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Effect of Deficit Irrigation and Irrigarion Types on Yield and Gross Margin of Onion in a Semi-Arid Sub-Saharean Africa Namibia, Omusati Region

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Abstract: A study was conducted at Ogongo Campus of the University of Namibia (UNAM) to compare efficiencies of flood and drip irrigation methods, normally used by small scale farmers in Omusati Region of Namibia, at 3 different irrigation levels of 100, 80, and 60% Crop evapotranspiration (ETo). Irrigating at lower levels than full irrigation is also referred to as deficit irrigation. The study compared gross margins and assessed yield and growth indicators under the two irrigation systems using onion as the crop. A split plot in a randomized complete block design (RCBD) experiment was carried out on a 43m x34 m plot with soil physical and chemical characteristics analyzed before cultivation. The yield productions of all treatments were highly significant at 0.4, 0.29 and 0.19 eta squared. Irrigation type was highly significant ($p < 0.001$). Irrigation level at 20wt is (p=0.008) irrigation level at 10 wt. is significantly different at ($p < 0.001$) and at 5wt it is also highly significantly different at ($p < 0.001$). However the interaction between level of irrigation and irrigation type are not significantly different at 20wt (p=0.415) and 10wt (p=0.224). Results show that more yields were obtained in drip irrigation by a margin of 5% for the 100% levels, by 9.4% for the 80 % levels and 9.5 % for the 60% levels. However, plant height were not significantly different at all the three levels (p =0.397) of irrigation. A higher plant height was obtained in drip irrigation treatment by a margin of 28.36% for the 100% levels, by 3.65% for the 80 % levels and 22.38 % for the 60% levels. In addition, the results showed that the gross margin for drip at 60 ETowas higher than for flood by 44.7% while at 80ETo the gross margin for drip was more than for flood by 64.6%. Gross margin is highly significantly different at all the three levels of irrigation (p =0.001) and also significantly different for the irrigation type ($p < 0.001$). The present study suggests that the small scale Namibia farming community should adopt deficit drip irrigation method instead of the old traditional flooding methods.

Keywords: Drip and flood irrigations methods, yield, plant height of onions, gross margin

Introduction

Irrigation is one of the key sectors identified to contribute to poverty reduction in the National Development Plan 5 (NDP5) (2017/18 – 2021/22)and the Namibia Vision 2030. The potential for fruits and vegetable production in the communal areas of Northern Namibia is high. Onion is one of the two crops identified by Namibia Agronomic Board (NAB) to implement the “Special Potato and Onion Scheme” (NAB, 2012) and also grown by small holder farmers in the NCR. Considering the climatic conditions of low rainfall and poor soil of Namibia, and also issues to do with climate change which have negative effects on rainfall, water scarcity in the country remains the critical problem to agricultural production, particularly, on crop production. Since irrigation provides effective means to increase crop yield and drip irrigation has been proven to be the most efficient way of irrigating (Postel, *et al*. 2001; Maisiri, *et al*. 2005; Holzapfell, *et al*. 2009), a gap existed to objectively compare the efficiency with which water is used in flood and drip irrigation systems on onion production in NCR of Namibia. In order to develop the best management practices for onion production, there was a need to compare the water use efficiencies of the flood and drip irrigation methods used for onion production among small scale farmers in NCR. Water saving can also come in the form of deficit irrigation i.e. applying different levels of irrigation. Investigations have been carried out worldwide regarding the effects of deficit irrigation on yield of mainly horticultural crops (Nagaz, Masmoudi, & Mechlia (2012); Ramalan, Nega, & Oyebode (2010)). It is important for agricultural engineers and farmers to understand which irrigation systems contribute to improved water use efficiency in Namibia. A gap therefore existed to compare the two systems with regards to water use.

