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Rotational Cropping Sequence Affects Nitrogen Fertilizer Requirements in Processing Pumpkins (*Cucurbita moschata*)

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***Abstract*. Field experiments were conducted over a 5-year period (1994–98) to determine the effect of various cropping systems (rotations) on fertilizer N requirements in processing pumpkins [*Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poir.] on medium- to fine-textured soil. Treatments consisted of a factorial combination of five N fertilization rates (0, 56, 112, 168, 224 kg·ha^{-1} N) and four pumpkin cropping systems: 1) pumpkins following corn (*Zea mays* L.); 2) pumpkins following soybeans [*Glycine max* (L.) Merrill]; 3) pumpkins following 2-years corn; and 4) pumpkins following fallow ground. Cropping systems were chronologically and spatially arranged in two complete cycles, with pumpkin studies taking place in 1996 and 1998. Averaged over the two studies, the optimal N fertilization rate for highest total weight of ripe fruit following soybeans was estimated at 109 kg·ha^{-1} N, compared to 128 kg·ha^{-1} N following fallow ground, even though yields were similar, suggesting a soybean N-credit of 19 kg·ha^{-1} N. Concurrently, the N fertilizer rate for highest total ripe fruit weight following corn was estimated at 151 kg·ha^{-1} N, and 178 kg·ha^{-1} following 2-years corn, indicating a negative rotation effect on pumpkin N requirements of 23 and 50 kg·ha^{-1} N, respectively. Minimum N fertilizer requirements, the N fertilizer rate associated with a ripe fruit yield of 50 t·ha^{-1}, were calculated at 45, 37, 69, and 47 kg·ha^{-1} N in the respective cropping systems. Negative effects from excessive N fertilization were greater in pumpkins following soybeans than in pumpkins following corn or 2-years corn, with reductions in total ripe fruit weight of 21%, 9%, and 3%, respectively, at the highest N rate. A critical level for preplant soil NO_3-N of 17.6 mg·kg^{-1} was identified above which there was little or no pumpkin yield response to N fertilization.**

Nitrogen is a critically important nutrient in pumpkin production, both from a yield and a maturity perspective. While too little N can result in reduced fruit size and low yields, excess N can delay flowering, causing high amounts of green fruit at harvest at the expense of ripe fruit production (Swiader et al., 1994). Additionally, N is also a major factor from an environmental standpoint. In Illinois, surface water N is dominated by agricultural sources, with the most important being N runoff from excess fertilizer rates (David and Gentry, 2000). This situation is of particular concern in tile-drained production areas of the state (≈35% of Illinois), where tiles take shallow groundwater from the bottom of the root zone and deliver it to streams that feed into surface water reservoirs, leading to NO_3-N concentrations >10 mg·L^{-1} N in more than 30% of the sites tested (David et al., 1997). In context of these mutual environmental and production consequences of mismanaged N fertilization, N fertilizer-use efficiency has become a major goal of Illinois pumpkin production.

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Nitrogen fertilizer-rate studies for pumpkins are relatively few, with varying results. In Illinois, fertilizer N requirements for 90% and 100% pumpkin (*Cucurbita moschata*) yield ranged from 44 and 158 kg·ha^{-1} N, respectively, on a dryland silty-clay loam (Swiader et al., 1988), to 148 and 245 kg·ha^{-1} N, respectively, on a fertigated fine-sand (Swiader and Moore, 2002). In New York, pumpkin (*Cucurbita pepo* L.) yield at two sites, one on a silt loam and the other on a sandy loam, was unaffected by three rates of N (67, 112, 157 kg·ha^{-1} N); however, a 0 kg·ha^{-1} N control was not reported at either location, making interpretation of results difficult (Reiners and Riggs, 1997).

