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Influence of Flow Rate and Hydraulic Head on Performance Evaluation of Micro -Drip Irrigation using Tomato (Lycopersicon esculentum) in Maiduguri semi-arid region of Borno State

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Abstract: *Globally one type of technology that may contribute to the improvement of water supply management and the associated food crisis is drip irrigation, the research was carried out to investigate the effect of hydraulic heads and flow rates on micro drip irrigation system using Tomato (Lycopersicon esculentum Mill) crop in Maiduguri, the field experiments was conducted at the Teaching and Research Farm, of the University of Maiduguri between February and April, 2019. To determine the optimal level that would maximize tomatoes fresh yield under semi-arid regions conditions. The treatment consisted of factorial combination of three level each of flow rate (0.5m³/s, 0.075m³/s and 1.0m³/s), hydraulic heads of (0.8m, 1m and 1.5m). The Tomatoes was used for the experiments. Treatment were laid out in a Randomized Complete Block Design (RCBD) replicated two times. Also, emitters discharge rates were measured in the field. The data was analyzed using ANOVA and means separated using DMRT at (P<0.05). The result of study revealed that flow rate of (0.75m3/s) and hydraulic (1m) consistently recorded the highest value of all parameter studied. It was closely followed by the combination flow rate (1.0m³/s) and hydraulic head 1.5m. From the finding of this research it could be concluded that flow rate 0.75m³/s combined with 1.0m drip hydraulic gave the best results. And also, considered as good agronomic record for semi-arid region with sandy loam in the study area.*

Keywords: *Emitter, Hydraulic and Flow rate*

1.0 INTRODUCTION

Water is essential substance for sustaining life on the earth. Its consumption by the agriculture sector accounts for about 70 – 80% use of available water in the world and continues to dominate the overall requirements of water. Most of the water is applied by traditional surface irrigation methods (basin, border and furrow) to irrigate crops, wherein the entire soil surface is almost flooded without considering the actual consumptive requirement of the crops. Moreover, It is expected that in the next decade several countries in the arid and semiarid areas of the globe will be under water scarcity or stress (Yang et al., 2003). However, world population is predicted to double in the next 50 years, so greater yields should be extracted from the current agricultural areas (Yang et al., 2003). Therefore, it becomes necessary to properly manage water at all levels in order to satisfy their food and fiber requirements. Management of water resources at macro level is quite costly and time taking, even though unavoidable. On the contrary the management of water at field level is relatively inexpensive, more feasible, and easily workable and can be implemented in short span of time.

In Northern Nigeria, however, irrigation is still predominantly a male affair (Abubakar 2002) and that tradition may rise due to the transaction costs for female to access irrigation pumps and other equipments. According to David, et al., (2016), 81% of farmers rated water management and /or poor drainage system as the most important abiotic constraint limiting dry season vegetable production. Ogunjimi and Adekalu (2002) advised that the problem of small-scale irrigation system especially for vegetable production in Nigeria needs to be further studied. In past many studies have been conducted on drip irrigation method, but still farmers prefer to adopt traditional flood irrigation methods. Therefore the use of drip irrigation system needs extensive publicity among the local farmers in the country for future adoption. Keeping the above facts in view this study was conducted on the design and performance evaluation of small scale drip and furrow irrigation methods in semi-arid region. Main objective of this study is to investigate the influence of flow rates and hydraulic heads on growths and fresh yield of tomatoes using micro drip irrigation and to suggest guidelines for farming community.

1.1 Drip Irrigation

Africa's regions with extended periods of drought and inadequate rainfall contribute to the continent's food shortage problem. While nature cannot be controlled, society does have the ability to develop and practice more efficient water usage techniques in order to improve water supply management (Evans, 2011).

One type of technology that may contribute to the improvement of water supply management and the associated food crisis is drip irrigation. Drip irrigation, in a nutshell, is the process of lacing your garden area with irrigation lines that feed into the root system of your plants, "dripping" water into them gradually. This is most efficient system because it allows you to directly hydrate you plants without having to water the surface.

