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YIELD, WATER PRODUCTIVITY AND ECONOMIC RETURN OF DEFICIT-DRIP-IRRIGATED TOMATOES IN KADUNA (NIGERIA)

Donatus Obiajulu Onwuegbunam[1*], Muyideen Abubakar Oyebode[2], Henry Evonameh Igbadun[2] and Habibu Ismail[2]

[1]Department of Agricultural and Bio-environmental Engineering, Federal College of Forestry Mechanization, Afaka, Kaduna; Forestry Research Institute of Nigeria
[2]Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria, Nigeria

Abstract: Compared to gravity flow systems, pressurized drip irrigation provides more efficient control of the amount of water applied, better irrigation uniformity, and a higher initial capital and operation costs. Hence, an economic analysis is required to determine its profitability over a projected time period. Field experiments were conducted in Afaka (Kaduna, Nigeria), during two dry seasons of 2018 and 2019 to determine the effect of regulated deficit irrigation on the yield, crop water productivity, and projected economic returns of UC 82B tomatoes under pressurized drip irrigation. The economic returns were evaluated using the benefit-cost ratio, net present values, and payback period analyses. The highest fresh fruit yield (19.0 t/ha) was obtained in the full irrigation treatment (T_1), while the highest crop water productivity (4.94 kg/m^3) was obtained in the deficit treatment with full irrigation at the vegetative and flowering stages followed by 60% of reference evapotranspiration at maturity (T_7). The project was found to be profitable over the projected years, with benefit-cost ratios of 1.90 and 1.69; payback periods of 2.7 and 3.2 years for T_1 and T_7, respectively. The full irrigation of tomatoes was therefore found to be more economical than deficit irrigation in the area, with water not being considered as a limiting factor in terms of costs. Gravity drip irrigation was recommended to reduce the pumping cost of irrigation and thereby increase the profit margin.

Key words: drip irrigation, tomato, yield, water productivity, economic return, Nigeria.

Introduction

Water stands out as the most dominant among the limiting factors for crop production and diversification. Water has been described as a limited resource and

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*Corresponding author: e-mail: donancy2001@yahoo.com

with the increasing world population and diverse use of water for domestic, agricultural, urban, and industrial purposes, there is a competing demand for its use among these variables (Kuşçu et al., 2009; FAO, 2019). Globally, water consumption is estimated to have increased more than twice as fast as the population in the last century, and the number of regions reaching the limits of sustainable water supply is increasing (UN-Water, 2021). Almost 70 percent of all water withdrawals are used in farming; with up to 95 percent in some developing countries. Hence, we need to use our water resources more wisely over time (FAO, 2019) and water has to be treated as a scarce or limited resource, with a much stronger focus on how its demand should be managed (UN-Water, 2021).

Essentially, for better water resource utilization at the farm level, an irrigation scheduling criterion should be applied so that the crop is irrigated at the right time with the right volume. However, under the condition of limited water supply, a so-called 'regulated water deficit' can be applied with the aim of supplying lower irrigation volumes compared to the crop water requirements during the whole crop cycle, but coinciding with some particular phenological stages that are the most sensitive to water stress (English et al., 1990; Kirda, 2002). In this way, smaller water amounts maximize the productive result (Mannini, 2004).

Kaduna State, including the study area (Afaka, Kaduna, Nigeria), is known for the cultivation of horticultural crops in the dry season through irrigation. Crops usually grown through irrigation in the area include cucumber, cabbage, carrots, tomatoes, maize, pepper, and onions (Plaisier et al., 2019) and the irrigation schemes are mostly small and medium sized.