When determining optimum N fertilization rates, producers should consider past cropping history. Studies commonly show that legumes can contribute up to 100 to 130 kg·ha^{-1} N to succeeding non-leguminous crops, significantly affecting fertilizer N requirements (Kurtz et al., 1984). In potato (*Solanum tuberosum* L.), optimum fertilizer N rates over a 3-year period averaged 72.5 kg·ha^{-1} N lower following red clover (*Trifolium pratense* L.) than following small grains (Porter and Sisson, 1991). Similarly, the optimal N rate for corn following soybean was 47 kg·ha^{-1} N lower than for corn following corn, even though yields were similar (Nafziger et al., 2000). Known as the "N rotation effect," most N benefits using legumes in crop rotations are attributed to increased levels of residual soil NO_3-N in the spring following legumes (Badaruddin and Meyer, 1994; Franzleubbers et al., 1994).

In Illinois, pumpkins are traditionally grown in rotation with corn and soybeans, with pumpkins sometimes following corn or 2-years corn, and other times following soybeans. Based on research with other crops, fertilizer N requirements are likely to vary, depending on cropping sequence. Soybean N-credits to ensuing crops typically range from 11 kg·ha^{-1} N for wheat (*Triticum aestivum* L.) and other small grains to 45 kg·ha^{-1} N for corn (Hoeft and Peck, 1998), with some estimates in corn as high as 90 kg·ha^{-1} N (Nafziger et al., 1984). Soybean N-credits specific for pumpkins have not been reported. The objective of this study was to determine optimal fertilizer N requirements in pumpkin, taking into account previous crops of corn and soybeans, and any rotational N-credits. In the process, the relationship between residual soil NO_3-N levels and pumpkin yield response to N fertilizer was evaluated over a range of cropping systems.

Materials and Methods

A series of field experiments were conducted over a 5-year period (1994–98) at the Univ. of Illinois Vegetable Crops Research Farm in Champaign, in which pumpkin was grown in rotation with corn or soybean. The soil at the site was a Flanagan silty loam (fine, montmorillonitic, mesic Aquic Argiudolls), along with some smaller areas of Drummer silty clay loam (fine-silty, mixed, mesic Typic Haplaquoll) and Catlin silt loam (fine-silty, mixed, mesic, Typic Argiudolls). Each of the soils at the site had no history of manure application. Treatments consisted of a factorial combination of five N fertilization rates (0, 56, 112, 168, 224 kg·ha^{-1} N) and four pumpkin cropping systems (rotations): 1) pumpkins following corn; 2) pumpkins following soybeans; 3) pumpkins following 2-years corn; 4) pumpkins following fallow ground. The cropping systems were chronologically and spatially arranged in two separate series, so as to allow two complete cycles with two autonomous pumpkin studies, one in 1996 and the other in 1998. In each study, a split-plot design was used, with pumpkin cropping systems as main plots, replicated four times, and N rates as subplots (11.0 m × 4.6 m). Corn and soybeans in main plots were grown using standard industry procedures (Illinois Agronomy Handbook, 1992), with broadcast application of 168 kg·ha^{-1} N made to corn and no N applied to soybeans. Following harvest of grain, corn and soybean plant residues were disked in the soil.

On 20 May 1996 and 26 May 1998, pumpkin 'Libby-Select' was machine-seeded in each N subplot in six rows 4.6 m long, spaced 1.8 m apart, with seeds spaced 0.25 m apart in each row. When seedlings developed two true leaves, plants were thinned to an in-row spacing of 0.5 m, resulting in a final pumpkin population of ≈10,750 plants/ha. About 1 week prior to seeding pumpkins, N fertilization rates were applied as urea-ammonium nitrate solution (28–0–0) broadcast and incorporated (15 cm) in the soil. Maintenance applications of P and K and other cultural requirements were in accordance with standard commercial pumpkin recommendations (Midwest Vegetable Production Guide, 1995). Overhead sprinkler irrigation was applied to provide a total (including rainfall) of ≈3.8 cm of water per week.

Weather conditions during the 1996 growing season were very conducive to pumpkin production, but lesser so in 1998. In both years, mean monthly air temperatures during the growing season were comparable to the 20-year average, except in Sept. 1998 where temperatures averaged 3.4 °C higher than normal (Table 1). Seasonal rainfall totaled 61.1 cm in 1996 and 69.6 cm in 1998, compared to the previous 20-year mean of 62.2 cm. In both years, rainfall totals in May were higher than normal, especially in 1996 with more than 20 cm of precipitation. This pattern continued in June 1998, with more than 2 times the normal precipitation occurring during the critical periods of female flowering and fruit set.

