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Growth and yield of *Akposoe* maize variety under different water placement depths in Ghana.

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Abstract

Maize *(Zea mays, L.)* is an important staple crop and had contributed significantly in ensuring food security and growth of Ghana's economy. Its productivity over the years has being limited by unpredictable rainfall pattern. The experiment was conducted to evaluate a PVC drip irrigation system using *Akposoe* maize variety under supplementary irrigation, during the 2011 major growing season in, Kumasi, Ghana. Irrigation water was applied at the surface (0 cm), 20 cm, 40 cm depth and 'no irrigation' as the control forming the four treatments. The experimental design was Randomized Complete Block Design (RCBD) in four replicates. The depth of irrigation water applied significantly influenced maize growth and dry matter yield. Ten weeks after planting, water applied at 20 cm depth, produced the tallest plant height (177.85 cm), biggest stem girth (8.95 cm) and highest dry matter yield (6085.06 kg/ha). The highest number of leaves (13.15) was recorded in the 20 cm and at 0 cm depth. Treatment 40 cm depth recorded the largest leaf diameter (9.73 cm) and longest leaf length (73.6 cm). The 'no irrigation' gave the shortest plant height (132.8 cm), smallest stem girth (6.8 cm), lowest number of leaves (10.40), smallest leaf diameter (7 cm), lowest leaf length (58.67 cm) and the lowest dry matter (2296.95 kg/ha). In general, the growth parameters monitored under drip irrigation was statistically similar, but significantly different compared to 'no irrigation' and surface and subsurface treatments. Generally the water application depth had a statistical significant effect on maize growth and yield.

Keywords: PVC drip irrigation, subsurface drip irrigation, supplementary irrigation, Akposoe maize variety.

INTRODUCTION

Maize is a major staple food for the people of Ghana and can be used in several food preparations. In the semi-deciduous regions of Ghana, maize is grown in the major season and minor seasons, mostly under rain-fed conditions. Growth and yield of maize is affected by the erratic nature of the rainfall. Rainfall during the major growing season is characterised by longer days between rainfall events leading to drought stress which invariably affects yield. Maize requires a uniform supply of moisture throughout the growing season (Ofori *et al*, 2006) and the effect of drought stress results in a reduction in growth and yield. Irrigation technologies offer suitable solutions to water supply to crops but with increasing demand and pressure on water resources by other sectors, effect of climate change on water resources and population growth, there is the need to increase water use efficiency so that a higher yield per drop of water can be achieved. Frequent drought stress in the largely rain-fed agricultural system is a major constraint that limits maize production in Ghana (Ohemeng-Dapaah, 1994; Kasei *et al.* 1995; Obeng-Antwi *et al*., 1999). Production zones are prone to drought stress because rainfall is unpredictable in terms of quantity and distribution during the growing season (Ohemeng-Dapaah, 1994; Kasei *et al*., 1995) resulting in significant yield reductions. For a typical example, total maize production in Ghana declined by 30% in 1982 as a result of drought stress throughout the country (GGDP, 1983). Drought is common in tropical environments, and is an important factor limiting maize production in low-income countries (Edmeades *et al.* 1998). Furthermore, maize yields are most sensitive to water stress, especially at flowering and pollination stages. For instance, NeSmith and Ritchie (1992) reported that the reductions in maize yield exceeded 90 % due to water deficit during flowering and pollination stages. The high water requirement of maize with their sensitivity to water stress indicates that limited or deficit irrigation can cause yield reductions, particularly in light-textured soils. Therefore, a frequent and uniform supply of water is extremely important for maize yield to meet the water requirements of plants. Therefore, innovative ways to increase the water use efficiency are needed. Irrigation technology such as drip irrigation that will supply water at a uniform rate may be adapted for more effective and rational use of limited supplies of water.

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Irrigation is the artificial application of water to the soil or plant, in the required quantity and at the time needed. Irrigation is widely carried out through surface, sub-surface and pressurized systems, characterized by the mode of transport of the water onto the point of application (Keller and Bliesner, 1990). When water is applied on the surface, a considerable amount is lost through evaporation, run off and deep percolation beyond the reach of the plant roots, making reducing water use efficiency in terms of quantity of water used per amount of plant yield obtained.

Drip irrigation method has higher water use efficiency than the traditional surface and sprinkler irrigation methods. On the other hand, field application efficiency in most traditional irrigation methods is still very low, typically less than 50 % and often as low as 30 % (Molden et al. 1998). Drip irrigation methods allow for much more uniform distribution of water as well as more precise control of the amount of water applied and also decrease nutrient leaching (Phene et al. 1994).

Drip irrigation is defined as "the slow, frequent application of small volumes of irrigation water to the base or root zone of plants" (Smeal, 2007). Advantages of drip irrigation system include, less water loss, reduction in weed growth, less labour requirements, minimal evaporation compared to other watering methods and less usage of fertilizer. The rest are reduced soil erosion, equal water distribution and higher crop production. The disadvantages include, clogging of drip holes, high initial cost, algae growth and easy damage to drip lines.

