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Performance of Roselle (*Hibiscus sabdariffa* L) as Influenced by Irrigation Schedules

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Abstract: Global outcry for food security necessitates both rain fed and irrigation farming to boost up world food production. This research therefore explored the possibility of growing roselle (*Hibiscus sabdarriffa*. L) under irrigation. The experimental treatments comprised five irrigation schedules with irrigation intervals (f) of 3, 5, 7, 9, and 11 days. The corresponding gross water requirements (GWR) were 37, 56, 74, 93, and 112mm. The crops were grown under check basin irrigation during the 2001/2002 and 2002/2003 irrigation seasons in Bauchi state, Nigeria. Results showed that difference in number of leaves per plant was significant ($p = 0.05$) with the fifth irrigation schedule ($f = 11$ days, GWR = 112mm) giving the highest value of 347 leaves per plant, while the first irrigation schedule ($f = 3$ days, GWR = 37mm) resulted in only 192 leaves per plant. Variations in plant height, number of branches per plant and canopy diameter were insignificant ($p = 0.05$). The influence of irrigation schedule on the yield of roselle measured with respect to fresh calyx weight was highly significant with a strong coefficient of determination of 97.1%. Yield soared with increase in seasonal irrigation depth. The increase followed a second degree polynomial, reaching a projected maximum of about 682 Kg/ha. The associated maximum seasonal application depth was found to be approximately 3389 mm. Results of this study indicate that maximum yield of roselle grown under irrigation could be attained with a weekly irrigation interval and a gross application depth of 188 mm.

Key words: Roselle, maximum, yield, irrigation

Introduction

Roselle (*Hibiscus sabdariffa*. L) belongs to the Malvaceae family, and is an annual or biennial plant cultivated in tropical and subtropical regions for its stem fibres, edible calyces, leaves and seeds. Cultivation of the crop has been reported throughout the Indian sub-continents, part of Asia, America, Australia and throughout Africa (Cobley, 1968). The crop is, however most suited to tropical climate. It is an important crop in several forms: The leaves are used for making soup, while the succulent calyces are used for making syrups, jelly, jam, chutney and alcoholic drink. It has been reported (Rao, 1996) that the plant is grown in some regions for fibre and pulp obtained from its stem. Close to 17% of edible oil is extractable from the seed, which is also used as poultry feed. Roselle is a short day plant with a critical photoperiod of 12-12.5 hours, and thrives best in hot, dry areas with a high humidity and temperature of about 25°C to 35°C (Hacket and Carolene, 1982). It has been shown that the plant requires optimum pH of 6-7 and rainfall of about 450-500 mm, which should be well distributed over 90-120 days during the growing season (Choudhury, 1977)

High productive potentials has been reported for Roselle grown under rainfed, through various agronomic practices such as weeding and spacing (Babatunde and Zechariah, 2001); nitrogenous fertilizer (Babatunde *et al*., 2002); intercropping, sowing dates, intra-row spacing and nitrogen fertilizer (Babatunde, 2003). However, Hinrichsen *et al*. (1997) highlighted that rainfed agriculture alone is inadequate to feed the bludgeoning populations in many parts of the world. It is therefore incumbent upon mankind to resort to both rainfed and irrigation farming for the widest array of food crops possible. This would augment world food production and put the human race a step forward towards attaining food security.

No attempt has, however, been made to grow same crop under irrigation especially in a country like Nigeria where the calyx is widely used in making a staple beverage called "zoborodo". This study therefore investigated the possibility of growing roselle under irrigation particularly under semi-arid weather conditions.

Materials and Methods

The on-station experiments were conducted during the 2001/2002 and 2002/2003 dry seasons at the Abubakar Tafawa Balewa University research farm. The farm is situated along latitude 10°17'N and longitude 09°49'E on a mean altitude of 609.3m above sea level in the northern guinea savannah ecological zone of Nigeria.

