Evaluation of Composted Cattle Manure Rate on Bulb Onion Grown with Reduced Rates of Chemical Fertilizer

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SUMMARY. A field experiment was conducted to evaluate yield performance and soil fertility of onion (*Allium cepa*) grown with beef cattle manure compost (CMC) under a reduced rate of chemical fertilizer for sustainable production in the 2006–07 growing season. Chemical fertilizer application rate was reduced to a third of the recommended rate of nitrogen (N), phosphorus (P), and potassium (K). Treatments consisted of five levels of CMC (0, 20, 40, 60, and 80 Mg·ha⁻¹). There was a significant increasing effect on growth and yield parameters by applying CMC compared with 0 Mg·ha⁻¹. In addition, there was also a significant increasing quadratic effect on yield on increasing CMC rates from 0 to 80 Mg·ha⁻¹ with an *R*² of 0.46. Maximum marketable yield was 62.7 Mg·ha⁻¹ at 40 Mg·ha⁻¹ CMC, which was due to increased stand reduction and unmarketable bulbs as well as decreased bulb weight at higher rates of CMC. The CMC rates had no effect on bulb dry weight and N or P concentration in the bulb and leaf. Furthermore, there was an increasing linear effect on soil pH, and organic matter (OM), available P, and exchangeable cations throughout vegetative growth and at harvest. We concluded that the excessive application of CMC did not affect onion yield and accumulated soil fertility.

Onion fertility has been an important subject with regards to onion productivity worldwide. In particular, onion has a shallow branched root system with most roots in the top 30 cm of soil (Portas, 1973; Weaver and Brunner, 1927). Characteristically, such a root system leads to the low density of roots in onion. This shallow root system means onion requires more fertilizer to produce the crop (Brewster, 2008; Greenwood et al., 1982).

For sustainable crop production, pesticides and herbicides are not allowed and application rates of mineral fertilizers are restricted legally in Korea. N, P, and K application rates for onion production are recommended as 240, 34, and 128 kg·ha⁻¹, respectively, where 67% of N and 60% of K fertilizer are applied in two split sidedressings [Rural Development Administration (RDA, 2006)]. In addition, the quantity of mineral fertilizer should be reduced to a third based on the recommended rates of N, P, and K to produce certified products without agricultural chemicals. Thus, nutrient management for

sustainable crop production depends on compost from animal manures or organic fertilizers. Compost can serve as an alternative to mineral fertilizers for improving soil structure (Dauda et al., 2008) and microbial biomass (Suresh et al., 2004). The rate, timing, and technique of application can be controlled by the grower; however, compost quality can vary considerably within the same source and different sources at various times of the year (Gaskell and Smith, 2007). Gaskell and Smith (2007) stated that the N availability from compost to the succeeding crop was variable, ranging from negative to low N recovery rates of 4% to 15%, to a high rate of 57%. Wallace (2006) developed guidelines for using the

carbon to N (C:N) ratio of the compost to determine its availability.

Moreover, the response of onion crops to manure depends on N availability for crop growth. N availability from manure varies greatly depending on the type of animal, type and amount of bedding, and age and storage conditions of the manure (Bary et al., 2000). Characterization of chemical constituents for inputs of the manure may help predict intermediate-term mineralization rates (Palm et al., 2001). However, the process may vary with weather conditions such as rainfall and temperature (Rosen and Allen, 2007). Long-term manure application based on N can result in the accumulation of other nutrients such as P and K in soil and eventually reach excessive levels (Bary et al., 2000). Further, over applying manure may also increase the risk of contaminating surface or groundwater with P (Biberacher et al., 2009).

Yield response to compost is greater in soils with low fertility, but response varies depending on the compost source (Gallardo-Lara and Nogales, 1987). When onion plants were grown in plots of sandy loam soil, compost applied over a two-year period at cumulative totals of 37 Mg·ha⁻¹ increased marketable yield (Bevacqua and Mellano, 1993). There was a significant linear effect on total onion yield with increasing fresh poultry litter applications from 0 to 22 Mg·ha⁻¹ (Boyhan et al., 2010). However, onion yield response to animal manure or compost rates was not always positive (Abdelrazzag, 2002; Gambo et al., 2008). Vidigal et al. (2010) reported that the application of 43 Mg·ha⁻¹ swine compost resulted in onion bulbs with greater size and higher marketable yield.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0929	ft ²	m ²	10.7639
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	kg·ha ⁻¹	0.8922
1	meq/100 g	cmol·kg ⁻¹	1
28.3495	oz	g	0.0353
0.001	ppm	g·kg ⁻¹	1000
1	ppm	mg·kg ⁻¹	1
2.2417	ton/acre	Mg·ha ⁻¹	0.4461
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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Although growers supporting sustainable agriculture have been trying to increase onion yield by increased compost application, the effect of compost may not be sufficient in the short term. The objective of this study was to evaluate the effect of composted beef manure on the yield of intermediate-day onion and soil fertility under reduced chemical fertilization rates during short-term practices.

