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Response of vegetative yield characters and yield of biomass fractions of wild-watermelon *Cucumis africanus* to irrigation interval and NPK fertilizer

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Wild-watermelon, *Cucumis africanus,* is among important indigenous crop plants in rural Limpopo Province of South Africa, primarily used as an ethno-botanical crop and a leafy green vegetable. An experiment laid out in a split-plot design and replicated five times was conducted at the Horticultural Research Unit, University of Limpopo, South Africa. The objective was to study the effects of irrigation frequency (2, 4 and 6 day interval) and fertilizer application rate of nutrient mixture containing nitrogen, phosphorus and potassium (NPK) (0 Kg NPK ha^{-1}, 60-40-20 kg NPK ha^{-1}, 120-80-40 kg NPK ha^{-1} and 180-120-60 kg NPK ha^{-1}) on leaf and non-leaf yield characters of *C. africanus*. The treatment of four day irrigation interval and 120-80-40 kg NPK ha^{-1}application rate produced significantly higher ($P \leq 0.05$) vegetative yield characters and biomass of plant fractions than the extreme treatments of short two day irrigation intervals and low 60-40-20 kg NPK ha^{-1}; and long six day irrigation intervals and 180-120-60 kg NPK ha^{-1}. In conclusion, the results of the study indicate that *C. africanus* can be successfully grown using conventional production methods and supply rural households with good yields of a leafy green vegetable as well as providing raw materials needed for ethno-botanical purposes.

Key words: Leafy vegetable, leaf yield characters, root/shoot ratio, ethno-medicine.

INTRODUCTION

Cucumis africanus is an indigenous plant of which the leafy parts are used as vegetables while the remaining parts, stems and roots, are used in ethno-medicine, thereby utilizing the whole plant. There are numerous varied species of indigenous plants used as food and for ethno-medicinal purposes in many rural areas of South Africa (Wehmeyer and Rose, 1983; Van Wyk and Gericke, 2000; Jansen van Resnsburg et al., 2007). Other workers have also found indigenous plants to be an important source of nutrients and vitamins for the rural population (Flyman and Afolayan, 2006). Rural farming communities have cultivated and collected these indigenous plants for generations as an additional food source. Many of these species are not readily amenable

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to conventional agronomic studies as often they are grown in small patches in home gardens (Jansen van Resnsburg et al., 2007; Faber et al., 2010). The indigenous plants of African tradition are being displaced in many areas, leading to a decline in production, use, and diversity of vegetables being grown (Seeiso and Materechera, 2011). Natural selection and farmer-based breeding practices have developed the genetic base of the most important vegetables, but the lack of attention by research and development is leading to the under-exploitation of these vegetables (Misra et al., 2008). The scenario thus far described encourages continuing genetic erosion, and further restricting the development options for the rural poor. This trend will clearly have a detrimental impact on the nutritional status of households, and the incomes of women farmers, in particular, who constitute the primary producers, consumers, and sellers of these vegetables (Smith and Eyzaguirre, 2007). Crucially, from a national and cultural standpoint, these vegetables constitute a most valuable natural resource that needs to be preserved. In recent decades there has been formal research by national agricultural research programmes and international research organizations on cultivation methods of traditional vegetables to improve their yield. Despite this fact responses of many indigenous crops to conventional method of production such as irrigation and fertilizer application are still not yet thoroughly exploited by researchers. Thus, given the role played by indigenous crop plants studies on conventional ways of their production needs urgent attention. The current study seeks to investigate the effect of irrigation and NPK fertilizer application on yield characters that contribute to total plant fraction biomass. These characters are among important determinants of overall plant suitability and compatibility for food and medicinal use. Plants that encounter limited nutrients or water supply are expected to partition more biomass to their roots and less to their stems and leaves.

MATERIALS AND METHODS

Site specifications

Experiments were conducted at Horticultural Research Facility of University of Limpopo, Limpopo Province, South Africa (23˚53'10'' S; 29˚44'15'' E) during the 2009 to 2010 summer growing season. Ambient day/night temperatures averaged 28/21°C, with maximum temperatures controlled using thermostatically-activated fans.

