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THE EFFECT OF VARYING RATES OF NITROGEN AND IRRIGATION ON YAM (*DIOSCOREA ALATA* L.) PRODUCTION

S.M.A. Crossman, C.D. Collingwood, M.C. Palada and J.A. Kowalski

Agricultural Experiment Station
University of the Virgin Islands
RR 02, Box 10,000
Kingshill, St. Croix, U.S. Virgin Islands 00850

ABSTRACT

A series of studies were conducted to evaluate the effects of varying rates of nitrogen fertilizer and applied irrigation, on yam production. Yam was grown in field trials with nitrogen applied at rates of 0, 100, 200 and 300 kg/ha. The application of nitrogen did not affect the production of yam tubers from either of two cultivars ('Binugas' and 'Gunung'). Yields were similar for both cultivars at all nitrogen levels. The results of another study showed that nitrogen applied to 'Gunung' at rates of 0, 50, 100 and 150 kg/ha significantly affected yield and dry matter production. Yam production decreased linearly as nitrogen rates increased. Two trials were conducted to evaluate the effect of varying irrigation rates (rain-fed and soil moisture maintained at 20, 40 and 60 kPa) on the production of 'Binugas' yams. The application of irrigation quadratically decreased the dry matter content of the yam tubers, in both trials.

INTRODUCTION

Yam, plants of the genus *Dioscorea*, is an important crop in the Caribbean, where production ranks second only to West Africa (Onwueme,1978). Due to high production costs, prices are higher for yam than for other tropical root crops.

Compared to other root crops, yam requires the most intensive management in order to obtain a high yield of good quality tubers. This includes proper plant nutrition and maintaining the soil moisture at optimum levels.

Even though yams are a popular food crop in the Virgin Islands, where prices for this crop are higher than for other tropical root crops, production in 1987 had declined drastically to approximately 20 percent of 1960 production levels. This was due primarily to a concurrent reduction in harvested agricultural cropland, which in 1987, was approximately 15 percent of the 1960 acreage (Moore, 1991). If this trend of reduced harvested cropland acreage continues, then production per unit land area must be increased to at least maintain the present level of local yam production. Yields can be substantially increased if factors including plant nutrition and water requirement are given adequate attention.

Even though many trials have been conducted in Africa and the Caribbean to determine the response of yams to fertilizer, minimal research of this nature has been conducted in the Virgin islands. Intensively managed and fertilized yams in Puerto Rico produced very high yields of marketable tubers and edible dry matter (Irrizary and Rivera,1985). Results of these trials have been inconsistent but positive responses have been reported in Africa and the Caribbean by Rouanet, 1976; Ferguson and Haynes ,1970; Gooding, 1970, 1971; Gurnah, 1974; and Igwilo, 1989. The level of these responses was affected by the accompanying cultural practices.

Different yam cultivars have been found to respond differently to the same fertilizer application (Ferguson and Haynes, 1970; Obigbesan et al., 1977). It is therefore important to know the response potential of the various yam cultivars to fertilizer applications. Responses will vary based upon soil type and local climatic conditions (Ferguson, 1980).

Koli (1973) reported that nitrogen was the most important nutrient element because its application significantly increases yields. Ferguson and Haynes (1970) found that compared with other crops, such as cereals, yam is relatively insensitive to nitrogen shortage. Lyonga (1982) found that applications of N at 60 days after planting gave better yields than earlier or later applications. The element appears desirable during the first half of the growing season. Subolo (1972) and Obigbesan and Agboola (1978) reported that yams extracted large quantities of N from the soil. Applications of N are most beneficial if available when the plants changes dependence from the seed piece to autotrophy. At this time the root system is extensive enough to absorb and utilize the fertilizer. Plants can then develop a large leaf area which provides a sufficiently large photosynthetic area for rapid tuber development and growth.

Yams do not tolerate prolonged periods of drought without a drastic yield reduction especially during the critical 2-3 month period when all of the food reserves of the seed piece has been exhausted. Moisture stress also delays tuber initiation. Tubers develop best when rainfall is frequent, so that the soil is almost constantly wet, but they also require good drainage for best growth. Gooding (1970, 1971) reported yield increases with increased rainfall up to 100 cm during the growing season.

Yams are traditionally grown by small farmers under rain-fed, subsistence conditions characterized by lack of fertilizer and pesticides. This management practice involves small investments, low risks, but results in low productivity and low income. Environmental conditions in the Virgin Islands pose stress conditions for plant growth - low annual rainfall, heavy soils, high soil pH and associated deficiencies in P and micronutrients.

The objectives of these studies were to evaluate the effect of nitrogen and irrigation application on the yield, tuber size and dry matter production of *D. alata* cultivars.

MATERIALS AND METHODS

The studies were conducted at the University of the Virgin Islands - Agricultural Experiment Station on St. Croix. The soil is a Fredensborg loamy, fine, carbonatic, isohyperthermic, shallow, typic calciustoll (Lugo-lopez and Rivera, 1980).