Materials and methods

FIELD EXPERIMENT. The present experiment was conducted at the Onion Research Institute's experimental farm, Changnyeong district, Korea (lat. 35°55'N, long. 128°47'E) during the 2006–07 seasons. The experimental site has been under continuous cultivation including rice (*Oryza sativa*) and onion. Top soil texture was silt loam with an OM content of 17.8 g·kg⁻¹, pH 7.4, 5.3 mg·kg⁻¹ residual nitrate nitrogen (NO₃-N), 104 mg·kg⁻¹ available P, and 0.50 cmol·kg⁻¹ exchangeable K before planting. Seeds of 'Changnyeongsindaego' onion, an open-pollinated cultivar for fall transplanting, were sown on 8 Sept. 2006, and transplanted in seven rows on 8 Nov. 2006 at a spacing of 15 cm in-row and 20 cm between rows. Beds were mulched with a sheet of transparent polyethylene. The bed size was 12 × 1.4 m, accommodating 560 plants per plot.

EXPERIMENTAL DESIGN. Treatments included CMC applied at rates of 0, 20, 40, 60, and 80 Mg·ha⁻¹ on a fresh weight basis. The composted cattle manure was obtained from a local compost producer. It included rice hull as bedding and was collected from a concrete floor and decomposed for about six months. Cattle manure compost sample analysis and nutrient rate applied at 20 Mg·ha⁻¹ are shown in Table 1.

Chemical fertilizer rates of 80 kg·ha⁻¹ N, 11.4 kg·ha⁻¹ P, and 42.5 kg·ha⁻¹ K based on the recommended rates of N, P, and K were applied in all treatments (RDA, 2006). Compost, fused phosphate fertilizer (P), one third of the urea (N), and 40% of potassium sulfate (K) were applied preplant with the rest split into two equal applications in February and March. The experimental design was a randomized complete block with three replicates. Irrigation was performed once at transplanting, while weeding and other cultural practices were completed as necessary.

SAMPLING AND ANALYSIS. Onion height, number of leaves, bulb diameter, and fresh weight were measured on 4 Apr. [147 d after transplanting (DAT)], 25 Apr. (165 DAT), 7 May (189 DAT), and 8 June (210 DAT) with 10 plants per replicate. The soil samples were collected for chemical analysis from the surface layer (0–15 cm) at the same time plant growth was measured and before fertilization. Harvesting was conducted after 80% of the tops had broken over at the neck on 8 June 2007. Onions were pulled from a 3.15 m² (2.25 × 1.4 m) area per experimental unit and placed on top of the ground for 2 d before removing tops. They were individually weighed and their bulb diameters were determined. Damaged, diseased, bolted, and doubled onions were culled as unmarketable yield.

After measuring plant height (centimeters) and bulb diameter (millimeters), onion plants were separated into the bulb and green leaves, followed by measuring fresh leaf weight (grams/plant) and bulb weight (grams/plant) on an individual plot basis. The samples at harvest were dried to a constant weight at 70 °C. The dried samples were ground,

weighed, and dissolved in hydrogen sulfate (H₂SO₄) and hydrogen dioxide (H₂O₂). Total N was measured by the Kjeldahl method. P was measured colorimetrically with an ammonium–vanadate–molybdate method (Gerick and Kurmies, 1952).

Air-dried soil samples were analyzed for pH, electrical conductivity (EC), OM, NO₃-N, available P, and exchangeable K. Organic matter was determined by the Tyurin method (Schollenberger, 1927) and NO₃-N content by reflectometry (RQ plus; Merck, Whitehouse Station, NJ). The Lancaster method (RDA, 2002) was used in determining available P. An atomic absorption spectrophotometer was used to measure exchangeable cations. Soil pH and EC were measured by both an electrometer and a conductivity meter.

Results and discussion

PLANT GROWTH AND BULB YIELD. Data presented in Table 2 indicate the response of growth characters based on different rates of CMC. The number of leaves and bulb diameter increased with increasing CMC rates at the vegetative growth stage (147 and 165 DAT). However, during the late growth stage (189 DAT), only the number of leaves was affected by CMC rates.