Experimental layout and treatments

An experiment was laid out in a split-plot design arrangement and replicated three times. Three irrigation intervals, namely, 2, 4 and 6 days, were accorded as main plots. During each irrigation interval, 1 000 ml tap-water was applied per pot. Irrigation water application treatments were applied seven days after transplanting. Sub-plot treatments were accorded to varying NPK application rates which were 0 Kg NPK ha^{-1}, 60-40-20 NPK kg ha^{-1}, 120-80-40 NPK ha^{-1} and 180-120-60 NPK ha^{-1}.

Experimental procedures

C. africanus seedlings were raised from seeds collected in the wild by rural women from the Sekhukhune area of the Limpopo Province. Seeds were put in seedling trays filled with Hygromix and irrigated daily until the three leaf stage. Uniform three-week-old *Cucumis* seedlings were transplanted to the pots one day after irrigating the growing medium to field capacity. Thirty centimetre diameter plastic pots, filled with 10 L steam-pasteurised sand and Hygromix (3:1 v/v), were placed on greenhouse benches at 0.5 m inter-row and 0.6 m intra-row spacing. NPK fertilizer (2:3:2) was given in split doses. First dose was applied at transplanting of seedlings into 30 cm plastic pots, while the remaining dose was applied in split applications of equal amounts at 7 and 14 days after the first application.

Data collection

At 40 days after transplanting (40 DAT) plants were harvested. Above- and below-ground plant parts were separated into roots, stems and leaves. Sample pots were emptied and roots carefully separated from the soil mixture using a gentle stream of water. Canopy area was measured using canopy area meter (LI-3100C, LI-COR, Bioscience, Lincoln, NE 68504 USA) and then fresh root, stem and leaf weights were determined using a standard balance scale. The collected data was recorded for the following leaf analysis characters: leaf biomass, shoot biomass, leaf length, Leaf width and canopy area; non-leaf yield characters: root biomass, stem biomass, main vine length, lateral vine length, lateral vine number and root length; and root/shoot ratio.

Data analysis

Analysis of variance of data measured was done using the general linear models procedure of STATISTIX 9 for Split-plot design. Means were separated using Fisher's least significant difference procedure at 0.05 level of probability (Steel and Torrie, 1980; Gomez and Gomez, 1984; Kuehl, 2000). When treatments were significant sum of squares were partitioned to determine the percentage contribution of source of variation to the total treatment variation (Little and Hills, 1981). Percentage increases in yield characters were computed by subtraction the lowest value from the highest and the dividing the result by the lowest value.

RESULTS

Vegetative yield characters of canopy area, leaf length and leaf width were significantly ($P \leq 0.05$) influenced by irrigation frequency and NPK fertilizer application rate, while leaf width was not significant (Table 1). Irrigation contributed 20.8 and 19.8% to variations in canopy area and leaf length, while the interaction between NPK rate and irrigation frequency contributed 30 and 33% to total variation, respectively. The biggest canopy area was 57% bigger than smallest area, while the longest leaf length was 47.5% longer than the shortest leaf length (Table 2). Canopy area ranged from 123.95 to 314.69 mm^2 in the four day irrigation interval with 0 and 120-80-40 kg ha^{-1} NPK fertilizer application, respectively. The ranges in leaf

Table 1. Analysis of variance for Leaf yield characters of *C. africanus* as affected by irrigation frequency and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/2010 growing season.

Source of variation	DF	Leaf yield characters					
		Canopy area (mm^2)		Leaf length (mm)		Leaf width (mm)	
		SS	%	SS	%	SS	%
Replicate (A)	2	18708	9.04	255.61	8.06	2.220	7.63
Irrigation (B)	2	7427	3.59ns	126.82	3.99ns	2.042	7.01ns
Error (A*B)	4	21157	10.22	264.89	8.35	3.228	11.09
NPK rate (C)	3	42988	20.77**	622.66	19.63**	5.081	17.45ns
B*C	6	62554	30.22**	1045.85	32.97**	4.901	16.84ns
Error (A*B*C)	18	54130	26.15	856.36	26.99	11.64	39.99
Total	35	206964	100	3172.19	100	29.11	100

** Significant (P< 0.05), DF=degree of freedom, SS=sum of squares, ns = non-significant.

Table 2. Leaf yield characters of *Cucumis africanus* as affected by irrigation frequency and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/10 growing season.

