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EFFECT OF WATER REGIMES AND NUTRIENT SOURCES ON CROP WATER USE EFFICIENCY AND LEAF YIELD OF INDIAN SPINACH (*Basella alba*)

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ABSTRACT

The experiment was carried out at the Department of Horticulture and Landscape Technology, College of Agriculture, Kabba, Kogi State, Nigeria, to investigate the effect of water regimes and nutrient sources on crop water use efficiency and leaf yield of Indian spinach. Treatment consisted of three water regimes: Water regime 1 (WR1) =20 litres applied once at 8 days intervals, Water regime 2 (WR2) = 10 litres of water applied at 4 days interval, Water regime 3 (WR3) = 5 litres of water applied at 2 days intervals and four nutrient sources: Nutrient Source 1 (NS1)=NPK fertiliser applied at 90 kg/ ha, Nutrient Source 2 (NS2) =poultry manure applied at 10 t/ha, Nutrient Source 3 (NS3) =cow dung manure at 10 t/ha and Zero Nutrient Source (NS0) =control. The design was a 3x 4 factorial arrangement fitted into a randomised complete block design (RCBD) with three replications. The parameters assessed were vine length, number of leaves; vine girth, shoot dry weight and crop water use efficiency. The results indicated that plots that received WR3 produced the best growth characters of Indian spinach. Numbers of leaves was highest in plots with WR3 compared to WR2 and WR1. Crop water use efficiency was highest in plots treated with WR3, followed by WR2 and the least crop water use efficiency was recorded in WR1. In terms of growth and leaf yield, plots with nutrient sources were better than the control. Plots with inorganic fertiliser (NPK 15-15-15) at 90 kg/ha) gave the highest leaf yield compared to poultry or cow dung manure. The least growth and leaf yield of Indian spinach was recorded in the control plots. Therefore, it is recommended that for optimum leaf yield of Indian spinach 5 litres of water should be applied at 2 days interval and complimented with the application of NPK fertiliser at the rate of 90 kg/ha to facilitate optimum production of Indian spinach.

Key Words: Water regime; nutrient sources; crop water use efficiency; Indian spinach

INTRODUCTION

Indian spinach (*Basella alba*), is one of the most popular indigenous vegetables in Nigeria and is commonly known as "Amunututu"among the Yoruba (Guarino, 1997). Indian spinach contains a high rate of vitamins, minerals, and antioxidants. Vitamin founds are vitamin A, vitamin C and high amounts of many B-complex vitamins such as folate, vitamin-B6 (pyridoxine), and riboflavin (Anonymous, 2013). Indian spinach is good source of iron, a micro element, required for red blood cell production. It is a good source of carotenoid pigment antioxidants such as ß-carotene, lutein, zea-xanthin that plays a healing role in ageing and various disease processes (Anonymous, 2013). It is also used for the treatment of many diseases such as dysentery, diarrhoea, anaemia, cancer etc. (Adhikari, 2012).

Drought stress is caused by water deficiency which may affect the yield and productivity of agriculture crop (Riccardi *et al*., 2016). The crop such as banana and Indian spinach requires uniform warm and moist conditions for optimum growth and yield (Ismail *et al*., 2004). Continuous declining of water resources and increase in food demand necessitate achieving greater efficiency in crop water use (Smith and Kivumbi, 2002). Water application is scheduling of when and how much water to apply to a field in order to maximise profit (Tariq and Usman, 2009). The purpose of scheduling is to maximise water application efficiencies by applying the exact amount of water needed to replenish the soil moisture. It minimises water-logging problems by reducing the drainage requirements and control root zone salinity problems through controlled leaching (Tariq and Usman, 2009).