Pumpkin fruits were harvested (12 Sept. 1996; 1 Oct. 1998) by hand from the middle 3.7 m × 4.6 m of each subplot when it was estimated that 80% of the primary fruits had reached commercial maturity, as indicated by a change in rind color from green to tan. The number and total weight of ripe and usable-green fruit were recorded. Non-usable fruit, including split and small fruit (<15-cm diameter), were not harvested.

In Spring 1996 and 1998, about 1 week before seeding pumpkins and just prior to application of N rates, a composite sample of 12 to 18 soil cores (2.5-cm diameter) was collected from each main plot to a depth of 30 cm and stored at –20 °C. When ready for analysis, soil samples were thawed and air-dried in the greenhouse, screened, and thoroughly mixed. Triplicate subsamples were analyzed for organic matter content by a modified Walkley-Black method (Schulte, 1988), total-N by salicylic acid-thiosulfate-H_2SO_4 digestion (Bremner and Mulvaney, 1982) followed by colorimetric assay (Cataldo et al., 1974), and NO_3-N after extraction with 0.5 M K_2SO_4 and colorimetric determination of the extracts (Cataldo et al., 1975). Analyses for organic matter and total N were performed on soil particles <0.6-mm diameter, and NO_3-N analysis on <2-mm diameter.

Data were evaluated by analyses of variance. When significant treatment effects ($P \leq 0.05$) were detected, least significant difference (LSD) procedures were used to compare cropping system effects. Trend analysis was used to partition main effects of N rate into linear, quadratic, and quadratic-plateau components. This latter form of regression analysis (SAS-NLIN procedure, SAS Institute, 1985) was chosen over quadratic regression when it resulted in a >10% reduction in residual error mean square and, at the same time, when it provided a better visual explanation of the data. Optimum N fertilizer requirements represented the lowest fertilizer N rate associated with highest yields of ripe fruit. Minimum N fertilizer requirements were associated with a ripe fruit yield of 50 t·ha^{-1}, the industry standard for the minimum economical yield level (D. Scheirer, personal communication).

Results and Discussion

Cropping systems and their respective grain yields, along with the initial soil properties at the start of the pumpkin experiments in 1996 and 1998 are shown in Table 2. In general, cropping system grain yields were good in both years and were representative of commercial corn and soybean production in Illinois (Illinois Agronomy Handbook, 1992). Soil analyses (0–30 cm) at the beginning of each of the pumpkin experiments (prior to application of N treatments) showed that the initial amounts of soil organic matter and total N were unaffected by cropping system, averaging 31.3 and 1.69 g·kg^{-1}, respectively, in 1996, and 35.5 and 1.92 g·kg^{-1}, respectively, in 1998. Similarly, preplant soil NO_3-N was not significantly influenced by cropping system; however, a trend occurred in both years (P = 0.15 in 1996; P = 0.08 in 1998) with NO_3-N levels generally highest following soybean and lowest following 2-years corn.

Ripe fruit production. The number of ripe fruit produced in 1996 was not affected by cropping system or N fertilization rate, with pumpkins averaging almost 9500 ripe fruits/

Table 1. Mean monthly air temperatures and rainfall totals for 1996 and 1998 cropping seasons at Champaign-Urbana, Ill.

	Temp (°C)			Rainfall (cm)		
Month	20-year mean (1976–95)	1996	1998	20-year mean (1976–95)	1996	1998
April	11.0	12.3	11.5	9.4	9.1	11.7
May	16.7	15.2	19.5	12.5	20.9	15.9
June	22.3	22.1	21.7	9.6	10.4	20.8
July	23.9	23.5	23.7	11.9	8.5	11.7
August	23.0	21.4	24.0	11.2	3.6	5.6
September	18.7	17.7	22.1	7.6	8.6	3.9

Table 2. Cropping systems, respective grain yields, and initial soil properties for pumpkin studies in 1996 and 1998.

