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Small Farm Gravity Drip Irrigation System for Crop Production

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ABSTRACT

This study involves the construction, installation and testing of a small farm gravity drip irrigation system on a land area of 900m² (30mx30m). It was done using a network of polyvinyl chloride (PVC) pipes of three sizes (which served as the main, submain and laterals), control valves (located on the sub main) and micro emitters (which controlled uniform application of water and fertilizer directly into the root zone of the plant by gravity). The water application uniformity of the system was determined by measuring emitter flow rates at the times required to fill a container of 1 litre. Fertigation chamber was incorporated into the system for fertilizer application. The average discharge rate from the emitters was 5.5 l/hr. The average wetting diameter and wetting depth of 60 cm and 1.5 m respectively were achieved. The emission uniform of 85% and above compared favourably with micro irrigation uniformity classification standard based on American Society of Agricultural Engineers (ASAE). It is recommended that the system be flushed after each irrigation season to prevent clogging.

KEYWORDS: Irrigation, Fertigation, Emitter, Gravity, Clogging, Drip.

1.0 INTRODUCTION

Irrigation is the artificial application of water to the soil for the purpose of crop production. Irrigation water is applied to supplement rainfall. In many areas of the world, the amount and timing of rainfall are not adequate to meet the moisture requirement of crops and so irrigation is necessary to meet the needs of food and fiber designed to allow farming in arid and semi-arid regions to reduce drought. The increasing need for crop production for the growing population is causing the rapid expansion of irrigation throughout the world.

Drip or trickle irrigation is one of the latest methods of irrigation, which is becoming increasingly popular in areas where there is water scarcity and salt problem. It allows water to be applied uniformly and slowly to the plant so that essentially all the water is placed in the root zone. In drip irrigation conventional losses, deep percolation, runoff, and soil water evaporation are minimized. Drip irrigation is categorized according to their placement in the field: surface drip system – water is applied directly to the soil surface, sub surface drip irrigation system- water is applied below the soil surface through perforated pipes. In this method, irrigation water is accomplished by using small diameter plastic lateral lines and a device called emitter or dripper at selected spacing to deliver water to the soil surface near the base of the plant (Black, 1976). The system applies water slowly to keep the soil moisture within the desired range for plant growth.

Drip irrigation offers small holders a practical method of improving irrigation efficiency and increasing the yields of most horticultural, orchard and field crops by marching frequently low volume applications of water and dissolved fertilizer to the rate of uptake by the crop. Thus the soil is maintained continuously in a condition, which is highly favourable to crop growth. As the application are localized close to the plant root zone, losses through drainage or by wetting inter-rows and ridges are minimized. Howell *et al.*, (1981) reviewed over 50 research reports on crop responses to drip irrigation. Affordable drip irrigation set for use in vegetable gardens is necessary (Adhikari, 2000).

2.0 MATERIALS AND METHODS

2.1 Location of Project Site

The study was carried out in the Department of Agricultural and Environmental Engineering Research Farm, University of Agriculture, Makurdi, Nigeria. Makurdi lies between latitudes 7°45' and 7°52'N of equator and longitude 8°35' and 8°41'E of Greenwich meridian. The town is located along the coast of the Benue River (Shabu and Tyonum, 2013). The land use in and around Makurdi is agricultural and the farmers mainly produce rice, guinea corn, maize, groundnut and vegetables like pepper, amaranthus, pumpkin. The area is in the tropics and has two seasons dry (May – October) and wet (November - April). The average annual temperature is 31.5 °C, while the relative humidity ranges between 65 – 69 % with annual rainfall varying between 1000 – 2500 mm (Isikwue *et al*, 2011).

2.2 Description of the Small Farm Drip Irrigation System

The materials that were used for the construction and installation of the small farm gravity drip irrigation system were: plastic water tank, mainline pipes, sub-mainline pipe, lateral pipes, water filter, valves/regulators, and micro emitters (improvised).

The system was a complete irrigation unit, all the pipes were made of PVC and it operated by gravity from a plastic tank of 2000 litres placed 2.8 m above the ground level so that the system will have enough head for water pressure. It has a fertigation chamber attached to the mainline. The lateral lines which were connected to the sub-main lines were laid along the crop rows and micro emitters installed at spacing of 30cm. There is a drain tap at the bottom of the water tank for frequent flush out and cleaning from suspended solid particles. It did not use any external power for normal operation. The layout of the system is as shown in Figure 1.

