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Comparative Performance of Okra (*Abelmoschus esculentus*) Under Subsistence Farming Using Drip and Watering Can Methods of Irrigation

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Abstract

Application of water to crops during the dry season in areas of scare water supply is very important to meet the food demand of the ever-increasing population globally. Thus, modified irrigation technique that poor resource farmers can afford and use easily was evaluated in this paper. A field experiment was conducted at the University of Ibadan Teaching and Research Farm to evaluate the performance of okra under modified bucket drip kit (BDK) and watering-can (WC) methods of irrigation for three growing seasons between 2011 and 2013. The BDK irrigation treatment had a higher mean percentage plant survival (92.9%) than those under the WC method (90.7%). The number of okra leaves, plant height and stem diameter were consistently higher under BDK irrigation than under WC irrigation for the three growing seasons. Harvested number of fresh fruits was only significantly higher under BDK method than WC method by 40.8% and 11.1%, respectively, for the second and third seasons. The plots under BDK irrigation system produced higher fresh fruit weight than the WC method by 0.1, 1.1, 7.4 t ha^{-1} respectively for the first, second and third seasons. The BDK performed better than WC in terms of okra growth and yields.

Keywords: Soil water; Bucket drip-kit irrigation; Watering-can irrigation; Okra yield

Introduction

Water supply is important for crop growth and production particularly in arid and semi-arid areas. Agriculture utilizes globally about 70% of all the water managed by man, and about 80% of the water used in the developing world [1]. However, the competition among the various sectors-agriculture, communities, industry, nature, etc. becomes stiffer and agriculture is most under pressures for scarce water resources, as the output per unit water is significantly lower than in the other economic sectors. The advent of climate change has brought about considerable uncertainty and curtailment of farming due to frequent drought occurrences and this has had severely negative impacts on the livelihood and food security-especially for rural communities.

In developing countries, rain-fed grain yields are on the average, 1.5 t ha^{-1} compared with 3.1 t ha^{-1} for irrigated yields, and increase in production from rain-fed agriculture has mainly originated from land expansion [2]. To identify management options for upgrading rain-fed agriculture, it is essential to assess different types of water stress in food production. Especially important is distinguishing between climate- and human-induced water stresses and between droughts and dry spells. In semi-arid and dry sub-humid agro-ecosystems rainfall variability can generate dry spells (short periods of water stress during critical growth stages) almost every rainy season. However, when rainfall is scarce, supplemental irrigation can increase yields significantly compared with completely rain-fed systems, and in arid regions this increase can be substantial [3].

Based on health impact from wastewater, the World Health Organization (WHO) classified irrigation into three distinct categories: flood and furrow, spray and sprinkler and localized irrigation methods [3]. Flood and furrow irrigation (FI) methods apply water on the surface and pose the highest risks to field workers, especially when protective clothing is not used [4]. Spray and sprinkler are overhead irrigation methods and have the highest potential to transfer pathogens to crop surfaces, as water is applied to edible parts of most crops and because aerosol borne pathogens are carried further. Localized techniques, such as drip-and-trickle irrigation present the lowest risk to farmers and cause minimal pathogens transfer to crop surfaces because water is directly applied to the root [5]. This is one of the best techniques that can be used in applying water to home landscapes, gardens and orchards. However, it is prone to clogging because of the turbidity of polluted water [6]. Martijn and Redwood [7] in their work on assessment of the effects of irrigation methods on crop performance in *Nguruman* irrigation scheme, reported that basin irrigation method had the highest yield (5.6 t ha^{-1}), followed by border strip and furrow, which had 5.0 t ha^{-1} and 4.2 t ha^{-1} respectively. Drip irrigation method had the lowest yield of 190 kg ha^{-1}. They stated that the poor performance of drip method was attributed to clogging of the drip nozzles by small particles in the irrigation water.

Recently, cheap bucket drip kit with better potential for use in low income countries are now being developed [8]. This is a controlled, slow application of water to the soil. The water flows under low pressure through plastic pipe or hose laid along each row of plants. Water drips into the soil from tiny holes called orifices which are either precisely formed in the hose wall or in fitting called emitters that are plugged into the hose wall at specified spacing.