Deficit Irrigation and Effect of flood and drip irrigation systems on yield and growth parameters

A number of studies have been carried out all over the world regarding the effects of deficit irrigation on yield of various crops (Gijón*et al.* 2007;Karasu, Kuș cu, Öz and Bayram (2015).According to Fereres and Soriano (2007); Kumar, Imtiyaz, Kumar and Singh (2007) investigated the impact of deficit irrigation strategies on onion yield and water savings and reported that applying 80 and 60% of ETc resulted in yield decreases of 14% and 38%, respectively, and saved 18% and 33%, respectively, of irrigation water compared to full irrigation. Ramalan, et al., (2010);Nagaz et al., (2012) also studied yield response of drip-irrigated onion under full and deficit irrigation with saline water in arid regions of Tunisia and found that the bulb fresh yields of deficit-irrigated treatment (deficit irrigation-60) were significantly lower than those in full irrigation treatment (full irrigation-100).

Severalresearchers reported (Maisiri*et al.*, (2005);Ibragimov, *et al.*, (2007) Malash*et al.*, (2008); Enciso*et al.*, (2012);Tagar*et al.*, (2012) reported that yields under drip were morethan those of flood irrigation method.In contrast to the others, Kumar, Imtiyaz, Kumar, and Singh (2007) also investigated the impact of deficit irrigation strategies on onion yield and water savings. They reported that applying 80% and 60% of crop water requirements resulted in yield decreases of 14% and 38% and saved 18 and 33% of irrigation water compared to full irrigation in 2 years, respectively.Enchalew*et al*., (2016) conducted a study on the effect of deficit Irrigation on water productivity of onion (Allium cepa) under drip irrigation. They reported that deficit irrigation did not affect that much the plant height of onion.

Cost and total labour requirements for crop production under flood and drip irrigation

According to Kadigi, Tesfay, Bizoza and Zinabou (2012) many irrigation schemes in the past failed due to a combination of factors, including high investment costs, poor planning and a lack of maintenance. Mendelsohn, Shixwameni and Nakamhela (2011) reported that crop commercialization in the northern communal areas is only possible for farmers with the resources to provide high cost of inputs such as irrigation, fertilizer and labor to produce surpluses which can be sold for cash incomes. In comparing the cost of production and net profit under various crops, various researchers (Michael, (2008); Prajapati et al., (2013) reported higher net profit under drip irrigation than that realized under surface irrigation. Tsegaye*et al.*, (2016) reported that deficit irrigation at 75% of ETc was economically recommended in their studied region, in southern Ethiopia.

Differences between irrigation methods are seen in capital outlays required to install different irrigation methods as Zimmermann (1999), highlighted the operating costs, the amount of labour and the level of skills required as some of the differences between the irrigation methods. The farmers in the reconnaissance visit by the researcher in Omusati in 2015 also reported that the initial cost of installing drip irrigation system is high. No literature could be found to confirm if the farmers' perception about high cost of drip irrigation is true. While it is possible that the initial cost of setting up the drip system may be higher compared to that for flood, it is hypothesized that the overall cost of operating the drip system will be low. Prajapati, Khasiya and Agrihotri (2013) compared the cost of production and net profit under irrigated banana and showed higher net profit to the extent of 12 to 20 % under drip irrigation as compared to surface irrigation. Determining all these under the conditions of small scale farmers in the NCR will contribute towards achieving and recommending the better irrigation method to farmers.A gap exists to compare the costs encountered in the two irrigation systems at Ogongo.

Objectives and Hypothesis

The primary objective of this study was to compare the water use efficiency (WUE) of different levels of drip and flood irrigation systems on onion production and to develop a best technical system for high onion yield for small scale farmers.

The specific objectives of the study were: (1) To compare the plant height and yield of onions under flood and drip irrigation systems at three (3) different irrigation levels (100, 80 and 60% potential evapotranspiration (ETo)) at Ogongo in Namibia, and (2)to determine and compare the cost of growing onion under flood and drip irrigation at three (3) different irrigation levels (100, 80 and 60% potential evapotranspiration (ETo)) of irrigation at Ogongo in Namibia.