Water use efficiency provides information about the relation between economic yield and plant water consumption (Yahya *et al.,* 2011). Crop water use efficiency is mostly used to describe irrigation effectiveness in terms of crop yield (Temesgen and Tasisa, 2020). Improvement in water use efficiency can be achieved through the development of proper water application scheduling techniques. (Bekele and Tilahun, 2007). Research has shown that farmers apply on average, twice the consumptive use of crops (Sani *et al*., 2008). Over application of water is dangerous and harmful to crops because it retards proper growth and subsequent yield (Sani *et al*., 2008). Many research works indicated that the best yield of crops such as maize was obtained by adopting the conventional 7 day interval (Mani and Dadari, 2003). The increase in irrigation frequency may result in an unacceptable increase in depth of water applied, a corresponding decrease in water use efficiency and consequent drainage problems as a result of high water table (FAO, 2013).

Both organic and inorganic fertilisers can be used in the production of crops, and each type has its own associated benefits. Organic fertilisers, such as farmyard manure and poultry or goat manure, can improve soil structure by enhancing aggregation, which can modify soil physical properties such as water holding capacity (Liang *et al*., 2009). Adding organic manure to soil can also lead to a reduction in pH and faster infiltration rates (Liang *et al*., 2009). Studies have shown that organic manure can improve crop productivity and increase farmers' income, especially in areas with soil degradation that has led to food shortages (Ouédraogo *et al*., 2001). Inorganic fertilisers, on the other hand, have been shown to improve crop yields and increase farmers' income through the efficient and rapid provision of essential nutrients for plant growth (Kim *et al*., 2010; Kibrom *et al*., 2015). They can also help to balance soil nutrients and pH, improving soil fertility and structure (Kim *et al*., 2010; Kibrom *et al*., 2015). Despite the benefits of Indian spinach, production of this vegetable has not been a viable option to farmers in the study area. There is the need to evaluate the potentials of different nutrient sources and the effect of water regimes to determine the productivity of Indian spinach. Therefore, the study is to investigate the effect of water regimes and nutrient sources on crop water use efficiency and leaf yield of Indian Spinach.

MATERIALS AND METHODS

The experiment was carried out at the Department of Horticulture and Landscape Technology, College of Agriculture, Kabba. The Indian spinach seed was procured at Ojafirade market, Kabba. Poultry droppings and cow dung were collected from the livestock section of the college. Kabba lies between latitude 7° 52'N and 7° 34'N longitude 6° 02'E and 7°42'E in the Guinea Savannah Agro-ecological zone of Nigeria. The area experiences a tropical climate with marked wet and dry seasons, high temperature joined with high humidity. Rainy season spans over seven months from mid-March or early April to October. The mean annual rainfall is 1329 mm per annum. Dry season spans from November to early March. Average means annual temperature of the area ranges between 30°C and 32°C. The topography of the site is gentle slope. The geology of the area is dominated by crystalline rocks while the soils are mostly of granitic parent material. The vegetation of the area is dominated by tall grasses and shrubs, also human activities have influenced the vegetation of the area.

Treatment consisted of three water regimes: Water regime 1 (WR1) =20 litres applied once at 8 days intervals, Water regime 2 (WR2) = 10 litres of water applied at 4 days interval, Water regime 3 (WR3) = 5 litres of water applied at 2 days intervals and four nutrient sources: Nutrient Source 1 (NS1) NPK 15-15-15 applied at 90 kg/ ha, Nutrient Source 2 (NS2) =poultry manure applied at 10 t/ha, Nutrient Source 3 (NS3) =cow dung manure at 10 t/ha and Zero Nutrient Source (NS0) =as a control. The design was a 3x 4 factorial arrangement fitted into a randomised complete block design (RCBD) with three replications.