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the root of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. Drip irrigation system distribute water through a network of valves, pipes, tubing, and emitters (Evans, 2011). Depending on how well designed, installed, maintained, and operated it, a drip irrigation system can be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation.

1.2 Low-Cost Drip Technology

Irrigation agriculture sector is facing increasing challenges in face of rapid population growth, decreasing the availability of land, and competition for scarce water resources (Frausto, 2000). To overcome these challenges and improve productivity and livelihoods of world's small-scale farmers who comprise the majority of farmers in developing countries, IDE has redesigned conventional irrigation systems to produce a series of dependable and affordable systems that more adequately meet small farmers' needs (Behr and Naik, 1999).

Low-cost drip technology, which is at 'market take-off', holds a great promise both in terms of water consumed and reducing rural poverty as well as encouraging urban farming in spaces that are often overlooked and underused. The resultant drip systems require a minimum filtration, are available in small packages, operate at low inlet pressure, and are easy to understand and maintain by small-scale farmers. It is worth noting that 'low cost' does not imply a low cost per ha, but rather refers to low initial capital outlay. The initial purchase of a number of kits required to cover one hectare is as costly as conventional drip irrigation systems (Haile et al., 2003).

2.0 MATERIALS AND METHODS

2.1 Experimental Site Description

The experiment was conducted at the University of Maiduguri Agricultural Engineering Teaching and Research Farm, (Latitude 11^0 54'N, Longitude 130^0E**,** altitude 354m above means sea level). It is located within the Sudan Savannah zone (Ohu and Folorunso, 1989). The rainy period in the area is between June and September with a mean annual rainfall of 500 mm. There is high temperature during most of the year with annual mean temperature of 38^0c.During the month of April to May; the temperature could be as high as 45^0c. However, during the harmattan period, the mean monthly temperature could be as low as 22^0C (Muni, 2002). The soil of the research farm had earlier been classified as Typic Upstisament (Rayar, 1984) with acolin formation and weakly aggregated. The soil has sandy loam texture, made up of 6% silt, 17% clay and 77% sand (Ohu and Folorunso, 1989).

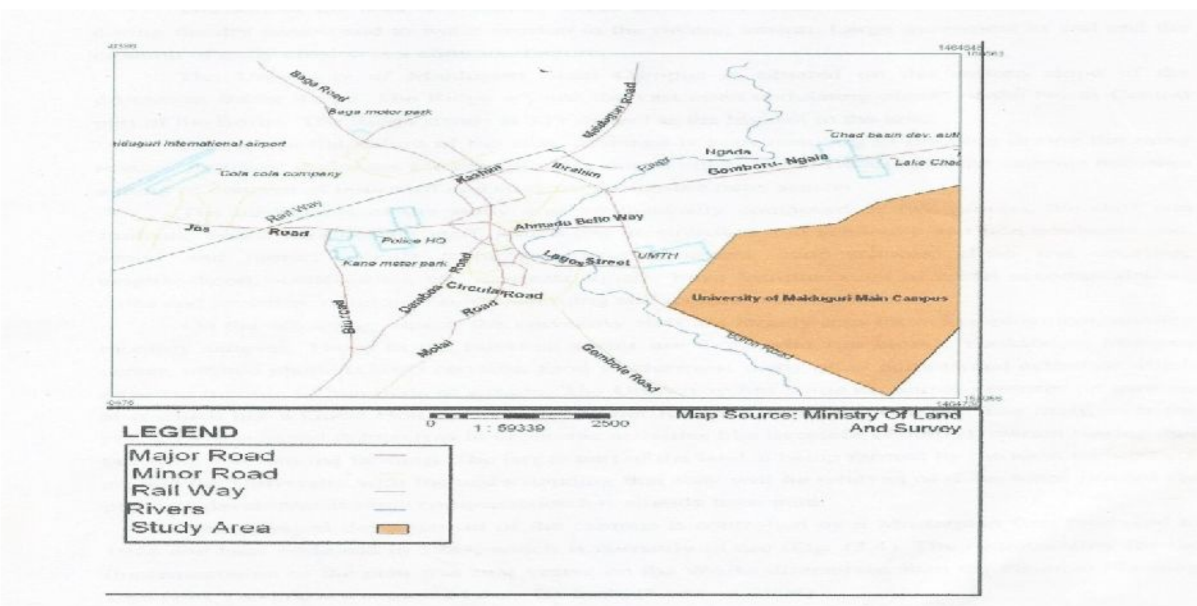

Figure 2.1 Maiduguri Road Map Showing the Study Area

Table 1: Soil Characteristics of the Experimental Site (0-30 cm)

