PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEM USING SWEET CORN UNDER VARIABLE WATER APPLICATION

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ABSTRACT
Gravitational drip irrigation system was developed using available materials. The system consisting of 4.0 l/hr Netafim pressure-compensating emitters was used to irrigate 0.0015 ha of land where sweet corn was planted under variable water applications in a randomised complete block design with three treatments. Treatment one (W₁) received water once per week, treatment two (W₂) received water twice per week, while third treatment (W₃) received water thrice per week. W₁ received 229mm per emitter; W₂ received 437mm per emitter, while 653mm per emitter was applied to W₃ throughout the experimentation period. Total biomass yield including bulk weight, stem weight, root weight and cob yield were determined using top loading digital weighing balance. Results obtained which were subjected to statistical analysis at 5% significant level show that there were significant differences in the crop growth, biomass and cob yield. Watering thrice per week resulted in the highest leaf area, plant height, root depth and weight. However, watering twice per week provided the highest fresh weight and cob yield. The trend in biomass yield showed that W₂ performed better. Watering twice per week appeared optimum for cultivation of sweet corn during water scarce season in Ibadan, Nigeria.

Keywords: Drip Irrigation, Agronomic parameters, Corn, Evaluation.

INTRODUCTION
Irrigation assists in stabilizing food production in a number of countries by either supplementary or replacing the need for natural precipitation. It serves as crop insurance against drought and increases crop yield and quality when rainfall is insufficient.

In Africa, an estimated 88% of all freshwater use is for agriculture, 7% for domestic purposes, and 5% for industry. In Europe, however, 54% is for industry, while agriculture accounts for 33%, and domestic use, 13% (Hinrichsen et al., 1993). The higher the level of development, the more water is used for domestic and industrial purposes and the less for agriculture. Irrigation contributed substantially to increase food production worldwide. Statistics show that irrigated land in the world rose from 8 million ha in 1980 through 48 million ha in 1990 to 94 million ha in 1950. Irrigated land has tripled to 260 million ha today of which two-third are in developing countries. Averaged globally, about 65% of all freshwater withdrawn each year is used to irrigate 16% of the world's cropland, some 60-90% of this water either evaporates or seeps into the ground before reaching crops (Miller, 1999). During the mid-1960s to mid-1980s, the Food and Agriculture Organization (FAO) estimated that the expansion of irrigation accounted for over 50% of the increase in global food production (Dina, 1993).

Despite the advances in irrigation practices and their attendant contributions in agricultural production, human population is increasing at an alarming rate. World population is expected to reach 7.8 billion by 2025 with 80 percent expected from developing countries (Mark et al., 2002). This will put greater pressure on world food security. The 1996 World Food Summit set a goal of halving the number of food insecure people from 800 million in 1995 to 400 million in 2015. However, according to projections by the International Food Policy Research Institute (IFPRI), it is unlikely that this goal will be achieved before 2030 at best. South Asia and Sub-Saharan Africa are the regions worst affected by food insecurity and malnutrition, being home to 60% of the world's food-insecure people and 75% of its malnourished children (Inocencio et al., 2003). Subsequently, more water will be withdrawn to satisfy domestic needs, coupled with this is the irregular distribution of rainfall in the semi-humid region of the tropics. Thus, an efficient method of irrigation that applies right quantity of water needed must be adopted if this goal is to be achieved.

By the year 2025, approximately 1.4 billion people or one-third of the population of developing countries will be living in areas of chronic water scarcity. People living in these areas will not have sufficient water resources to
maintain even their 1990 average levels of per capita water consumption in the agricultural, industrial and environmental sectors, and much less avenue to increase these levels to acceptable standards (Sakthivadivel et al. 2001). Since agriculture consumes over 80% of all the water in developing countries, there will be intense pressure to transfer water out of agriculture to meet the needs of the other sectors and to increase the efficiencies of irrigation water use at both system and field levels.

In order to reduce water use in agriculture, drip irrigation is often preferred over other irrigation methods because of high water application efficiency on the account of reduced losses, limited surface evaporation and reduction in losses due to percolation (Rajput and Patel, 2005). The optimal use of irrigation according to Yuan et al. (2005) is the supply of sufficient water according to plant needs in the rooting area and, high-frequency water management by drip irrigation minimises soil as a storage reservoir for water, provides at least daily requirements of water to a portion of the root zone of each plant, and maintains a high soil matric potential in the rhizosphere to reduce plant water stress.

Hence, the objectives of the study are to design and construct an improvised gravity drip irrigation system for developing countries and experimentally determine the effect of irrigation frequency on growth parameters of sweet corn on a demonstration plot.