Table 1: Summary of experimental treatments used in the field trial

Irrigation Schedule Ref. No.	MAD (%)	NWR (mm)	GWR (mm)	Irrigation Interval (days)	Application Time (secs.)
S1	20	26	37	3	67
S2	30	39	56	5	100
S3	40	52	74	7	134
S4	50	65	93	9	167
S5	60	78	112	11	201

This region is characterized by cool dry harmatan winds from November to February, with ambient temperature range between 10-37^oC. The soil in the site is predominantly silty clay loam for the top 30cm.

Tillage and seed bed preparation were done manually. The crops were grown on check basins (plots) under five irrigation schedules as summarized in Table 1. Each treatment was replicated four times in a randomized complete block design. The basins were surrounded by a 1m strip of fallow land to act as buffer to sub-surface lateral movement of water. The entire farm was given a pre-irrigation and 4-6 seeds of red variant Roselle sown at spacing of 50cm x 60cm. These were later thinned to two plants per stand.

Irrigation schedule is a term that specifies two operational parameters for managing farm irrigation systems, viz: irrigation interval and net water requirement (James, 1988). Net water requirement (NWR) is the amount of water needed during irrigation to replenish the soil moisture deficit, thereby restoring the soil back to field capacity. NWR was calculated according to Benami and Ofen (1984) as follows.

$$NWR_{(mm)} = (Fc_{weight} - WP_{weight}) \times Bd \times DRZ \times MAD \times 10\text{--} \quad 1$$

Where:

FC_{weight} = field capacity of soil on dry weight basis, %

WP_{weight} = wilting point of soil on dry weight basis, %

BD = soil bulk density, g/cm^3

DRZ = design root zone depth of the crop, mm

MAD = management allowable deficit.

Average field capacity, wilting point and bulk density of the soil were 14.76%, 5.23% and 1.45 g/cm^3 respectively. Design root zone depth is the depth of soil that contributes 80-90% of the crop water use. This value was taken as 650mm- the upper limit of the range reported by Doorenbos and Pruitt (1977) for such vegetable crops. Management allowable deficit is a subjective managerial criterion based on the scheduling concept being adopted and the specific soil-plant-atmosphere characteristics. Farm irrigation systems are customarily scheduled based on an average "safe" MAD of 50% (Stegman *et al.*, 1980; Stern, 1985; Mazumder, 1983). However, there exist possibilities of increasing or decreasing this average MAD level by up to 30%, denoting the conventional "dry" and "wet" treatments respectively (Stegman, 1983). Based on this, the MAD spectrum used in computing the NWRs for the various irrigation schedules were 20, 30, 40, 50 and 60%.

The intrinsic heterogeneity of soils dictates that in order to achieve high adequacy of irrigation, it is necessary to apply water slightly in excess of the calculated NWR. This increased amount of water to apply is the gross water requirement (GWR). GWR was calculated on the basis of an assumed systems application efficiency as follows.

$$GWR\ (mm) = \frac{NWR\ (mm)}{AE} \quad 2$$

Where:

AE: Systems application efficiency.

GWR were calculated at an assumed application efficiency of 70% a typical value for well designed and operated basin irrigation systems (Merriam *et al.*, 1980).

Irrigation interval defines the time stretch in days between successive irrigations. This was calculated from Benami and Ofen (1984) as follows.

$$\text{Irrigation interval} = \frac{NWR_{(mm)}}{ETa_{peak}\ (mm/day)} \quad 3$$

Where:

ETa_{peak} = Peak actual crop evapotranspiration

$$Eta_{peak} = ETo_{peak} \times Kc_{peak} \quad 4$$

Where:

ETo_{peak} = peak reference crop evapotranspiration (mm/day)

Kc_{peak} = peak crop coefficient.

Average peak crop coefficient was taken as 1.2 from a generalized Kc chart by Doorenbos and Pruitt (1977). Reference crop evapotranspiration was calculated on a monthly basis using the FAO version of the Penman-Montieth combination equation according to Allen *et al.* (1998) as follows:

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + Y\,\frac{900}{T+2732}\,U_2\,(I_5 - I_a)}{\Delta + Y\,(1+0.34U_2)} \quad 5$$

Where:

Δ = slope of vapour pressure curve, kpa/^oc.