Drip irrigation technology is relatively new in Nigeria and the Federal Government in collaboration with the Food and Agriculture Organization (FAO) of the United Nations, has considered its adoption to increase food production. In this vein, the FAO has expressed support for the promotion of a 20–25 ha pilot drip irrigation system in Nigeria through its Technical Cooperation Programme (TCP), starting with the identification of suitable sites for the project (Ewepu, 2022). The promotion also aims to provide an enabling and attractive environment to encourage more youth, smallholder farmers, and other vulnerable groups to produce high-value crops through drip irrigation. The drip irrigation project was supported by the FAO through a $350,000 grant for its promotion in Niger State, Nigeria. The funding is part of the Technical Cooperation Programme for FAO member nations (Staff Reporter, 2021).

Drip irrigation is a fixed system requiring high investment in labor and the acquisition of equipment for water collection, conveyance, control, and distribution. Hence, energy and labor costs are important factors to consider for the effective operation and management of the system. These represent significant additional costs of production. In comparison with a gravity (low pressure) drip irrigation system, the pressurized (high pressure) system provides better irrigation uniformity as well as better control of the amount of water applied through its pressure compensating emitters; water and nutrients (through fertigation) are most evenly distributed across the field irrespective of the field size, shape, or slope, thus giving every plant the first-class treatment (NETAFIM, 2021). A non-pressure-compensating drip emitter has varying output flows at varying inlet pressures, so the flow varies along uneven terrain, with each dripper emitting a different amount of water depending on its location on the supply line. In such instances, the pressure on a drip emitter varies due to the slope of the land and the length of the supply tube (Drip Depot, 2018). Although the high-pressure drip system is necessary for the development of precision agriculture, it requires a higher initial capital cost than gravity drip systems.

The choice of pump power to run a high-pressure drip irrigation system depends on how available and accessible the energy resources are in an area. Electricity is mostly preferred because it has reduced labor requirements and higher efficiency, and results in lower energy costs (NETAFIM, 2015). However, when electricity is unavailable or irregular (as is the case in the study area), alternative power sources such as gasoline, diesel, or solar may be used. Generally, the challenge with electricity supply in Nigeria is so serious that fossil fuel generators power about thirty percent of micro, small, and medium enterprises (Omorogbe, 2021). The smallholder irrigation farmers in the study area use gasoline engine pumps for irrigation, but this is not adequate for large-scale farms requiring a larger pump capacity (greater than 10 hp); diesel engine pumps have to be employed to meet the higher power requirements (NETAFIM, 2015). Hence, the cost estimation for a hectare of field in the study location is based on diesel as the pump power source.

An economic analysis is required to determine whether the improved performance of the pressurized system justifies its use in terms of returns on investment. That is, an economic evaluation estimating all the expected annual or seasonal expenditures and returns in the irrigation project is required as an indicator of whether the implementation of the irrigation system is worthwhile (Letey et al., 1990; Silva et al., 2003). Generally, there is no information on the economic viability of drip irrigated tomatoes for the study area. The objectives of this study are to evaluate the yield, water productivity and economic returns of field-grown drip-irrigated tomatoes in response to full and deficit irrigation regimes.

Material and Methods

Study area

The study was carried out at the experimental farm of the Federal College of Forestry Mechanization, Afaka, Kaduna, located at latitude $10^0$36‘N and longitude

$07^0 25$'N. The climate of Kaduna is characterized by a clear distinction between the dry and rainy seasons. The rainy season lasts from mid-April to early October. Kaduna has an annual mean rainfall of 1200 mm (Onwuegbunam et al., 2018). The temperature range is 28–36^{0}C for the maximum scale and 15–23^{0}C for the minimum scale. The harmattan is at its peak between December and February and the relative humidity is very low. Thereafter, the weather is hot in March and April, with March recording the highest mean temperature of 35^{0}C (Onwuegbunam et al., 2018). The humidity ranges from 24% to 83%, with the lowest occurring in February and the highest in August (NIMET, 2015; KSWB, 2015).

Experimental procedures

The research was carried out as growth stage-based deficit irrigation trials in the 2017/2018 and 2018/2019 irrigation seasons. The trial spanned from December 12 to March 11 in both seasons. The experiment was laid in a randomized complete block design and replicated three times. The experimental factor is the level of deficit irrigation applied at three crop growth stages as described in Table 1.