The research hypotheses that were tested under 95% confidence level are as follows:

1. H_0 :Yield of onions does not differ on average across different irrigation types and across irrigation levels.
2. H_0 :Onion yield on average does not differ due interaction between irrigation level and irrigation type.
3. H_0 There is no differences in the production costs of onion cultivated under drip irrigation and flooding.

Materials and Methods

The study was conducted at semi-arid Ogongo Campus farm in 2015. The annual rainfall ranges between 300 - 400 mm.According to Mendelsohn *et al.,* (2013), soils at Ogongo are dominated by Aerosols group of Kalahari in the North Central of Namibia. These types of soils have poor nutrient content and little water holding capacity.

The experiment was a 2 x 3 split plot experiment in a randomized complete block design replicated three times. The main plot factor was irrigation treatments namely flood and drip irrigation systems. The subplot factors were irrigation applied at 100% crop evapotranspiration (ET_o), 80% ET_o and 60% ET_o for both drip and flood systems. Treatments were replicated three times to give a total of 18 plots. Each plot was 10 m x 3 m. The spacing between plots and blocks were 5 m and 2 m, respectively, to avoid water infiltration effects. Each plot had 2 rows of onion plants and 29 - 30 plants in each row with a total plant population of approximately 60 in every plot. The total experimental area size was 34 m x 43 m = 1 462 m^2 or 0. 1462 ha. Treatments were randomly assigned to blocks and plots and sampling was randomly generated using the GenStat computer package (Genstat, 2003).

The equipment which were used during the research included Scale - used to measure the yield of onions in kilograms; 2 x 25 mm Zenner water meter - used to measure the total volumes of water used during the growing seasons under flood and drip systems; Vernier Calipers - used to measure circumference and sizes of onion bulbs; Hand hoe and a rake –used to cultivate the land, loosen up and level the soil; 50 meter measuring tape – used to measure the experimental site area; Ropes and sticks - used to mark the experimental site area and Ruler – used to measure the plant heights for all the crops.

The site was ploughed with a disc harrow to clear the field of grass and to loosen the soil for bed preparation. After plots were measured out correctly, drip lines were placed on the beds. Irrigation systems were installed and all connections were properly sealed to minimize water leaks and losses.Water meters were installed at the main line to measure the total water delivered to each plot.

Onions were sown on 13 trays of 25 x 12 holes, then they were transplanted in the morning to avoid damage to onion as it was during the dry season of the year. Based on the normal practice of local small scale farmers, fertilizer was not applied.For all treatments, an onion plant population of 73 800 per ha was used. This is approximately in line with the 70 000 plants per hectare the farmers growing onions at Etunda Irrigation Scheme in Namibia are using. In-row spacing was 15 cm and inter-row spacing was 1 m for easy use of implements.

For flood irrigation, water was pumped straight into the furrows. For the drip system, water was pumped first from the reservoir into the tank of the family drip system. The family drip system consists of a 200 litres water tank at an elevation of 1.5 m to allow water to flow from the tank to the main liners, laterals and emitters with the help of gravity.

Plant height is one of the descriptive parameters which may indicate growth, plant vigor, yield responses of onion plants to various management treatments, such as irrigation methods (Heady, 1957; Ashok, Sasikala & Pal, 2013). Plant heights were recorded at weekly intervals. Plant height was measured following one of the procedures described by Heady (1957). Three random plants were selected per row in a plot and the heights of the plants recorded in cm every week during the whole growing season. Plant height was measured using a ruler from the soil surface to the top of the longest mature leaf.

As the study was done during the dry season, the plants were irrigated daily to apply moisture required by the plants. Weeding and monitoring of water leakages was a routine for the researcher. The plots were weeded weekly to control weeds so that they would not become problematic at the end of the day. This was done before watering or sometimes after watering for easy removal or uprooting of weeds. Pests like wireworm and beetle were identified feeding on plant roots and as a result they were controlled by picking them up by hand as they were not many.Onions were harvested when crops matured as indicated by the tops of onion falling over and beginning to dry. The bulbs were carefully dug out of the soil with a hoe. Thereafter onions were collected and graded according to their sizes. The best 20, 10 and 5 bulbs were selected and weighed. During harvesting onion from each plot were kept separated to simplify the recording process and also to obtain accurate results from the plots. The yields for whole plots were also measured and converted to yield per ha.