Drip irrigation is an efficient method for minimizing the water used in agriculture. Frequency of water application is one of the most important factors in drip irrigation management because of its effect on soil water regime, root distribution around the drip holes, the amount of water uptake by roots and the amount of water percolation under the root zone (Coelho and Or 1999, Assouline 2002, Wang *et al*. 2006).

METHODOLOGY

Description of study area

The field experiment was conducted at the Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology, located at latitude 06˚ 41'N, longitude 01˚ 33'W and altitude of 295.7m. The site has an area of 320 m^2. Mean annual rainfall is about 1300mm. Average maximum and minimum temperature is about 31˚C and 23˚C respectively. The rainfall distribution is bimodal with the major season rainfall running from March to July and the minor season running from August to November.

The peak evapotranspiration rates occur in February (5.44 mm). The month of March was characterized by high rainfall during the study period. The soil of the study area is predominantly sandy-loam with the following characteristics; field capacity *(FC)* 27.08%

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(*volumetric*), permanent wilting point *(PWP)* 8.38% (*volumetric*), available moisture content was 18.7 % volumetric and the dry bulk density 1.215 g/cm^3

Experimental design

The experimental design was Completely Randomised Design (CRD) of three water application depths, namely surface placement at depth 0 cm, 20 cm placement depth and 40 cm placement depth and No Irrigation as the control treatment. The layout of the experiment is as shown in Figure 1.0 It consisted of four plots, with 4 treatments in each plots.

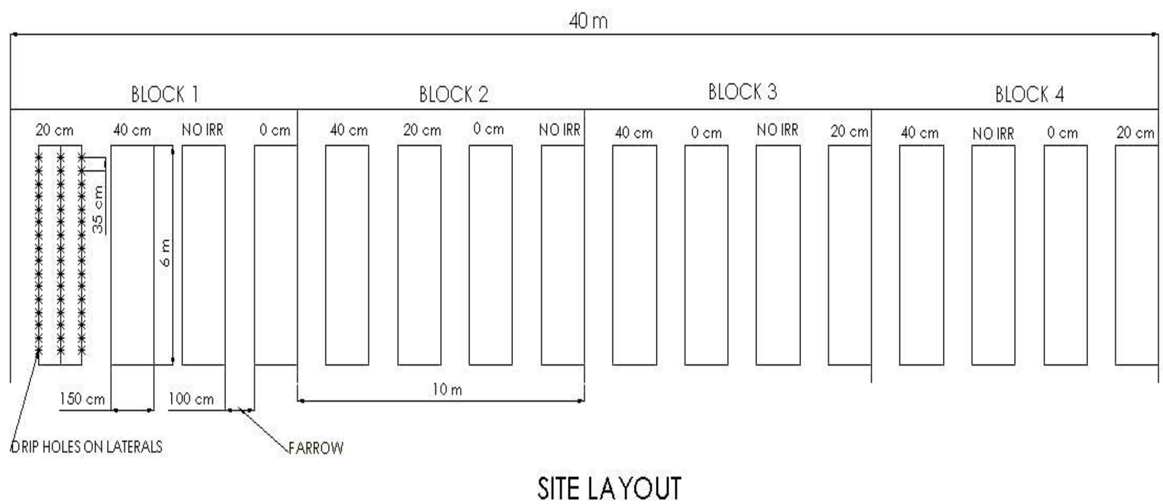

Figure 1.0 Layout of experimental plot

Each plot measured 6m x 10m. There was a buffer zone of 1.0 m between plots. The buffer zone was there to prevent the crops from merging when they matured and also to help to distinguish between the different plots. For the purpose of the experiment the following growth stages were adopted for the variety used in the experiment. The time ranges of individual growth as observed and adopted for the experiment based on the variety and the following growth stages were adopted as shown in Table 2.

Table 1.Akposoe maize variety was planted and water was supplied by a simple PVC drip irrigation system with water placed at the ground surface, 20 and 40 cm below ground surface.

Growth stage	I	II	III	IV
Time	March 5 – March 18	March 19 – April 11	April 12 – May 8	May 9 – May 28
Duration	14 days	21 days	27 days	20 days

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

Data collection and analysis

Important data collected during the experiment included: amount of water applied during the period, plant height, stem girth, number of leaves, leaf diameter, leaf length, oven air dried above and below ground biomass, the grain yield at 13.5% moisture content. The data collected were subjected to descriptive statistical analysis and ANOVA test to see the effects of water application depth on maize growth and dry matter yield.

RESULTS AND DISCUSSIONS

Amount of water applied

Amount of water required during the growing season and amount of irrigated water applied to each treatment plot are presented in the following Table 2a and 2b.

