Fertilizer-nitrogen management in onion-tropical pumpkin rotation in Puerto Rico

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Introduction

- Onion (*Allium cepa* var. *cepa* L.) and tropical pumpkin (*Cucurbita moschata*) contribute about 13% of the total gross agricultural income for horticultural crops in Puerto Rico, estimated at about $54.5M (2010)
- An onion-tropical pumpkin rotation is typical for vegetable production systems of Puerto Rico
- Soils of the semiarid-southern coast are 2:1 clays, high CEC, pH>7, 2-3% organic matter (Mollisols and Vertisols) considered of "high fertility" (Table 1)
- Onion is a high cash crop with very shallow root system that is frequently irrigated using drip irrigation
- Onion is fertilized with high N rates in efforts to maximize yield and bulb size
- Tropical pumkin is expected to have a deeper root system that will take up residual soil N and fertilizer rates are usually lower.
- There is no published information that describes the environmental impact of fertilizer N (i.e. on groundwater NO_3 concentrations, residual soil NO_3-N, leached N concentrations, or N losses in runoff) in vegetable production fields of Puerto Rico.

Objectives

- Quantify the effects of three fertilizer-N levels on yields of an onion-pumpkin rotation
- Evaluate the influence of fertilizer-N rate on residual soil NO_3^- and soil solution inorganic N (NH_4^+ and NO_3^-)

Materials and methods

- Soil is Guayacan clay (GyB) series (Fine-loamy, mixed, superactive, isohyperthermic Typic Haplocalcids) and is considered of "high fertility" (Table 1).

Table 1. Soil fertility characterization [1] (0-15 cm) of plots prior to experiment initiation.

pH	OM	NO3-N	Olsen P	Ca	Mg	K	Na	CEC	S	Fe	Mn	Zn	Cu	B
	%	----mg/kg---		------------------cmolc/kg-------------					-------------------mg/kg----------------					
8.2 [2]	2.3	58.7	16.3	20.4	8.9	1.1	0.5	30.8	20	6.0	1.8	1.7	5.5	1.3
0.2	0.2	50.6	18.3	0.9	0.9	0.1	0.1	1.8	3.5	0.7	0.7	0.3	1.4	0.1

1 - pH – 1:1 soil:water; organic matter (OM) – weight loss on ignition; NO_3-N – water extractable; P – Olsen-bicarbonate; Ca, Mg, K, Na – ammonium acetate extractable; SO_4-S – K_2HPO_4 extractable; Fe, Mn, Zn, Cu – DTPA-TEA extraction; B – hot water extractable.
Mean of 12 plots prior to experiment initiation to a depth of 0-15 cm.
2 - mean (top) and standard deviation (bottom)

- Experiment was in a private farm in Guánica, Puerto Rico (17º58'42"N, 66º54'07"W)
- Soil preparation: disking, subsoiler, disking and soil harrow.
- Raised beds (1.82 m distance) with drip irrigation lines
- Onion (var. Mercedes) planted at 614,818 plants/ha, Pumpkin (var. Soler) planted at 2,990 plants/ha
- Experimental design was completely randomized with three treatments and four replicates
- Onion fertilizer-N rates of 140 (N-1), 196 (N-2), 253 (N-3) kg N/ha (30 kg N/ha pre-plant) and weekly fertigation
- Pumpkin followed onion on the same plots with fertilizer-N rates of: 112 (N-1), 196 (N-2), and 281 (N-3) kg N/ha via bi-weekly drip irrigation
- N sources were urea, ammonium sulphate (AS) and potassium nitrate (PN), with N ratios (urea-N:AS-N:PN-N) of 2:1:1 for N-1, 2.7:1.7:1 for N-2 and 3.5:2.5:1 for N-3, treatments.
- Agronomic crop performance indicator and yields were measured
- Suction-cup lysimeters installed at 6 and 12" depths to monitor soil-solution inorganic N for three fertigation events
- Pest control was followed using farmer's best management practices
- Soils were sampled pre-plant and post harvest at 0-15, 15-30, 30-60, and 60-90 cm for 1M KCl extractable NO_3-N

Experiment timeline

22-oct-12
Onion planting

15-apr-13
Pumpkin planting

1-oct-13 to present
Fallow

19-july-13
Pumpkin harvest

1-mar-13
Onion harvest

Results and Discussion

Table 2. Fresh onion yields and size distribution as influenced by fertilizer-N levels.