Determining and comparing the cost and total labour requirements for growing onion under flood and drip irrigation at 3 levels.

Cost analysis was carried out using prices of the drip irrigation system from Sinclair Service cc and installation at current price levels, and onion production costs were determined based on NAB standards (NAB, 2015). Both fixed and variable costs were calculated for each irrigation system (N$ /ha/season), and the gross margin of the product under the tested irrigation systems were derived to compare these systems. The pump and engine, main control units, and lateral control units, main and sub-main lines, manifold, laterals, emitters and gathering the system were already installed for this study thus their cost were not considered. Gross margin analysis was done and profit and loss components were compared. This was done using graphs and tables.

Comparing yield and plant heights of onions under flood and drip irrigation systems at 3 levels.

Parametric analysis of variance model was used to test the hypothesis of equality of mean yields and plant heights of the treatments versus that of at least one of the treatment mean is not equal. In cases where the null hypothesis of equality of means was rejected, post hoc or pairwise comparisons were performed using Duncan and Turkey's pairwise methods. The Analysis of Variance models were first validated by performing a model diagnostic test.

Results and Discussions

Plant Height

Plant height are not significantly different at all the three levels of irrigation (p =0.397). Figure 1shows a comparison of plant height for flood and drip irrigation at different levels.

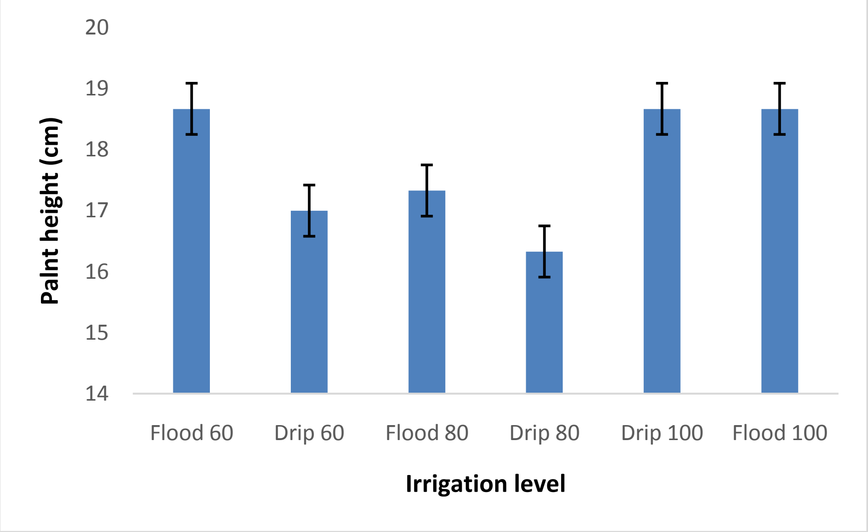

Figure 1: Comparison of plant height among the irrigation systems

Results show higher plant height were obtained in drip irrigation by a margin of 28.36% for the 100% levels, by 3.65% for the 80 % levels and 22.38 % for the 60% levels.Results are in line with Enchalew*et al.*, (2016) who also found that deficit irrigation did not affect much the plant height of onion. In contrast to that Srinivas and Hegde (1990) reported that the plants were 3% taller under the drip irrigation than the basin irrigation. In another study Karam*et al.*, (2002) reported that water stress caused by the deficit irrigations significantly reduced leaf number, leaf area index and dry matter accumulation of lettuce.

Following the grading and weighing of onions into the best 20, 10 and 5 bulbs, analysis of variance of a model in STATA was conducted to explore their difference at the p= 0.1. Table 1 shows a summary Analysis of Variance for comparing the effects of different irrigation type, irrigation level and their interaction on yield. Meanwhile ANOVA at eta squared value was computed to explore the magnitude of reported difference of the three levels of irrigation. According to Cohen (1988) eta squared is classified as small at 0.01, medium at 0.06 and large at 0.14.