The inter-row spacing was 0.55 m while the intra-row spacing was 0.457 m. The intra-row spacing (between the plants along the row) fitted into the spacing between emitters on the lateral. The field layout comprised ten plots (each representing a treatment), which were replicated three times. Each plot was of dimensions 5 m by 1.1 m, and hence, 5.5 m^2 per block (replication). This spacing resulted in an approximate plant density of 40,000 plants/ha, as recommended by FAO (2013).

Irrigation system

Irrigation was carried out by means of a pressurized drip irrigation system with an average discharge of 2.44 l/hr, an emission uniformity of 94% and an optimum operating pressure of 240 kPa. The water source for the irrigation system was fresh water from a borehole within the site. A gasoline-powered centrifugal water pump was used in powering the irrigation system.

The drip irrigation running time for administering water according to the treatments was expressed by Kumari et al. (2014) in the form:

$$T_{drip} = \frac{N_p V}{N_e Q \times EU} \tag{1}$$

where T_{drip} = drip irrigation time (hours), Np = number of plants served by one lateral, V = volume of water applied per plant in drip irrigation system (l), Ne = number of emitters in one lateral, Q = average emitter discharge (l/hr), EU = emission uniformity (fraction).

Table 1. Treatment descriptions.

Treatment number	Treatment tag	Treatment descriptions
T_1	$V_{100}F_{100}M_{100}$	Full irrigation (100% ET_o) at all crop growth stages (control)
T_2	$V_{80}F_{100}M_{100}$	Irrigating with 80% ET_o at vegetative stage, full irrigation at flowering and maturity stages
T_3	$V_{100}F_{80}M_{100}$	Irrigating with 80% ET_o at flowering stage, full irrigation at vegetative and maturity stages
T_4	$V_{100}F_{100}M_{80}$	Irrigating with 80% ET_o at maturity stage, full irrigation at vegetative and flowering stages
T_5	$V_{60}F_{100}M_{100}$	Irrigating with 60% ET_o at vegetative stage, full irrigation at flowering and maturity stages
T_6	$V_{100}F_{60}M_{100}$	Irrigating with 60% ET_o at flowering stage, full irrigation at vegetative and maturity stages
T_7	$V_{100}F_{100}M_{60}$	Irrigating with 60% ET_o at maturity stage, full irrigation at vegetative and flowering stages
T_8	$V_{40}F_{100}M_{100}$	Irrigating with 40% ET_o at vegetative stage, full irrigation at flowering and maturity stages
T_9	$V_{100}F_{40}M_{100}$	Irrigating with 40% ET_o at flowering stage, full irrigation at vegetative and maturity stages
T_{10}	$V_{100}F_{100}M_{40}$	Irrigating with 40% ET_o at maturity stage, full irrigation at vegetative and flowering stages

Field experimental design (2017, 2018)

Water productivity

The water productivity (WP) was expressed as the crop output (yield) per unit of water consumptively used (Ragab, 2017; Igbadun et al., 2012; Talukder and Ali, 2008):

$$WP = \frac{Y}{SCWU} \tag{2}$$

where WP = crop water productivity (kg/m^3), SCWU = seasonal crop water use (mm), Y = fruit yield (t/ha).

Economic considerations

The economic returns of the drip-irrigated tomatoes were evaluated in terms of the benefit-cost ratio (BCR), net present value (NPV), and payback period (PBP). The analyses were based on the comparison between the full irrigation treatment (control) and the deficit irrigation treatment, which had the highest value of water productivity.