An examination of the top, bulb, and root weight showed a quadratic function at 189 DAT (Table 3). Bulb weight showed a quadratic effect at 210 DAT as well. The quadratic equation for marketable yield was $y = -32.748x^2 + 298.26x + 5406.2$ and $R^2 = 0.46$ (Fig. 1). The derived value of this equation was 45.5 Mg·ha⁻¹ CMC and its maximum yield was 60.9 Mg·ha⁻¹. However, according to Fisher's protected least significant difference, maximum calculated yield

Table 1. Chemical properties of composted cattle manure compost on dry weight basis and nutrients applied by 20 Mg·ha⁻¹ (8.9 tons/acre) rate.

	Moisture content (g·kg ⁻¹) ^z	Organic matter	N ^x	P	K	Ca	Mg	Ammonium-nitrogen (mg·kg ⁻¹) ^z	NO ₃ -N	pH 1:5	C:N (ratio)
Contents ^y	601	380.7	14.3	2.5	27.5	9.9	10.6	15.2	1,748.7	8.2	15.5
Nutrients applied (kg·ha ⁻¹) ^z	—	3,040	115	20	220	79	85	0.12	13.95	—	—

^z1 g·kg⁻¹ = 1000 ppm, 1 mg·kg⁻¹ = 1 ppm, 1 kg·ha⁻¹ = 0.8922 lb/acre.

^ySample was dissolved in 5 mL (0.17 fl oz) hydrogen sulfate and 5 mL hydrogen dioxide).

^xN = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, NO₃-N = nitrate nitrogen, C = carbon, N = nitrogen.

Table 2. Changes in number of onion leaves, plant height, and bulb diameter as affected by cattle manure compost rates.

Cattle manure compost rates (Mg·ha ⁻¹) ^z	Leaves (no./plant)			Plant ht (cm) ^z			Bulb diam (mm) ^z		
	DAT ^y			DAT			DAT		
	147	165	189	147	165	189	147	165	189
0	6.1	7.9	7.0	43.6	71.8	72.6	15.0	24.1	56.6
20	5.9	8.4	7.3	43.5	69.8	77.3	13.3	31.6	60.3
40	6.9	8.3	7.7	44.4	67.0	76.0	14.4	29.9	63.3
60	6.3	7.8	7.7	46.5	70.2	76.1	16.6	27.5	64.1
80	6.5	8.5	7.7	46.9	69.3	73.3	16.0	29.6	59.9
LSD (0.05) ^x	0.5	0.6	0.6	NS	4.8	NS	1.6	5.3	NS
CV (%) ^w	5	4	4	5	4	4	6	10	8

^z1 Mg·ha⁻¹ = 0.4461 ton/acre, 1 cm = 0.3937 inch, 1 mm = 0.0394 inch.^yDays after transplanting.^xFisher's protected least significant difference at $P \leq 0.05$.^wCoefficient of variation.

Table 3. Changes in top, bulb, and root weights of onion on fresh basis as affected by cattle manure compost rates.

Cattle manure compost rates (Mg·ha ⁻¹) ^z	Top wt (g/plant) ^z			Bulb wt (g/plant)			Root wt (g/plant)		
	DAT ^y			DAT			DAT		
	165 ^z	189	210	165	189	210	147	165	189
0	61.3	54.3	4.2	20.4	115.2	181.8	1.61	1.67	0.48
20	66.9	69.7	4.8	27.1	139.2	201.8	1.66	1.20	0.69
40	62.9	67.6	4.3	30.1	159.8	205.9	1.93	1.53	0.83
60	60.2	70.5	4.1	24.6	156.2	198.0	2.35	1.55	0.81
80	66.9	64.4	4.7	27.7	141.2	200.9	2.15	1.78	0.67
LSD (0.05) ^x	NS	6.8	NS	5.3	16.7	12.8	NS	NS	0.25
CV (%) ^w	7	6	16	11	7	4	21	27	20
Regression	P	0.001	—	—	<0.001	0.011	—	—	0.008
	R^2	0.67(Q) ^v	—	—	0.80(Q)	0.53(Q)	—	—	0.56(Q)

^z1 Mg·ha⁻¹ = 0.4461 ton/acre, 1 g = 0.0353 oz.^yDays after transplanting.^xFisher's protected least significant difference at $P \leq 0.05$.^wCoefficient of variation.^vQ = quadratic.

does not differ from yields at 20 or 40 Mg·ha⁻¹ CMC. In addition, stand reduction was negatively affected by increasing CMC (Table 4). The CMC rate of 80 Mg·ha⁻¹ resulted in a significant increase in stand reduction compared with 20 or 40 Mg·ha⁻¹ ($P \leq 0.05$). This result was presumably because of an increased salt concentration at higher CMC rates. P uptake in onion bulb tissue was significantly higher at 40 Mg·ha⁻¹ CMC than the control but did not increase with higher CMC rates. Furthermore, N levels in bulb and leaf tissue did not differ significantly over the range of CMC application rates.

