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Full Length Research Paper

Effects of deficit irrigation on winter silage maize production in Zimbabwe

Rusere F[*1], Soropa G[1], Svubure O[1], Gwatibaya S[2], Moyo D[1], Ndeketeya A[1], Mavima G.A[1]

[1]Department of Irrigation and Water Engineering, Chinhoyi University of Technology, P. Bag 7724, Chinhoyi, Zimbabwe
[2]Department of Agricultural Engineering, School of Agricultural Sciences and Technology, Chinhoyi University of Technology, P. Bag 7724, Chinhoyi, Zimbabwe

Abstract

A study was carried out to determine the effects of deficit irrigation on silage maize production at Clysdale farm in Banket, Mashonaland West province of Zimbabwe. The experiment was carried out on three main plots representing three treatments with six replications for each treatment. The three treatments were irrigating at 100% (T 100), 80% (T 80) and 60% (T 60) of crop water requirements. The experiment was laid out in a completely randomized design. Water use efficiency, cob yield, leaf area and total fresh yield were determined. The results showed that leaf area, total fresh yield and cob yield decreased by 13.38%, 22.18% and 15.23 respectively while water use efficiency increased by 15.87 % under T80 treatment during the 2008 season. For T60 leaf area, total fresh yield and cob yield decreased by 30.59%, 39.66% and 27.08% while water use efficiency increased by 31.46% during the 2008 season. The same trend was observed again for T80 in 2009 where leaf area, fresh yield and cob yield decreased by 15.99%, 16.47% and 11.23% respectively while water use efficiency increased by 18.1%. For T60 during the same season leaf area, fresh yield and cob yield decreased by 35.2%, 42.37% and 25.94% respectively while water use efficiency increased by 28.39%. From the experiment it can be concluded that deficit irrigation results in a significant decline in silage maize yield and an increase in water use efficiency.

Keywords: Silage Maize, Deficit Irrigation, Yield, Water Use Efficiency.

INTRODUCTION

Silage is fermented, high moisture fodder that can be fed to ruminants or used as a biofuel feedstock for anaerobic digesters (Gheysari et al., 2007). It is fermented and stored in process called ensilage or silaging and usually made from grass crops, including maize, sorghum or other cereals using the entire green plant. In Zimbabwe, silage maize is usually grown in summer under rain fed conditions. However during this period fodder for livestock feeding is in abundance. A problem faced by most livestock farmers is the low availability of forage in winter and spring dry season (May to November). Silage production during winter is low because most of the commercial farmers with irrigation opt to grow winter wheat, which has high returns (Adam et al., 1997).

For those who decide to grow silage there is likely to be conflicts in the allocation of limited water resource. Temporal and spatial imbalance in the distribution of rainfall and the consequential non-availability of water at the required period is resulting in reduced production of sustainable and reliable food supply. Often, crop failure occurs because of unavailability of water at some critical growth stages due to limited water resources for irrigation purposes. Achieving greater efficiency of water use will be a primary challenge for these farmers hence the need for employment of techniques and practices that deliver a more accurate water supply to the crops. In this context, deficit irrigation can play an important role in increasing water use efficiency.

*Corresponding Author Email: farirairusere@gmail.com; Tel: +263 773 317 276

Deficit irrigation is the scheduling method where irrigation is purposefully carried out not to fully meet water requirements of the crop, and plants are allowed to extract soil moisture beyond readily available water in the plant root zone (Bekele and Tilahun, 2007). Deficit irrigation is needed where essential resources such as water, capital, energy and labour are limited. Under deficit irrigation, crops are deliberately allowed to sustain some water deficit and yield reduction. The irrigator aims to increase water use efficiency (WUE) by reducing the amount of water at irrigation or by increasing the irrigation interval. Yensew and Tilahun (2009) noted that practicing deficit irrigation by reducing the amount of water per irrigation results in a decline of grain yield, increase in irrigated area and high water use efficiency Therefore it is necessary to develop new irrigation scheduling approaches not necessarily based on full crop water requirements, but ones designed to ensure optimal use of allocated water. The expectation is that any yield reductions will be countered with the benefits gained through diverting the saved water to irrigate other crops or for domestic and industrial purposes.

However, excessive moisture stress is the most limiting factor in maize production (Pandey et al., 2000, Cakir, 2004). During establishment, it kills young plants and reduces plant density. During vegetative stage, it restricts leaf growth and expansion so resulting in stunted growth. With increasing moisture stress, the dry matter production of the crop decreases directly by decreasing cell division and enlargement and indirectly by reducing rate of photosynthesis. Much of the past research on water stress on maize has consisted of full withholding of irrigation and conditions of severe water stress (Farre et al., 2000, Farre and Faci, 2009). It is quite possible that deficit irrigation spread over the full growing season may result in increased water use efficiency despite a decline in yields. The decline in yield per unit crop may be compensated by an increase in area of production.