The production cost comprised the initial investment in procuring the irrigation equipment and the costs for the system operation and maintenance. The various costs considered relate to land rent, land preparation, repairs and maintenance, scheduled irrigation durations, seeds (seedlings), transplanting, fertilizer application, weeding, pest control and harvesting. Water charges were estimated as the cost of installing the borehole for water supply and subsequently, the pumping energy requirement. The repair and maintenance cost was estimated as a percentage (4%) of the total capital cost. Kuşçu et al. (2009) and Cetin et al. (2004) used values of 3% and 6% of total system cost for repair and maintenance, respectively.

The pumping energy determined the amount of fuel consumed in powering the irrigation system. For the pressurized system, the pumping energy cost was determined as a function of the pump brake horsepower needed to discharge the design volume for the irrigated area. Harrison (2012) and Scherer (2017) expressed the pump brake horsepower as follows:

$$BHP = \frac{Q \times TDH}{3960 \times E_p} \tag{3}$$

where BPH is the brake horsepower, Q is the total discharge, TDH is the total dynamic head, and E_p is the pump efficiency (= 0.75).

The total dynamic head of the pump is the sum of the total static head, the pressure head, and the velocity head. For the source borehole, the total static head is the distance from the pumping water level in the well to the ground surface, plus the vertical distance of lift of the water to the discharge point (irrigated area). The pressure head is the optimum operating pressure of the pressurized drip irrigation system, converted into a head (m). The velocity head is the energy of the water based on its velocity. Its value is very small and negligible when computing the losses in an irrigation system (Scherer, 2017).

For each treatment, the seasonal fuel consumption is calculated based on the total irrigation time, which was determined by the seasonal water applied. The fuel consumed per unit time of design pump use as expressed by Martin et al. (2011) and Harrison (2012) is as follows:

$$C_f = \frac{EPS}{BHP} \tag{4}$$

where C_f is the fuel consumed (gal/hr), EPS is the fuel energy performance efficiency (hp-hr/gal), and BPH is brake horsepower (hp).

EPS values are given as 12.5 hp-hr/gal and 8.66 hp-hr/gal for diesel and gasoline, respectively (Martin et al., 2011; Harrison, 2012). Hence, the seasonal fuel consumption is as follows:

$$C_f \times IT_{seasonal} \tag{5}$$

where $IT_{seasonal}$ is the seasonal irrigation time per treatment (hr).

Benefit-cost ratio

The benefit cost ratio (BCR) is obtained by dividing the present value of the benefits by the present value of the costs (Savva et al., 2002; Michael, 2009):

$$BCR = \sum_{t=1}^{n} \left[\frac{\frac{B}{(1+r)^i}}{\frac{C}{(1+r)^i}} \right] \tag{6}$$

where BCR = benefit-cost ratio, n = number of years of anticipated project life, i = discount rate selected on the basis of cost of capital, r = interest rate, B = benefits accrued, C = costs incurred.

The discount rate i was determined as follows:

$$i = \frac{1}{(1+r)^{\,n}} \tag{7}$$

where the terms are defined as above.

Returns on the produce were based on a prevailing market price of \$0.51 per kg on a fresh fruit basis in 2018 and 2019. The interest rate used in the study was 11% and was based on an 11-year average interest rate of 10.81% between 2007 and 2018 in Nigeria (CBN, 2018). The capital and operating costs for the project were stated on a per hectare basis.

It has been recommended that using the BCR alone may not be sufficient to determine how profitable a project is and therefore other forms of financial analysis must also be used to make better financial decisions (FundsNet, 2022).

Net present value

The worth of the project is estimated by subtracting the costs from the returns on a year-to-year basis to obtain the net return stream (cash flow). This is then discounted to the present values, which are added over the project life period to obtain the net present value or worth. The net present value is estimated as follows (Michael, 2009):

$$NPV = \sum_{t=i}^{n} \frac{B_t - C_t}{(1+i)^t} \tag{8}$$

where B_t = benefit estimated for each year of the project, \$; C_t = cost estimated for each year of the project, \$; t = time period of project life, that is, 1, 2, 3 … n; n = number of years of the anticipated project life; i = discount rate based on the cost of capital.