	Cropping system		Initial soil properties[z]		
Pumpkin study	Previous crop	Grain yield (t·ha^{-1})	Organic matter (g·kg^{-1})	Total N (g·kg^{-1})	NO_3-N (mg·kg^{-1})
1996	Corn[y]	8.1	33.0	1.74	4.4
	Soybean	2.6	30.8	1.80	7.0
	Corn–corn	7.6	32.1	1.64	2.8
	Fallow	---	29.4	1.59	6.5
			NS	NS	NS
1998	Corn[x]	9.1	36.4	1.94	9.8
	Soybean	3.3	34.8	2.00	13.3
	Corn–corn	10.5	37.0	1.94	4.1
	Fallow	---	33.6	1.79	8.9
			NS	NS	NS

[z]Properties are at the start of the respective pumpkin experiment, in spring before application of N treatments.
[y]Crops were grown in 1995, and also 1994 for corn–corn.
[x]Crops were grown in 1997, and also 1996 for corn–corn.
[NS]Nonsignificant at $P \leq 0.05$.

Table 3. Effect of cropping system and N fertilization rate on pumpkin fruit production in 1996.

	Ripe fruit			Green fruit			Total fruit	
	Count (no./ha)	Fresh wt (t·ha^{-1})	Avg fresh wt (kg/fruit)	Count (no./ha)	Fresh wt (t·ha^{-1})	Avg fresh wt (kg/fruit)	Count (no./ha)	Fresh wt (t·ha^{-1})
Cropping system								
Corn	10,068	59.0[z]	5.90	4,003	16.7a[y]	4.23	14,070	75.7 a[z]
Soybean	9,127	55.7	6.17	4,062	17.7a	4.46	13,189	73.4 a
Corn–corn	9,284	52.8	5.70	3,405	13.8b	4.13	12,689	66.6 b
Fallow	9,503	53.5	5.81	4,182	18.0a	4.40	13,685	71.5 ab
Significance	NS	NS	NS	NS	*	NS	NS	**
N rate (kg·ha^{-1})								
0	8,311	41.2[z]	5.00	3,584	15.7	4.39	11,896	56.9[z]
56	9,446	54.2	5.92	3,696	16.0	4.38	13,145	70.2
112	10,232	62.3	6.22	3,958	17.0	4.46	14,190	79.3
168	10,036	60.7	6.18	3,995	16.6	4.22	14,031	77.3
224	9,448	57.8	6.17	4,331	17.4	4.07	13,779	75.2
Significance	NS	L**Q***	QP**	NS	NS	NS	NS	L***Q***

[z]Cropping system × N rate interaction significant at $P \leq 0.05$.
[y]Mean separation for cropping systems by LSD at $P \leq 0.05$.
NS, **, ***Nonsignificant or significant at $P \leq 0.01$ or 0.001; L (linear), Q (quadratic), QP (quadratic-plateau).

ha (Table 3). Concomitantly, the mean fresh weight of ripe fruit was also unaffected by cropping system, but increased with increasing N rate up to 112 kg·ha^{-1}, where fruits averaged 6.2 kg each. Significant interactions between cropping system and N rate influenced ripe fruit yield in 1996, as the relative increase in total weight of ripe fruit to applied N was markedly greater following corn or 2-years corn than following soybeans or fallow ground (Table 4). Additionally, reductions of total weight of ripe fruit of ≈22% and 13% occurred at the high N rate following soybeans or fallow ground, respectively, but not following corn or 2-years corn. Overall, the response pattern of total weight of ripe fruit to applied N in 1996 was quadratic following either soybeans or fallow ground, and quadratic-plateau (leveling-off at the high N rate) following corn or 2-years corn. From the response functions generated from the data, highest total weight of ripe fruit was estimated at 67.3 t·ha^{-1} with 161 kg·ha^{-1} N following corn, 63.8 t·ha^{-1} with 116 kg·ha^{-1} N following soybeans, 62.1 t·ha^{-1} with 205 kg·ha^{-1} N after 2-years corn, and 60.8 t·ha^{-1} with 139 kg·ha^{-1} N following fallow ground (Table 5). Minimum N fertilizer requirements, associated with a ripe fruit yield of 50 t·ha^{-1}, were calculated at 33, 13, 66, and 30 kg·ha^{-1} N in the respective cropping systems.