Ibragimov et al. [9] conducted an experiment in okra under drip irrigation and reported high yield (4188 kg ha^{-1}) and water use efficiency (8.23 kg ha^{-1} mm^{-1}). According to the study of, drip irrigation system consistently increased tomato yields (11-80%) due to high water use efficiency [10]. Zotareli [11] reported that the yield obtained for the duration of 15 and 30 minute drip irrigation treatment and basin irrigation was 15.2, 15.1 and 10.8 t ha^{-1}, respectively. The maximum water use efficiency of okra for 15 minute drip irrigation duration was 705.2 kg $^{-1}$ ha^{-1} cm^{-1}. The water saving was 60% by adopting drip irrigation compared to basin irrigation.

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Okra (*Abelmoschus esculentus* L. Moench) is a fast growing and highly nutritional crop that is commonly grown in the tropics mainly for its pod fruits. It is a good source of calcium, derived from fruits and leaves, 90 mg per 100 g and 70 mg per 100 g respectively. The secondary use is the oil from its seeds, which is about 20% of the seed content. The objective of the study was to compare the growth and yield of okra under drip and watering-can methods of irrigation.

Materials and Methods

Experimental site

The experiment was conducted at the Teaching and Research Farm of the University of Ibadan, Nigeria. Ibadan lies between latitudes 7°25′ to 7°31′ N and longitudes 3°51′ to 3°56′ E. The site has a mean altitude of 180-190 m above sea level. The experiment was a randomized complete block design (RCBD), with bucket drip kit and watering-can methods of irrigation as treatments replicated four times. Growth and yield data were analysed using analysis of variance and simple correlation.

The drip system was laid out to supply water, each having 3 drip lines (laterals), measuring about 35 m. The bucket which served as a reservoir for the drip system was placed 1 m high on a table to allow for flow of water by gravity to the plants through the network of pipe.

Each lateral had 10 slits which allow for supply of drops of water to the plants in rows as presented in Figure 1. Plant spacing of 30 cm within row and 45 cm between rows was used. Soil samples were collected randomly from different spots at 0-30 cm depth bulked together and analyzed before planting to ascertain the base line properties. The bulked sample soil was analysed for physical and chemical parameters such as pH, exchangeable acidity, exchangeable bases, heavy metals, and particle size distribution as described by Vincent et al. [12]. Change in soil moisture was monitored with the aid of tensiometer in the first season. The measurements of okra growth parameters such as number of leaves, plant height, and stem diameter began at 2 weeks after planting to fruition. This was done on a weekly basis. Number of fruits per plant and fresh fruit weight on weekly basis were also determined. Data collected were subjected to analysis of variance (ANOVA) using SPSS 16.0 and where the F-value was found to be significant, the means were separated using LSD.

Results and Discussion

Properties of the soil and irrigation water

The result of the pre-cultivation analysis of the soil of the experimental plot is presented in Table 1. The soil has an organic carbon content of 17.86 g kg^{-1} and total nitrogen content 0.85 g kg^{-1}. It is a slightly acidic soil with a pH of 6.20. Available phosphorus, manganese and zinc are in adequate amounts of 7.81 mg kg^{-1}, 98.30 mg kg^{-1}, and 10.23 mg kg^{-1} respectively with a sandy loam texture. The result of the water analysis is presented in Table 2. This showed that the water used for irrigation belonged to Class 1, excellent, non-saline water because it has EC of < 5 dS/m and TDS of < 500 mg/l [2]. The average soil water retained under BDK irrigated plot was higher than under WC irrigated plot by 10.3%, indicating that soil under drip irrigation absorbed and retained more water for crops to use than soil irrigated with watering can. Figure 5 shows the mean water use efficiency for drip irrigation

Figure 1: Components of a drip system showing the reservoir, the supply tube, the header tape and the laterals line beside the okra on the field.