Payback period of the investment

The payback period is the time it takes the cash flow of a project to pay back the initial investment. A discounted payback period is used to take into account the depreciation of the project assets. The discounted payback period shows the period in which an investment reaches its break-even point, considering the time value of money. The discounted payback period (Discounted payback period: method and example, 2017) is computed as follows:

$$DPP = LPNC + \frac{AVC}{DCD} \tag{9}$$

where DPP = discounted payback period (year); LPNC = last period with a negative total discounted cash flow (year); AVC = absolute value of the total discounted cash flow at the end of LPNC ($); DCD = discounted cash flow during the period after LPNC ($).

Results and Discussion

The yield and water productivity (WP) for all the treatments are shown in Table 2. The pooled WP in terms of crop water use varied between 3.61 kg/m^3 and 4.94 kg/m^3. The WP showed significant differences among the treatments, with the highest occurring in T_7, which is, the application of 60% ET_o irrigation amount at the maturity stage, and 100% ET_o at both vegetative and flowering stages. The WP values obtained in several studies on tomatoes showed a wide range of results, depending mainly on the cultivar type, yield values, amount of water applied, amount of water consumptively used, and the irrigation practice adopted. The WP values are within the range (4.2–13.4 kg/m^3) obtained by Singh et al. (2009) for the Rupali cultivar with a yield of 13.70 to 29.90 t/ha under SWA of 337 to 700 mm in Abohar, Punjab, India. Tya and Othman (2014) obtained a WP range of 0.32 to 0.85 kg/m^3 for the pevabo tomato cultivar (determinate type) with a fresh fruit yield range of 9.3 to 14.2 t/ha and seasonal irrigation application depths of 1360 to 3080 mm under a basin irrigation system at Yola, the ecological savanna zone of Nigeria.

Table 2. The yield, crop water use and water productivity of drip-irrigated tomatoes.

Treatment	Y (t/ha)	CWU (mm)	WP (kg/m^3)
T_1 ($V_{100}F_{100}M_{100}$)	19.0a	393.5a	4.82c
T_2 ($V_{80}F_{100}M_{100}$)	18.4b	388.0b	4.74d
T_3 ($V_{100}F_{80}M_{100}$)	18.1c	377.0c	4.80cd
T_4 ($V_{100}F_{100}M_{80}$)	17.6d	360.5e	4.88b
T_5 ($V_{60}F_{100}M_{100}$)	17.9cd	368.0d	4.86bc
T_6 ($V_{100}F_{60}M_{100}$)	17.6d	358.0e	4.92ab
T_7 ($V_{100}F_{100}M_{60}$)	16.8e	339.5f	4.94a
T_8 ($V_{40}F_{100}M_{100}$)	16.3f	335.5g	4.87b
T_9 ($V_{100}F_{40}M_{100}$)	15.6g	325.5h	4.79cd
T_{10} ($V_{100}F_{100}M_{40}$)	11.0h	305.0i	3.61e
SE±	0.7219	8.9779	0.1252

Y is the fresh fruit yield (t/ha); CWU is the crop water use (mm); WP is the water productivity (kg/m^3).