Interval (Days)	NPK rate (kg ha^{-1})	Leaf yield characters		
		Canopy area	Leaf length	Leaf width
		mm^2	-------------- mm ------------	
2	0	213.12^{bc}	19.33^{abcd}	4.967^{abc}
	60-40-20	136.02^{c}	12.03^{bcd}	4.233c
	120-80-40	185.36^{bc}	16.83^{bcd}	5.033^{abc}
	180-120-60	205.99^{b}	21.27^{abc}	4.900^{abc}
4	0	123.95^{c}	7.50^{d}	4.633^{bc}
	60-40-20	234.12^{b}	24.97^{ab}	5.233^{abc}
	120-80-40	314.69^{a}	32.40^{a}	6.033^{a}
	180-120-60	208.27^{bc}	20.83^{abc}	5.067^{abc}
6	0	145.29^{c}	12.83^{bcd}	4.267^{c}
	60-40-20	256.83^{ab}	23.90^{ab}	5.900^{ab}
	120-80-40	265.72^{ab}	24.33^{ab}	5.967^{ab}
	180-120-60	149.45^{c}	9.03^{cd}	5.167^{abc}

Column means with the same letter were not different at 5% level according to the least significant difference (LSD) test.

length and width were respectively 7.5 mm at 4 day interval and 0 NPK to 32.4 mm at 4 day interval and 120-80-40 kg ha^{-1} NPK and 4.233 mm at 2 day interval and 60-40-20 kg ha^{-1} NPK to 6.033 mm at 4 day interval and 120-80-40 kg ha^{-1} NPK.

Non leaf-based yield characters of lateral vine length and root length of *C. africanus* were significantly ($P \leq 0.01$) affected by NPK fertilizer application rate, while the interaction between irrigation interval and NPK fertilizer application rate was only significant ($P \leq 0.01$) on lateral vine length. Main vine length and number of lateral vines exhibited non-significant variances ($P \leq 0.05$) in response to irrigation frequency and NPK fertilizer application rate treatments (Table 3). NPK fertilizer application rate contributed corresponding 14.6 and 29.6% to total treatment variation in lateral vine length and root length. Treatment interaction between irrigation interval and NPK rate contributed 31.8% to total treatment variation on lateral vine length. The longest lateral vines and roots of respectively 93.67 and 53.33 cm were obtained when 6 day interval and 60-40-20 kg ha^{-1} NPK and 4 day interval and 120-80-40 kg ha^{-1} NPK were applied (Table 4).

Biomass yields of plant fractions, roots, stems, leaves and shoots, and the ratio of roots to shoots showed varied ($P \leq 0.01$ and $P \leq 0.05$) differences in response to the Treatments. Roots responded to the treatment interaction which contributed 35.78% to treatment variation, stems responded positively irrigation which contributed 6.11 to total variation in treatment, leaves and shoot yields responded to NPK application and treatment interaction both being responsible for respectively 16.77 and 35.86% of variation in treatments in leaves and 16.09

Table 3. Analysis of variance for Non-leaf yield characters of *C. africanus* as affected by irrigation frequency and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/10 growing season.

Source of variation	DF	Non-leaf yield characters							
		Main vine length		Lateral vine length		Root length		No. vines/plant	
		SS	%	SS	%	SS	%	SS	%
Replicate (A)	2	1923.70	2.7	2809.4	15.1	86.220	2.0	0.167	0.73
Irrigation (B)	2	14597.6	20.6^{ns}	2527.4	13.5ns	522.72	11.9ns	0.500	2.17^{ns}
Error (A*B)	4	10967.8	15.4	1884.6	10.1	191.28	4.4	5.333	23.19
NPK rate (C)	3	6823.20	9.6^{ns}	2720.2	14.6***	1300.3	29.6***	3.667	15.94^{ns}
B*C	6	16323.1	23.0^{ns}	5935.9	31.8***	827.28	18.8^{ns}	0.833	3.62^{ns}
Error (A*B*C)	18	20393.2	28.7	2777.3	14.9	1461.2	33.3	12.50	54.35
Total	35	71028.6	100	18654.9	100	4388.9	100	23.00	100

***Significant (P< 0.01), ** Significant (P< 0.05), DF=degree of freedom, SS=sum of squares, ns = non-significant.

Table 4. Non-leaf yield characters of *Cucumis africanus* as affected by irrigation frequency and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/10 growing season.