Comparative advantages of drip irrigation system over other methods have been observed over the years with sweet corn. When effluent from domestic waste was used, the contact between the effluent and the crop was less in drip irrigation compared to other methods and this reduces the possible contamination by pathogens (Pescod et al., 1984). It was observed that trickle irrigated plots received less than 45% of pan evaporation in all season resulting in increased in water use efficiency. Marketable tomato (Lycoperscon esculentum) planted with trickle irrigation showed a yield of 22% increase more than with furrow irrigation. No significant change was observed in soluble salts concentration in the soil (Bogle et al., 1989). Sweet corn is a high moisture commodity and sold on the basis of high quality alone. It is very succulents, has a rather shallow root system and does not yield well if adequate soil water is not readily available (Vittum et al., 1963). Irrigating sweet corn with micro-drip (emitter discharge of less than 0.5$l/h$) irrigation may improve yield, reduce drainage flux (excess water removal) and affect the water content distribution within the root zone especially within $0.6 - 0.9$ m soil layer when compared with the conventional drip irrigation (Assouline, 2002)

**MATERIALS AND METHODS**

Improved gravity drip irrigation was designed and constructed. The system consists of two tanks (100 $l$ and 120 $l$), sub-mainline, mainline, laterals, and emitters (Fig.1). Use of the refill tank together with the constant head tank and pressure compensating emitters eliminated problem of pressure variation commonly experienced in conventional family drip irrigation system. Head losses in lateral pipe and mainline were determined by (Larry, 1998):

$$H = (K/2)(D/L)(Q^2/2g)$$

In which $K$ is friction factor that depends on pipe material, $L$ is Length of pipe ($m$), $Q$ is Flow rate ($l/min$), $D$ is diameter ($cm$) and $C, M, n$ are constants based on the method of computation. $K = 0.811 F/g$.

$F$ is a friction factor from the Moody diagram which depends on the magnitude of Reynolds Number ($N_R$); and acceleration due to gravity ($g$). $N_R$ is given by:

$$N_R = DV/\nu$$

$D$ is diameter of pipe (cm), $V$ is average velocity ($cm/s$), and $\nu$ is kinematic viscosity.

For laminar flow,

$$F = 16 / N_R$$

Pressure variation in lateral and mainline was determined using

$$P_d = P_u - y(h_1, \pm \Delta Z)$$

Where; $P_d, P_u$ are Pressures at down and upstream positions respectively ($KP$), $h_1$ is energy loss in pipe between up and downstream position ($m$), $\Delta Z$ is difference in elevation between up and down stream positions ($m$) and $y$ is unit constant ($y = 9.81$ for $P_d$ and $P_u$ in ($KP$) and $h_1, \Delta Z$ in meters). Thus total loss $h_1$ is calculated from

$$h_1 = fh_1 + M_1$$

Where $f$ is constant that depends on method of estimation of $h_1$ and number of emitter outlets. $h_1$ is friction loss in pipe between up and downstream locations ($m$) and $M_1$ is Minor loss through the fittings ($m$). The total head loss ($h_1$) computed from equations 1 to 6 was 0.96$m$, but the recommended minimum pressure head from the manufacturer chart (Larry, 1998) for flow rate
against pressure head for pressure compensating emitters using 4l/hr emitter to deliver 1.4 l/hr average value (to compensate for the head loss in pipes) was 2 m. Hence, the refill tank was placed 2 m above the datum.

Lateral pipe of 16mm diameter and mainline of 25 mm diameter were selected. Field experimentation was conducted at the National Horticultural Research Institute (NIHORT), Idisin, GRA, Ibadan, Oyo State, Nigeria. A plot of 6 m x 2.5 m was demarcated. Randomised complete block design was used. The block consisted of three replications each of 1.5 m x 2.5 m and a spacing of 0.75 m in between two replications. Each replication had fifteen plant stands at spacing of 0.75 m x 0.5 m. Ten plants were analysed in each replication.

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Figure 1: Gravitational Drip Irrigation Model.

