Evaluation of Poultry Litter and Organic Fertilizer Rate and Source for Production of Organic Short-day Onions

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SUMMARY. In a 3-year study of poultry litter applications on short-day onion (*Allium cepa*) production, where rates ranged from 0 to 10 tons/acre, there was an increasing linear effect on total onion yield. Jumbo (≥ 3 inches diameter) onion yield did not differ with increasing poultry application rates, while medium (≥ 2 and < 3 inches diameter) yields decreased with increasing applications of poultry litter. In addition, organic-compliant fertilizers, 4N-0.9P-2.5K at 150 to 250 lb/acre nitrogen (N), as well as 13N-0P-0K at 150 lb/acre N and in combination with 9N-0P-7.5K totaling 150 lb/acre N were evaluated. Comparison of these commercial organic-compliant fertilizers indicated that there were no differences in total or jumbo yields, while medium yields generally decreased with increased N fertilizer rate.

Onions are an important crop grown on 15,000 acres in southeastern Georgia with over a \$125 million value (Boatright and McKissick, 2006). Mild short-day onions known as Vidalia onions are the number one vegetable crop in the state by crop value. Vidalia onions were produced on ≈ 400 certified organic acres in 2007–08 according to the Georgia Department of Agriculture (V. Mullins, personal communication). This represents the single largest organic vegetable produced in the state, with the 2007 Census of Agriculture reporting 2015 acres used for all organic production in Georgia [U.S. Department of Agriculture (USDA), 2009]. By contrast, total vegetable production in Georgia exceeds 170,000 acres, with a farm gate value (gross farm revenue) over \$800 million (Boatright and McKissick, 2007).

A number of studies have been conducted evaluating the organic production of onions (Beek, 2005; Boyhan et al., 2006; Boyhan and Hill, 2008; Gonçalves and Sousa e Silva,

2004; Piazza et al., 2003; Russo, 2005; Sharma et al., 2004). These studies have evaluated fertility, insect control, weed control, transplant production, various cropping systems, and varieties.

In evaluations of different media, including media for organic seedling production and different fertilizer sources, it was found that onion and bell pepper (*Capsicum annuum*) seedlings required additional time in the greenhouse to obtain sufficient size before transplanting when using organic media and fertilizer (Russo, 2005). Additional experiments after transplanting with conventional potting media indicated that bell pepper required higher rates of organic fertilizers compared with conventional fertilization, but this was not the case with onions. Boyhan and Hill (2008) found that fertilizer requirements were higher with organic fertilizer sources compared with conventional fertilizers presumably

because nutrients were less available in organic compounds due to slow mineralization rates.

Dry bulb onions in Georgia are produced from seedlings grown on-farm in high-density plantings, which are transplanted to their final spacing (Boyhan and Kelley, 2007). Seedlings of short-day onions in southeastern Georgia could be produced organically with 4 to 6 tons/acre poultry litter with ≈ 60 lb/ton N or with organic fertilizer (3N-0.9P-2.5K) at 130 lb/acre N as long as compost was also used at 5 or 10 tons/acre (Boyhan and Hill, 2008). The N recommendation for onion transplant production in southeastern Georgia is 130 lb/acre (Boyhan and Kelley, 2007).

Onions require a significant amount of fertility to produce adequate yields of well-sized onions, which insures mildness in short-day onions. In Georgia, N recommendations for short-day onion production are from 125 to 150 lb/acre for dry bulb onion production (Boyhan and Kelley, 2007). This can be easily achieved with inorganic fertilizers, but recommendations with organic fertilizer sources have not been developed for short-day onion production.

Comparisons of conventional and organic farms matched by soil type indicated that organic practices improved soil quality (Liebig and Doran, 1999). This included a 22% increase in organic matter, 20% more total N, lower bulk density, and higher water holding capacity. Nutrient levels were above crop needs in both systems, suggesting that there was a potential for nutrient leaching in both systems.