Two trials were conducted to evaluate the effect of varying rates of nitrogen on the production of *D. alata* cultivars. In the first trial ammonium sulfate was split-applied to provide nitrogen at rates of 0,100, 200 and 300 kg/ha to plots planted with cultivars 'Binugas' and 'Gunung'. The first half of the nitrogen and all of the phosphorous (100 kg/ha using triple super phosphate) was applied at one month after planting. The second half of the nitrogen and all of the potassium (100 kg/ha using potassium sulfate) was applied at 3 months after planting. The soil pH was 7.8 for both trials and soil N was 116 and 95 ppm for 'Binugas' and 'Gunung', respectively (Table 1).

Field plots were established using sprouted yam tuber pieces weighing approx. 115 g. as the planting material. Plots were 3 m x 3.7 m and consisted of 3 rows (ridges), spaced 1 m apart. Plants were spaced 0.3 m within rows. The experimental design was a randomized complete block with four replications. A drip irrigation system was installed consisting of 1.27 cm poly-hose (Hardie Irrigation) as the sub-mains and Drip Strip Plus (Hardie Irrigation) tubing with laser drilled orifices 0.3 m apart as the laterals.

Each plot was harvested at 6 months after planting. Tubers from 10 plants in the center row of each plot were harvested. The weight of marketable tubers was recorded.

In a second trial cultivar 'Gunung' was evaluated for the effect of nitrogen applied at varying rates. Ammonium sulfate was applied to provide nitrogen at rates of 0, 50, 100 and 150 kg/ha. Phosphorous and potassium were both applied at rates of 75 kg/ha using triple super phosphate and potassium sulfate, respectively. All of the fertilizer was applied two months after planting. The initial soil pH was 7.9 with a N content of 90 ppm (Table 1). The experimental design, plot size, layout and establishment, and harvesting method were similar to the previous trial. At harvest (seven months after planting), the total and marketable weight of tubers were recorded. Tuber subsamples from each replication were peeled, sliced, then dried at 70°C to obtain the dry matter content.

Two trials were conducted to evaluate the effect of varying irrigation rates on the production of *D.alata* yams. Cultivar 'Binugas' was grown in field plots with irrigation applied to maintain soil moisture levels of 20, 40 and 60 kPa. A rain-fed (no applied irrigation) treatment was also included. Nitrogen was applied at 100 kg/ha using ammonium sulfate, and P and K were both applied at 75 kg/ha (using triple super phosphate and potassium sulfate, respectively). Asimilar drip irrigation system as previously described was installed in trial plots. Tensiometers (Irrometer Co., CA) were placed in the root- zone in the center rows of plots, to monitor soil moisture content. When tensiometer readings exceeded the level for a specific treatment, the irrigation system was turned on until the soil moisture content was increased to the desired level. Semi-automatic timers were used to turn the irrigation system on and off . Water flow meters were used to measure the amounts of water applied to each treatment. The experimental design, plot sizes, layout, establishment, harvesting method and dry matter content determination were similar to the nitrogen rate trials. Rainfall during the 1992 and 1993 growing seasons were 830 and 511 mm, respectively (Fig .1). Yams were harvested at seven and six months after planting in 1992 and 1993, respectively.

Statistical analyses of data were performed following the statistical analysis system procedures (SAS Institute, Inc. 1988).

RESULTS AND DISCUSSION

The application of nitrogen at rates up to 300 kg/ha did not affect production of either of the two cultivars ('Binugas and 'Gunung') utilized in the study. Yields were very similar for both cultivars at all application rates, and there was a trend for higher yields from the 0 nitrogen plots.

Production of 'Gunung' yams was influenced by the nitrogen fertilization treatments in the second trial. There was a negative linear response of total and marketable yields to the rates of applied nitrogen (Table 2). Yields decreased as the nitrogen application rate increased. The percent dry matter of the tubers was not affected by the treatments but total dry matter production had a linear response (Table 2). Nitrogen applied at the low rates (0-50 kg/ha) produced higher yields and dry matter than at the higher rates (100-150 kg/ha).

These trials have indicated that supplemental applications of nitrogen to soils testing at nitrogen levels of 95 to 116 ppm will suppress yam yields in the Virgin Islands. A lack of response to high levels of N have been reported in Barbados by Gooding (1970), and yields were decreased in Trinidad (Chapman, 1965).

The response pattern to the irrigation rates was similar for both years. Yields were much higher in the first year probably due to the longer growing season. During both growing seasons the only parameter to be influenced by the application of irrigation was the dry matter content of the tubers Tables 3 and 4). There was a quadratic decrease in dry matter content as the irrigation rate, hence the soil moisture content, increased.

The water use efficiency data for both years (Tables 5 and 6) indicate that rainfall was the biggest contributor to soil moisture during the growing season (336.6 and 206.7 m^3 for 1992 and 1993, respectively). The yield data indicates that despite a higher rainfall amount during the 1992 growing season, a more beneficial response to supplemental irrigation was obtained during the longer growing season compared to 1993. Irrigation was an economically viable practice, but was more beneficial during 1992. Irrigation returns were similar for the 60 kPa treatment for both years but were much higher for the 20 and 40 kPa treatments in 1992 ($102 for both treatments) than 1993 ($40 and $67 for the 20 and 40 kPa treatments, respectively) .