Soil type (USDA soil classification)	Sand loamy
Clay (%)	8.0
Silt (%)	11.8
Sand (%)	80.2
P^h	6.8
Field capacity (vol. %)	16.2
Wilting point (vol. %)	3.2
Available water content (vol. %)	13.0
Bulk Density (g/cm^3	1.70
Organic matter (%)	3.99

2.2 Treatments and Experimental Design

The experiment was carried out with two irrigation methods. The irrigation methods are drip and furrow irrigation methods. The experimental factor to be considered in this work are two drip irrigation variables (inflow discharge Q, and hydraulic head H) each at three level to make nine treatments respectively and the design proposed to be laid in Randomized Complete Block Design (RCBD) due to the advantage of replication and error reduction in the process. There shall be three (3) replications to make a total of twenty-seven (27) treatments. Inflow discharge was varied from 0.5l/s. 0.75l/s, and 1.0l/s, whereas the hydraulic head was 0.5m, 1.0m and 1.5m respectively.

2.3 Land preparation

Since the land at the experimental site was uncultivated for about two years. Therefore it was cleared manually using cutlasses and rakes, and ploughed by disk plough. The aim of the study was to compare the drip and furrow irrigation methods with regard to water saving, increase in yield, and water use efficiency of drip and furrow methods. For this purpose the total area under experiment was about 12m^2 and was divided into two portions equally. One portion about 12 by 4m^2 was occupied by drip and the other portion about 12 by 4m^2 by furrow irrigation method as shown in fig.

2.4 Installation of drip irrigation system

Drip irrigation system were consist of 110 mm PVC (Polyvinyl chloride) mainline connected to 63 mm PVC pipe sub-main line, which was connected to 16mm lateral line. The distance between row to row and plant to plant was kept 1m and 0.5m respectively as suggested by (Oke, et al., 2016). In total 24 laterals were laid on the ground surface along the lines of plants each 4m long with 8 emitters.

2.5 Estimation of Coefficient of variation

There are certain variations in everything in the World, no two things are really identical. Likewise, no two emitters are identically manufactured; there would be a little variation between them. Therefore, coefficient of variation is used to evaluate the flow rate uniformity of the emitters that was used in the research work. Following formula was used to calculate the coefficient of variation (ASAE 2002).

$$\mathbf{Cv} = \frac{\sigma}{qav} \times \mathbf{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

2.6 Emission uniformity (EU)

EU is the ratio between the average discharge in the quarter receiving less water and the average discharge at the system level it is used to describe the predicted emitter flow variation along a lateral line and can be assumed as synonymous to that of distribution uniformity (DU). The formula was used to calculate emission uniformity (Keller and Bliesner 1990).

$$\mathbf{EU} = [1.0 - \frac{1.27CV}{n^{\frac{1}{2}}}]\frac{qm}{qa} \dots\dots (2)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(q1-qav)^2}{n}} \dots\dots (3)$$

σ = Standard deviation Cv = Coefficient of variation: n = No. of emitters; qm = Maximum flow; qa = Average flow

2.7 Preparation of furrow irrigation system

For furrow irrigation system, furrow and ridges were prepared manually using hoes and shovels. The row to row and plant to plant distance was same as in drip irrigation. In all the total number of furrow and ridges were 26 and 27 respectively. The length of each furrow and ridge was 4m while each ridge was comprised of 9 plants

2.8 Statistical Analysis

All data collected in the Research were subjected to Analysis of Variance (ANOVA) as describe by Gomez and Gomez (1984) using Excel software. Different between treatments mean will be separated using Statistic8.0

3.0 RESULT AND DISCUSSION

3.1 Influence of hydraulic head and inflow rates on Emission Uniformity under 1-9 Emitter

The result obtained on the Influence of hydraulic head and flow rate on the tomato plant height were illustrated in Table 1.