In 1998, the number and mean weight of ripe fruit were unaffected by cropping system or N fertilization rate, with pumpkins averaging 7860 ripe fruits/ha and 6.2 kg/fruit (Table 6). Similar to that in 1996, significant interactions between cropping system and N fertilization rate affected ripe yield in 1998, as the positive response in total ripe fruit weight to applied N was greater following corn or 2-years corn than following soybeans or fallow ground (Table 7). However, unlike in 1996, total weight of ripe fruit in 1998 decreased at the high N fertilization rates following corn or 2-years corn, as well as after following soybeans or fallow ground, resulting in a quadratic response in total ripe weight to N fertilization in all cropping systems. From the response functions generated from the data, highest total weight of ripe fruit was estimated at 57.4 t·ha^{-1} with 140 kg·ha^{-1} N following corn, 51.2 t·ha^{-1} with 103 kg·ha^{-1} N following soybeans, 55.7 t·ha^{-1} with 151 kg·ha^{-1} N after 2-years corn, and 52.8 t·ha^{-1} with 116 kg·ha^{-1} N following fallow ground (Table 5). Minimum N fertilizer requirements in 1998 were calculated at 56, 61, 72, and 63 kg·ha^{-1} N, respectively.

Green fruit production. In 1996, the production of green fruit was relatively unaffected by cropping system or N fertilization rate (Table 3). The one exception to this response was lower total weight of green fruit following 2-years corn than in the other cropping systems. Averaged over N rates, green fruit accounted for about 21% of the total fruit weight produced following 2-years corn, compared to ≈24% in the other cropping systems.

In 1998, the number, total yield, and mean fresh weight of green fruit were significantly affected by both cropping system and N fertilization rate (Table 6). Total weight of green fruit was generally highest following soybeans (accounting for 34% of the total fruit weight) and lowest following 2-years corn (accounting for 26% of the total fruit weight produced). In each cropping system, the number and total weight of green fruit increased linearly, while mean weight of green fruit decreased, with increasing rates of N fertilization. Based on visual observation, it appeared that much of the green fruit produced in 1998 consisted of the delayed set of primary fruit, whereas in 1996, it most likely represented a second set of fruit that plants were able to start after development of the initial set.

Total fruit production. Total fruit number, consisting of the sum of usable ripe and green fruit, was not affected by cropping system or N

Table 4. Interaction of cropping system and N fertilization rate on pumpkin ripe fruit weight and total fruit weight in 1996.

N rate	Ripe fruit wt				Total fruit wt			
	Cropping system							
(kg·ha^{-1})	Corn	Soybean	Corn–corn	Fallow	Corn	Soybean	Corn–corn	Fallow
	(t·ha^{-1})							
0	40.7	45.4	36.0	42.8	56.4	62.5	49.2	59.6
56	53.5	60.9	47.3	55.0	69.9	77.6	60.5	72.6
112	67.0	63.2	58.5	60.6	85.2	80.9	72.0	79.1
168	67.5	59.4	59.3	56.6	83.8	77.5	73.6	74.4
224	66.1	49.5	62.8	52.6	83.2	68.3	77.7	71.5
Significance	QP**	Q**	QP***	Q*	QP**	Q**	QP**	Q**

*, **, ***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively; QP (quadratic-plateau), Q (quadratic).

Table 5. Regression models for the effects of N fertilization rate on pumpkin ripe fruit weight and total fruit weight in 1996 and 1998 for various cropping systems (previous crops).