For the production of organic short-day onion, there was a significant linear effect on total onion yield by increasing the application of poultry litter from 0 to 25 Mg·ha⁻¹ with an R^2 of 0.719 (Boyhan et al., 2010). The result might be due to the absence of chemical fertilizer application with

organic onion production and high nutrient content (32 g·kg⁻¹ N, 23 g·kg⁻¹ P, 26 g·kg⁻¹ K) in the poultry litter used for onion production. Also, the authors mentioned that most growers had reported adequate yield response with a poultry litter application of 10–15 Mg·ha⁻¹. Even though compost or animal manure were effective at improving soil OM content and soil fertility, especially in regards to long-term applications (Haynes and Naidu, 1998; Prasad, 2009), the effectiveness of animal manure on bulb onion production was not always positive. According to Abdelrazzag (2002), increasing rates of chicken manure tended to reduce onion yield, and high sheep manure rates did not significantly enhance the yield either. Those results could be due to the harmful effect of increased EC because of manure application. Gambo et al. (2008) reported that increasing rates of farmyard

manure did not have significantly positive effects on onion bulb yield. Also, in an organic system trial with five rates of organic compost (0–60 Mg·ha⁻¹), the calculated maximum yield of marketable bulbs was obtained with 43.4 Mg·ha⁻¹ of swine manure (Vidigal et al., 2010). Similarly, the onion bulb yield was not significantly influenced by gamma-irradiated sewage sludge or farmyard manure rates of 5, 10, and 15 Mg·ha⁻¹ (Rathod et al., 2008).

According to Sullivan et al. (2001), in the Pacific northwestern United States, manure or compost application before seeding onion was not recommended because salts from manure or compost might reduce seed germination and increase water stress. Last, the transplanted onion in our research showed a significantly higher stand reduction at 80 Mg·ha⁻¹ than at 40 Mg·ha⁻¹ of manure.

SOIL CHEMICAL PROPERTIES. The OM and available P content were significantly affected by increasing CMC rates at both 147 and 210 DAT (Table 5). Manure rates had a linear effect on soil nutrients, P, and K at the vegetative growth stage (147 DAT). However, NO₃-N content was not significantly different among treatments.

Nitrate-N availability is highly variable. Also, N mineralization is dynamic based on soil conditions. The release or immobilization of N from compost depends on compost quality, such as age, stability, and feedstock used (Prasad, 2009). The estimated percent of total N that is potentially mineralized after application depends

on the compost C:N ratio (Wallace, 2006). According to this assumption, a C:N ratio of 15.0, which is equivalent to that of CMC in our study, could produce a mineralized N rate of 10% or less from organic N in the first year. The very low mineralization of N was observed in our study, which had low soil NO₃-N content at the vegetative stage. This may be a result of the higher N consumption by microorganisms during manure decomposition in soil than N released from manure during the vegetative growth stage. In addition, soil available P and exchangeable K were linearly affected by increasing CMC application with an R² of 0.37 and 0.54, respectively, at the vegetative

growth stage. P deficient onion appears stunted and develops slowly. Normally, onion is affected by P during the early growth stages since root systems are limited and cool soil temperature reduces P diffusion or movement to root surfaces (Brown, 2000). However, the effectiveness of P application in soil was not always evident (Al-Moshileh, 2001; Boyhan, 2007; Lee et al., 2003). Onion generally absorbs equal amounts of N and K (Salo et al., 2002; Sullivan et al., 2001) and in some studies, more K than N (Lee, 2010; Lee et al., 2009). Nevertheless, the K fertilization efficiency on onion yields was inconsistent among studies. Onion bulb yield increased up to 84 kg·ha⁻¹ (Boyhan, 2007), 190 kg·ha⁻¹ (El-Bassiony, 2006), 286 kg·ha⁻¹ (El-Al et al., 2010). By contrast, there was zero effect of K in other studies on onion with rates of 0 or 150 kg·ha⁻¹ (Al-Moshileh, 2001; Lee et al., 2003), or 50 or 150 kg·ha⁻¹ (Amin et al., 2007). This inconsistency might be due to either the difference in preplant K content or K sources from OM in the soil.

