Journal of Applied Horticulture, 6(2):72-75, July-December, 2004

Soil moisture regime effect on the performance of watermelon under varying nitrogen levels in a semi-arid region

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Abstract

Watermelon is a crop with a high economic value, which is grown and traded for export in many countries. With the expansion of land under irrigation and provision of irrigation facilities in many of the semi-arid regions including Nigeria, local farmers now grow the crop under irrigation, which hitherto, was restricted to rainy season or under residual moisture. A field study was carried out to investigate the effects of varying levels of nitrogen (0, 50, 100 or 150 kg N ha^{-1}) and irrigation regime (7, 14 or 21-day intervals) on the performance of watermelon at Kadawa (11°39'N, 08°02'E), Nigeria. The result revealed that nitrogen significantly affected the growth, yield and yield components in the range of 50-150 kg ha^{-1}. Similarly, frequency of irrigation affected some of the growth parameters; however, the total and marketable yields were not significantly affected when irrigation regime was delayed up to 21-day interval. Thus, the volume of water would be reduced thereby increasing efficient use of water in the region which is the major limiting factor during the dry season farming.

Key words: Irrigation levels, fertilizer levels, and watermelon, semi arid region

Introduction

Watermelon, *Citrullus lanatus* (Thunb), is cultivated through out the tropics and subtropics and has a worldwide distribution. It is a crop with a high economic value and is grown and traded for export. The fruit is mainly eaten raw as a fresh juicy desert. It is relatively low in food value especially protein and most of its nutrient value lies in its content of sugar and vitamins. Most well drained soils, whether clayey or sandy, can be managed to produce the crop. However, the best soils are sandy loams. Like many other crops, it also requires soils that are rich in essential nutrients, particularly nitrogen. The influence of nitrogen is manifested on both the vegetative and reproductive processes (Ogunremi, 1978; Cirulli and Ciccarese, 1981; Majia *et al.*, 1996 and Uwa, 2000)

Watermelon performs better during the dry season under irrigation or residual moisture. However, excessive humidity in rainy season affects flowering and encourages the prevalence of pests and diseases. The crop prefers a hot, dry climate with mean daily temperature of 22 to 30°C, maximum and minimum temperatures for growth are about 35 and 18°C, respectively. The optimum soil temperature for root growth is in the range of 20-35°C (FAO, 2001). Fruits grown under hot, dry conditions have a high sugar content of 11 % in comparison to 8 % under cool humid condition. Thus, the crop is expected to have optimum yield in semi- arid region under irrigation where the climate may be conducive for its production. The crop has a high moisture content of about 92 % and sometimes serves as a source of water for human consumption (FAO, 2001). Despite high moisture content, its seasonal water requirement is between 400 to 600 mm under tropical climate. There have been studies on the performance of the crop by varying moisture regimes, soil types, crop variety, physiological and environmental factors as reported by Doneen and MacGillivray (1943) and Erdem and Nedim (2003) but not much is done on the influence of varying water regime and nitrogen level.

Hitherto, farmers in the semi-arid zone of Nigeria grow watermelon during the rainy season or under residual moisture, but with expansion of irrigable land and provision of irrigation facilities, they now devote substantial hectares to watermelon production under full irrigation. The aim of this study was to assess the N- response of watermelon since the tropical semi-arid soils are known to be inherently low in soil fertility, and to determine the most appropriate moisture regime for sustainable production during the dry season. It is necessary to determine the optimum irrigation frequency for watermelon production because farmers have the tendency to waste irrigation water which usually leads to problems such as leaching of nutrients (especially nitrogen), rising water table, water logging and increase in soil salinity level.