Table 1: Influence of hydraulic head on and inflow rates on Emission Uniformity under 1-9 Emitter.

Emitters	Minimum discharge Qm	Average discharge Qav	$\sum(q - qav)2$	Standard deviation σ	Coefficient of variation (Cv)	Emission Uniformity (EU)	SE±
1	0.690	0.793	1.745	1.401	1.401	65.911	0.809
2	0.940	1.293	1.651	0.916	0.916	61.170	0.529
3	0.950	1.633	1.438	0.712	0.712	51.009	0.411
4	1.028	0.685	2.316	1.849	1.849	102.055	1.068
5	0.928	0.618	2.244	1.796	1.796	103.443	1.037
6	0.640	0.427	1.813	1.909	1.909	100.518	1.102
7	1.023	0.682	1.515	0.591	0.591	134.685	0.341

8	0.988	0.658	1.543	0.844	0.844	128.110	0.488
9	0.840	0.560	1.073	0.326	0.326	141.552	0.188

The coefficients of variation and emission uniformity of randomly selected laterals were determined in order to test the performance of the drip irrigation system. The results are presented in (Table 1) which show that the coefficient of variation of randomly selected laterals was 1.401, 0.916, 0.712, 1.848, 1.796, 1.909, 0.591, 0.844 and 0.326 respectively. Likewise the emission uniformity of randomly selected laterals was 65.9, 61.2, 51, 102, 103, 100, 134, 128 and 142 % respectively. These results suggest that the system was working satisfactorily according to its design

3.2 Growth Characteristics Performance

3.2.1 Influence of hydraulic head and flow rate on tomatoes plants height at 2-10 weeks after transplanting (WAT) were illustrated in table 2

The result obtained on the Influence of hydraulic head and flow rate on the tomatoes plant height were illustrated in Table 2.

Table 2: Influence of hydraulic head and flow rate on the tomatoes plant height

	WEEKS AFTER TRANSPLANTING				
Treatments	**2**	**4**	**6**	**8**	**10**
Hydraulic head (m)					
H1`(0.8)	11.00	18.00	30.00	48.30	51.10
H2 (1.0)	13.00	20.10	34.00	49.30	53.30
H3 (1.5)	11.50	19.00	31.00	48.50	52.30
Significance	Ns	*	*	*	
SE±	0.432	0.495	0.658	0.058	0.589
Flow rate (m^3/s)					
Q1(0.5)	11.00	17.90	33.00	47.30	51.10
Q2 (0.75)	12,00	18.00	35.00	46.20	49.00
Q3(1.0)	11.20	16.40	34.00	45,10	50.20
Significance	Ns	*	*	*	*
SE±	0.234	0.343	0.768	1.32	1.008
Interaction					
HD x FR	*	*	*	*	*
Control FR	11.00	15.00	30,00	44.20	49.00

Plants height progressively increased with age of crop up to harvest, irrespective of irrigation method (Table 2). Tomato plant height at different growth stages varied significantly due to irrigation level and hydraulic head. The treatments used were significantly ($p< 0.05$) influence the plant height of tomato. The highest plant height at all week after transplanting (WAT) of 13.00cm, 20.10cm, 34.00cm, 49.30cm, and 53.30cm was recorded in H2 respectively. It was followed by H3 at same WAT with corresponding values of 11.50cm, 19.00cm, 31.00cm, 48.50cm and 52.30cm respectively. While the least plant height were recorded between H1 and control (furrow). These results are in conformity with the findings of Locasio and Smajstrala (1996) and Candido et al. (2000). Similarly flow rates used as treatments were remarkable influenced the tomato plant height. The highest was recorded in Q2 with corresponding values 12.00m^3/s, 18.00m^3/s, 35.00m^3/s, 46.20m^3/s except in 10WAT where it had 49.00m^3/s. The interaction between inflow rate and discharge were significant as illustrated in Table 2.