Table 2a and 2b*.Amount of water supplied during the growing season (i.e. irrigation water plus effective rainfall) for all treatments.*

Table 2a

Treatment	Irrigation water supplied (mm)	Effective rainfall during crop growing stages (mm) and SPAN (Days)				Total water supplied: Irrigation water + Effective rainfall (mm)
		I 14 days	II 24 days	III 27 days	IV 20 days	
40 cm Depth	162.1– 338.9	119.245	181.61	135.89	0	598.845 - 775.645
20 cm Depth	162.1– 338.9	119.245	181.61	135.89	0	598.845 - 775.645
0 cm Depth	162.1– 338.9	119.245	181.61	135.89	0	598.845 - 775.645
No Irrigation	0	119.245	181.61	135.89	0	436.745

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pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

Table 2a and 2b*.Amount of water supplied during the growing season (i.e. irrigation water plus effective rainfall) for all treatments.*

Table 2b

Growth Stages	**I**	**II**	**III**	**IV**
Time	March 5 - March 18	March 19 - April 11	April 12 - May 8	May 9 - May 28
Duration	14 days	24 days	27 days	20 days
Rainfall (mm)	119.25	181.61	135.89	0
Irrigation water applied (mm)	0	78.9	115.65	55.5
Total water supplied (mm)	119.25	260.51	251.54	55.5

Total water supplied is the summation of effective rainfall and irrigation water applied during the growth stages of the crop development (i.e. I-Initial stage, II- Crop development stage, III-Mid stage, and IV- Late season stage). Accordingly, water flow from drip hole was not uniform (observed flow), it is in range as indicated above but effective rainfall during crop growing was the same for all crop stands as indicated in the table above. Treatment 40cm, 20cm and 0cm depth respectively were irrigated within three (3) days interval. Treatment which was not irrigated (No Irrigation) showed very often symptoms of wilting indicating critical water stress during the crop growing season whiles treatments that were irrigated did not show any sign of wilting.

Growth parameters

Plant growth parameters monitored were plant height, stem girth, leaf diameter, number of leaves and leaf length.

Figures;(1a Plant height; 1b. Stem girth; 1c. Leaf diameter;1d. Number of leaves;1e. Leaf length)

Plant height

The plant height showed a significant difference at Week 4, 5 and Week 8 (week 8 to 10 week had the same values for all the growth parameters).

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

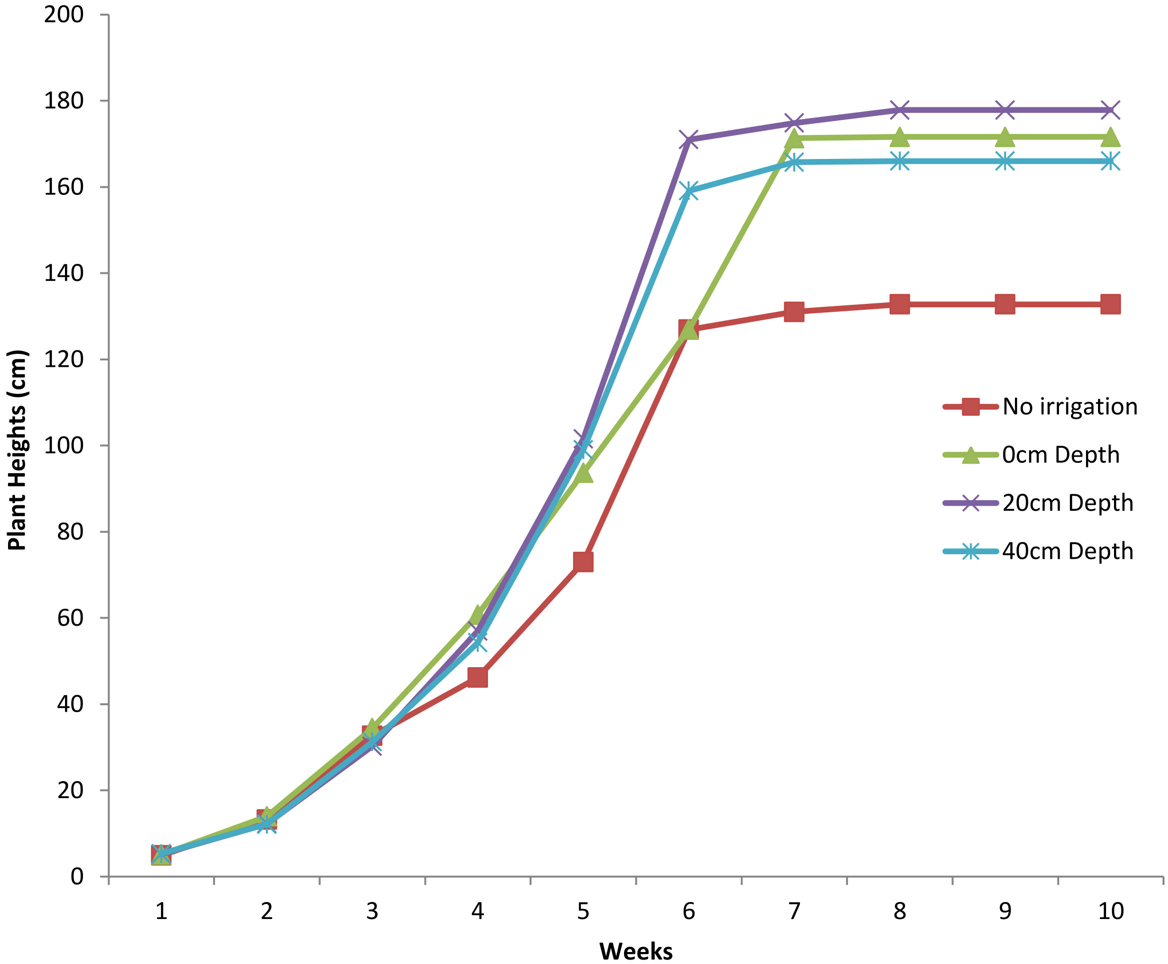

Figure 1a. Plant height (cm)