Materials and methods

The study was conducted in the dry season (March-May) of 2000, 2001 and 2003 at the Irrigation Research Station, Kadawa (11°39′N, 08° 03′E; at an altitude of 500m above sea level) in Kano state, Nigeria. The study area is within the semi- arid region of northern Nigeria with the mean daily air temperature of 26°C over the year while the maximum value is 42°C occurring in the month of March/April and the lowest of 11°C in December. The mean monthly relative humidity is 27 %, which occurs within the dry season period, while that of wet season is 64 %. At the early stage of the dry season, the mean air temperature is low (average of 21°C) while towards the end, the air temperature is very high (average of 30°C); it is during this period the mean potential evapotranspiration was found to be 5.8 mm/day (KRIP, 1994). At the start of the experiments, the soils had 0.057%N, 4.9 ppm P, 0.72% organic carbon, 6.2 pH (0.01M$CaCl_2$), and 5.96 cmol kg^{-1} CEC. The watermelon variety used for the study was 'Sugar Baby', a commonly produced variety in the region. The variety is characterized by medium size, round shaped fruit with dark green skin, red flesh and early maturity (about 80-85 days). The treatments tested were factorial combinations of four levels of nitrogen (0, 50, 100 or 150 kg Nha^{-1}) and three irrigation regimes (7, 14 or 21-day intervals), replicated three times and arranged in a randomized block design. Sowing was done in beds (basins) and three seeds were sown per hole and thinned two weeks after planting (WAP) to one plant at inter- and intra-row spacing of 1.5 and 2.0m, respectively. Single super phosphate (18% P_2O_5) and Muriate of potash (60% K_2O) fertilizers were applied at the rate of 45 kg ha^{-1} each of P_2O_5 and K_2O, respectively, around the sowing hole. Nitrogen was applied in the form of urea (46% N), and the amount varied according to the treatment. Nitrogen was applied in a split application, half at planting along with the other two fertilizers, and the second half at 4WAP.

In all plots, irrigation was applied pre-planting to facilitate soil leveling, a second irrigation was applied just after sowing, and thereafter every week until four weeks after sowing when the irrigation treatment was imposed *i.e.* irrigation applied at 7, 14 or 21 day interval from the fourth week up to two weeks before harvest.

A basin size of 6 x 8m was used for each of the treatments. The project site has a slope of 1.8 to 2.0 percent. The soil moisture characteristics were determined using pressure membrane apparatus for determination of field capacity and wilting point. Based on the soil information (sandy loam with average available soil moisture of 125 mm/m and average bulk density of 1.63 g cm^{-3}), the stream size was determined using the equation below:

$$V = qt = \frac{10}{E_a} PS_a DA \quad \text{......... (1)}$$

Where;

V = volume of water applied (m^3)

q = stream size (l/s)

t = supply duration (s)

E_a = application efficiency

S_a = total available soil moisture (mm/m)

P = fraction of total available soil moisture that allows unrestricted evapotranspiration

D = root depth (m)

A = acreage (ha)

Values for D and P used were 1.0 m and 0.35 as given by Doorenbos and Pruitt (1992), though the value of D selected is the minimum for the crop but it is the active root zone where most of the water is abstracted under adequate water supply (FAO, 2001). The E_a of 65 % was used as designed for the scheme (KRIP, 1994). To bring the soil to field capacity, equation (1) was used to determine the stream size (in volume) of 673 m^3/ha, which is equivalent to 3.23 m^3 applied for the experimental plot size of 0.0048 ha. To supply this quantity of water, a calibrated 100 mm cut-throat flume was used for measuring the stream size diverted into the basin. The equation for the flume (Othman, 1997) is given below:

$$q = 0.0525H^{2.105} \quad \text{......... (2)}$$

Where q = stream size entering the basin (l/s) and H= measured head in the flume (cm).