Work has been done to predict the availability of plant nutrients from organic sources over time. Whitmore (2007), for example, found that 40% of the total N from composted chicken manure was available in the first year,

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	kg·ha ⁻¹	0.8922
0.5	lb/ton	kg·Mg ⁻¹	2
0.0254	mil	mm	39.3701
2.2417	ton/acre	Mg·ha ⁻¹	0.4461
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

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with the remainder available in subsequent years at a rate of 6% to 12% per year. Jakse and Mihelic (2001) found that vegetables, including onions, fertilized with inorganic fertilizers produced almost twice as much yield compared with compost and 40% more than cattle manure. A study evaluating the emission of nitrite (N_2O), a greenhouse gas, from a conventional farming system that compared a clover (*Trifolium repens*) cover before onion planting, compared with two organic systems (Van Der Weerden et al., 2000). The organic systems had an herb-ley (multispecies pasture) cover before planting. One of the organic systems was rotated and the other was ploughed. The conventional system produced twice as much N_2O compared with the organic system from sowing to harvest. However, the differences between the systems were not significant if the initial plowing of the covers was included.

The objective of this study was to evaluate the effect of fresh poultry litter and sources and rates of commercially available organic-compliant fertilizers on total yield and graded yield of short-day onions.

Materials and methods

These experiments were conducted at the Vidalia Onion and Vegetable Research Center in Lyons, GA (lat. $32^\circ 5' \text{N}$, long. $82^\circ 12' \text{W}$) on a Tifton soil (Fine-loamy, siliceous, thermic Plinthic Paleudults). The research site was on certified (Georgia Crop Improvement Assn., Athens, GA.) land. In the 2004–05 season, a combination of equal parts of seeds ‘XON-202Y’ (Sakata Seed, Morgan Hill, CA), ‘HSX-18201 F₁’, ‘HSX-19406 F₁’, and ‘HSX-61304 F₁’ (Hortag Seed, Chapel Hill, NC) were used. All of these seeds were conventionally grown, but were untreated per organic standards and represent main season onion varieties in the Vidalia growing region of southeastern Georgia. In the 2004–05 season, there was insufficient untreated seeds of any one variety, therefore, a combination of these varieties was used. In the 2005–06 and 2006–07 seasons, untreated seeds of ‘Savannah Sweet’ (Seminis Vegetable Seeds, St. Louis), which is also a main season variety, were used.

Onion seeds were sown in high density plantings on 1 Oct. 2004, 19 Sept. 2005, and 18 Sept. 2006 and

were grown according to University of Georgia Cooperative Extension Service recommendations for organic onion transplant production in compliance with National Organic Program (NOP) rules (Boyhan, 2007; Boyhan and Kelley, 2007). Onion seeds were sown on beds formed with 6-ft centers with four rows planted per bed with 12 inches between rows. Each row had 60 seeds per linear foot.

In the 2004–05 season, onions were grown without plastic mulch with half the treatment rate applied at transplanting (13 Dec. 2004) and half on 20 Jan. 2005. Treatments in the 2005–06 and 2006–07 seasons were evenly applied over the entire bed just before final bed shaping and covered with 1.5-mil-thick black plastic mulch with two drip-tape lines [8 mil thick, 6-inch emitter spacing (T-Tape; T-Systems International, San Diego)]. Approximately 10-week-old onion bareroot transplants with 50% of their tops removed were transplanted on 13 Dec. 2004, 12 Dec. 2005, and 21 Nov. 2006 into prepared beds. Beds for these experiments were formed on 6-ft centers with a bed width of 4 ft and a height of 7 inches. Four rows of onions were transplanted with 12 inches between rows and 5.5-inch in-row spacing. The experimental design was a randomized complete block design with four replications. The experimental unit in the 2004–05 season was 10 ft of planted bed, and in the 2005–06 and 2006–07 seasons, the experimental unit was 20 ft of planted bed.