The experimental field was ploughed, then double harrowed for proper pulverisation and divided into plots (5.5 m × 4.5 m). Prior to planting, 15 representative soil samples were randomly taken, thoroughly mixed together, air dried, sieved through a 2-mm sieve and used for the determination of bulk density and particle size as described by (Carter 2008). Total porosity was calculated from the values of bulk density and particle density. Organic matter was determined by the Walkley and Black’s dichromate wet oxidation method (Nelson and Sommers, 2015). Total N was determined by Micro-Kjeldahl digestion method. Available P was determined by Bray-1 extraction followed by Molybdenum blue colorimetric (Bray and Kurtz, 1945). The exchangeable bases (K+, Ca2+ Mg2+ and Na+) were extracted by Ethylene Diamine Tetra Acetic Acid (EDTA) titration method (Jackson, 1962). Soil pH was determined in 1: 2 soil-water ratios using digital electronic pH meter. Indian spinach seed was first raised in a germination box and was transplanted after two weeks of emergence. Each replicated plot contains 6 plant stands of Indian spinach with a spacing of 1.5m x 1.5m. Plot sizes consist of 5.5m by 4.5m to give experimental field of 115 m^2. Individual transplanted plants were supported with a bamboo stick of 1.6 m in length so as to expose the leaves to direct sun light. using hoe and cutlasses at two weeks’ intervals. The Indian spinach shoot was sprayed with neem extract at the rate of 10g/20litres of water to control insect attack on the leaves. Weeding was done manually using hoe and cutlasses at two weeks interval.

Growth and yield assessments were taken at ten weeks after transplanting. The parameters assessed were vine length, number of leaves; vine girth and shoot dry weight. The Crop Water Use Efficiency (CWUE) was according to (Michael, 2009) and computed using the equation

$$CWUE = \frac{Y}{ET_C}$$

Where Y was the Crop yield (kg/ha) and ETc was the total amount of water used in evapotranspiration (mm). Data were subjected to analysis of variance (ANOVA) using the GenStat statistical package (GenStat, 2007). Means were separated using the Least Significant Difference (LSD) at 5% level of probability.

RESULTS

The physical and chemical properties of the soil before the experiment are presented in Table 1. The results indicated the soil to be sandy clay loam with pH 5.71. The bulk density was 1.36 g cm^{-3}. The soils had total porosity of 41.66%. The soil organic matter was 3.41 %; nitrogen and available phosphorus were 0.27 g/kg and 1.92 mg kg^{-1}, respectively. The K^{+}, Ca^{2+}, Mg^{2+} and Na^{+} were 0.47, 2.36, 3.73 and 3.43 cmol kg^{-1} respectively. The proximate composition of the organic manure used shows high contents of nitrogen (2.81 to 3.62 %), phosphorus (1.18 to 1.36 %) and potassium (0.86 to 3.14 %) (Table 2). The effect of water regimes on growth characters of Indian spinach is presented in Table 3. The result shows that vine length, number of leaves and vine girth were significantly influenced by the different water regimes used. Longest vine, highest number of leaves and thickest plant were observed in plots treated with WR3, this was closely followed by WR2 while the shortest vine, lowest number of leaves and thinnest plant occurred in plots with WR1. No significant difference was observed in shoots dry weight of Indian spinach due to water regime used in both seasons (Table 3). NS1 produced the longest vine, highest number of leaves and thickest plant in 2020 and 2021. The results also indicated that vine length, number of leaves, vine girth and shoot dry weight of plot with NS2 and NS3 were similar and significantly inferior to NS1. The lowest vine length, number of leaves, vine girth and shoot dry weight were observed in plot with NS0 (control). No significant interaction occurred between water regime and nutrient source used.

Table 4 presents the effect of water regime on fresh yield of Indian spinach. In 2020, WR3 plots produced the highest leaf yield (30.41t/ha), followed by WR2 (28.47) which was similar to WR3 but superior to WR1. However, in 2020, WR3 was significantly better in fresh leaf yield compared to WR2 and WR1 that produced similar leaf yield. Mean of the two years indicated that WR3 produced the greatest yield, followed by WR2, while WR1 gave the least leaf yield (Table 4).