The economic analyses of the drip-irrigated tomatoes were based on a comparison between the deficit treatment with the highest water productivity, that is T_7, and the fully irrigated treatment, T_1. The pooled mean annual benefit-cost ratios (BCRs) for the two irrigation seasons are presented in Table 3 for T_1, T_7, and T_{7+}; T_{7+} being a re-designation of T_7 to depict the extra yield and the additional irrigated land with the water saved. The BCR values for T_1, T_7, and T_{7+} were 1.90, 1.69, and 1.74, respectively, showing that the investment in pressurized drip irrigation of UC 82B tomatoes in Afaka (Kaduna, Nigeria) was profitable following each of the irrigation strategies; the BCR was higher than 1. This means that for every \$1 invested in the drip irrigation project, there was a discounted profit value of \$1.90, \$1.69 and \$1.74 for T_1, T_7 and T_{7+}, respectively. T_1 gave the highest BCR compared to T_7 and T_{7+}, regardless of the additional yield from the water saved in T_7. The reason for this was the additional capital cost of procuring drip irrigation units to cater for the extra land cultivated with the water saved. The cost of procuring the additional drip irrigation unit (\$3,765) was higher than the cash inflow from the yields of the additional cultivated land (\$1,387) in T_{7+} with the water saved. The gain from the additional land cultivated with the water saved (1,146 m^3) was 4.2 tons, an economic gain that was not significant for the cash outflow. It was, therefore, inferred that economic returns on pressurized drip irrigation were higher under full irrigation than deficit irrigation in the study area. Tewelde (2019) obtained a similar outcome when evaluating the economic water productivity of sesame crops under full and deficit irrigation in Woreda Kafta-Humera, Tigrai-Ethiopia, with full irrigation having the highest economic returns in comparison to deficit treatments.

Table 3. Benefit-cost ratio analysis of drip-irrigated tomatoes for a 10-year project period.

Cost parameters	Treatment		
	T_1	T_7	T_{7+}
Capital cost (\$)	19261	19261	23026
Operation and maintenance cost (\$)	26444	25871	31962
Cash outflow (\$)	45705	45131	54988
Cash inflow (\$)	103749	91500	114415
Interest rate (%)	11	11	11
Discounted cash outflow (\$)	32291	31967	38800
Discounted cash inflow (\$)	61374	54128	67684
Benefit-cost ratio	1.90	1.69	1.74

However, the experiment involved non-conventional irrigation methods and made use of jars, bottles and large collectors. Adeboye et al. (2015) evaluated the economics of drip-irrigated soybeans in Ile-Ife, Nigeria and obtained the highest economic water productivity under full irrigation as a reference treatment. This suggests that while deficit irrigation has proved to be the most viable option in water-scarce regions, its use is not economically justifiable in areas where water is not a limiting factor and the water price is relatively low.

The results generally showed that pressurized drip irrigation of tomatoes was profitable in the study area. As stated by Adeboye et al. (2015), a low-income farmer can benefit from the use of high cost (imported) drip lines, but if the drip irrigation system is properly maintained, it will be continuously used for crop production after several years. Local production of drip lines is necessary to avoid the high costs of importation. Also, the gravity drip irrigation system eliminates the cost of operating and maintaining the pumps, except for the lifting of water to the supply reservoir. The system is recommended for crops of higher economic value because of the high initial costs. Cetin et al. (2004) recommended a drip irrigation system for crops with higher economic value such as apples, as all growers of drip irrigated apples in the Inegöl district of Bursa province, Turkey reported positive returns despite relatively high initial investments.

Net present value analysis and payback period

The net present values (NPVs) for the drip irrigation project on a per hectare basis were computed over the system's service life. The NPV and payback period (PBP) for the fully irrigated and deficit irrigated treatments are presented in Tables 4, 5 and 6. T_1 gave a payback period of 2.7 years with a corresponding NPV of \$1,966 and a cumulative NPV of \$29,083 at the end of the projected service life of the irrigation system. A regression analysis of the discounted cash flows over the system's service life, given by Equation 10, showed that the cash flow would cease in the 14th year, that is, four years after the useful life of the system.

$$Discounted\ cash\ flow = -214359 * year + 3 * 10^6 \tag{10}$$

On the other hand, the deficit treatment (T_7) gave a payback period of 3.2 years with a corresponding NPV of \$4,088 and a cumulative NPV of \$22,158 at the end of the projected system's service life. Similar to equation (10), the cash flow would cease in the 11th year, that is, one year after the useful life of the system.

$$Discounted\ cash\ flow = -186231 * year + 2 * 10^6 \tag{11}$$

The full irrigation treatment produced better economic returns in terms of the net present values and payback periods than the deficit treatments. It can be concluded that the full irrigation of tomatoes was preferred in the study area, as the water saved in deficit irrigation, which was used for extra cultivation, did not produce yields that could outweigh the cash outflow for the additional cultivation.