Interval (Days)	NPK rate (kg ha^{-1})	Non-leaf yield characters			
		Main vine	Lateral	Root length	No. vines
		----------------- cm ------------------			
2	0	90.00	42.67^{c}	32.67^{bc}	2.00
	60-40-20	85.33	44.00^{c}	32.33^{bc}	2.67
	120-80-40	104.7	40.00^{c}	50.00^{a}	1.67
	180-120-60	77.33	33.00^{c}	28.67^{c}	1.33
4	0	82.33	35.33^{c}	31.33^{bc}	1.67
	60-40-20	133.7	50.00^{c}	45.33^{ab}	2.00
	120-80-40	158.7	82.00^{ab}	53.33^{a}	1.33
	180-120-60	140.7	52.00^{c}	32.67^{bc}	1.67
6	0	112.0	41.33^{c}	25.67^{c}	2.00
	60-40-20	156.3	93.67^{a}	27.33^{c}	2.33
	120-80-40	95.67	47.00^{c}	34.33^{bc}	1.67
	180-120-60	174.7	56.33^{bc}	38.00^{abc}	1.67
		ns			ns

Column means with the same letter were not different at 5% level according to the least significant difference (LSD) test.

and 33.58 of treatment variation in shoots. The ratio of roots to shoot responded positively to irrigation interval which contributed 19.12% of variation in treatments (Table 5). The highest and lowest plant fraction biomass yields ranged from 65.4 to 213.5 g m^{-2} in roots, 358 to 843.2 g m^{-2} in stems, 251.9 to 992.6 g m^{-2} in leaves and 610 to 1835.8 g m^{-2} in shoots (Table 6).

DISCUSSIONS

Since antiquity to date useful plants have been handled by human societies for medicinal and food purposes. The need for conservation of genetic resources, mostly those of wild relatives of crop plants, which can be useful in case of genetic erosion or for crop improvement, is the driving force behind our interest of studying the wild food plants. *C. africanus* is a multipurpose crop plant with all plant fractions used. The leaves are used as a vegetable, while roots, stems as well as leaves have ethno-medicinal functions (Brandt and Muller, 1995). Thus, for *C. africanus* to be able to fulfil these multi-purpose functions good vegetative yield characters and biomass yields of plant fractions must be produced in sufficient amounts. The exploration of producing these indigenous crop plant using conventional methods of irrigation and fertilizers can yield significant production potentials in smallholder farming systems. In the study the intermediate treatment of four day irrigation interval and 120-80-40 kg NPK ha^{-1}application rate produced significantly higher (P ≤ 0.05) vegetative yield characters than the extreme treatments of short two day irrigation

Table 5. Analysis of variance for fresh biomass yield of plant fractions and root/shoot ratios of *C. africanus* as affected by irrigation interval and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/2010 summer growing season.

Source of variation	Df	Plant fraction (g m^{-2})									
		Roots		Stems		Leaves		Shoot		R:S ratio	
		SS	%	SS	%	SS	%	SS	%	SS	%
Replicate (A)	2	28562	27.33	142136	10.28	225561	9.30	725563	10.23	0.006	8.82
Irrigation (B)	2	2654	2.54	84466	6.11***	149285	6.16	415860	5.87	0.013	19.12**
Error (A*B)	4	2193	2.09	8966	0.65	108182	4.46	168888	2.38	0.003	4.41
NPK rate (C)	3	10026	9.59	206979	14.97	406811	16.77**	1141275	16.09**	0.012	17.65
B*C	6	37388	35.78***	392273	28.37	869727	35.86**	2380591	33.58**	0.008	11.76
Error (A*B*C)	18	23676	22.66	547727	39.62	665690	27.45	2257464	31.84	0.024	35.29
Total	35	104499	100	1382546	100	2425257	100	7089642	100	0.068	100

** Significant ($P< 0.05$), *** Significant ($P< 0.01$), Df=degree of freedom, SS=sum of squares, R:S=Root to shoot, ns=non-significant.

Table 6. Fresh biomass yield of plant fractions and root/shoot relationships of *C. africanus* as affected by irrigation interval and NPK application rate at 40 days after transplanting (40 DAT) during the 2009/2010 summer growing season.