Table 1. Pre- planting soil analysis

Parameter	Values
Sand (gkg^{-1})	671.49
Silt (gkg^{-1})	150.51
Clay (gkg^{-1})	178.00
Soil texture	Sand clay loam
Soil p H	5.71
Bulk density (gkm^{3})	1.36
Total porosity (%)	41.66
Organic matter (%)	3.41
Total N (%)	0.27
Available phosphorus p (mg/kg)	1.92
	0.47
Exchangeable K (cmol/kg)	
xchangeable Ca (cmol/kg)	2.36
Exchangeable Mg (cmol/kg)	3.73

Table 2. Composition of the material used

Properties	Poultry manure	Cow dung manure
Organic C (%)	37.4	44.4
Total N (%)	3.62	2.81
C/N	10.3	15.8
Phosphorus (%)	1.36	1.18
Potassium (%)	3.14	0.86
Calcium (%)	1.21	1.34
Magnesium (%)	0.76	0.63

All plots with nutrient sources produced leaf yield of Indian spinach which were similar in 2020 and significantly better than the control plots. However, in 2021, NS1 gave the highest leaf yield (32.63), followed by NS3, then NS2 while the control plots gave the least leaf yield of Indian spinach. Means of the two seasons indicated that NS1 had significant highest leaf yield (30.52 t/ha) while NS2 and NS3 produced similar leaf yield and their yield were significantly better than the control plots. The leaf yield of the control plots was 17.42 t/ha.

Crop water use efficiency of Indian spinach as influenced by water regime used is presented in Table 5. Significant differences were observed in crop water use efficiency of the Indian spinach in 2020 and 2021. The best crop water use efficiency was recorded in WR3, this was significantly better than WR2 while the least crop water use efficiency occurred in regime WR1. The result indicated that crop water use efficiency of plot with WR3 was the best, followed by WR2 while WR1 recorded the poorest crop water use efficiency.

Table 3. Growth characters

Treatment	Vine length (cm)			Number of leaves			Vine girth@5cm above the ground			Shoot dry weight (%)		
Water regime (WR)	2020	2021	Mean	2020	2021	Mean	2020	2021	mean	2020	2021	Mean
Wr1	53.1c	61.8b	57.5c	22.7c	31.4b	27.1c	0.74b	1.01b	0.88b	23.1	20.4	21.7
Wr2	64.7b	60.2b	62.5b	36.8b	34.9b	35.9b	1.18a	1.21ab	1.20a	22.8	20.6	21.7
Wr3	73.4a	68.1a	70.8a	48.6a	53.4a	51.0a	1.36a	1.47a	1.42a	23.4	21.8	22.6
LSD	4.71	3.11	3.21	2.87	5.40	5.42	0.21	0.34	0.24	Ns	Ns	Ns
Nutrient source (NS)												
Ns0	46.4c	51.3c	48.9c	26.4c	23.8c	25.1c	0.74b	0.98b	0.90b	21.4	19.6c	20.5b
Ns1	71.4a	68.3a	69.9a	47.4a	51.3a	49.4a	1.28a	1.32a	1.30a	21.8	23.6a	22.7a
Ns2	63.4b	66.8a	65.1ab	46.8a	43.4b	45.1ab	1.07a	0.99b	1.03b	22.4	21.1b	21.8a
Ns3	60.8b	59.6b	60.2b	41.6b	43.8b	42.7b	1.13a	0.96b	1.05b	23.6	22.4ab	23.0a
Lsd	5.73	4.98	6.83	3.09	4.11	4.91	0.29	0.13	0.19	Ns	0.16	0.21
Interaction												
Wr vs Ns	ns	ns	Ns	Ns	Ns	Ns	Ns	Ns	ns	Ns	Ns	Ns

Table 4. Leaf yield

Treatment	Shoot yield characters of Indian spinach (t/ha)		
Water regime (WR)	2020	2021	Mean
Wr1	22.42b	26.41b	24.42b
Wr2	28.47a	25.91b	27.19ab
Wr3	30.41a	29.66a	30.04a
LSD	5.41	2.46	4.18
Nutrient source (NS)			
Ns0	18.43b	16.41c	17.42c
Ns1	28.41a	32.63a	30.52a
Ns2	28.21a	26.30b	27.26b
Ns3	25.17a	27.41ab	26.29b
LSD	3.67	6.33	3.21
Interaction			
Wr vs Ns	Ns	Ns	Ns