Sweet corn seeds were planted at three seeds per hole and at spacing of 0.7 m x 0.5 m as recommended by Doorenbos and Kassam, (1979). The planting was done around 10.00 h of 22 November 2004. Live mulch, Chromolinea odorata at the rate of 3000 kg/ha was applied. The whole plot was irrigated on Tuesday 22 November 2004 and Friday 25 November 2004 to cushion the effect of the sun prior to experimentation. Irrigation water treatment started on Monday 29 November 2004. Irrigation water from the constant head tank was applied using 4.0 l/hr. Netafim pressure-compensating emitters designed for irrigation of vineyards, orchards, nurseries and greenhouses. Water application was done on Mondays, Wednesdays and Fridays. All treatments received water on Mondays; W₂ and W₃ treatments received water on Wednesdays while only W₃ treatment alone-received water on Fridays. In other words, W₁ received water once per week, W₂ received water twice per week, while W₃ received water three times in a week. Total depth of water applied in the three treatments for the whole period of experimentation was 19.78 x 10³ mm. W₁ received 229.10mm per plant; W₂ received 436.60mm per plant, while 652.73mm was applied per plant to W₃ respectively. Depth of water applied per plant to W₃ fall within the 500mm and 800mm depth of water suggested by Doorenbos and Kassam (1979), for maximum production of a medium maturity grain crop. W₁ and W₂ were chosen to evaluate induced effects of water stress.

Sprouting began on the 29th November 2004 and water was applied for 15 minutes from 1 to 26 days after emergence (DAE). Also 29 to 46 DAE, water application duration was 25 minutes, while between 48 to 53 DAE the application time was increased to 30 minutes. For the period 55 to 62 DAE, the time of water application was 35 minutes and finally, water application duration was 40 minutes 65 to 70 DAE. The increase in duration of water
application was necessitated due to observed water stress the on planted crop. The experiment was carried out at the peak of the dry season in Ibadan when the field was at the permanent wilting point (PWP) and observed water stress leading to drying of vegetation was noticed on the experimental field before land clearing and preparation. The soil on the experimental field is sandy loam (54% sand, 28% silt and 18% clay), having 6% moisture content at the PWP.

Growth parameters such as plant heights were measured using a metre rule from the soil surface to the tip of the terminal bud, while the number of leaves was counted manually at 7-day intervals and stem diameter measured using vernier calliper. Leaf area was measured empirically by the relationship 0.75 x length x breadth given by Saxena and Singh (1985). Cobs were harvested fresh on 8 February 2005 and their masses (root weight and total biomass) were evaluated. Scientific Application Software (SAS) was used for the analysis of variance (ANOVA).

RESULT AND DISCUSSION

Average discharge per emitter was found to be 1.32 l/h. It was observed that plants under treatments $W_2$ and $W_3$ tasselled earlier than other plants under $W_1$ due to the fact that the most sensitive stage of crop development when water is inevitable is between flowering (tasselling) and fruit set. Hence, the quantity of water required to simulate tasselling in plants under $W_1$ was less than the required. This was similarly reported by Slatyer (1969) that a frequently observed effect of water stress in the pre-flowering stage is a delay in date of flowering, although some observations of advanced flowering have also been made.

Effects of water application on cob growth, cob yield, biomass and weekly observation are presented in Tables 1, 2 and 3. Results obtained indicated significant differences in the crop growth; biomass and cob yield at 5% significant level for the three treatments.

Average leaf area was best under $W_3$, followed by $W_2$ and $W_1$ the least in Table 1. This result is expected in view of the fact that the amount of water utilized by a plant is assumed to be proportional to its canopy development under similar weather conditions. This is also in agreement with the work of Inas et al. (2001). Plants under $W_3$ performed more luxuriantly than those under $W_2$ and $W_1$. Similarly, root depth performed best under $W_3$. However bulk weight was best under $W_2$. This trend is expected because sweet corn being a shallow rooted crop with few days of gestation could survive under minimum application of water. However, in order to forestall any imminent drought, a little above the minimum for as long as it does not necessarily affect the farmer's expenditure could be applied.

Table 2 shows the effect of drip irrigation on biomass. Results indicate that $W_3$ was more preferred. Compared with the results of Table 1 there seems to be contradictory output. This outcome is unexpected because crop handling and metering of water differ from one farmer to the other which is considered to be the end user of the drip irrigation system. Table 3 presents the result of weekly observation. This shows that $W_2$ and $W_3$ performed better.

The total cost of the drip irrigation system (materials of construction and labour) as at October 2004 when it was constructed was N 19 520.00 (USD 139.5). Maintenance and repair costs of the reservoirs and pipes were estimated to cost 2% of the initial cost of purchase while emitters were estimated at 6.5% of initial cost. Reservoirs (Refill tank and Constant head tank) and pipes (Lateral and Main) costs N 2300.00k and N 3385.00k, while Netafim emitters purchased from Dizengoff Agric (a division of Dizengoff W.A. Ltd., Iwo Road, Ibadan) cost N 11250.00k. Raw water used for irrigation costs N 16.78 at the rate of N 05.00 per litre. Hence total operating, repair and maintenance cost including raw water supply cost to the nearest Naira was N 862.00. From the cost analysis, only the cost of raw water supply vary for each of the treatments due to variable volume of water applied. Similarly, cost of labour is also variable as a result of different number of days of water applications per week. The cost of procuring sweet maize (hybrid) was N 100/Kg as at 2004 at the National Horticultural Research Institute where the experimentation was carried out. The cob yields per hectare for $W_1$, $W_2$ and $W_3$ were 5 889kg, 11 272kg and 11 070kg respectively. Highest cost was incurred in $W_3$ while cost incurred on $W_2$ and $W_1$ were lower. Highest cost in $W_3$ was as a result of cost of water. Obviously from yield, $W_2$ was most profitable followed by $W_3$ and $W_1$. This shows that frequency of water application seems non-commensurate with revenue generation.