3.2.2 Influence of drip hydraulic head and Flow Rate on number of branch per plant at 2-10 Weeks after Transplanting (WAT) of Tomatoes were illustrated in table 3

The result obtained on the Influence of hydraulic head and inflow rate on the tomatoes number of branch per plant were shown in Table 3.

Table 3: Influence of hydraulic head and flow rate on tomatoes number of branch per plant

	WEEKS AFTER TRANSPLANTING				
Treatments	**2**	**4**	**6**	**8**	**10**
Hydraulic head (m)					
H1(0.8)	4.00	8.00	24.00	34.00	43.00
H2(1.0)	5.00	9.00	25.00	37.00	47.00
H3(1.5)	4.00	9.00	22.00	34.00	40.00
Significance	Ns	*	*	*	
SE±	0.123	1.002	0.982	0.023	0.02
Flow rate (L/s)					
Q1(0.5)	6.00	8.00	26.00	36.00	47.00
Q2(0.75)	5.00	8.00	23.00	35.00	45.00
Q3(1.0)	5.00	7.00	25.00	35.00	42.00
Significance	Ns	*	*	*	
SE±	0.127	1.001	0.081	0.123	0.21
Interaction					
HD x FR	NS	*	*	*	*
Control FR	4.00	7.00	20.00	29.00	41.00

All means within a column followed by same letters are not different at the 5% level of significance

The hydraulic head and discharge variations used as treatments significantly ($p<0.05$) influenced the number tomato branch per plant as shown in Table 3. It shows that the treatment H2 has the highest number of branches from the beginning to the end with values (5.0, 9.00, 25.00, 37.00, and 47.00) respectively. While the treatment H3 produced the least number of branches among the irrigated treatments. The control (furrow) treatment recorded the least compared to the irrigated treatments. Similarly flow rates used as treatments were remarkable influenced the tomato plant's number of branch. The highest was recorded in Q2 with corresponding values 6.00m³/s, 8.00m³/s, 26.00m³/s, 36.00m³/s and 476m³/s respectively. It was closely followed by Q2 with values (5.00, 8.00, 23.00, 35.00, and 45.00) m³/s. The least of the irrigated treatments was observed in treatment Q3. The control treatment recorded the least of all the treatments with corresponding values 4.00, 7.00, 20.00 29.00 and 41.00 m³/s respectively. The interaction between inflow rate and discharge were significant as illustrated in Table 3.

3.2.2 Influence of Drip hydraulic head and Flow Rate on Number of Leaf per Plant at 2-10 Weeks after Transplanting (WAT) of Tomatoes were illustrated in Fig 2 below.

The flow rate and discharge variations used as treatments significantly ($p<0.05$) influenced the number tomato leaf per plant. The highest number of leaf per plant at all weeks except week 10 were recorded in H2 (1.0) head of 16.00, 54.00, 134.00 and 485.00 respectively. It was closely followed by H3 (1.5) except in week 2 and 6 with corresponding values of 52.00, 479.00 and 690.00 respectively. Moreover, the least value number of leaf per plant at all weeks was observed in the control treatment (furrow) with corresponding values (14.00, 51.00, 111.00, 440.00, and 620.00) respectively. Similarly, there were significant difference observed among the mean of the number of leaf per plant recorded under inflow rate at ($p<0.05$). The highest values of 17.00, 55.00, 132.00 478.00 and 675.00 number of leaves per plant at all weeks were recorded in Q1 respectively. It was closely followed by Q2 and then Q3 respectively. For more details see figure 2 below