Table 5. Crop water use efficiency

Treatment	Crop water use efficiency (kg/m2)		
Water regime (WR)	2020	2021	Mean
Wr1	0.56c	0.53b	0.55c
Wr2	0.62b	0.59ab	0.61b
Wr3	0.73a	0.64a	0.69a
LSD	0.06	0.04	0.03
Nutrient source (NS)			
Ns0	0.61	0.58	0.60
Ns1	0.64	0.56	0.60
Ns2	0.63	0.56	0.60
Ns3	0.61	0.56	0.59
LSD	Ns	Ns	Ns
Interaction			
Wr vs Ns	Ns	Ns	Ns

DISCUSSION

Plots with WR3 produced the best growth characters of Indian spinach. Water is a major constituent of all living organism involved in important biochemical processes including photosynthesis. In this study, vine length, number of leaves and vine girth at 5cm above the ground recorded lower value in plots with longer irrigation days than plots with shorter irrigation days. The lowest value for vine length, number of leaves and vine girth at 5cm above the ground were recorded in plot with WR1. Gonzales *et al*. (2009) made similar observation for Chenopodium quinoa Willd. (Quinoa). Indian spinach which received WR1 had the lowest shoot dry weight value. This agrees with several authors that drought water stress influences plant growth and limits productions (KY-Dembele *et al*., 2010; Hsiao and XU, 2000; Busso, 1998; Hampson and Simpson, 1990).

Numbers of leaves was highest in plots with WR3 compared to WR2 and WR1. Ordinarily, plants as part of their survival strategy to reduce water loss during periods of water stress may reduce formation of new leaves. Lawlor and Leach (1985) submitted that decrease in number of leaves is a common effect of drought. In this study however, number of leaves under the longest irrigation day's interval were lower compared with plots with shorter irrigation days.

Crop water use efficiency describes irrigation effectiveness in terms of crop yield (Temesgen and Tasisa, 2020). Improving in water use efficiency can be achieved through the development of new irrigation scheduling techniques (Bekele and Tilahun, 2007). Crop water use efficiency was highest in plots with WR3, this was followed by WR2 while the least crop water use efficiency was recorded in WR1. The results indicated that plots with WR3 were the best efficiency method of crop water use in this study. The method minimises water logging problems by reducing the drainage requirements and control root zone salinity problems through control leaching (Tariq and Usman, 2009). Plots with WR2 and WR3 leaf yield were 11.3% and 23.0% higher than plots with WR1.

All plots with nutrient sources were better than the control plot in growth and leaf yield in 2020 and 2021. The significant response of growth such as vine length, numbers of leaves, stem girth and leaf yield could be due to the timely release of nutrient to the soil. Dauda *et al*., (2008) reported that one of the ways by which soil nutrients could be boosted is by application of organic and inorganic fertilisers. This could be responsible for the better performance of Indian spinach with applied nutrients. Plots with inorganic fertiliser (NPK at 90 kg/ha) gave the highest leaf yield compared to either poultry or cow dung manure. This could be that nutrient from NPK fertiliser was released faster and plants consequently use it for the development of leaves. The work supports the findings of Ayoola and Adeniyan (2006) who opined that nutrients from mineral fertiliser enhance the establishment of crops. The least growth and leaf yield of Indian spinach was observed in the control plots. This was expected because Indian spinach of the control plots only depends on inherent soil nutrients and its availability. The percentage increase in Indian spinach leaf yield due to the different nutrient sources used ranged from 50.9 – 92.4%.

CONCLUSION

Application of water to Indian spinach of 5 litres at 2 days interval gave the highest growth, leaf yield and crop water use efficiency, this was better than either when 10 litres of water was applied at 4 days interval or 20 litres at 8 days interval. Application of NPK fertiliser to Indian Spinach at rate of 90Kg/ha gave yield about 92.4% higher than control; 17.2% and 41.5% higher than when poultry manure and cow dung were used. Therefore, it is recommended that for optimum leaf yield of Indian Spinach 5 litres of water should be applied at 2 days interval with complimentary application of NPK fertiliser at the rate of 90Kg/ha.

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