CONCLUSION

Gravity drip irrigation system has been designed and constructed using available materials. The problem of pressure fluctuation
common in family drip irrigation system has been eliminated by the use of pressure compensating emitters. It is recommended that if sweet corn is to be planted during dry season in humid tropical environment such as Ibadan, gravitational drip irrigation system of average discharge of 1.32 l/h per emitter watered twice weekly is to be employed.

Table 1: Effect of Drip Irrigation on Crop Growth and Cob Yield.

<table>
<thead>
<tr>
<th>Trt</th>
<th>Leaf Area (cm²)</th>
<th>Plant Height (cm)</th>
<th>Root Depth (cm)</th>
<th>Bulk Weight (g)</th>
<th>Cob Yield (g)</th>
<th>Stem Diameter (cm)</th>
<th>Stem Weight (g)</th>
<th>Root Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>1133.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>79.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.89&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.95&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₂</td>
<td>1308.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>109.76&lt;sup&gt;d&lt;/sup&gt;</td>
<td>12.21&lt;sup&gt;d&lt;/sup&gt;</td>
<td>113.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28.18&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>71.13&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.10&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₃</td>
<td>1628.5&lt;sup&gt;e&lt;/sup&gt;</td>
<td>121.40&lt;sup&gt;e&lt;/sup&gt;</td>
<td>13.71&lt;sup&gt;f&lt;/sup&gt;</td>
<td>111.30&lt;sup&gt;f&lt;/sup&gt;</td>
<td>27.67&lt;sup&gt;f&lt;/sup&gt;</td>
<td>7.15&lt;sup&gt;e&lt;/sup&gt;</td>
<td>62.19&lt;sup&gt;f&lt;/sup&gt;</td>
<td>7.05&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>1305.4&lt;sup&gt;e&lt;/sup&gt;</td>
<td>26.72&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4.42&lt;sup&gt;e&lt;/sup&gt;</td>
<td>55.28&lt;sup&gt;e&lt;/sup&gt;</td>
<td>20.26&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.96&lt;sup&gt;e&lt;/sup&gt;</td>
<td>37.23&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6.27&lt;sup&gt;e&lt;/sup&gt;</td>
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</table>

Table 2: Effect of Drip Irrigation on Biomass.

<table>
<thead>
<tr>
<th>Trt</th>
<th>Cob Weight (g)</th>
<th>Root Weight (g)</th>
<th>Stem Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.46&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.37&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₂</td>
<td>2.79&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13.44&lt;sup&gt;d&lt;/sup&gt;</td>
<td>21.54&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₃</td>
<td>3.11&lt;sup&gt;e&lt;/sup&gt;</td>
<td>12.14&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24.74&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>1.06&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.59&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.06&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 3: Effect of Drip Irrigation on Weekly Observation

<table>
<thead>
<tr>
<th>Trt</th>
<th>Plant Height (cm)</th>
<th>Number of Leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>48.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₂</td>
<td>66.58&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>W₃</td>
<td>59.23&lt;sup&gt;e&lt;/sup&gt;</td>
<td>8&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>10.15</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Trt – Treatment
W₁ - Receives water only on Mondays
W₂ - Receives water on Mondays and Wednesdays
W₃ - Receives water on Mondays, Wednesdays, and Fridays
LSD – Least Significant Difference

Treatments comparison between:
W₁ and W₂: <sup>a</sup> Significantly Different  <sup>b</sup> Not Significantly Different
W₂ and W₃: <sup>c</sup> Significantly Different  <sup>d</sup> Not Significantly Different
W₃ and W₁: <sup>e</sup> Significantly Different  <sup>f</sup> Not Significantly Different

LIST OF REFERENCES


Acknowledgements

Two of the authors, T. A. Ewemoje and S. O. Afolayan, wish to acknowledge the support of the Centre for International Cooperation, Ministry of Foreign Affairs State of Israel (MASHAV), being participants at different trainings organised by the Regional Meteorological Training Centre in Tel Aviv.