Parameter	Content (2011)	Content (2012)	Critical values (FAO 2012)
pH (water)	6.2	6.5	6.5-7.5
Organic Carbon (g kg^{-1})	17.86	4.0	10-15
N (g kg^{-1})	0.85	1.0	1.0-1.5
P (mg kg^{-1})	7.81	12	10-20
Exchangeable Bases (cmol kg^{-1})			
Ca	1.41	0.9	2.0-5.0
Mg	0.7	0.9	0.3-1.0
Na	0.8	0.6	0.6
K	0.71	0.4	0.15-0.3
Exchangeable Acidity (cmol kg^{-1})	0.2	0.2	0.1-0.5
Exchangeable micronutrients (mg kg^{-1})			
Mn	98.3	24.8	20-25
Fe	36.3	26.8	20-25
Cu	1.69	2.0	1.2-2.0
Zn	10.23	10.0	1.0-5.0
Sand (g kg^{-1})	792	800	850
Clay (g kg^{-1})	128	130	50
Silt (g kg^{-1})	80	70	100
Textural class	Sandy loam	Sandy loam	

Table 1: Soil physical and chemical properties of experimental site prior to sowing.

Elements	Quantity	Critical value (FAO, 2012)
Ca (mg/l)	40.9	60.0
Mg (mg/l)	8.7	20.0
K (mg/l)	13.7	20.0
Na (mg/l)	43.0	70.0
Mn (mg/l)	0.2	0.2
Fe (mg/l)	0.1	0.3
Cu (mg/l)	0.003	0.3
Zn (mg/l)	0.2	2.0
Cd (mg/l)	0.01	0.01
Co (mg/l)	0.1	0.05
Cr (mg/l)	0.0	0.1
Pb (mg/l)	0.5	5.0
Ni (mg/l)	0.2	0.2
pH	7.6	6.5-8.4
EC (dS/m)	0.3	5.0
HCO_3^- (mg/l)	26.8	60.0
SO_4 (mg/l)	0.74	100.0
Cl (mg/l)	73.6	70.0
SAR	8.6	10.0
TSS (mg/l)	214.6	500.0
TDS (mg/l)	211.2	200-4000

Table 2: Irrigation water analysis.

across the three planting seasons to be 0.49 kg/l while that of watering can was 0.32 kg/l.

Seed germination

The higher rate of seed germination was recorded under drip irrigation for the first two growing seasons as presented in Table 3. Although, there was no significant difference in the germination percentage, drip irrigated plots were higher in seed germination percentage than watering can irrigated plots by 2.20% and 4.40% respectively for first and second growing seasons. This was most probably because the amount of water flowing from the drip nozzle was completely utilized by the sown seeds without any waste as a result of direct discharge of water at the planted spot in form of droplets for easy absorption by the soil.

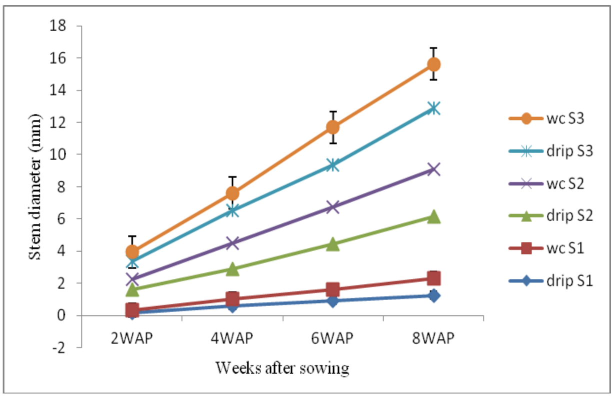
Crop performance

The mean plant height of okra under drip and watering can irrigation for the three growing seasons is presented in Figure 2. In the first season, okra plant height obtained from drip irrigated plots was significantly (P = 0.05) higher than plants irrigated with watering can from 4WAS to 8WAS. On the average, drip irrigated okra plants were higher than watering can irrigated plants by 28.8 cm in the first season. The same trend was followed for the remaining two growing seasons. The result justified the fact that the water supplied was available for okra plants under drip irrigation to utilise maximally since water was discharged directly to the base of the plants at low pressure. Also, drip irrigation probably kept the root zone at the field capacity; therefore there was no shortage of water for the physiological functions of the plant. IITA reported that the heights of okra under the surface and drip were 87 and 90 cm, respectively [13]. They attributed this to availability of water for the physiological functions of the plants under drip irrigation system. The mean stem girth and number of leaves for various weeks were consistently higher under the drip method than watering can method of irrigation for three consecutive growing