Treatments in all seasons included fresh poultry litter applied at rates of 0, 2, 4, 6, 8, and 10 tons/acre. The poultry litter was obtained from the same poultry producer each year. Poultry litter sample analysis averaged over 2 years is shown in Table 1.

In the 2005–06 season, four treatments of organic-compliant fertilizer with formulation 4N–0.9P–2.5K (Perdue AgriCycle, Seaford, DE) were applied at rates of 150, 200, and 250 lb/acre N and 13N–0P–0K (Nature Safe, Cold Spring, KY) were applied at 150 lb/acre N. In the 2006–07 season, two treatments were applied, including 4N–0.9P–2.5K applied at 150 lb/acre N and 13N–0P–0K with 9N–0P–7.5K (Nature Safe), which were applied to

Table 1. Typical nutrient content of poultry litter used for onion production.

Nutrient content (lb/ton) ^a							
N	P	K	Ca	Mg	S	B	Zn
64	45	52	64	17	9	<1	<1

^a 1 lb/ton = 0.5 kg·Mg⁻¹, N = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, S = sulfur, B = boron, Zn = zinc. Analyzed on a dry weight basis in 2003 and 2004 by Agricultural and Environmental Services Laboratories, University of Georgia, Athens.

supply a total of 150 lb/acre N, half from each source.

In the 2004–05 season, onions were harvested on 31 May 2005. In the 2005–06 season, onions were harvested on 20 Apr. 2006, and in the 2006–07 season, onions were harvested on 24 Apr. 2007. Onions were pulled and laid on top of the ground for 2 d before having their tops and roots removed. They were then weighed to determine total yield and then heat cured for 24 h at 95 °F before being graded into medium (≥ 2 and < 3 inches diameter) and jumbo (≥ 3 inches diameter) size classes (USDA, 1995). Damaged, diseased, misshapen, and small onions were culled in the grading process.

Data were analyzed with Stata 10.1 (Stata Corp., College Station, TX). Poultry litter data were analyzed with analysis of variance with a model including treatments, replications, and years. This was followed by regression analysis of linear and quadratic effects. The organic-compliant fertilizers were analyzed for each year with analysis of variance.

Results and discussion

There was no poultry litter rate by year interaction, thus results were combined over years. There was a significant linear effect on total onion yield with increasing poultry litter applications from 0 to 10 tons/acre with an R^2 of 0.719 (Fig. 1). Jumbo (≥ 3 inches diameter) yield did not differ between different poultry litter rates; however, medium (≥ 2 and < 3 inches diameter) yields had significantly lower yields with increasing poultry litter rates.

In 2006, there were no differences for total yield or jumbo yield between organic-compliant fertilizers used at 150, 200, and 250 lb/acre N (Table 2). There were significantly more medium-sized onions

Fig. 1. Effect of poultry litter application on total (jumbo + medium + culls), jumbo (≥ 3 inches diameter), and medium (≥ 2 inches and < 3 inches diameter), and onion yield with total and medium yield having a significant linear response for 3 years (2005–07); total yield ($y = 1243x + 27,986$, $R^2 = 0.719$), medium yield ($y = -140x + 2,664$, $R^2 = 0.729$); 1 inch = 2.54 cm, 1 ton/acre = 2.2417 Mg·ha⁻¹, 1 lb/acre = 1.1209 kg·ha⁻¹.

Table 2. Evaluation of organic fertilizers for production of short-day onions in 2006–07 at the Vidalia Onion and Vegetable Research Center, Lyons, GA.

Treatments	Nitrogen	Total yield ^z	Jumbo yield ^z	Medium yield ^z
(lb/acre) ^y				
2006				
4N–0.9P–2.5K	150	35,955	23,341	1,742
4N–0.9P–2.5K	200	49,432	31,418	908
4N–0.9P–2.5K	250	46,664	26,372	871
13N–0P–0K	150	44,685	22,742	91
2007				
4N–0.9P–2.5K	150	41,201	31,989	3,149
13N–0P–0K	150	33,241	22,642	2,732
+ 9N–0P–7.5K ^x				
Probabilities				
2006		0.372	0.724	0.012
2007		0.330	0.326	0.666

^zTotal yield = jumbo (≥ 3 inches diameter) + medium (≥ 2 inches and < 3 inches diameter) + culls; 1 inch = 2.54 cm.