Stem girth

There was no significant difference on the stem girth from week 1 to Week 7 against 'no irrigation' and the irrigated treatments (40cm, 20cm and 0cm water application depth), but significant difference showed up in week 8 against 'no irrigation' and the irrigated treatments 940cm, 20cm and 0cm water application depth)

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

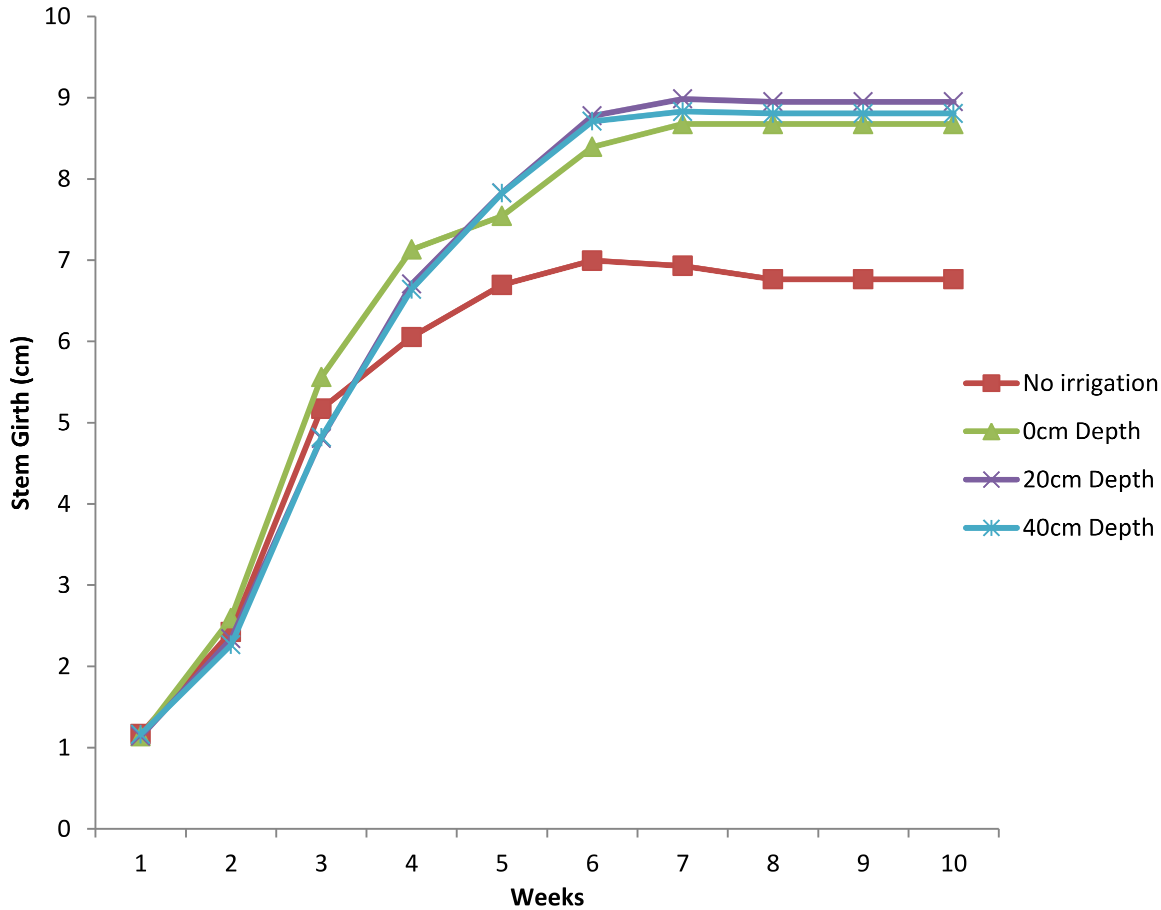

Figure1b. Stem girth (cm)

Number of leaves

The number of plant leaves was not significantly ($P<0.05$) different among treatments from week 1- 4. At 8th to 10th week, treatment 40cm, 20cm and 0cm had significantly ($P<0.05$) higher number of leaves than "No irrigation" at an LSD of 1.6 fig.1e.