Interval (Days)	NPK rate (kg ha^{-1})	Plant fraction (g m^{-2})				
		Roots	Stems	Leaves	Shoots	Root:Shoot
2	0	162.96^{ab}	564.20^{bcd}	648.15^{bc}	1212.3^{bcd}	0.139^{abc}
	60-40-20	111.11^{bcd}	496.30^{cd}	513.58^{bcd}	1009.9^{bcd}e	0.110^{bc}
	120-80-40	162.96^{ab}	535.80^{bcd}	504.94^{bcd}	1040.7^{bcd}e	0.156^{ab}
	180-120-60	134.57^{bc}	459.26^{cd}	402.47^{bcd}	861.70^{cd}e	0.153^{ab}
4	0	65.430^{d}	358.02^{d}	251.85^{d}	609.90e	0.106^{bc}
	60-40-20	108.64^{bcd}	681.48^{abc}	735.80^{ab}	1417.3^{abc}	0.079^{c}
	120-80-40	213.58^{a}	843.21^{a}	992.59^{a}	1835.80^{a}	0.114^{bc}
	180-120-60	106.17^{bcd}	634.57^{abcd}	501.23^{bcd}	1135^{bcd}e	0.098^{bc}
6	0	112.35^{bcd}	464.20^{cd}	455.56^{bcd}	919.80^{bcd}e	0.135^{abc}
	60-40-20	154.32^{abc}	779.01^{ab}	716.05^{ab}	1495.1^{ab}	0.0103^{bc}
	120-80-40	98.770^{cd}	477.78^{cd}	370.37^{cd}	848.10^{cd}e	0.122^{bc}
	180-120-60	139.51^{bc}	470.37^{cd}	319.75^{cd}	790.10e	0.196^{a}

Column means with the same letter were not different at 5% level according to the LSD test. ns = none significant. LSD = Least significant difference.

intervals and low 60-40-20 kg NPK ha^{-1}; and long six day irrigation intervals and 180-120-60 kg NPK ha^{-1}. This was shown by leaf morphological characters of larger canopy area, longer leaf length and wider leaf width, which are good required for photosynthetic assimilates production and nutrient absorption; thereby yielding of good quality crop. Other workers confirmed that water and nutrient application promote yield in various vegetables, Jefferson (2005) in timothy (*Phleum pratense* L.) cultivars, Li et al. (2008) in leguminous shrub (*Bauhinia faberi* var. *microphylla*), Jilani et al. (2009) in cucumber, Singh (2009) in *Amaranthus tricolor* L., Okorogbona et al. (2011) in Chinese cabbage (*Brassica rapa* L. subsp. *chinensis*), Gupta et al. (2011) in black henbane (*Hyoscyamus niger* L.), Deivasigamani and Thanunathan (2011) in glory lily (*Gloriosa superba* L.). The intermediate category produced higher fresh biomass yields of roots, stems, leaves and shoots, as well as longer root length. In addition, these results indicate that *C. africanus* can be successfully grown using conventional methods to promote food security and help in the fight against the 'hidden hunger', a condition characterized by micro-nutrient deficiencies which are contained in significant amounts in indigenous crop plants (Flyman and Afolayan, 2006). According to several informants wild green leafy vegetables increase the amount of blood in the body which is likely to refer to the high iron content of many wild greens (Misra et al., 2008). However, chemical analyses were beyond the scope of this study, and therefore, the information on the nutrient contents is entirely based on literature. The potential effect of African leafy vegetables on the nutritional status of a particular population will depend, among other things, on the species that are geographically and seasonally available; the species that are known and socio-culturally acceptable or popular as food; and the frequency of consumption and the amount consumed. Most of these traditional leafy vegetables have a potential for income generation but fail to compete with exotic vegetables at present due to lack of awareness. Consumption of traditional diets known to these societies are said to have many beneficial effects such as prevention of some age related degenerative diseases – arteriosclerosis, stroke, etc. (Jansen van Resnsburg et al., 2007). Despite these advantages, most traditional plant foods are generally uncultivated and underutilized.

Conclusion

The intermediate treatment of four day irrigation interval and 120-80-40 kg NPK ha^{-1}application rate ranked superior among the treatments in the study, producing larger canopy area, longer leaf length, wider leaf width, longer root length and higher fresh biomass yields of roots, stems, leaves and shoots. The results of the study indicate that *C. africanus* can be successfully grown using conventional methods for production of leafy greens and provide raw materials needed to produce ethno-botanicals to promote food security and sustainable rural livelihoods. However, more research work still needs to be conducted to determine the effects of water and nutrients on nutritional composition of various plant fractions of *C. africanus* and assessment of its potential use in intercropping with staple cereal crops such as maize, sorghum and pearl-millet.

Conflict of Interest

The authors have not declared any conflict of interest.

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