Year	Previous crop(s)	Model	r^2	N requirement (kg·ha^{-1}) Maximum yield	Minimum economic yield[z]
		Ripe fruit wt			
1996	Corn	$Y = 40.0 + 0.339X - 0.00105X^2$			
		$Y = 67.3$, if $X \geq 161$	0.75	161	33
	Soybean	$Y = 46.2 + 0.302X - 0.00130X^2$	0.51	116	13
	Corn–corn	$Y = 35.9 + 0.255X - 0.00062X^2$			
		$Y = 62.1$, if $X \geq 205$	0.63	205	66
	Fallow	$Y = 43.3 + 0.252X - 0.000905X^2$	0.54	139	30
		Total fruit wt			
	Corn	$Y = 55.5 + 0.372X - 0.00121X^2$			
		$Y = 84.1$, if $X \geq 154$	0.73	154	---
	Soybean	$Y = 63.2 + 0.303X - 0.00126X^2$	0.50	120	---
	Corn–corn	$Y = 49.0 + 0.249X - 0.00055X^2$			
		$Y = 77.0$, if $X \geq 224$	0.73	225	---
	Fallow	$Y = 60.2 + 0.265X - 0.00098X^2$	0.55	135	---
		Ripe fruit wt			
1998	Corn	$Y = 37.2 + 0.287X - 0.00102X^2$	0.62	140	56
	Soybean	$Y = 43.9 + 0.141X - 0.00068X^2$	0.39	103	61
	Corn–corn	$Y = 35.0 + 0.275X - 0.00091X^2$	0.60	151	72
	Fallow	$Y = 40.0 + 0.220X - 0.00095X^2$	0.41	116	63
		Total fruit wt			
	All crops	$Y = 56.8 + 0.271X - 0.00098X^2$	0.55	139	---

[z]Associated with a ripe fruit weight of 50 t·ha^{-1}.

Table 6. Effect of cropping system and N fertilization rate on pumpkin fruit production in 1998.

	Ripe fruit			Green fruit			Total fruit	
	Count (no./ha)	Fresh wt (t·ha^{-1})	Avg fresh wt (kg)	Count (no./ha)	Fresh wt (t·ha^{-1})	Avg fresh wt (kg)	Count (no./ha)	Fresh wt (t·ha^{-1})
Cropping system								
Corn	8,414	50.1 a[z, y]	6.02	4,600 c	19.6 b	4.41 a	13,014	69.7
Soybean	7,205	46.9 b	6.59	6,601 a	23.9 a	3.71 b	13,806	70.8
Corn–corn	8,220	48.6 ab	5.99	4,421 c	17.2 c	3.98 a	12,641	65.9
Fallow	7,601	46.8 b	6.25	5,735 b	21.7 ab	3.90 b	13,336	68.5
Significance	NS	**	NS	**	**	*	NS	NS
N rate (kg·ha^{-1})								
0	6,501	38.5[z]	5.96	4,219	17.8	4.37	10,720	56.2
56	7,993	50.1	6.36	4,741	19.7	4.19	12,735	69.8
112	8,628	54.1	6.38	5,451	21.1	3.95	14,079	75.2
168	8,387	51.2	6.28	5,974	22.2	3.82	14,361	73.4
224	7,791	46.7	6.09	6,310	22.4	3.67	14,101	69.1
Significance	NS	Q***	NS	L***	L**	L***	QP**	L*Q***

[z]Cropping system × N rate interaction significant at $P \leq 0.05$.
[y]Mean separation for cropping systems by LSD at $P \leq 0.05$.
NS, **, ***Nonsignificant or significant at $P \leq 0.01$ or 0.001; L (linear), Q (quadratic), QP (quadratic-plateau).

Table 7. Interaction of cropping system and N fertilization rate on pumpkin ripe fruit weight in 1998.

N rate	Cropping system			
($kg{\cdot}ha^{-1}$)	Corn	Soybeans	Corn–corn	Fallow
	($t{\cdot}ha^{-1}$)			
0	37.4	42.6	34.5	39.3
56	49.0	52.7	48.3	50.4
112	58.4	49.5	55.2	53.4
168	55.2	47.6	53.5	48.3
224	50.6	42.1	51.6	42.6
Significance	$L^{*}Q^{**}$	Q^{*}	$L^{**}Q^{**}$	Q^{**}

*,**Significant at $P \leq 0.05$ or 0.01, respectively; Q (quadratic), L (linear).