^y1 lb/acre = 1.1209 kg·ha⁻¹.

^x75 lb/acre nitrogen from 13N–0P–0K and 75 lb/acre nitrogen from 9N–0P–7.5K.

with 4N–0.9P–2.5K fertilizer applied at 150 lb/acre N compared with this fertilizer applied at 200 or 250 lb/acre N or 13N–0P–0K at 150 lb/acre N.

In 2007, there were no differences in total, jumbo, or medium yields between 4N–0.9P–2.5K applied at 150 lb/acre N or 13N–0P–0K and 9N–0P–7.5K used in combination at 150 lb/acre N (Table 2).

Although there was an increasing linear effect with increasing poultry litter application, most growers have reported adequate yield response with an application of 4 to 6 tons/acre poultry litter. In a study on producing onion transplants, similar results were found where increasing poultry litter rates resulted in larger transplants,

while the least significant difference test indicated that a rate of 4 to 6 tons/acre would be adequate (Boyhan and Hill, 2008). In 2 of 3 years of this study, black plastic mulch was used, which may have conserved the fertility of the poultry litter under the plastic, preventing losses to leaching or it may have increased the mineralization rate, resulting in more nutrients available to the crop. Both of these effects have been reported in the literature, although there was no treatment by year interaction effect in this study (Carrera et al., 2007; Suarez-Rey et al., 2008). This might account for growers reporting using lower levels of poultry litter with acceptable yield results. Plastic is not used in conventional

onion production in southeastern Georgia; however, about half of the organic onions produced use plastic mulch, primarily as a weed control measure.

As organic production has increased, commercial sources of organic fertilizers have become more readily available. The 4N–0.9P–2.5K is a pasteurized and pelleted fertilizer made from poultry waste. Other fertilizers such as 13N–0P–0K and 9N–0P–7.5K are manufactured from rendered animal parts. These fertilizers have percentages of N, phosphorus, and potassium comparable to conventional mineral fertilizers and, in this study, performed similarly to inorganic fertilizers in other studies (Boyhan et al., 2007). However, growers and others have complained that, in some cases, these products do not perform as the analysis suggests. Current fertilizer recommendations are based on using conventional inorganic fertilizers (Boyhan and Kelley, 2007). Using organic fertilizers requires the product to mineralize to a form plants can absorb, which may slow plant response to fertilizer application. To compensate for this, we have been recommending using 50% more fertilizer than the analysis would suggest or applying the fertilizer 14 to 28 d before normal timing of applications.

The decrease in medium yields with increasing fertilizer as shown in Fig. 1 and Table 2 is not an unknown phenomenon (Boyhan et al., 2007). Other studies have shown that as yields increase, there is a decrease in medium yields as more bulbs grow into the larger class size (Boyhan et al., 2009).

The total marketable yield (jumbo and medium) over the 3 years for treatments with 4 tons/acre or greater poultry litter was over 20,000 lb/acre and at 6 tons/acre or greater was over 24,000 lb/acre. This compares favorably with conventional onion production, which averaged 28,500 lb/acre in 2006 (Boatright and McKissick, 2007). For the purposes of budget development and risk rated returns in onions, we use 20,000 lb/acre (Boyhan and Kelley, 2007).

In conclusion, fresh poultry litter as well as commercial organic fertilizers can be used to produce high yields of quality onions. The relatively long season of overwintering

short-day onions allows the use of fresh poultry litter, while meeting the NOP guidelines of 120 d from application to harvest. Organic-compliant fertilizers offer greater flexibility of timing application, but performance related to mineralization may be problematic.

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