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

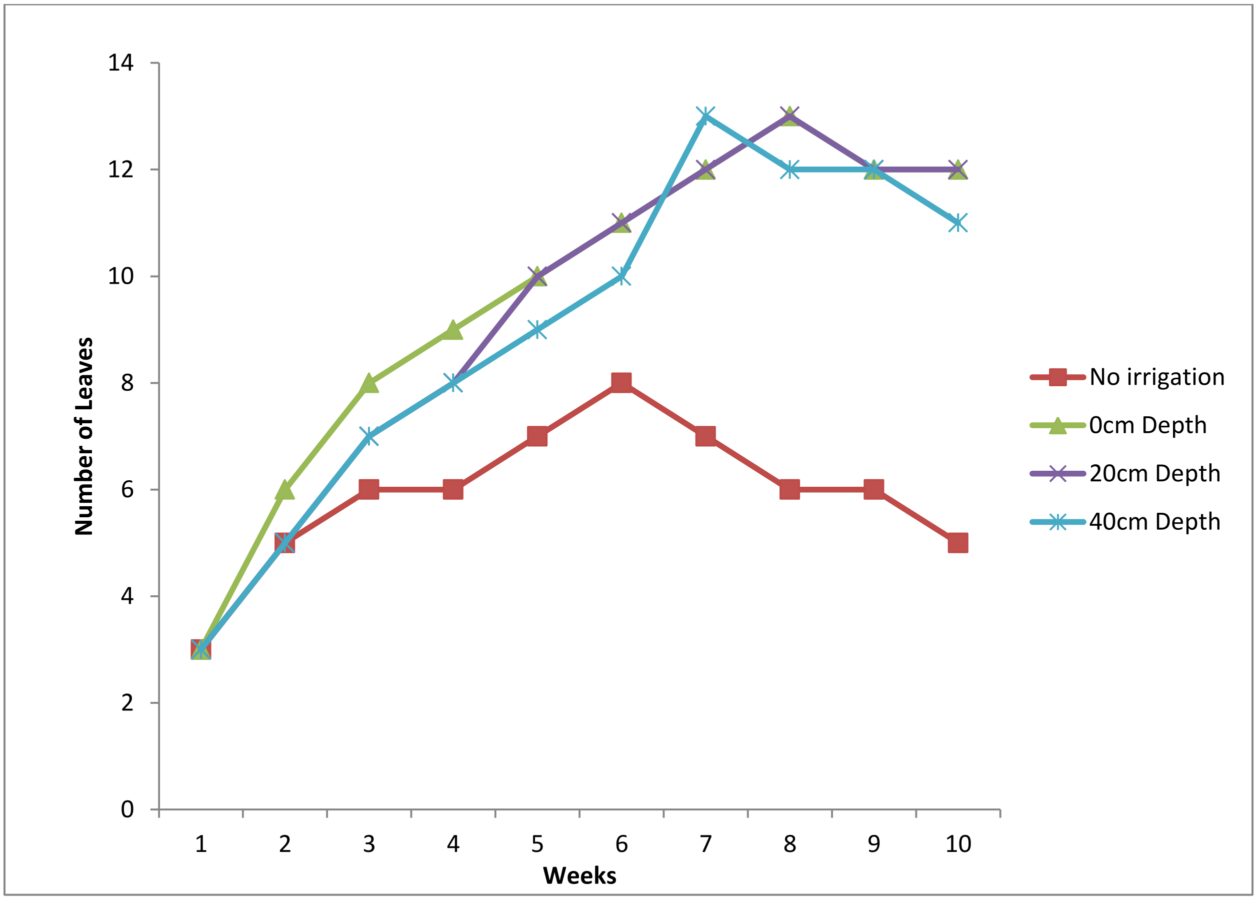

Figure1e. Number of leaves

Leaf diameter

Week 4 and Week 8 appeared to have a significant difference in terms of the leaf diameter against 'no irrigation' and the irrigated treatments (40cm, 20cm and 0cm water application depth).