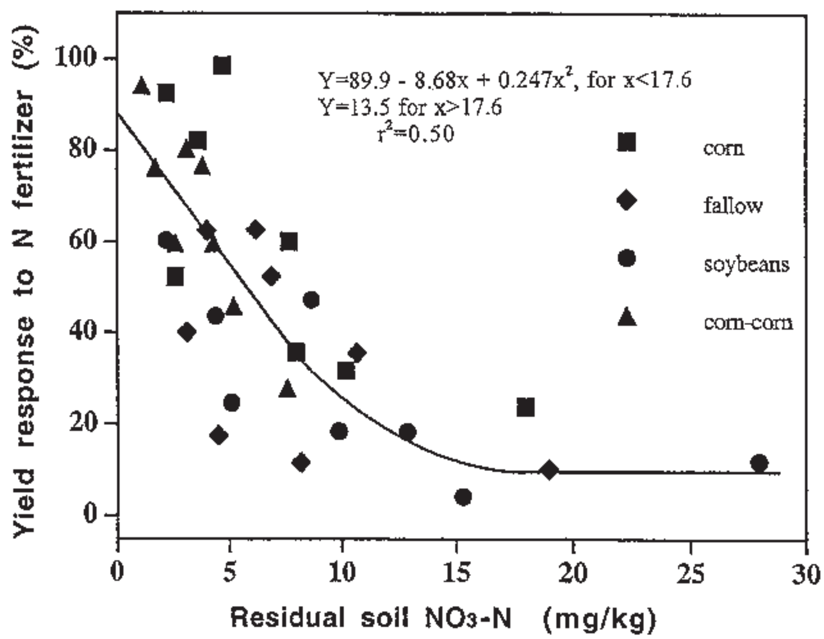

Fig. 1. Relationship between percentage yield response of ripe fruit to N fertilization and residual soil NO_3-N levels. The percent yield response of pumpkin to N fertilization was calculated as 100 × (maximum yield – control-plot yield)/control-plot yield; with control-plot yield representing the yield in the 0-$kg{\cdot}ha^{-1}$ N plots, and maximum yield estimated from the regression of ripe fruit yield vs. N rate as shown in Table 5.

fertilization rate in 1996, averaging ≈ 13,400 fruits/ha (Table 3). Similar to the response in ripe yield, significant interactions between cropping system and N fertilization rate affected total yield, as the response pattern of total fruit weight to increasing rates of applied N in 1996 was quadratic in pumpkins following either soybeans or fallow ground, and quadratic-plateau following corn or 2-years corn (Table 4). Maximum total fruit weight in 1996 was estimated at 84.1 $t{\cdot}ha^{-1}$ with 154 $kg{\cdot}ha^{-1}$ N following corn, 81.4 $t{\cdot}ha^{-1}$ with 120 $kg{\cdot}ha^{-1}$ N following soybeans, 78.1 $t{\cdot}ha^{-1}$ with 135 $kg{\cdot}ha^{-1}$ N following fallow ground, and 77.0 $t{\cdot}ha^{-1}$ with 225 $kg{\cdot}ha^{-1}$ N after 2-years corn (Table 5).

In 1998, total fruit number was unaffected by cropping system, but increased with increasing N fertilization rate up to N at 168 $kg{\cdot}ha^{-1}$ (Table 6). Unlike in 1996, total fruit weight in 1998 was not influenced by significant interactions between cropping system and N rate. Averaged over cropping systems, total fruit weight showed a quadratic response to applied N, with maximum total yields estimated at 75.6 $t{\cdot}ha^{-1}$ with 139 $kg{\cdot}ha^{-1}$ N (Table 5).

Soil NO_3-N and yield response relationships. The relationship between the percent response of total ripe fruit weight to N fertilization and residual soil (0–30 cm) NO_3-N levels is shown in Figure 1. Soil NO_3-N levels were used for this analysis because analytical methods for NO_3-N are relatively quick and simple when compared to total soil mineral N (Mulvaney, 1996), and because soil NO_3-N can be highly reflective of previous cropping practices (Anderson et al., 1997; Porter and Sisson, 1991).