Therefore, combining equations (1) and (2), supply duration t (minutes), was determined:

$$t = \frac{3.23}{0.0525H^{2,105}}\left(\frac{1000}{60}\right) \quad \text{......... (3)}$$

t was therefore dependent on H. In each irrigation (7, 14 or 21-day interval), the volume of 3.23 m^3 of water was applied in addition to allowing water to pass for 0.3 of the total time in order to allow the required depth to enter into the soil and attain uniform distribution of water in the basin. Consequently, total volume of water applied was 4.199 m^3 . This transformed equation (3) into equation (4):

$$t = \frac{4.199}{0.0525H^{2,105}}\left(\frac{1000}{60}\right) \quad \text{......... (4)}$$

The values of H varied between 5 and 7 cm depending on the depth of water in the field channel supplying to the experimental plot (Table 1). Therefore, a calibration table was developed linking time in minutes and the average value of H, measured in each irrigation. Computations for volume of water supplied were made with the calibration table. The total volume of water applied for each irrigation interval was similarly determined (Table 2).

Results and discussion

Growth parameters: The growth parameters studied were number of leaves per plant, vine length and number of branches per plant (Table 3). Nitrogen application significantly affected all the parameters in the three years of study. The number of leaves per plant increased significantly up to 100 kg N ha^{-1} and remained at par with 150 kg Nha^{-1}. Similar response was observed for the vine length and number of branches plant^{-1}. However, in 2003, for vine length and number of branches plant^{-1}, the fertilized plots were at par and out performed the control. The positive response in growth resulting from N application could be associated to the

Table 1. Calibration table using relation of H and t

H (cm)	5	5.2	5.3	5.4	5.5	5.7	5.9	6	6.3	6.4	6.5	6.7	6.9	7
Time (m)(t)	45	42	40	39	37	35	32	31	28	27	26	25	23	23
Volume (m^3)(V)	4.2	4.25	4.22	4.27	4.22	4.3	4.22	4.24	4.25	4.23	4.21	4.32	4.22	4.35

Table 2. Number of irrigations and total volume of water applied

	7-day irrigation interval	14- day irrigation interval	21- day irrigation interval
Number of irrigations	12	9	7
Average volume of water applied (m^3) in the 3 Years	50.92	33.89	29.61

Table 3. Effect of nitrogen and irrigation on performance of watermelon at Kadawa, Nigeria

	Number of leaves plant^{-1}		Vine length (cm)			Number of branches plant^{-1}		Number of fruits plant^{-1}		Mean fruit weight (kg)		Marketable yield (t ha^{-1})			Total fruit yield (tha^{-1})		
	2000	2001	2000	2001	2003	2000	2003	2001	2003	2000	2001	2000	2001	2003	2000	2001	2003
Nitrogen (kgNha^{-1})																	
0	96b	129b	156c	172c	100b	7.86b	3.84b	2 .45b	3.72c	2.55b	4.11b	12.8c	21.8c	8.22c	15.0c	26. 1b	29.5d
50	101b	136b	178b	197b	137a	8.59b	4.53ab	2.95a	3.83bc	3.11a	5.17a	21.0b	29.5b	14.8b	23.9b	37.0a	41.1c
100	163a	148a	188ab	210a	151a	11.7a	4.91a	3.29a	4.57ab	3.45a	5.03a	29.2a	34.8a	21.3a	33.4a	41.9a	72.4b
150	178a	148a	200a	201ab	155a	11.0a	5.13a	3.25a	4.65a	3.45a	5.61a	29.4a	34.8a	22.4a	31.8a	43.1a	92.4a
SE	12	3.7	6.2	3.2	7.68	0.56	0.257	0.122	0.255	0.168	0.298	2.22	1.52	2.03	2.27	2.40	3.66
Irrigation interval (days)																	
7	121	146	172	202a	152a	9.82	5.28a	2.84	4.43	2.95	5.20	20.4	29.4	16.7	22.4b	36.1	61.3
14	136	137	185	191b	125b	9.52	3.93c	3.11	4.00	3.13	5.07	23.6	30.8	16.5	27.0ab	37.9	59.3
21	147	138	184	191b	131b	10.0	4.60b	3.01	4.14	3.34	4.66	25.2	30.6	16.9	28.6a	37.1	55.9
SE	10.4	3.2	5.3	2.7	6.66	0.49	0.223	0.106	0.221	0.145	0.259	1.93	1.29	1.83	1.97	2.02	3.30