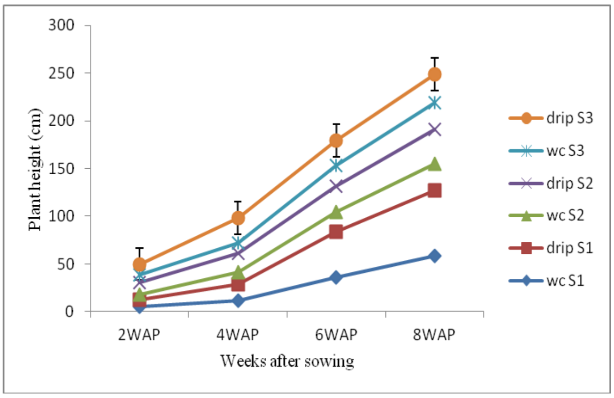
Treatment	Soil moisture potential (bars)	% germination		
	Season 1 (2011)	Season 1	Season 2	Season 3
Drip	0.43a	88.90	94.4a	95.55a
Wc	0.35a	86.70a	90a	95.55a

Means with the same alphabet(s) in the same column are not significantly different at P = 5%

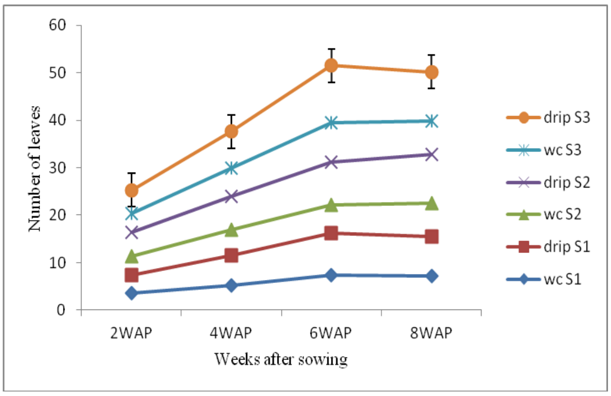
Table 3: Effects of bucket drip kit and watering can methods of irrigation on soil moisture and percentage of plant survival.



S1: Season 1, S2: Season 2, S3: Season 3, WC: Watering can, Drip: Drip kit
Figure 2: Okra stem diameter as influenced by drip and watering can irrigation methods for three growing seasons.



S1: Season 1, S2: Season 2, S3: Season 3, WC: Watering can, Drip: Drip kit
Figure 3: Okra plant height as influenced by drip and watering can irrigation methods for three growing seasons.



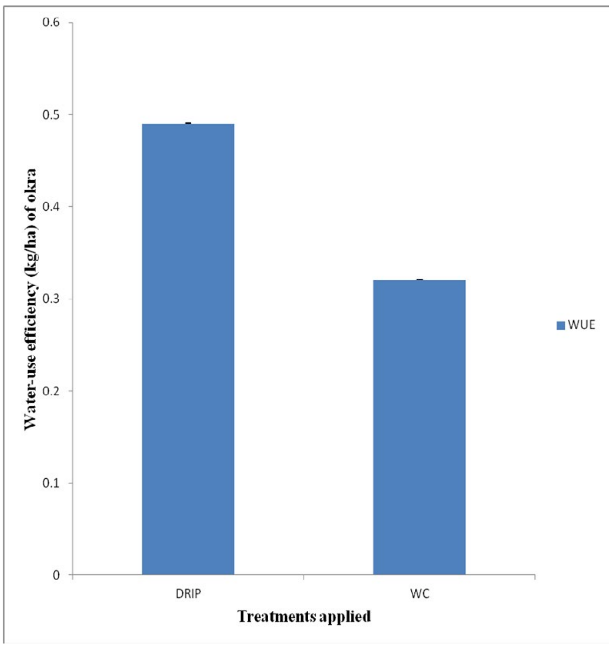
S1: Season 1, S2: Season 2, S3: Season 3, WC: Watering can, Drip: Drip kit
Figure 4: Okra number of leaves as influenced by drip and watering can irrigation methods for three growing seasons.