Deficit irrigation has not been adopted as a strategy in silage maize production in Zimbabwe hence its effect on yield and water use efficiency is not known. Considering the scarcity of irrigation water during winter in Zimbabwe there is a need to establish the benefits of adopting deficit irrigation as a water saving technique. Therefore this study was conducted to determine the effects of deficit irrigation on winter silage maize production in Zimbabwe. The aim of the experiment was not to reduce the amount of water applied per interval but rather using treatments with longer intervals between irrigation events.

STUDY SITES AND METHODS

Study site

The research was carried out at Clydesdale farm, which is 18 km south east of Banket, in Mashonaland West province of Zimbabwe during the winters of 2008 and 2009. The study area was located in natural region IIa with an annual rainfall of between 700 mm and 1000mm. Mean winter temperatures range from 12-18°C and mean summer temperatures of 24-32°C. The natural regions are a classification of the agricultural potential of the country, from natural region 1, which represents the high altitude wet areas to natural region V, which receives low and erratic rainfall averaging 550 mm per annum (Vincent and Thomas, 1960). The soils varied from varied from sandy loam-to-loam and soil depth ranged 1.0 to 1.2 m.

Crop water requirement and irrigation scheduling

Irrigation treatments

Irrigation treatments were applied as follows, T(100) no stress representing 100% crop water requirements, T(80) mild stress, 80% crop water requirements and T(60) severe stress, 60% crop water requirements Irrigation intervals were 10 days, 14 days and 18 days for T 100, T80 and T60 treatments respectively. Irrigation scheduling was done as shown by table 1 below.

Experimental design

The experiment was laid out in a Completely Randomized Design (CRD) with three treatments and six replicates for each treatment. The experiment was carried on three plots each of area 50m x 20m. Maize seed SC 403 was sown in winter at a depth of 3cm with an in-row spacing of 15cm and inter-row spacing of 65cm. Atrazine was used as post emergent herbicide to control weeds 2 weeks after sowing the seeds. Before sowing 80kg/ha Compound D was applied as a basal fertilizer and a top dressing of ammonium nitrate at the rate of 80kg/ha was applied six weeks after planting.

Data collection

Crop measurements

Biocuts were taken ninety two days after planting. Six samples were taken for each treatment. Leaf area was recorded by stripping the plants plotting the outline of the leaves on graph paper and measuring the area covered by the leaves on the graph paper. Total fresh yield was determined as the total above ground biological yield (grain and all other parts). For drying the maize, a polystyrene box measuring 1m x 1m x 2m was constructed. An oil fueled heater coupled to clamp on water heater thermostat was then placed at the bottom of the box. The thermostat was set at 70°C. The maize was

Table 1. Irrigation dates and amounts of water applied for the maize trial during 2008 and 2009

Amount of water applied								
2008	**2009**	**(T 100)**	**2008**	**2009**	**(T 80)**	**2008**	**2009**	**(T 60)**
24/5	14/5	60	24/5	14/5	60	24/5	14/5	60
4/6	24/5	60	7/6	28/5	60	11/6	2/6	60
14/6	3/6	60	21/6	12/6	60	29/6	20/6	60
24/6	13/6	60	5/7	26/6	60	17/7	8/7	60
3/7	23/6	60	20/7	10/7	60	4/8	26/7	60
13/7	3/7	60	4/8	24/7	60			
23/7	13/7	60	18/8	7/8	24			
2/8	23/7	60						
Total		480mm			384mm			300mm

*No rainfall was received during the experiments.

Table 2. Effect of deficit irrigation treatments on leaf area, yield and water use efficiency during the 2008 season.

Treatment	Leaf area (cm^2)	Fresh yield (t/ha)	Cob yield (t/ha)	Water use efficiency(g/mm)
T 100	3557[a]	59.5[a]	7.68[a]	10.33[a]
T 80	3081[b]	46.3[b]	6.51[b]	11.94[b]
T 60	2469[c]	35.9c	5.60[c]	13.58[c]
Mean	3069	47.23	6.6	11.95
LSD	140.1	0.969	0.2099	0.14
F pr value	<0.001	<0.001	<0.001	<0.001

[a] numbers with the same letter are not significantly different.

then dried in the chamber at that temperature for 48 hours. Cob yield was measured as weight of harvested grain in each plot and adjusted to 12.5% moisture, then converted to tonnes per hectare for each treatment. Water use efficiency (g/mm) was calculated by dividing dry matter yield (kg/ha) by evapotranspiration (mm). Evapotranspiration (Et_a) was calculated during the growing season using the soil water balance equation below adopted from Malek and Bingham (1993).

ET_a = I+ P+ Cr- Dw- Rf+ ΔS

Where: ET_a is the actual evapotranspiration (mm),
I is the amount of irrigation water applied (mm),
P is the precipitation (mm),
Cr is the capillary rise (mm),
Dw is the amount of drainage water (mm),
Rf is the amount of runoff (mm), and
ΔS is the change in the soil moisture content (mm)

Capillary rise was assumed negligible because of the deep water table. However, there was no precipitation and runoff recorded during the experiments. For these reasons, the amount of water applied in the various treatments was therefore equal to the actual evaporation (ET_a).