Table 1: Summary Analysis of Variance table for comparing the effects of different irrigation type, irrigation level and their interaction on yield

Treatments	Yield (20wt)	Yield (10wt)	Yield (5wt)
Type of irrigation (T)	< 0.001***	< 0.001***	< 0.001***
Level of irrigation (L)	0.088^{ns}	< 0.001***	< 0.001***
T X L	0.415^{ns}	0.224^{ns}	0.08^{ns}
		Eta Square values	
Type of irrigation (T)	0.22	0.18	0.16
Level of irrigation (L)	0.47	0.29	0.19
T X L	0.03	0.02	0.02

ns p >0.05, * p ≤ 0.05, ** p ≤ 0.01, *** p ≤ 0.001

The yield productions of all treatments are highly significant at 0.47, 0.29 and 0.19 eta squared. Irrigation type is highly significant ($p < 0.01$). Irrigation level at 20wt is (p=0.008) irrigation level at 10 wt. is also significant at ($p < 0.01$) and at 5wt it is also highly significant at ($p < 0.01$). However the interaction between level of irrigation and irrigation type are not significantly different at 20wt (p=0.415) and 10wt (0.224). At 5wt, yield (p =0.08; 0.02 eta squared) is significantly different as compared to 20wt and 10wt.

Table 2 shows a post Hoc analysis performed using Turkey and Duncan's Multiple Range Test, to determine which irrigation level produces the highest 20 bulbs yield. Statistical analysis indicated that 100% ETo level of irrigation had the highest 20 bulb yield which was significantly higher than those of 80 and 60% ETo. Although the yield trend followed the level of irrigation, the results indicated no statistically difference in yield of onions at 80 and 60% irrigation level.

Table 2: Mean comparison based on Turkey's Method

Irrrigation level	Means		
	20wt	10wt	5wt
60	167.7a	84.5a	42.58a
80	176.9ab	90.13a	46.12b
100	194.3b	19.35b	50.17c

Means with the same letter within a column are not statistically significant different at 5% significance level.

The yields for onion for the whole plots were also measured and converted to yield per hectare. Table 3shows yields of onion for the type and level of irrigation. The highest level of yields were obtained from the 100% ETo level followed by 80% ETo level and then 60% ETo. The drip irrigation however showed higher yields than the flood irrigation at all the 3 levels.

Table 3: Total yields of onion per ha for the type and level of irrigation

Irrigation type and level	Production/(kg ha^{-1})
Drip irrigation at 60 ETo	19780.10
Drip irrigation 80 ETo	20350.20
Drip irrigation 100 ETo	20790.70
Flood irrigation 60 ETo	17900.40
Flood irrigation 80 ETo	18430.70
Flood irrigation 100 ETo	19770.00

Results show that more yields were obtained in drip irrigation by a margin of 5% for the 100% levels, by 9.4% for the 80 % levels and 9.5 % for the 60% levels. Results also show that yields for drip at 60% ETo were better than flood at 60% ETo by 9.5%. Drip 80% ETo was better than flood 80% ETo by 9.429%. Drip 100% ETo was better than flood 100% ETo by 4.9%. Drip 60% ETo was better than flood 100% ETo by 0.05%. Drip 80% ETo was better than flood 100 % ETo by 2.85%. Drip 100% ETo was better than Drip 60% ETo by 5.11%. 100% drip ETo was better than Drip 80% ETo by 2.12%.

The results of this study have shown that the yield of onion crop was higher under drip irrigated plots. Enciso*et al.*, (2012) found that drip irrigation systems more than doubled yields and increased onion size while using at least 44% less water. Ramalan*et al.*, (2010) reported yields of 37.2 tons per hectare with no irrigation deficit, compared to where there was a deficit level of 75% of total available water, the yield dropped to 24.32 tons per hectare for onions. However Kumar et al., (2007) reported that applying 80 and 60% of crop water requirements resulted in yield decreases of 14 and 38% and saved 18 and 33% of irrigation water compared to full irrigation in 2 years, respectively. Nagazet al., (2012) also found that the onion bulb fresh yields of deficit-irrigated treatment (deficit irrigation-60) were significantly lower than those in full irrigation treatment (full irrigation-100).