Table 4. Pooled net present value analysis for the fully irrigated treatment (T_1).

Yr.	Capital ($)	O & M ($)	CO ($)	CI ($)	CF ($)	i, 11%	DCF ($)	Σ DCF ($)	PBP (Yr)
1	19,261	2,102	21,363	9,651	-11,712	0.9009	-10,552	-10,552	
2		2,208	2,208	10,134	7,926	0.8116	6,433	-4,119	
3		2,318	2,318	10,640	8,322	0.7312	6,085	1,966	2.68
4		2,434	2,434	11,172	8,738	0.6587	5,756	7,722	
5		2,556	2,556	11,731	9,175	0.5935	5,446	13,168	
6		2,683	2,683	11,144	8,461	0.5346	4,523	17,691	
7		2,817	2,817	10,587	7,770	0.4817	3,743	21,434	
8		2,958	2,958	10,058	7,099	0.4339	3,080	24,514	
9		3,106	3,106	9,555	6,449	0.3909	2,521	27,035	
10		3,262	3,262	9,077	5,815	0.3522	2,048	29,083	

O & M is operation and maintenance cost; CO is cash outflow; CI is cash inflow; CF is cash flow; DCF is discounted cash flow; PBP is payback period.

Table 5. Pooled net present value analysis for 1 ha of the deficit irrigated treatment (T_7).

Yr.	Capital ($)	O & M ($)	CO ($)	CI ($)	CF ($)	i, 11%	DCF ($)	Σ DCF ($)	PBP (Yr)
1	19,261	2,057	21,318	8,512	-12,806	0.9009	-11,537	-11,537	
2		2,160	2,160	8,937	6,777	0.8116	5,501	-6,036	
3		2,268	2,268	9,384	7,116	0.7311	5,203	-834	
4		2,381	2,381	9,853	7,472	0.6587	4,922	4,088	3.17
5		2,500	2,500	10,346	7,846	0.5934	4,656	8,744	
6		2,625	2,625	9,829	7,203	0.5346	3,851	12,595	
7		2,756	2,756	9,337	6,581	0.4816	3,169	15,764	
8		2,894	2,894	8,870	5,976	0.4339	2,593	18,357	
9		3,039	3,039	8,427	5,388	0.3909	2,106	20,463	
10		3,191	3,191	8,005	4,815	0.3521	1,695	22,158	

Table 6. Pooled net present value analysis for 1 ha of the deficit irrigated treatment (T_{7+}).

Yr.	Capital ($)	O & M ($)	CO ($)	CI ($)	CF ($)	i, 11%	DCF ($)	Σ DCF ($)	PBP (Yr)
1	23,026	2,640	25,666	10,643	15,023	0.9009	13,534	-13,534	
2		2,772	2,772	11,175	8,403	0.8116	6,820	-6,714	
3		2,910	2,910	11,734	8,824	0.7311	6,451	-263	
4		3,056	3,056	12,321	9,265	0.6587	6,103	5,840	3.04
5		3,209	3,209	12,937	9,728	0.5934	5,773	11,613	
6		3,369	3,369	12,290	8,921	0.5346	4,769	16,382	
7		3,538	3,538	11,676	8,138	0.4816	3,919	20,301	
8		3,715	3,715	11,092	7,377	0.4339	3,201	23,502	
9		3,900	3,900	10,537	6,637	0.3909	2,594	26,096	
10		4,095	4,095	10,010	5,915	0.3521	2,083	28,179	

Beyond the useful life, an asset is deemed to be cost-ineffective or not fit for operation or usage but it has been proved that the useful life of a system can be extended following a regular maintenance schedule as recommended by the original equipment manufacturer (ToolSense, 2022).