Rainfall amounts of 511 to 830 mm during a six to seven months growing season appears to be adequate for yam production. A longer growing period definitely results in increased yield and increased water use efficiency.

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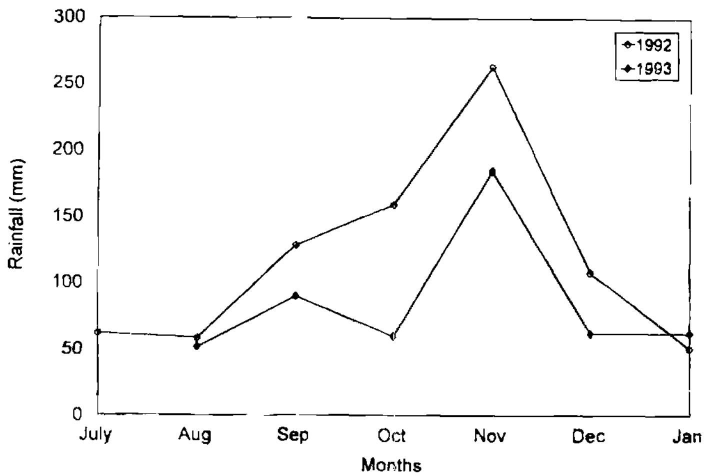

Figure 1. Monthly rainfall amounts during 1992 and 1993 yam growing seasons.

Table 1. Soil test data for plots used in yam nitrogen application trials.

Cultivar (YR)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	pH	OM (%)
BINUGAS (1992)	116	14	343	4250	7.8	6
GUNUNG (1992)	95	3	328	4017	7.8	2.5
GUNUNG (1993)	90	18.4	343	4556	7.9	4.4

Table 2. Effect of applied nitrogen on 'Gunung' yam production.

Nitrogen rate (kg/ha)	Size (g)	Total yield (t/ha)	Marketable yield (t/ha)	Dry matter (%)	Total dry matter (t/ha)
0	480	23.9	18.5	20.5	4.9
50	372	21.4	18.1	19.6	4.2
100	465	18.1	15.1	19.7	3.6
150	253	10.5	7.6	19.3	2.1
Significance	NS	L**	L*	NS	L**
Contrasts					
Low vs High	NS	*	*	NS	**
0 vs 150	NS	**	*	NS	**
50 vs 150	NS	*	*	NS	*

NS, *, ** Nonsignificant or significant at P = 0.05 or 0.01, respectively.
Linear (L) response.

Table 3. Effect of irrigation on 'Binugas' yam production (1992).

Irrigation rate (kPa)	Tuber Size (g)	Total yield (t/ha)	Marketable yield (t/ha)	Dry matter (%)	Total dry matter (t/ha)
20	500	25.2	23.5	21	5.3
40	480	23.8	20.7	20.9	5
60	775	23 8	21.6	21.8	5.2
Rain	357	20 2	17.1	22.6	4.6
Significance	NS	NS	NS	Q*	NS

NS,* Nonsignificant or significant at P = 0.05
Quadratic (Q) response.

Table 4. Effect of irrigation on 'Binugas' yam production (1993).

Irrigation rate (kPa)	Tuber Size (g)	Total yield (t/ha)	Marketable yield (t/ha)	Dry matter (%)	Total dry matter (t/ha)
20	308	14	10.1	18.3	2.5
40	367	16.2	9.8	17.4	2.8
60	336	13.2	8.7	18.9	2.5
Rain	373	14.8	10.4	19.7	3.1
Significance	NS	NS	NS	Q**	NS

NS,** Nonsignificant or significant at P = 0.01
Quadratic (Q) response.

Table 5. Estimated water use (applied) and efficiency of irrigated 'Binugas' yam (1992).

Irrigation rate (kPa)	Total Water use (l/plt)	Total Water use (cu. m)	Irrigation water cost ($/ha)	Water cost efficiency ($/t)	Returns to irrigation water ($/$)
20	4.6	153.0	647.2	27.5	101.8
40	4.1	135.0	571.1	27.6	101.6
60	3.2	105.6	447.3	20.8	135
Rain[1]	10.1	336.6	-	-	-

Water cost = $4.23/cu m
[1]Rainfall computed based on 1 mm =4047 l
Yam price = $2.80/kg
Water cost efficiency = cost of water to produce 1 ton of yam

Table 6. Estimated water use (applied) and efficiency of irrigated 'Binugas' yam (1993).

Irrigation rate (kPa)	Total Water use (l/plt)	(cu. m)	Irrigation water cost ($/ha)	Water cost efficiency ($/t)	Returns to irrigation water ($/$)
20	5.1	168.8	713.8	70.8	39.5
40	2.9	96.8	409.3	41.8	67.1
60	1.4	45.0	190.4	21.9	127.7
Rain[1]	6.2	206.7	-	-	-

Water cost = $4.23/cu m
[1]Rainfall computed based on 1 mm = 4047 l
Yam price=$2.80/kg
Water cost efficiency = cost of water to produce 1 ton of yam