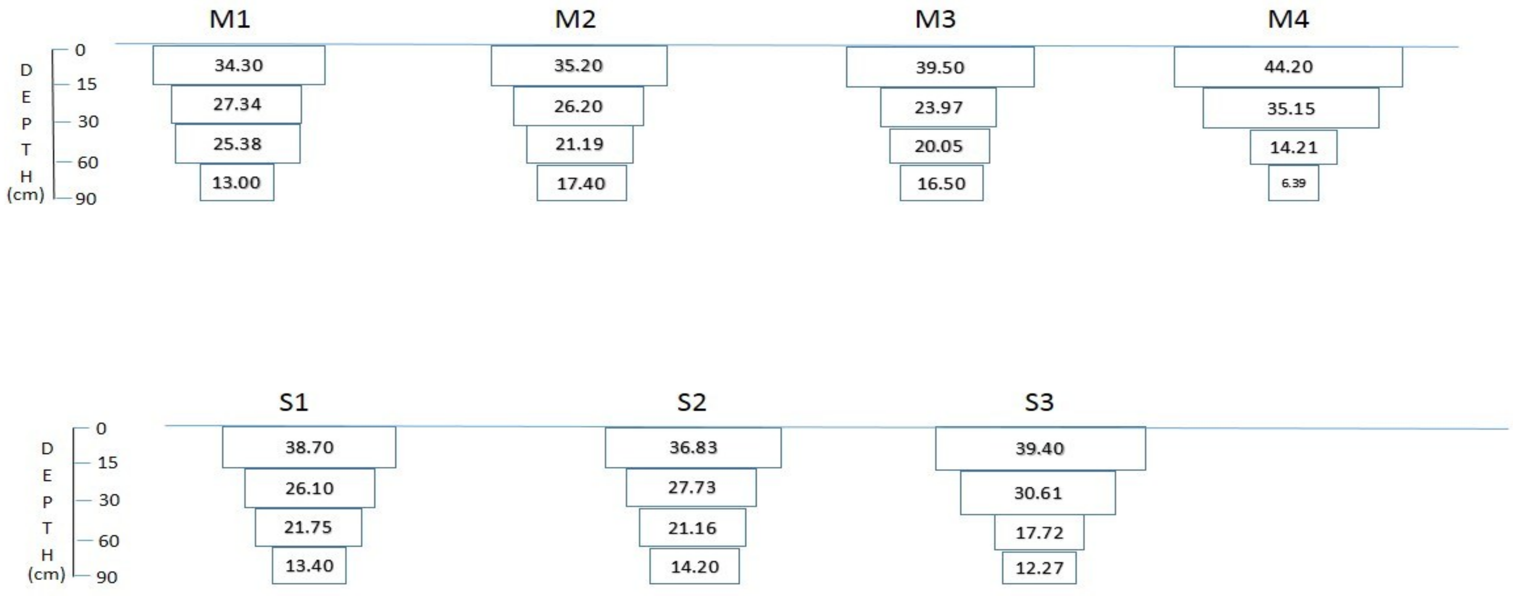


Fig. 17. Soil moisture extraction pattern (%) from different soil layers as influenced by irrigation schedules and tillage

Summary

6. SUMMARY

A field experiment was conducted during 2012-13 at the college of Horticulture, Vellanikkara to evaluate different irrigation schedules and tillage practices for fodder maize in summer rice fallows. The main objective of the experiment was to determine the most profitable irrigation schedule for fodder maize in rice fallows under different tillage practices. Another objective is to study the soil moisture extraction pattern and water use efficiency under different treatments.

The experiment was laid out in split plot design with four main plots and three sub plots replicated thrice. The treatments comprised of four levels of irrigation at IW/CPE ratios 1.0, 0.7 and 0.4 and a control plot with residual moisture and three tillage treatments comprising of herbicide based zero tillage, minimum tillage and conventional tillage. Seeds were sown at a spacing of 30 cm x 15 cm on 29-11-2012. Harvesting of herbage was done 64 days after sowing (DAS). Main observations recorded were growth parameters, green fodder yield, weed growth, nutrient content and uptake, consumptive use of water, water use efficiency and soil moisture extraction pattern. Economics of fodder production was also worked out.

Observations on growth parameters were taken at 30 days after sowing (DAS) and at harvest. Leaves, stems and roots of randomly selected plants were separated and dry weights were recorded separately. Based on growth observations, leaf area, leaf:stem ratio and shoot:root ratio were determined. Analyses of variance were performed on all data collected using the statistical package, ‘MSTAT’. Where the F-test was significant (at 5 per cent level of significance), the least significant difference (LSD) was used to compare means at P= 0.05. A summary of salient findings is given in this chapter.