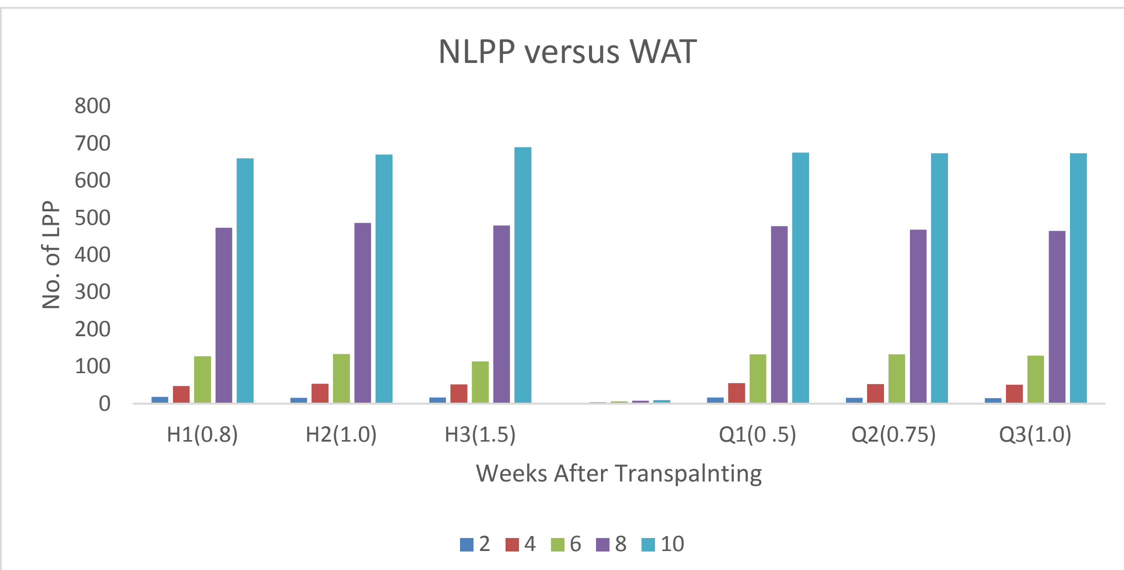

Figure 2: NLPP versus Week after transplanting

3.3 Influence of Drip hydraulic head and Flow Rate on Yield and Yield Parameters of Tomatoes

As illustrated in table 4, the interaction effect of irrigation levels and hydraulic heads on number of fruits per plant was also found significant (Table 4). Drip irrigation scheduled at Q1 (1.0) produced significantly higher number of fruits per plant (42.34) than all other irrigation levels. Lowest numbers of fruits were recorded with Q3 (1.5) with value (37.23) and was at par with Q2 (0.75) flow rate. Among the hydraulic heads, highest number of fruits per plant was recorded with H2 at (1.0) as (41.22) and was significantly superior over all other hydraulic heads. While the lowest number of fruits per plant was recorded by H3 at (1.5) as (37.56). Among the interaction effects, significantly higher number of fruits per plant was observed in flow rate at Q1 (0.5) with hydraulic head H2 (1.0) as (44.00) while the less number of fruits (36.36/plant) was observed with flow rate Q3 and H3 treatment.

Table 4: Influence of the hydraulic head and flow rates on Tomatoes yield (kg)

Flow rate (Q)	Hydraulic head (H)			
	H1(0.8)	H2(1.0)	H3(1.5)	Mean
Q1(0.5)	43.34	44.00	39.67	42.34
Q2(0.75)	39.00	41.67	36.67	39.11
Q3(1.0)	37.34	38.00	36.34	37.23
Mean	39.89	41.22	37.56	
Cv 0.23%				
S.E 0.034				
C.D (p=0.05)				

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This experiment was done to see effect of different hydraulic head and flow rates on growth and yield of tomatoes using drip irrigation. The study was aimed to identify optimum drip variables for tomatoes production for the study. The collected data were subjected to analysis of variance (ANOVA) and the results were as follows:

(i) Results of this investigation showed that flow rate 0.75 m^3 and 1m drip hydraulic head gave the best plant height, number of leaves per plant and number of branches per plant and fresh yield of the tomatoes at all Week after transplanting, as well at the maturity.

(ii) The combined effect of flow rates at 0.75 m^3 and 1m hydraulic gave the best result. It is therefore suggested as the best practice in the study area.

4.2 Recommendations

(i) Since tomatoes crop responded positively to different flow rates and drip hydraulic heads used from finding of this research, it could be concluded that (1.0m) hydraulic head combined with flow rate (0.75m3/s) gave the best results. And also, considered as good drip irrigation parameters and agronomic record for semi-arid region with sandy loam in the study area.

(ii) Further investigations may be needed to be carried out at different seasons of the year, location, soil type, tomatoes varieties and different farmer practice to come up with precise and comprehensive recommendation.

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