Rn = net radiation at the crop surface, MJm^{-2}/day.

G = soil heat flux density, MJm^{-2}/day.

Table 2: Effect of irrigation schedule on growth characters of Roselle (mean of 2 dry seasons)

Irrigation Schedule Ref. No.	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Canopy diameter (cm)
S1	53.82	19	193	7.64
S2	43.39	10	195	7.31
S3	71.58	20	203	7.71
S4	48.35	9	209	7.20
S5	52.29	16	348	6.79
Level of sig.	NS	NS	**	NS

** = significant at 5%

Table 3: Contribution of irrigation schedules on the growth and yield of Roselle

Growth / yield components	Coefficient of determination (R^2) (%)
Plant height	0.0
Number of branches per plant	1.4
Number of leaves per plant	57.6*
Canopy diameter	57.4*
Fresh calyx weight	97.1*

• = Significant at 1 %

T = air temperature at 2m height, ^{o}c
U_2= wind speed at 2m height m/s
I_s= saturated vapour pressure, Kpa.
I_a = actual vapour pressure, Kpa.
(I_s - I_a) = saturated vapour pressure deficit, Kpa.
Y = psychrometric constant, Kpa.

ETo was calculated for the last five years and the average peak value (7.6mm/day) which occurs in March / April was used in computing the irrigation intervals.

The water application time was calculated as follows, (Hart *et al.*, 1980):

$$Ta = \frac{FnL}{600QuE} \qquad 6$$

Where:
T_a = application time, minutes
F_n = net water requirement, mm
Q_u= unit inflow rate, m^2/s

The crops were grown on basins of dimensions 3m x3m, hence L was taken as 3m A small petrol engine centrifugal pump with discharge of 5 l/s was used for delivering water to the field. This gave a unit inflow rate of $1.66667x10^{-3}$ m^2/s.

Growth and yield data collected were plant height, canopy diameter, number of branches per plant, number of leaves per plant and fresh calyx weight. Analysis of variance, correlation and regression were done using the MINITAB computer software. Direct, combined and indirect contributions were obtained using a computer simulated pathway analysis newly developed by Agada and Babatunde (2005)

Results and Discussion

Growth characteristics: The influence of irrigation schedule on plant height, number of branches per plant and canopy diameter of Roselle was not significant (Table 2). Number of leaves per plant was however significantly influenced ($P < 0.05$) by irrigation schedule. The observed variations in growth parameters is supported by the calculated coefficients of determination between the irrigation schedules and the growth and yield indices presented in Table 3. From Table 3 it is observed that plant height and number of branches per plant that sowed a non-significant variation among the treatments in Table 2 both gave very low and equally insignificant coefficient of determination. However, the significant variation ($P < 0.05$) in the number of leaves per plant in Table 2 is buttressed by the high coefficient of determination (57.6%) recorded against the growth parameters - the highest value obtainable for the growth expression. The fact that plant height and number of branches per plant were not significant, can be proven further from the result of the regression analysis which aimed at obtaining the coefficients of determination between the irrigation schedules and the growth / yield characters presented in Table 3. The result of Pathway analysis showing the relationship between growth and yield is presented in Table 4. In spite of the fact that canopy diameter was not significantly influenced ($P < 0.05$) by irrigation schedule (Table 2), the coefficient of determination for this growth character was found to be significant ($P < = 0.05$). The reason for this anomalous trend apparently sterms from the very high direct contribution (655.13%) which this growth parameter has on fresh calyx weight that revealed a highly significant difference among the treatments. may be attributed to its highest direct contribution of 655.13 % to fresh calyx weight as presented in Table 4.