Crop growth

Significant differences were noted between the levels of irrigation with respect to plant height, number of leaves/plant, leaf width, leaf length, leaf area, leaf area index, leaf: stem ratio and shoot: root ratio, leaf dry matter and stem dry matter.

Plant height was high in plots irrigated with IW/CPE = 1.0 with herbicide based zero tillage at both the stages of observation. Plants showed an increase in the number of leaves with increased levels of irrigation. Leaf length and width also showed similar trend as that of leaf number. With respect to tillage methods, plant height and number of leaves were more in herbicide based zero tillage but leaf length was higher in conventional tillage.

Leaf area index (LAI) for fodder maize varied from 0.45 to 5.01 and leaf area 532.87 cm^2 to 10184.39 cm^2 depending upon the treatment and stage of observation. There was a rapid increase in LAI and leaf area with increased levels of irrigation. The highest leaf area and LAI values were observed in herbicide based zero tillage and the lowest in minimum tillage. Leaf: stem ratio decreased with increased levels of irrigation. Shoot: root ratio increased with increased levels of irrigation. Tillage methods did not influence either leaf: stem ratio or shoot: root ratio.

Leaf and stem dry matter increased with increased levels of irrigation both at 30 DAS and at harvest. Higher leaf and stem dry matter was noticed in herbicide based zero tillage when compared with other tillage methods.

Based on growth parameters, it can be concluded that irrigation at IW/CPE ratio 1.0 showed the maximum influence on plant height, leaf number, leaf width, leaf length, leaf area index, leaf:stem ratio and shoot:root ratio. Similarly, herbicide based zero tillage was better with respect to plant height, leaf number, leaf area and LAI.

Fodder production

Green fodder yield from each plot was recorded immediately after cutting and expressed in Mg/ha. Irrigation levels influenced forage yields significantly. The highest herbage yield was recorded in IW/CPE=1.0 which was superior to others.

Significant differences were noted between tillage methods too with respect to forage yield and dry matter production. The highest green herbage yield and dry matter production were recorded in herbicide based zero tillage.

Nutritive quality and nutrient uptake

Plant samples from all the treatments were collected at harvest; leaves and stems were separated, chopped and dried in a hot air oven at 80 ± 5^0C for 24 to 48 hours till constant weight was achieved. The samples after grinding were used to find out percentage content of nitrogen, phosphorus, potassium, calcium, magnesium, crude protein and crude fibre, of both leaves and stems.

Analyses of data on nutritive value showed significant differences between the treatments. In general, nutritive value of leaves was higher than stems. When crude protein content of both leaves and stems are considered, high values were noticed in control plots with no irrigation. Crude fibre content of stems was more than the leaves and showed no significant differences between the treatments. However, crude fibre content was higher in leaves in control plots receiving more number of irrigations.

There was no significant difference between levels of irrigation or tillage methods with respect to percentage content of phosphorus, potassium, calcium and magnesium. In the case of available nutrients in soil too, there was no significant differences between the treatments. Uptake of all the nutrients studied (N, P, K, Ca and Mg) were higher in the plots receiving more number of irrigations with herbicide based zero tillage.

Moisture studies

The consumptive use increased with increase in the level of irrigation. Significant differences were noticed among tillage methods with respect to consumptive use. Consumptive use was higher in conventional tillage and herbicide based zero tillage compared to minimum tillage. There was significant differences between levels of irrigation with respect to crop water use efficiency. Crop water use efficiency increased with increased levels of irrigation.

Field water use efficiency increased with increased levels of irrigation. There was significant difference between tillage methods too with respect to field water use efficiency. The highest field water use efficiency was noticed in herbicide based zero tillage and the lowest in minimum tillage.

Maximum depletion of soil water was observed from top 0-15 cm soil layer irrespective of the treatment and then gradually decreased with the increase in soil depth.

Economics

Among the various treatment combinations, irrigation at IW/CPE ratio 1.0 with herbicide based zero tillage is the best option for fodder maize as it gives the highest B: C ratio and net returns.

Conclusion

From the results obtained, it can be concluded that fodder maize cultivation with 40 mm irrigation scheduled at IW/CPE ratio 1.0 with herbicide based zero tillage is superior with respect to fodder yield and net returns, and hence suited for summer rice fallows where water for irrigation is available. Depending on mean daily evaporation values in Kerala, this translates to irrigation with 40 mm water (40 L/m^2) at an interval of 6-9 days.