Conclusion

The highest water productivity of tomatoes in terms of yield per water consumptively used was obtained under deficit irrigation when the crop was irrigated with 100% ETo at the vegetative and flowering stages, then with 60% ETo at the maturity stage. However, this did not translate to higher economic returns as full irrigation treatment at all the growth stages produced the highest benefit-cost ratio and net present value as well as the lowest payback period in comparison to the deficit treatments. Full irrigation at all crop growth stages is, therefore, recommended for the study area. The economic gains from the water saved under deficit irrigation were not significant, as the cash outflow from the cultivation of extra land outweighed the cash inflow.

For higher economic returns, the pressurized drip irrigation system can be replaced by the gravity type since the energy requirement is restricted to lifting the water to the irrigation overhead storage tank, thus reducing, or eliminating the pumping costs of water application.

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PRINOS, PRODUKTIVNOST VODE I POVRAĆAJ ULAGANJA U PROIZVODNJI PARADAJZA PRI PRIMENI DEFICITARNOG NAVODNJAVANJA KAPANJEM U KADUNI (NIGERIJA)

Donatus Obiajulu Onwuegbunam[1*], Muyideen Abubakar Oyebode[2], Henry Evonameh Igbadun[2] i Habibu Ismail[2]

[1]Department of Agricultural and Bio-environmental Engineering, Federal College of Forestry Mechanization, Afaka, Kaduna; Forestry Research Institute of Nigeria
[2]Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria, Nigeria

R e z i m e

Za razliku od gravitacionih sistemima za navodnjavanje, sistem navodnjavanja kapanjem pod pritiskom omogućava efikasniju kontrolu količine vode koja se koristi u te svrhe, veći stepen ujednačenosti prilikom navodnjavanja i veće početne kapitalne i operativne troškove. Stoga je potrebno sprovesti ekonomsku analizu kojom bi se utvrdila profitabilnost ovih sistema tokom projektovanog vremenskog perioda njihovog korišćenja. Eksperimenti na terenu sprovedeni su na lokalitetu Afaka (Kaduna, Nigerija), tokom dve sušne sezone, 2018. i 2019. godine, kako bi se utvrdio uticaj regulisanog, deficitarnog navodnjavanja na prinos, produktivnost vode u usevu i projektovani povraćaj ulaganja u proizvodnju paradajza UC 82B, u uslovima navodnjavanja kapanjem pod pritiskom. Povraćaji ulaganja procenjeni su korišćenjem cost-benefit analize, metode neto sadašnje vrednosti i analize perioda otplate. Najveći prinos svežeg ploda (19,0 t/ha) dobijen je u tretmanu potpunog navodnjavanja (T_1), dok je najveća produktivnost vode u usevu (4,94 kg/m3) postignuta u deficitarnom tretmanu sa potpunim navodnjavanjem u fazi vegetacije i cvetanja, što je praćeno sa 60% referentne evapotranspiracije pri zrelosti (T_7). Utvrđeno je da je projekat profitabilan tokom projektovanih godina, sa odnosom koristi i troškova od 1,90 odnosno 1,69; sa periodom otplate od 2,7 odnosno 3,2 godine za T_1 odnosno T_7. Stoga je utvrđeno da je potpuno navodnjavanje paradajza ekonomičnije od deficitarnog navodnjavanja u ovoj oblasti, pri čemu se voda ne smatra ograničavajućim faktorom u pogledu troškova. Gravitaciono navodnjavanje kapanjem preporučeno je da bi se smanjili troškovi rada pumpe i time povećao profit.

Ključne reči: navodnjavanje kapanjem, paradajz, prinos, produktivnost vode, povraćaj ulaganja, Nigerija.

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[*]Autor za kontakt: e-mail: donancy2001@yahoo.com