Figure 1: Layout of Small Farm Gravity Drip Irrigation System (SFGDIS)

2.3 Installation of the Small Farm Drip Irrigation

The installation of the small farm gravity drip system was divided into three stages, this includes the followings:

- (i) Construction of the water tank stand, fertigation chamber stand and installation of the tanks
- (ii) Laying of pipes and fittings
- (iii) Testing of fittings and determination of emitter flow rate

A water tank stand of burnt bricks was constructed at a height of 2.8 m above ground level to achieve minimum pressure requirements. Water was supplied into the water tank (water source) by a water tanker vehicle. The system was connected to the water source and a simple filter was screwed into a union and connected to the mainline pipe to prevent clogging of emitters. Fertigation chamber on a stand of 1.00 m high was connected to the system through the main line pipe. Six control valves were installed on the sub mainline. The laterals were attached to the sub mainline slopping down the ground along the plant rows. Plates 1– 5 show the construction of the stands, laying and fixing of fittings into the pipes.

Plate 1: Water source stand

Plate 2: Fertigation chamber and stand

Plate 3: Connecting lateral pipes

Plate 4: Monitoring flow rate of the emitters

Plate 5: Monitoring flow rate uniformity

2.4 Parameters Tested

The following tests were carried out:

- Determination of emitter discharge rate
- Water application Uniformity
- Determination of emission uniformity of the discharge rate of each control valves

3.0 RESULTS

3.1 Emitters Discharge Rates and the Wetting Behaviour

The average discharge rates of the sampled emitters according to the valves and distances from the water source are presented in Table 1. The wetting depth ranged from 0.1m to 1.5m and the average wetting diameter was 60 cm. The wetting pattern is shown in Plate6 and plate7 shows the spinach growing under this system.

Table 1: Discharge Rates (l/hr) of Sampled Emitters (microemitters)

Control Valves	1	2	3	4	5	6
Head Lateral (closest to water source)	5.5 (11)*	5.5 (11)	5.5 (11)	5.5 (11)	5.5 (11)	5.5 (11)
Middle Lateral (5 m away from water source)	5.5 (11)	5.5 (14)	4.6 (13)	4.6 (13)	5.5 (14)	5.5 (14)
End Lateral (farthest from the water source)	5.5 (14)	4.6 (13)	5.5 (14)	4.6 (13)	5.5 (14)	5.5 (14)

* Figures in bracket represent the time (min) taken to fill 1 litre container.

Plate 6: Wetting pattern

Plate 7: Spinach growing under the system

3.2 Emission Uniformity (Us)

The 25 % discharge rates of all sampled emitters was used to test the efficiency of emission (emission uniformity) of the six control valves. Table 2 presents the average daily emission uniformity for the first week from all the six control valves, while Table 3 shows the average values for the seven weeks. The average values for each of the control valves for the seven weeks as compared with the ASAE (1996) are presented in Table 4.

Table 2: Average Daily Emission Uniformity (%) of the emitters from the six control valves

Days	Control Valves					
	1	2	3	4	5	6
	Emission Uniformity (%)					
1	86	86	86	89	86	86
2	98	98	97	98	98	95
3	92	88	87	93	85	86
4	98	98	96	96	89	97
5	87	86	84	84	86	98
6	86	87	85	89	90	83
7	87	90	86	90	90	88

Table 3: Emission uniformity from the six control valves for seven weeks

Weeks	Control Valves						Average
	1	2	3	4	5	6	
	Emission Uniformity (%)						
1	86	86	86	89	86	86	87
2	98	98	97	98	98	95	97
3	92	88	87	93	85	86	89
4	98	98	96	89	97	97	96
5	87	86	85	84	84	98	87
6	86	87	85	98	90	83	88
7	87	90	86	90	90	88	89

Table 4: Average Emission Uniformity for seven weeks in comparison with ASAE (1996a)

Weeks	Monitored Emission Uniformity, Us (%)	ASAE 1996 classification
1	87	Good (90 – 80%)
2	97	Excellent (Above 90%)
3	89	Good (90 – 80%)
4	96	Excellent (Above 90%)
5	87	Good (90 – 80%)
6	88	Good (90 – 80%)
7	89	Good (90 – 80%)

4.0 DISCUSSION

4.1 Discharge Rates and Emission Uniformity

Table 2, showed that all the emitters (with the exception of two emitters each from the middle and end laterals) had approximately the same discharge rates of 5.5 l/hr. The little difference could be as a result of pressure loss (head loss) due to distance from source of water. It is clearly evident that it took less time (11 mins) for the emitters at the head lateral to fill one- litre container, while the middle and end laterals took more time (13 – 14 mins). Slight variation in the uniformity of emitter flow rate may have resulted from clogging, leakage or incomplete flushing, wearing of emitter components as they were adjusted several times in order to achieve a desired flow rate in line with observation of Smajstrla (2012). The clogging may be as a result of the improper flushing or fertigation (even though filter was incorporated). This problem of clogging could be handled (as also recommended by Storie, 1995) by periodic cleaning of filters, checking the pressure drop across the filter, checking the holes in the screens, and/or flushing the laterals at least two or three times a year.