seasons as shown in Figures 3 and 4 respectively. Averagely, the number of okra leaves obtained from drip irrigated plots was significantly (p = 0.05) higher than those from plots irrigated with watering can method by 14.2%, 28.7% and 27.6% respectively for the first, second and third seasons. This implies that number of leaves available for photosynthesis under drip irrigation were higher than watering can irrigated plants, which could determine to a large extent the assimilates for growth and yield. Similar results were reported by Singh and Rajput [14] that plants grown under drip irrigation had more number of branches and plant heights compared to that of surface irrigated plants. They stated that the above ground matter that included stem diameter had positive significant correlation with yield under drip irrigation (0.99^{**}). It was concluded that the carbon dioxide exchange rates varied considerably under the different methods of irrigation due to difference in irrigation timings and quantity of water applied. On the average basis, the stem diameter of okra plants from drip irrigated plots was consecutively and significantly higher than those of the plants irrigated with watering can by 12.1%, 12.8% and 16.8% respectively for the first, second and third growing seasons of 2011 and 2012. Although, there was no difference between the two methods of irrigation in terms of number of okra fruits in the first season of year 2011, however significant higher number of okra fruits was obtained from drip irrigated plots compared with plots irrigated with watering can in the subsequent seasons (Table 4). In the second and third growing seasons, drip irrigated plots had higher number of fresh okra fruits than plots irrigated with watering can by

Treatment	Number of fruits/ha			Fresh fruit weight (t ha^{-1})		
	Season 1	Season 2	Season 3	Season 1	Season 2	Season 3
Drip	518,518a	666,666a	888,888a	0.89a	3.03a	12.51a
Wc	518,518a	394,814b	790,369b	0.78a	1.98b	5.1b

Means with the same alphabet(s) are not significantly different. P = 5%

Table 4: Okra yield as influenced by drip and watering can irrigation methods for three growing seasons (2011-2012).



WC: Watering can, Drip: Drip kit

Figure 5: Mean water-use efficiency of okra across three planting seasons.

271, 852 and 98, 519 fresh fruits per hectare, respectively. The total fresh fruit weight obtained from drip was higher than that of watering-can irrigated plots for the three growing seasons as presented in Table 4. Higher significant fresh okra fruit weight was obtained under drip irrigation than watering can method in the second and third season by 1.1 t ha^{-1} and 7.4 t ha^{-1}, respectively. This is because drip irrigation provides a consistent supply of water to the entire root area on a continuous basis so that "drench and dry-out" stresses are reduced. This is in agreement with the findings of Anthony and Singandhupe [15], who reported that yield increase for okra under BDK irrigation by 20.69% with the water saving of 44.92%. This result also supports Saxena and Gupta [16], who reported that plants receiving drip irrigation had significantly higher yield than furrow and basin for okra.

Conclusion

The findings obtained from this work showed that plant growth parameters and yield were greater with bucket drip kit irrigation as compared to the watering-can method. The difference observed between plant growth parameters under both methods of irrigation indicated the greater water use efficiency by bucket drip kit irrigation over the watering can, as drip irrigation delivers water close to the plant or only to the soil-plant vicinity. The drip system also has the tendency to make large quantity of water available to the plants gradually such that there will be no runoff and deep percolation. The effect is higher percentage germination and plant survival as compared to the watering-can method. Although bucket drip kit irrigation can be tedious in its installation as compared to the watering can, it saves time, energy, labour and water during the process of water supply to plants after the drip lines have been laid out. The drip kit irrigation is highly affordable for subsistence farming for sustainability of livelihood.

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