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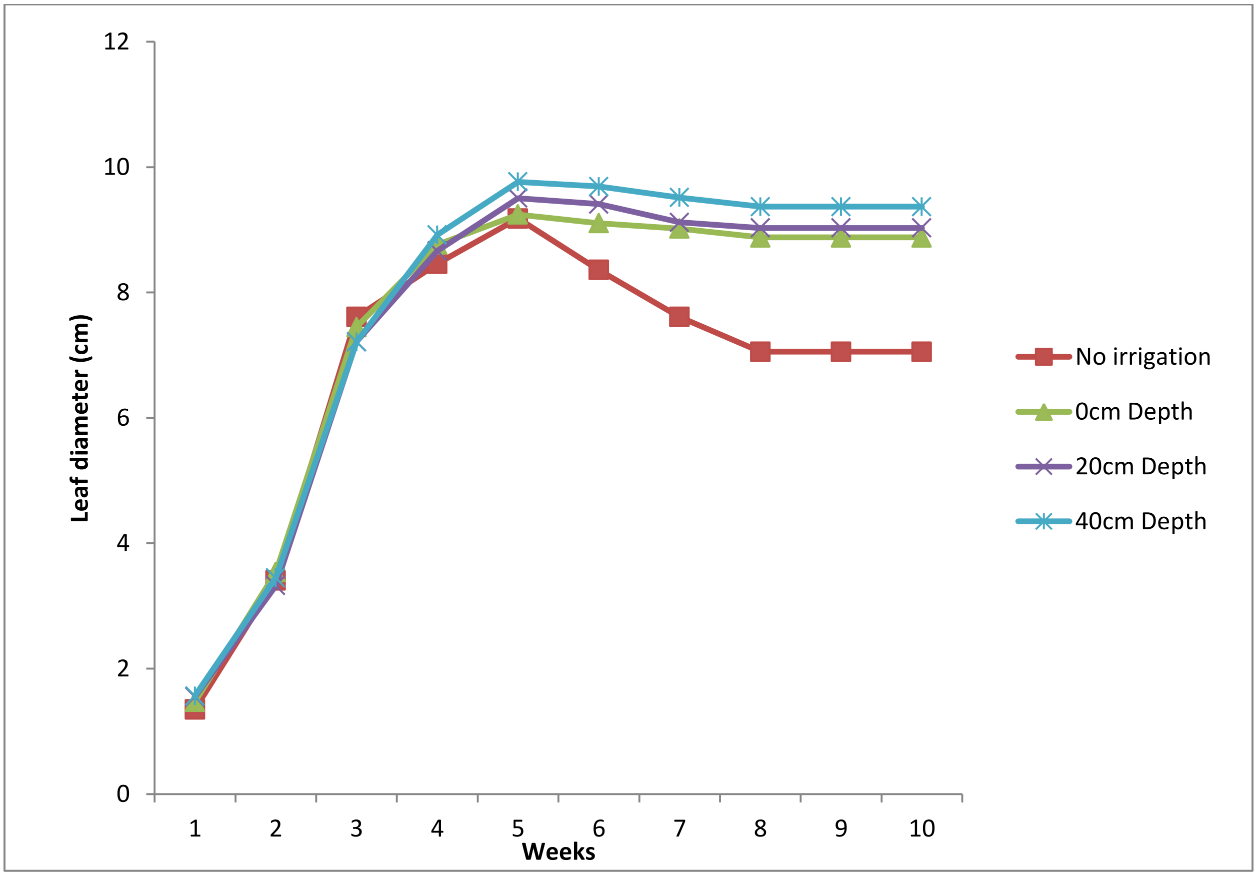

Figure 1c. Leaf diameter (cm)

Leaf length

Leaf length showed a significant difference at the 12th Week against 'no irrigation' and the irrigated treatments (40cm, 20cm and 0cm water application depth), as indicated on the figure above.