Table 4. Response of total fruit yield to N fertilization

	Percent yield increase			Percent marginal yield increase		
Years	2000	2001	2003	2000	2001	2003
Nitrogen(kgNha^{-1})						
0	-	-	-	-	-	-
50	59.3	41.8	39.3	59.3	41.8	39.3
100	123	60.5	145	63.7	18.7	106
150	112	65.1	213	-11.0	4.6	68

vital role it plays as an essential constituent in plant growth and protein synthesis, which translate into leaf production and expansion. Secondly, the response may be due to the low N content of the soil of the experimental site (0.57 g kg^{-1}).

The effect of varying irrigation regimes was significant only on the vine length and the number of branches per plant. The 7-day irrigation interval produced statistically longer vines and higher number of branches per plant in 2001 and 2003. Differences were not significant in 2000. The vegetative growth stage coincided with the period of extremely high temperatures and high evaporation in the region and this will suggest while the growth response was higher with the most frequent irrigation. The interaction between N and irrigation was significant on vine length in 2001. The longest vine (232cm) was produced under 7- day irrigation and 100 kg N ha^{-1}.

Yield and yield parameters: The parameters studied include number of fruits per plant, mean fruit weight, total and marketable fruits yield (Table 3). The response of these parameters to N application was positively significant in the range of 50-100 kg Nha^{-1}. However, in 2003 the total yield responded to N application up to 150 kg Nha^{-1}. The positive effect of N on the number of fruits and mean fruit weight might have contributed to higher total and marketable yield. Earlier it was reported that nitrogen enhanced vegetative growth and this would result in production of more assimilates, which would ultimately accumulate as yield (Whitaker and Davis, 1962; Majia, 1998 and Uwa, 2000). The percent increase in total yield was highest when N was raised from 50 to 100 kgha^{-1}, except in 2001. Similar result was obtained when the percent marginal increase in total yield was computed (Table 4). The regression analyses for total and marketable yield against nitrogen for the three years are presented in Table 5.

The influence of variation in irrigation regime had no significant effect on the yield and yield parameters except on total fruit yield in year 2000. The highest total yield was obtained at 21-day interval although it was statistically at par with irrigation at 14-day interval. The positive out come of this result is that delaying irrigation up to 21 days produced yields not significantly different from the more frequent regimes (7 or 14-day intervals) and this implies reducing the number of irrigation and hence the cost of production. Consequently, the water use efficiency (data not recorded) would be enhanced. Watermelon typical of the Cucurbitaceae family is deep rooted and has some level of tolerance to water stress. In fact, it was reported by FAO (2001), that one heavy irrigation might be sufficient to bring the crop to maturity under climate of moderate evaporation and deep soil. Therefore, the three weeks irrigation interval after the crop has fully established is recommended for cultivation of the crop in this region.

The study has therefore, shown that watermelon can respond to high level of N fertilization (50-150 kgha^{-1}), however, irrigation schedule can be delayed to as much as 21 days without affecting the yield while reducing the volume of water by about 50 percent.

Table 5. Regression analysis

Year	Total fruit yield	Marketable fruit yield
2000	$Y=14.46+0.28x-0.001x^2;(R^2=0.52)$	NA
2001	$Y=26.95+0.135x(R^2=0.42)$	$Y=22.86+0.0984x(R^2=0.49)$
2003	$Y=24.92+0.452x(R^2=0.79)$	$Y=9.029+0.102x(R^2=0.42)$

NA = not available

Acknowledgement

The authors are grateful to the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria, for providing funds for the work and to our able technician, Mr. Nuhu Mohammed.

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