Fertilizer N rate	Total yield	Total marketable yield	Total bulbs	Total marketable bulbs	Small	Medium	Large	colossal
kg N/ha	---------kg/ha--------		------------#/ha--------		---------------------%---------------			
Farmer	42,455	36,008	263,803	178,525	9	52	32	0.3
140	37,466a[1]	31,883a	247,165a	159,298a	11	55	29	1
196	40,031a	33,276a	294,387a	177,529a	12	61	21	1
253	43,007a	36,498a	295,284a	185,001a	11	54	28	3
Mean	40,740	34,416	275,160	175,088				

1 - Columns with different letters are significantly different at p<0.05 as determined with Fisher's LSD test.

- Mean onion plant population was 319,417, with 39% and 69% bulb formation at 10 and 11 weeks, respectively.
- Fertilizer N rate did not affect total onion yield, total marketable yield, total number of fruits, total marketable fruits, and size classification (Table 2)
- Growers can take a conservative approach to fertilizer-N application for onion production in the Guánica area, in a similar rotation and nutrient management program as the one that was historically used
- Pre-plant soil NO_3-N (0 to 30 cm) ranged from 89 to 282 kg N/ha and could explain lack of response above the 140 kg N/ha fertilizer treatment

Table 3. Tropical pumpkin number of fruits and yields as influenced by fertilizer-N levels.

Fertilizer N rate	Marketable Number	Marketable Yield	Non-marketable Number	Non-marketable Yield
kg N/ha	fruits/ha	kg/ha	fruits/ha	kg/ha
112	5738a[1]	29274a	520ab	1765a
196	2977b	15126b	933a	3273a
281	8495c	44645c	325b	1615a

1 - Columns with different letters are significantly different at p≤0.05 as determined with Fisher's LSD test.

- Highest yields were obtained with 281 kg N/ha (Table 3)
- Pumpkin marketable yields and number of fruits were highest with 281 kg N/ha plots with 196 kg N/ha had an unusually high number of discarded fruit due to disease incidence

Table 4. Sufficiency levels of nutrients in onion indicator leaf 11 weeks after transplanting.

	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	-----------------------g/kg---------------------						----------------mg/kg----------------				
- 95% CI[1]	47.7	2.5	38.9	13.14	5.37	11.1	191.6	38.9	28.4	19.1	24.5
+ 95% CI	51.0	3.0	47.4	16.03	6.69	12.8	269.1	50.3	40.6	25.2	30.5

1 - 95% confidence intervals

- Sufficiency levels of nutrients in onion indicator leaves can be calculated based on lack of response to fertilizer-N (Table 4)

Table 5. Plant vegetative biomass, harvest index, nutrient extraction and nutrient uptake in onion and tropical pumpkin rotation as influenced by fertilizer-N.

Fertilizer N rate	Plant biomass dry wt. Vegetative	Plant biomass dry wt. Fruit	Plant biomass dry wt. Vegetative + fruit	Concentration Vegetative-N	Concentration Fruit-N	N extraction Vegetative	N extraction Fruit	N extraction Vegetative + fruit	Harvest Index
kg/ha	-------------kg/ha-------------			-------g/kg-------		---------g/ha----------			
				----Onion----					
140	2258	3050	5307	23.2	19.6	52	59	111	0.57
196	2408	2930	5337	24.5	22.5	59	64	122	0.54
253	2509	3433	5942	23.9	22.2	60	76	135	0.59
Mean	2392	3137	5529	23.9	21.4	57	66	123	0.57
P<0.05	ns	ns	ns	ns	ns	ns	ns	ns	ns
				----Tropical pumpkin----					
112	2339a [1]	5523a	7862a	27.6a	27.7ab	64a	155a	219a	0.70a
196	2857a	2656b	5513b	28.4a	22.5a	81ab	62b	143b	0.47 b
281	3425a	6097a	9522a	27.9a	31.1b	91b	188a	279c	0.64a

1 - For each crop means within a column with different letters are significantly different at P≤0.05 as determined using Fisher's LSD test.