Cost of various equipment

The total installation cost of the drip irrigation was N$ 10 710. The system was connected to the main pump station. This is the fixed cost of the drip irrigation system.The flood irrigation system's total installation cost was N$8 479.98. This constituted the fixed cost of the flood irrigation system. The total cost of drip irrigation was more than the flood irrigation.

The gross margin analysis for drip irrigation 60%ETo indicated that the drip irrigation system generated N$ 72 990.60/ha using the current prices of onions as per NAB gazetted prices(NAB, 2015). The total variable costs amounted to N$45 690 /ha.The gross margin analysis for flood irrigation 60% ETo indicated that the drip irrigation system generated N$ 40 312.4/ha using the current prices of onions as per NAB gazetted prices (NAB, 2015). The total variable costs amounted to N$ 67 090/ha.

The gross margin analysis for drip irrigation 80%ETo indicated that the drip irrigation system generated N$ 62 111.20/ha using the current prices of onions as per NAB gazetted prices (NAB, 2015). The total variable costs amounted to N$ 59 990/ha.The gross margin analysis for flood irrigation 80% ETo indicated that the drip irrigation system generated N$ 21 994.2/ha using the current prices of onions as per NAB gazetted prices (NAB, 2015). The total variable costs amounted to N$ 88 590/ha

The gross margin analysis for drip irrigation 100%ETo indicated that the drip irrigation system generated N$ 50 454.2/ha using the current prices of onions as per NAB gazetted prices (NAB, 2015). The total variable costs amounted to N$ 74 290/ha.The gross margin analysis for flood irrigation 100%ETo indicated that the drip irrigation system generated N$ 12 630.00/ha using the current prices of onions as per NAB gazetted prices (NAB, 2015). The total variable costs amounted to N$ 105 990/ha.

The results showed that the gross margin for drip at 60% % ETo performed significantly higher than for 60% flood by 81%. This shows that drip performed better than flood.Gross margin is highly significantly different at all the three levels of irrigation ($p = 0.001$) and also significantly different for the irrigation type ($p = <.001$).The 60% levels for both flood and drip showed highest gross margin followed by 80% and lastly 100%. This is in line with Zimmermann (1999); Prajapatiet al., (2013) who also reported that net profit under irrigated banana under drip irrigation resulted in higher net profit to the extent of 12 to 20 % realized over surface irrigation. The main advantages of drip irrigation compared to other methods as highlighted by Michael (2008) include, saving in water, reduced labor cost, higher crop yields, increased fertilizer use efficiency and reduced energy consumption. Kadigi*et al.,* (2012) also highlighted that irrigation has the potential to enhance food security and economic growth and to achieve this, investment must be profitable for the farmer.

The gross margin analysis for drip irrigation at 60 %ETo indicated that the drip irrigation system generated N$ 72 990.60/ha using the current prices of onions as per NAB gazetted prices, whilst the gross margin analysis for flood irrigation 60 %ETo generated N$ 40 312.4/ha. Gross margin for drip irrigation were significantly higher than for the flood irrigation at all levels of ETo. Farmers who can afford drip irrigation systems will earn higher margins with lower yield than farmers who would use drip and get higher yields. This is caused by cost of water which increases significantly from 60ETo to 100 % ETo. In the event that flood irrigation is chosen to be used then 60 % ETo flood level would be recommended.

When gross margin for drip and flood irrigation are compared at 80 %ETo, drip irrigation gross margin out performed flood irrigation by 182.4% which is almost 3 fold. Thus 80 %ETo irrigation has higher gross margin which can contribute to income as the cost of water is lower. More-over, at 100 %ETo, drip irrigation gross margin was 299% higher than flood irrigation gross margin which was four fold. This indicates that drip irrigation has higher returns than flood irrigation at any level of ETo as it uses less water resulting in demand costs as well.