In seven of the plots (three following corn; four following 2-years corn), with preplant soil NO_3-N testing <5 $mg{\cdot}kg^{-1}$, the relative increase in total ripe fruit weight to N fertilization was more than 75%. Conversely, in two of the plots (following fallow ground), the relative increase in total ripe fruit weight to N fertilization was small (<20%), even though soil NO_3-N levels were less than 10 $mg{\cdot}kg^{-1}$. In several of the plots following soybeans, moderate to high levels of preplant soil NO_3-N (>10 $mg{\cdot}kg^{-1}$) were associated with low response of ripe fruit weight to N fertilization. When the combined data for the 2 years were fit to a quadratic-plateau response model ($r^2 = 0.50$), total ripe fruit weight showed a positive response to N fertilization at soil NO_3-N levels <17.6 $mg{\cdot}kg^{-1}$, and limited or no response to applied N if soil NO_3-N measured ≥17.6 $mg{\cdot}kg^{-1}$. This value is in line with the critical levels of 15.9 $mg{\cdot}kg^{-1}$ for preplant soil NO_3-N (Schmitt and Randall, 1994), and 21.0 $mg{\cdot}kg^{-1}$ for presidedress soil NO_3-N (Bundy and Andraski, 1993) reported for corn response to N fertilization on other medium- to fine-textured soils in the upper Midwest.

In total, these results demonstrate that fertilizer N requirements for pumpkins on loam soil will vary depending on cropping system, with N requirements increasing following corn or 2-years corn in the rotation, and decreasing following soybeans. Despite generally similar yields, the optimal N fertilization rate for highest total weight of ripe fruit following soybeans, for the two pumpkin studies, was estimated at 109 $kg{\cdot}ha^{-1}$ N, compared to 128 $kg{\cdot}ha^{-1}$ N following fallow ground, suggesting a soybean N-credit of around 19 $kg{\cdot}ha^{-1}$ N. In contrast, the optimal N fertilization rate for highest total weight of ripe fruit following corn or 2-years corn averaged 151 and 178 $kg{\cdot}ha^{-1}$, respectively, indicating a negative rotation effect on pumpkin N requirements of 23 $kg{\cdot}ha^{-1}$ N following corn and 50 $kg{\cdot}ha^{-1}$ N following 2-years corn.

Current Univ. of Illinois fertilizer guidelines for pumpkins recommend 134 $kg{\cdot}ha^{-1}$ N, plus a N-credit of 28 to 34 $kg{\cdot}ha^{-1}$ N when following soybeans or other legumes (Gerber and Swiader, 1985). Based on these data, the above recommendations appear reasonably accurate for pumpkins following soybeans, but somewhat underrated following corn. Including 2-years corn in the rotation with pumpkin is likely to require high rates of N fertilizer (151–205 $kg{\cdot}ha^{-1}$ N), with some of this N subject to possible leaching losses. Negative effects from excessive N fertilization were greater in pumpkins following soybeans than in pumpkins following corn or 2-years corn, with reductions in total weight of ripe fruit at the highest N rate (224 $kg{\cdot}ha^{-1}$ N) averaging 21%, 9%, and 3%, respectively, over the two studies.

The yield responses and experimental conditions in these studies are typical of main-season pumpkin production in Illinois, where 50 $t{\cdot}ha^{-1}$ represents the minimum economic yield threshold, and top yields of ripe fruit commonly exceed 60 $t{\cdot}ha^{-1}$. The high levels of total ripe fruit weight in the 0 $kg{\cdot}ha^{-1}$ N control plots are indicative of the relatively high inherent N-fertility status common to these soils. Differences among cropping systems for their effects on optimal N fertilization rates are likely to be more pronounced in less N-fertile soils (Kurtz et al., 1984). Although the relationship between the relative response of total ripe fruit weight to added N fertilizer and soil NO_3-N levels was only moderately correlated ($r^2 = 0.50$), the estimated critical level of soil NO_3-N of 17.6 $mg{\cdot}kg^{-1}$ may serve as a general guideline identifying sites on medium- to fine-textured soils where pumpkin is likely to respond to N fertilization. The results of this research may be extendable to other pumpkin and winter squash types with similar N requirements.

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