Data analysis

Data was analyzed using GenStat for Windows statistical package, GenStat for Windows is a general statistics package that offers a vast range of tried and tested high-quality statistical techniques backed up with publication quality graphics.

RESULTS AND DISCUSSION

Maize cob yield, fresh yield, leaf area and water use efficiency from each treatment are shown in table 1 and table 2 below. In 2008 treatment T 100 had the highest leaf area, fresh yield, and cob yield but had the lowest water use efficiency while treatment T 60 had the lowest leaf area, fresh yield and cob yield but the highest water use efficiency. The same trend was observed again during the 2009 season as shown in table 2. The results showed that leaf area was significantly different ($p<0.05$) with increase in deficit irrigation. The leaf area was 3614cm^2 for treatment T 100, 3036 cm^2 for T 80 and 2342cm^2 for T 60 in 2008. Treatment T 80 resulted in an average decrease of 13.38% and 15.99% for 2008 and 2009 respectively and 30.59% and 35.2% for T 60 for 2008 and 2009 respectively. This was likely because in the deficits irrigation treatments, the plants significantly reduced leaf area to reduce the amount of water lost through transpiration. Cakir (2004) and Traore et al., (2000) observed that water stress reduces leaf area in maize. During vegetative stage, water stress restricts leaf growth and expansion so resulting in stunted growth. With increasing moisture stress, the dry matter

Table 3. Effect of deficit irrigation treatments on leaf area, yield and water use efficiency during the 2009 season.

Treatment	Leaf area (cm^2)	Fresh yield (t/ha)	Cob yield (t/ha)	Water use efficiency(g/mm)
T 100	3614[a]	58.3[a]	7.48[a]	10.11[a]
T 80	3036[b]	48.7[b]	6.64[b]	11.94[b]
T 60	2342[c]	33.6c	5.54[c]	12.98[c]
Mean	2997	47.23	6.55	11.67
LSD	212.8	1.78	0.23	0.27
F pr value	<0.001	<0.001	<0.001	<0.001

[a] numbers with the same letter are not significantly different

production of the crop decreases directly by decreasing cell division and enlargement and indirectly by reducing rate of photosynthesis.

Total fresh yield was also significantly different ($p<0.05$) with increase in deficit irrigatrion. The results showed that fresh yield treatment T 80 resulted in an average decline of 22.18% and 16.47% for 2008 and 2009 respectively and 39.66% and 42.37% for T 60 for 2008 and 2009 respectively. Fresh yield decreased with increase in deficit irrigation and this was likely because the reduced evaporation resulted in less carbon accumulation and thus decreased biomass development. The biomass production in the experiment was proportional to the availability of water. As the stress intensity increased, biomass production decreased. These findings were in agreement with the experimental results reported in other studies which attributed lower leaf production and dry matter to water stress (Yenesew and Tilahun, 2009).

Cob yield was also significantly different ($p<0.05$) with increase in deficit irrigation as in table 2 and 3 The results showed that cob yield treatment T 80 resulted in an average decline of 15.23% and 11.23% for 2008 and 2009 respectively and 27.08% and 25.94% for T 60 for 2008 and 2009 respectively. From Table 2 and 3 an increase in level of irrigation water enhanced the dry matter production. Significantly higher cob yield was obtained from the treatment T 100 (7.68t/ha and 7.48t/ha) for 2008 and 2009 seasons respectively and T 60 obtained the lowest yield (5.0 t/ha and 5.54t/ha) for 2008 and 2009 seasons respectively. These findings were in agreement with the experimental results reported by Mugabe and Nyakatawa, (2000) who observed that in wheat, applying three quarters and half of the crop water requirements resulted in a yield decrease of 12 and 20% in 1996 and 7 and 20% in 1997 seasons respectively. However, at individual farmer's level, maximum yield is obtained when the entire crop water requirement is fulfilled; practicing deficit irrigation suggests that increasing the areas irrigated with the water saved would compensate for any yield loss.

Water use efficiency (WUE) of maize was significantly different ($p<0.05$) with increase in deficit irrigation. The results showed that WUE for treatment T 80 resulted in an average increase of 15.89% and 18.10% for 2008 and 2009 respectively and 31.46% and 28.39% for T 60 for 2008 and 2009 respectively. This might be as a result of limited evaporation in the deficit irrigation treatments. Yenesew and Tilahun (2009) also observed that crop WUE was the lowest (1.72 kg/m^3) at optimum irrigation water application and the highest (2.96 kg/m^3) at stress of 75% deficit throughout the growth season. However these results contrasts with those by Farre and Faci (2006) who observed that in maize water use efficiency decreased with decreasing irrigation.

CONCLUSION AND RECOMMENDATIONS

From the experiment it can be concluded that deficit irrigation results in a significant decline in silage maize yield but also results in increased water use efficiency. Deficit irrigation can be used in areas were water is scarce. Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gain by maximizing water use efficiency and full irrigation can be used in areas were water is not scarce.

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