Under flood irrigation, the 60 %ETo Gross margin was 219% higher than 100ET_o Gross margin which is more than 3 fold higher. Thus the higher the flood ETo the lower the returns as cost of water increases exponentially and although yield increases, the increase is much smaller than the cost increase and gross margin thus declines.

When 60 % ETo flood is compared to 80 % EToflood, the gross margin increased by 83% from 80 % ETo to 60 % ETo. This shows that increasing ETo is not a viable option when irrigating either using drip or flood. Irrigation at 60 %ETo performed significantly higher in both treatments and this could be attributed to the cost of water that increases with increase in ETo.

The gross margin analysis for drip irrigation 100 % ETo indicated that the drip irrigation system generated N$ 50 454.2/ha using the current prices of onions as per NAB gazetted prices and the gross margin analysis for flood irrigation 100 ETo indicated that the drip irrigation system generated N$ 12 630.00/ha using the current prices of onions as per NAB gazetted prices. Overall all drip irrigation systems were better that flood on gross margin showing that farmers should choose drip over flood.

Conclusions and Recommendations

Plant height and Yield

For plant height the level of irrigation are not significantly different at all the three levels (p =0.397). Results show higher plant heights were obtained in drip irrigation by a margin of 28.36% for the 100% levels, by 3.65% for the 80 % levels and 22.38 % for the 60% levels.

The results for the yield of Onion in this study have shown that the crop yield was higher under Drip irrigated plots than flood. The yield productions of all treatments are significantly different at 0.4, 0.29 and 0.19 eta squared. Irrigation type is highly significant (p< 0.001). Irrigation level at 20wt is (p=0.008) irrigation level at 10 wt. is also significant at (p <0.001) and at 5wt it is also highly significant at (p<0.001). However the interaction between level of irrigation and irrigation type are not significantly different at 20wt (p=0.415) and 10wt (0.224). A post Hoc analysis using Turkey and Duncan's Multiple Range Test, to determine which level produces the highest yield showed that there is a significant difference with the 100 % ETo levels out weighing the rest followed by 80% ETo and finally level 60% ETo.

Results show that more yields were obtained in drip irrigation by a margin of 5% for the 100% levels, by 9.4% for the 80 % levels and 9.5 % for the 60% levels. Overall total yields were better for drip irrigation than flood by 8%.

Gross margin

Gross margin for drip irrigation were significantly higher than for the flood irrigation at all levels of ETo applied when compared. Farmers who can afford drip irrigation system will earn higher margins with lower yield than farmers who would use drip and get higher yields. In the event that flood irrigation is chosen to be used then 60 % ETo flood level would be recommended. Drip irrigation showed higher returns than flood irrigation at any level of ETo as it uses less water resulting in demand costs as well.

60 % ETo performed significantly higher in both treatments and this could be attributed to the cost of water that increases with increase in ETo. The study shows that the gross margin is highly significantly different at all the three levels of irrigation (p =0.001) and also significantly different for the irrigation type (p = <.001). The hypothesis that there will be no differences in the production costs of onion cultivated under drip irrigation and flooding was accepted.

Drip irrigation was significantly observed as the most efficient in terms of plant height, onion yield and gross margin. Even though Drip irrigation is expensive to buy, the potential to boost annual net income among the rural poor can be achieved. Drip irrigation system in Namibia is important with the aim of eradicating poverty and hunger and increasing the incomes of approximately two million population.

Recommendations and dimensions for future research

The agriculture sector is very important to the livelihood of the Namibian people. Results show that progress should be made towards improving the water use efficiencies of drip and flood irrigation systems as well as yield. Flood irrigation system should be phased out in a country like Namibia because the system uses large volumes of water and makes it difficult for farmers to pay their bills. It is also advisable that small scale farmers should make use of the system that is most efficient and which will save water and increase yield.

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