Yield and seasonal application depth: Fig. 1 shows the relationship between fresh calyx yield of roselle and seasonal depth of water applied. The trend line equation of Fig. 1 shows that the response of roselle yield to varying irrigation schedules is a diminishing return function. This conforms with the general results for most agricultural crops as reported by Vaux and Pruitt (1983) and Stegman *et al.* (1980). The fact that the relationship between yield and seasonal irrigation water applied for roselle is a diminishing return function implies that there exists an optimum and then a maximum irrigation level for this crop. By differentiating the second degree polynomial of yield versus seasonal applied depths, a maximum application depth of 3389.25 mm was

Table 4: Direct, combined and indirect contributions of some growth character on fresh calyx weight of irrigated Roselle presented as percentage (mean of 2 seasons)

Growth / Yield character	Direct contribution	Percentage
Plant height		205.90307
Number of branches per plant		0.01334
Number of leaves per plant		178.67857
Canopy diameter		655.12757
Total		1039.72255
Combined contribution		
Plant height and Number of branches per plant		-2.64546
Plant height and Number of leaves per plant		23.01701
Plant height and Canopy diameter		-393.72150
Number of branches per plant and Number of leaves per plant		0.19764
Number of branches per plant and Canopy diameter		2.92708
Number of leaves per plant and Canopy diameter		-569.31483
Total		-939.54005
Residual		-0.18250
Grand Total		100.00000
Indirect contribution		
Plant height via Number of branches per plant		0.92181
Plant height via Number of leaves per plant		-8.02024
Plant height via Canopy diameter		137.19167
Number of branches per plant via Plant height		-114.50760
Number of branches per plant via Number of leaves per plant		8.55493
Number of branches per plant via Canopy diameter		126.69753
Number of leaves per plant via Plant height		8.60959
Number of leaves per plant via Number of branches per plant		0.07393
Number of leaves per plant via Canopy diameter		-212.95423
Canopy diameter via Plant height		-76.91237
Canopy diameter via Number of branches per plant		0.57180
Canopy diameter via Number of leaves per plant		-111.21403

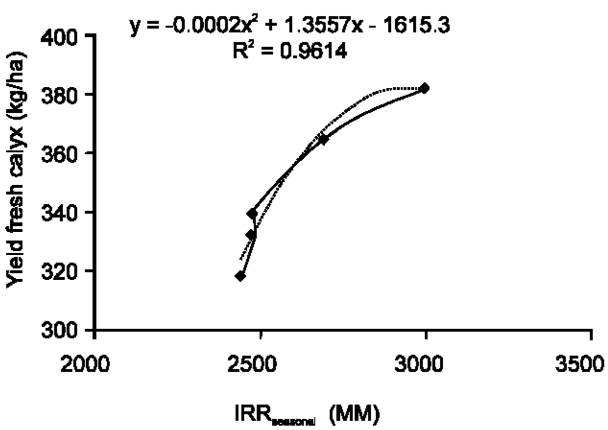

Fig. 1: Relationship between fresh calyx yield and seasonal irrigation water applied for roselle grown under irrigation

obtained. The corresponding projected maximum yield of roselle grown under irrigation in Bauchi, Nigeria was obtained to be close to 682.103 kg/ha. Seasonal applied depths of water from the five treatments ranged from 2444 – 3000 mm, which are all less than the projected maximum application depth of 3389.25mm. This gives provision to increase the depth of water applied by 11-28%. Most Irrigation farmers in Nigeria and as well as other sub-Saharan countries are small holder peasant farmers. The farming practice of these farmers is dependent purely on ancestral skills. These farmers incline very strongly to weekly irrigation interval. This way, roselle with a growth season of about 18 weeks would require 18 irrigations. If production is targeted at the maximum value then a maximum of 188mm of water should be applied each time. Application depths less than this value would invariably result in yield reduction due to under irrigation, whereas applied depths higher than the maximum 188mm would likely cause lower yield because of the effects of over irrigation.

Conclusion: Roselle (*Hibiscus Sabdariffa*) was successfully grown under check basin irrigation in Bauchi State Nigeria having semi-arid weather characteristics. The differences in plant height, number of branches per plant and canopy diameter were found to be minimal for the five irrigation schedules that served as experimental treatment. The number of leaves and crop yield measured from the fresh calyx weight, however showed remarkable differences. The projected maximum yield of roselle grown under irrigation within Bauchi was found to be about 682 Kg of fresh calyx per hectare. This yield is attainable under a weekly irrigation interval, and a gross water requirement of 188mm.

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