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* Originals not seen

Appendices

APPENDIX I

a) Weather data during the crop period

Month	Standard week	Total rainfall (mm)	Mean maximum temperature (0^C)	Mean minimum temperature (0^C)	Relative humidity (%)		Mean wind velocity (Km/hr)	Total sunshine hours	Mean evaporation (mm/day)
					Max	Min			
Nov	47	3.4	32.8	22.9	92.9	56.7	2.8	5.31	3.2
	48	6.4	33.1	21.9	68.4	38.1	4.8	9.6	4.9
Dec	49	0	33.3	23.7	81	44.6	5.9	8.8	4.8
	50	0	33	21.7	75.4	41.1	5.9	8.6	4.7
	51	0	31.9	24.3	63.1	43.9	10.4	7.6	6.4
	52	13.6	33.4	23.6	73.6	44.8	5.5	7.1	4.6
Jan	1	0	34.5	23.1	83	38.3	3.3	8.4	4
	2	0	33.7	22.9	69.1	35.3	5.6	6.9	4.6
	3	0	33.6	21.1	69.4	34.7	5.6	9.7	5.1
	4	0	34.5	22.1	55.4	26.3	6.4	9.7	5.9
Feb	5	0	34.4	22.4	70	31.7	2.9	9.5	5.1
	6	0	35.1	23.6	81.1	40	0	8.6	4.9

APPENDIX II

a) **Cost of inputs per hectare**

Sl no.	Input	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1.	Seed	50 kg	30	1,500
2.	FYM	10 Mg	600	6,000
3.	Urea	260 kg	6	1,560
4.	Rock phosphate	300 kg	10	3,000
5.	MOP	66 kg	16	1056
	Total			**13,116**

b) **Cost of cultivation for one hectare**

Sl no.	Particulars	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1.	Land preparation , bund ,channel formation	8 women	240	1,920
2.	Application , Incorporation of FYM and basal application of fertilizers	7 women	240	1,680
3.	Sowing of seeds	20 women	240	4,800
4.	Thinning and gap filling	3 women	240	720
5.	Top dressing of fertilizer	2 women	240	480
	TOTAL			**9,600**

c) **Additional costs for main plots**

Plot	M_1	M_2	M_3	M_4
Harvesting and irrigation (Rs.)	**1200**	**1680**	**2400**	**3360**

d) **Additional costs for sub plots**

Plot	S1	S2	S3
Herbicide cost and application charges (Rs.)	1170	0	0
Country plough (Rs.)	0	1800	0
Tractor (Rs.)	0	0	3600

Abstract

Irrigation and tillage practices for fodder maize (*Zea mays* L.)in rice fallows

By

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THESIS

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ABSTRACT

A field experiment was conducted at the College of Horticulture, Vellanikkara during 2012-13 summer season to study the response of fodder maize (*Zea mays* L.) to different irrigation practices and tillage methods. The treatments consisted of four levels of irrigation (irrigation at IW/CPE ratios of 0.4, 0.8 and 1.0 and no irrigation) and three tillage methods (herbicide based zero tillage, minimum tillage and conventional tillage). The experiment was laid out in split plot design with three replications.

The study revealed that fodder maize responded well to frequent irrigations and herbicide based zero tillage. Biometric characters such as plant height, number of leaves/plant, leaf area, leaf area index and shoot: root ratio were higher in frequently irrigated plots with herbicide based zero tillage whereas leaf: stem ratio was lesser in frequently irrigated plots. Stem dry matter, total dry matter production and fresh forage yield were higher in frequently irrigated, herbicide based zero tillage plots.

There was no significant difference between levels of irrigation or tillage methods with respect to per cent content of phosphorus, potassium, calcium and magnesium. However, nitrogen and crude protein contents decreased with increased levels of irrigation. Leaf crude fibre increased with increased levels of irrigation but no differences in stem crude fibre was noticed among treatments. Uptake of nutrients was higher in herbicide based zero tillage plots receiving more number of irrigations.

Consumptive use, field water use efficiency and crop water use efficiency were higher in frequently irrigated plots (IW/CPE= 1.0 and 0.7). Frequently irrigated plots extracted more water from the top layers. In general, fodder maize extracted 61-79 per cent of the total water use from the top 30 cm soil layer.

Among the irrigation schedules IW/CPE=1.0 recorded the highest gross returns, net returns and B: C ratio followed by IW/CPE=0.7. Among the different

tillage methods herbicide based zero tillage resulted in the highest net returns and B: C ratio.

It can be concluded that fodder maize cultivation with 40 mm irrigation scheduled at IW/CPE ratio 1.0 with herbicide based zero tillage is superior with respect to fodder yield and net returns, and hence suited for summer rice fallows where water for irrigation is available. Depending on mean daily evaporation values in Kerala, this translates to irrigation with 40 mm water (40 L/m^2) at an interval of 6-9 days.