Flushing measures can be taken to prevent emitter clogging. An improperly managed filter station can waste water and threaten a drip system's fitness and accuracy (Granberry, 1996) and this can result in low yield or total crop failure. Chemical fertilizer was added through the fertigation chamber, which was stirred thoroughly to dissolve. The sediments were not monitored as to particularly evaluate the performance of filter but the high performance of the system generally can speak for the effectiveness of the filters. The discharge rates from the different control valves having almost the same value (uniform) irrespective of time indicates the uniformity of the emitters. This implies that the system has achieved some level of efficiency in terms of performance (hydraulic properties) and pressure distribution of the emitters.

The result (values obtained) compared favourably with ASAE (1996). This was confirmed by the no over-irrigation and no under-irrigation observed in the field. This has also proved further the effectiveness of the system in water management and optimization when water is a limiting factor for crop production.

4.2 Wetting Depth and Wetting Pattern

The average wetting circumference of 60 cm is large enough for production of leafy vegetables and crop vegetables. This wetting circumference is in line with the findings of Moshe (2003) that wetted diameter for a single dripper may be 30, 60, and 120 cm in light, medium and fine textured soils respectively. In line with the finding of Swaider (2002), the wetting depth of up to 1.5m for the period which was attained by this system can accommodate 0.3 – 1.0 m effective rooting depth for small vegetables (such as spinach, carrot, lettuce, cabbage, garlic, onions etc), 0.7 – 1.5 m rooting depth for vegetables of solanium family (as egg plant, sweet pepper, tomatoes) and 0.6 – 1.5 m rooting depth for vegetables of cucumber family (pumpkin, sweet melon, water melon etc). The system can also be used to grow legumes (beans, peas, groundnut, soybeans) of 0.1 m rooting depth.

The implication of good performance is that there was uniform water application, good pressure distribution, provision of enough moisture (water) for the plants within the crop root zone (adequate wetting depth), good filtration and uniform distribution of fertilizer. The physical appearance of the spinach grown with the system attested the effectiveness of its performance. The plants had adequate supply of water and fertilizer. Combine surface drip irrigation and nutrients management was achieved. This was in line with the report of Roberto (2005) and Ochedikwu (2015) that high nutrient and water management have been developed for several vegetable crops, including collard, mustard, spinach, and romaine. In addition, the system is well suited to meet all small scale farmers' needs, both from an economic as well as an engineering standpoint, with many advantages as compared to traditional method.

5.0 CONCLUSION

This technology is affordable, it will enable small-scale farmers to efficiently utilize marginal quantity of water, reduction of weed infestation, and reduction in high cost of energy in lifting water from the wells or reservoir. The average wetting diameter and wetting depth of 60 cm and 1.5 m respectively were achieved. The irrigation system represented by the flow rate (5.5 l/hr) achieved a high degree of uniformity of water application throughout the rootzone. Also the variability among emitters used in this irrigation system is low as attested by the high water application uniformity. The emitter clogging recorded was not significant. It is recommended that this system be introduced to and be adapted by the small scale farmers in Nigeria for water conservation and management. Also that frequent evaluations be carried to identify and correct emitter clogging problems.

6.0 REFERENCES

- Adhikari D (2000). Simplified and low cost drip irrigation manual. International Development Enterprises, Kathmandu Nepal.
- ASAE (1996). Field evaluation of micro-irrigation systems. EP405.1. ASAE Standards. Amer. Soc. Agric. Engr., St. Joseph, MI. pp. 756-759.
- Black JDF (1976). Tickle irrigation – a review. HortAbstr, 46: 1-7, 69- 73.
- Granberry D, Harrison, MKA, Kelly WT (1996). Drip chemigation- injecting fertilizer, acid and chlorine. Cooperative Extension Service, University of Georgia, Bulletin 1130.
- Howell TA, Bucks DA, Chesness JL (1981) Advances in trickle irrigation. Proc. Natt. Irrig. Symp. 2nd, 1980 pp 69- 71.
- Isikwue M O, Onyilo A F (2010). Influence of land use on the hydraulic response of a loamysand tropical soil. Journal of Emerging Trends in Engineering and Applied Sciences. Vol.1 No. 2: 144 – 149. <http://www.jeteas.scholarlinkresearch.org> ISSN: 2141-7016.
- Ochedikwu AEF (2015). Performance evaluation of small farm gravity drip irrigation system for vegetable production. Master of Engineering thesis submitted to the Department of Agricultural and Environmental Engineering University of Agriculture, Makurdi Nigeria.
- Roberto N (2005.) Fertilization combined with irrigation (fertigation). Extension Service Irrigation and Soil Field Service. pp 2 – 5.
- Smajstrla A, Boman GBJ, Haman DZ, Pitts DJ., Zazueta FS (2012). Field evaluation of micro-irrigation water application uniformity. Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. PP 1- 10.

Storlie C (1995). Treating drip irrigation system with chlorine. Rutgers Cooperative Extension Services Fact Sheet FS795.

Swaider J, Ware G (2002). Producing vegetable crops (5th ed.). Interstate Publishers, Inc. Dansville.II.

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