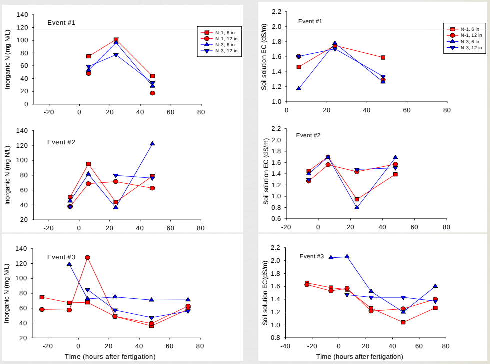
- Mean onion vegetative N uptake was 57 kg N/ha and fruit N extraction was 66 kg N/ha, with no significant difference among treatments (Table 5).
- Pumpkin vegetative N uptake ranged from 64 to 91 kg N/ha and fruit N extraction ranged from 155 to 188 kg N/ha, and was highest for 281 kg N/ha treatment
- Pre-plant profile (0 to 100 cm) NO_3-N was >200 kg N/ha, and in spite of this, there was crop response to fertilizer-N

Table 6. Economic analysis of N fertilization for onion and pumpkin production.

Fertilizer N	Fertilizer-N cost	Difference in cost	Gross profit	Value/Cost
kg N/ha	$/ha	$/ha	$/ha	$ crop/$ fert-N
		----Onion----		
140	1,080		18,289	
196	1,225	145	18,416	0.9
253	1,363	284	20,459	7.7
		----Tropical pumpkin----		
112	740		10,308	
196	958	219	5,326	-23.4
281	1,179	439	15,720	12.7

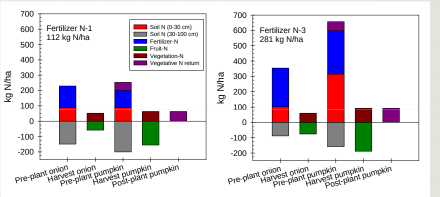
- Fertilizer represents 5.3 to 6.7 % of estimated production costs in onion ($20,248) and 14.9 to 23.8 % in pumpkin ($4,960) (Table 6)
- In onion, for every $ invested above 140 kg N/ha there is a benefit of $0.9 and $7.7 for 196 and 252 kg N/ha
- In pumpkin, for every $ invested above 112 kg N/ha there is a benefit of -$23 and $12.7 for 196 and 281 kg N/ha, respectively.
- Disease incidence caused both loss in yield and economic losses for 196 kg N/ha treatment.

Figure 1. Soil solution inorganic N and electrical conductivity at two depths (6 and 12 inches) during three fertigation events with 140 (N1) and 265 kg N/ha (N3) treatments.



- Each fertigation event delivered 14.8 kg N/ha (13.2 lb N/acre) for N-1 and 28.8 kg N/ha (25.7 lb N/acre) for N-3 fertilizer treatments.
- No significant different between samples collected before fertigation and after the fertigation events. This suggests that inorganic N is persistent in the soil solution, even days after fertigation.
- Mean inorganic N concentrations were 66.8 and 60.0 mg N/L for N-1 and N-3 fertigation treatments, respectively (6 in depth).

Figure 2. Partial soil and crop N budget for onion-tropical pumpkin rotaion. Residual soil inorganic N after pumpkin has not been analyzed.



- There was a higher surplus soil inorganic N in N-3 treatment which was concentrated in the top 30 cm.
- In spite of the improvement in agronomic yield, the high residual soil N and potential environmental impact may warrant fertilization at the lower N rates.

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