Conclusions

Cattle manure compost improved yield of intermediate-day onion and soil fertility under reduced rates of chemical fertilizer. However, CMC application over 40 Mg·ha⁻¹ did not increase onion bulb yield but accumulated soil nutrients. Further long-term studies should be carried out to clarify residual and beneficial effects from compost regarding crop and soil quality.

Fig. 1. Marketable onion bulb yield response to cattle manure compost rates with quadratic curve, regression equation and R² values (* represents $P < 0.05$); 1 Mg·ha⁻¹ = 0.4461 ton/acre.

Table 4. Comparison of cattle manure compost rate effects on onion bulb yield, stand reduction, bulb dry matter, and tissue nutrient uptakes.

Cattle manure rates (Mg·ha ⁻¹) ^z	Yield (Mg·ha ⁻¹)		Stand reduction (%)	Bulb dry wt (%)	Bulb (kg·ha ⁻¹) ^y		Leaf (kg·ha ⁻¹)	
	Marketable	Unmarketable			N ^y	P ^y	N	P
0	53.6	0.27	3.8	9.5	49.3	9.4	9.2	0.9
20	59.0	0.29	2.5	9.0	48.5	15.9	9.1	1.3
40	62.7	0.22	1.9	9.3	54.9	16.7	10.6	1.8
60	57.4	0.25	3.8	9.3	66.6	12.7	9.2	1.0
80	58.0	0.29	6.0	9.0	60.5	15.1	7.5	1.4
LSD (0.05) ^x	4.7	NS	2.7	NS	NS	6.6	NS	0.78
CV (%) ^w	4	33	40	5	18	19	26	34
Regression	P	0.025	—	—	0.042	0.090	—	—
	R ²	0.46 (Q) ^v	—	—	0.28 (L) ^v	0.25 (Q)	—	—

^z1 Mg·ha⁻¹ = 0.4461 ton/acre.

^yN = nitrogen, P = phosphorus, 1 kg·ha⁻¹ = 0.8922 lb/acre.

^xFisher's protected least significant difference at $P \leq 0.05$.

^wCoefficient of variation.

^vQ = quadratic, L = linear.

Table 5. Influence of cattle manure compost rates on soil pH, organic matter (OM), and nutrient content at vegetative stage [147 d after transplanting (DAT)] and at harvest (210 DAT).

Cattle manure compost rates (Mg·ha ⁻¹) ^z	Vegetative stage						Harvest					
	pH 1:5	OM (g·kg ⁻¹) ^z	NO ₃ -N ^y (mg·kg ⁻¹) ^z	P ^y (mg·kg ⁻¹) ^z	Cations ^y (cmol·kg ⁻¹) ^z		OM (g·kg ⁻¹)	NO ₃ -N (mg·kg ⁻¹)	P (mg·kg ⁻¹)	Cations (cmol·kg ⁻¹)		
					Ca ^y	Mg ^y				K	Ca	Mg
0	6.8	16.6	55.0	100.1	5.4	1.2	14.7	26.3	90.2	0.40	4.5	1.4
20	7.0	19.2	35.5	103.5	5.9	1.1	19.7	29.6	133.9	0.73	6.0	1.4
40	7.2	27.9	53.9	169.3	6.9	1.1	18.8	27.8	122.1	0.59	6.0	1.5
60	7.2	25.9	55.2	131.6	6.6	1.2	20.5	27.3	160.4	0.73	8.8	1.7
80	7.3	31.1	49.8	186.0	6.8	1.5	22.8	29.4	156.0	0.77	6.4	1.7
LSD (0.05) ^w	0.3	5.0	17.8	68.1	NS	0.3	4.1	NS	46.7	0.30	2.1	0.3
CV (%) ^v	2	11	20	28	17	13	12	37	19	25	18	11
Regression	<0.001	<0.001	—	0.016	—	—	0.002	—	0.006	0.034	0.027	0.006
R ²	0.62 (L) ^u	0.74 (L)	—	0.37 (L)	—	—	0.55 (L)	—	0.46 (L)	0.30 (L)	0.32 (L)	0.45 (L)

^z1 Mg·ha⁻¹ = 0.4461 ton/acre, 1 g·kg⁻¹ = 1000 ppm, 1 mg·kg⁻¹ = 1 ppm, 1 cmol·kg⁻¹ = 1 meq/100 g.^yNO₃-N = nitrate nitrogen, P = available phosphorus, Cations = exchangeable cations, K = potassium, Ca = calcium, Mg = magnesium.^wFisher's protected least significant difference at P ≤ 0.05.^vCoefficient of variation.^uL = linear.

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