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

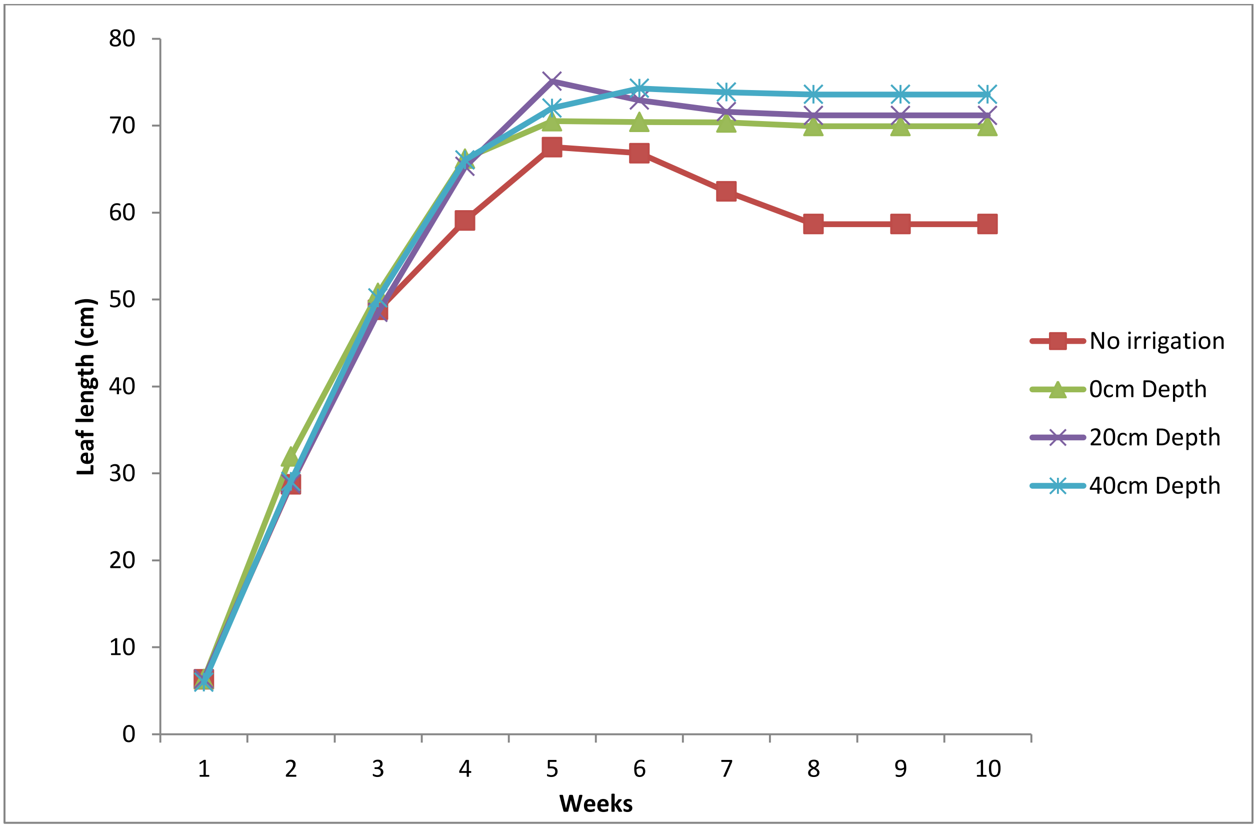

Figure 1d. Leaf length (cm)

Yield parameters

Yield parameters considered were grain yield, above ground biomass, below ground biomass and root length.

Grain yield

The grain yield varied from 6085 kg/ha – 2297kg/ha at 13.5% moisture content, Figure 2 below. The above ground biomass, below ground biomass and root length also varied from 12670 kg/ha – 5945 kg/ha, 1992.9 kg/ha - 1385.6 kg/ha and 29.850 cm - 28.125 cm respectively. The maximum yield was obtained from the water application depth of 20cm, relatively; 'no irrigation' treatment recorded the lowest yield. The maximum above ground biomass was obtained from treatment zero cm and lowest obtained from 'no irrigation' treatment, 0 cm and 20 cm treatment recorded the highest root length and lowest was recorded on 'no irrigation' treatment. The grain dry matter yield and above and below ground biomass of the maize plant are presented in Tables 3 and 4 respectively. ANOVA test showed that there is a significant difference between treatments in terms of grain dry matter yield and above and below ground biomass. It was shown that there was a significance differences between 40 cm, 20 cm and 0 cm and 'no irrigation' treatment. It was also revealed that there were significance difference

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

between irrigated treatments (40cm, 20cm and 0cm) and 'no irrigation' treatment. There was no significant difference between treatments for the below ground biomass as indicated on Table 4 below.

Table 4.Means of above and below ground biomass

Treatment	Above ground biomass (kg/ha)	Below ground biomass(kg/ha)	Root length(cm)
0 cm	12670 a	1992.9	29.850 a
20 cm	12057 c	2084	29.850 a
40 cm	12345 b	1862.2	29.025 b
No Irrigation	5945 d	1385.6	28.125 c
LSD (0.05)	**6143.98**	**NS**	**1.5**

Treatment means having the same letters along the column are not significantly different from each other at P < 0.05.

The maize dry yield at 13.5% moisture, above ground biomass, below ground biomass and root length, is further classified into four results as indicated in Table 5 to show the relationship between the effects of water application depth on maize growth and yield performance. From the table below it can be inferred that, the 20 cm depth of water application treatment produced significantly the highest dry matter yield, above ground biomass and below ground biomass, whilst the No Irrigation treatment produced the least in terms of dry matter yield, above ground biomass and below ground biomass.

pISSN: 2026-5204 ***ISSN-L***: 2026-5204 VOL. 1, No.1(1), Pp. 14-29, August, 2014

Table 5*.Grain yield (13.5% moisture content), above and below ground biomass for maize under different treatments*

Treatments	Mass of dry grain at 13.5% kg/ha	Above ground biomass (kg/ha)	Below ground biomass(kg/ha)	Root length(cm)
0 cm	5320.0 b	12670 a	1992.9	29.850 a
20 cm	6085.1 a	12057 c	2084	29.850 a
40 cm	5050.6 b	12345 b	1862.2	29.025 b
No Irrigation	2297.0 c	5945 d	1385.6	28.125 c
LSD (0.05)	**1984.65**	**6143.98**	**NS**	**1.5**

Treatment means having the same letters along the column are not significantly different from each other at P < 0.05

CONCLUSION

The objectives of the project were to assess maize growth under 'no irrigation', surface and subsurface drip irrigation system and also to compare dry matter yield of maize under 'no irrigation, surface and subsurface drip irrigation systems.

Inferring to the results gotten, maize growth and dry matter yield under drip irrigation gave the highest (40 cm, 20 cm and 0 cm). For the growth, plant height, leaf diameter and leaf length, the 40 cm depth of water application was the highest followed by 20 cm, 0 cm and 'no irrigation being the least. The stem girth and the number of leaves under the drip irrigation, 20 cm depth of water application gave the highest followed by 40 cm, 0 cm and 'no irrigation being the least.

For the dry matter yield, at 13.5% moisture, 20 cm depth of water application produced the highest, (6085.1 kg/ha), followed by 0 cm (5320 kg/ha), 40 cm (5050.6 kg/ha) and 'no irrigation being the least (2297 kg/ha). 0 cm depth of water application gave highest above ground biomass (12670 kg/ha), followed by 40 cm (12345 kg/ha), 20 cm (12057 kg/ha) and 'no irrigation (5945 kg/ha) being the least. 20 cm gave the highest below ground biomass (2084 kg/ha), followed by 0 cm (1992.9 kg/ha), 40 cm (1862.2 kg/ha) and 'no irrigation (1385.6 kg/ha) being the least. For the root length, 20 cm and 0 cm gave the highest (29.9 cm), followed by 40 cm with 'no irrigation (28.1 cm), being the least. It can therefore be concluded that, the drip irrigation produced the highest growth yield and maize dry matter as compared to the conventional 'no irrigation' system since.

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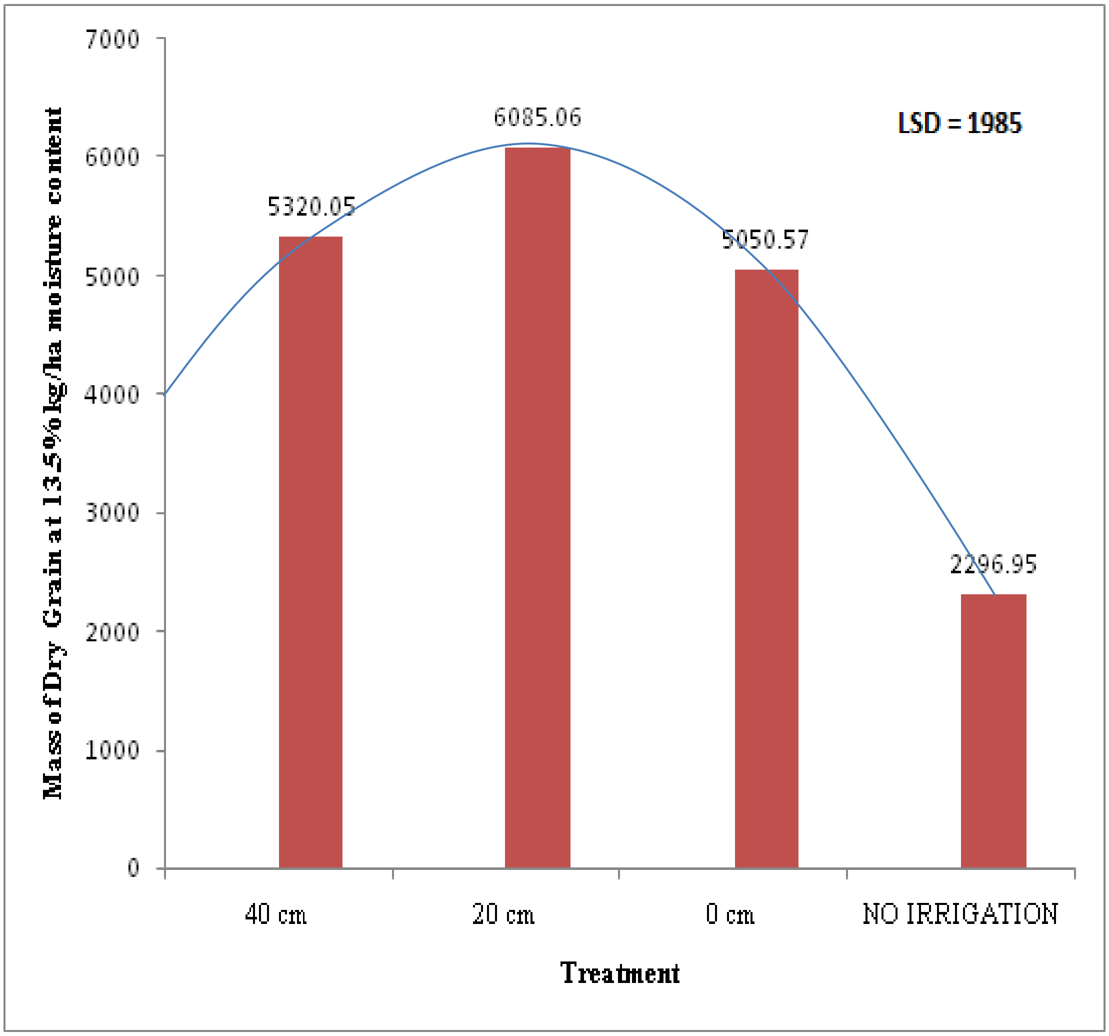

Figure 2. *Dry grain at 13.5% moisture (kg/ha)*

RECOMMENDATION

- There is the need to determine the long-term effects of the depth of pipe placement and depth of water application on maize growth and yield.
- The experiment should be repeated to ascertain the optimum depth of water application for other maize varieties such as *obaatanpa, dobidi, abrotia, okomasa* and as well as other crops such as, tomato, pepper, garden egg and water melon.
- The experiment should be repeated to determine fertilizer (fertigation) application through the design system.
- Economic analysis should be under taken to determine cost and benefits of the effects of depth of pipe placement and depth of water application on maize performance.

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