Scientia Horticulturae 124 (2010) 299–305

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effect of application methods of organic fertilizer on growth, soil chemical properties and microbial densities in organic bulb onion production

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ARTICLE INFO

Article history:
Received 23 April 2009
Received in revised form 16 December 2009
Accepted 7 January 2010

Keywords:
Liquid organic fertilizer
Organic farming
Plastic mulch
Short-day onions
Allium cepa L

ABSTRACT

This study was carried out to maximize the fertilization efficiency of mixed organic fertilizer (OF) for organically managed onion (*Allium cepa* L.) production during the one growing season of 2005–2006. The organic fertilizer was made of organic materials like sesame oil cake, rice bran and molasses and minerals like illite and mountainous soil. Four organic topdressing treatments, which all followed the same basal fertilization with solid OF, consisted of solid OF without mulch (OF/OFnM), liquid organic fertilizer without mulch (OF/LOFnM), liquid organic fertilizer under mulch (OF/LOFuM) and liquid organic fertilizer over mulch (OF/LOFoM). Chemical fertilizer (CF) and no fertilizer (NF) were treated as controls. The solid organic fertilization base was 2.0 ton ha^{-1}, and 4.57 ton ha^{-1} and was used for topdressing. The total amount of liquid organic fertilization was 133.2 ton ha^{-1}, which was divided into 6 applications from February through March. The OF/LOFuM and OF/LOFoM topdressings did not reduce onion height, leaf number or bulb diameter as compared to chemical fertilizer, whereas no mulch treatments made onion growth significantly poorer. Onion top weight in CF was significantly higher than that in OF groups at the peak growth stage, while there was not much difference in bulb weight between the CF and OF/LOFoM treatment. Finally, the onion marketable yield was 45.9 ton ha^{-1} in the OF/LOFoM treatment, which exceeded that in the CF treatment by up to 1.9 ton. Furthermore, OF/LOFoM was the most effective among all the treatments in transferring the nutrients from sink to source. CF made the soil pH more acidic than OF did, and the electrical conductivity (EC) remained higher with CF than OF as well. While organic fertilizer helped to keep the NO_3-N content stable throughout the growing season, the concentration rapidly oscillated up and down according to CF fertilization. Organic fertilizer increased population number of soil microorganisms like aerobes, actinomycetes in the field.

1. Introduction

The transition from conventional to organic farming is accompanied by changes in an array of soil chemical and biological properties and processes that affect soil fertility. Fundamental differences, both qualitative and quantitative, in the flow and processing of nutrients result from soil amendment, plant community structure, tillage, and elimination of synthetic fertilizers and pesticides (Bossio et al., 1998; Clark et al., 1998). Studies comparing soils of organically and conventionally managed farming systems have documented higher soil organic matter and total N with the use of organic practices (Alvarez et al., 1988; Drinkwater et al., 1995; Reganold, 1988). Increases in soil organic matter following the transition to organic management occur slowly, generally taking several years to detect, but can have a dramatic effect on long-term productivity (Clark et al., 1998; Drinkwater et al., 1995; Wander et al., 1994). Changes in other soil properties have been found to be more variable, perhaps due to differences in climate, crop rotation, soil type, or length of time a soil has been under organic management (Drinkwater et al., 1995; Werner, 1997). Soil pH becomes higher, plant-available nutrient concentrations may be higher and the total microbial population increases under organic management (Clark et al., 1998; Dinesh et al., 2000; Reganold, 1988).

Organic fertilizers, which mainly come from crop residues like rice bran, various oilseed cakes and animal byproducts like meat bone meal, blood meal, fish meal and crab meal, are sometimes distinguished from animal manure or compost based on animal waste. They contain specifically high levels of nutrients, e.g. N in oilseed cakes and blood meal and P in rice bran and meat bone meal, and are also high in organic matter content and a variety of micronutrients in general (Blatt, 1991; Cayuela et al., 2008), so that they have been widely used as alternative fertilizers for organically grown fields. However, the apparent deficiency of an adequate supply of plant-available N from organic fertilizer, resulting from a slow rate of mineralization, makes crop yields in fields treated with

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doi:10.1016/j.scienta.2010.01.004

organic fertilizer lower than in those treated with chemical fertilizer (Blatt, 1991). Therefore, the application of organic N topdressing in the form of liquid organic fertilizer, often called compost extract or tea, during the growing season has been evaluated (Gross et al., 2008; Hadad and Anderson, 2004). Various organic materials have been recognized as soil amendments and disease controllers, including the control of brown spot disease and augmentation of bacterial numbers by rice bran (Osunlaja, 1989) and the increase in plant growth and reduction of nematodes population by oil cakes (Khan and Saxena, 1997). However, there have been problems like the accumulation of NO_3 in vegetables and increased soil EC concentration in organic farming caused by excessive application of animal manure and organic fertilizer (Lee et al., 2004; Sohn et al., 1996).

One of the goals of nutrient management is to supply nutrients in a timely manner to maximize crop yield and quality. Cumulative nutrient uptake by an onion crop follows a sigmoid or s-shaped curve during the growing season and the period of rapid nutrient uptake starts during bulbing. Onions take up roughly at least 110 kg ha^{-1} of nitrogen, potassium and calcium, and substantially lower amounts of sulfur, phosphorus and magnesium (Sullivan et al., 2001). Nevertheless, onion root systems consist of superficial roots that are rarely branched and lack root hairs, requiring much larger supplies of nutrients than what will be taken up and, hence, the yield of onion bulb responds little to nitrogen fertilization rates (Halvorson et al., 2008; Shock et al., 2004). Plastic mulches have generally been used for soil warming, moisture conservation and weed control in onion production as in production of many other vegetables (Islam et al., 2002). Polyethylene film, however, can reduce the efficiency of fertilizer use in the middle of the growing season, since the mulches hinder the infiltration of additional fertilizer into the soil around the onion root system (Yang et al., 2006). In addition, polyethylene film has not been regarded as an ecological input within organic farming practices (Moreno and Moreno, 2008).

The aim of this study was to examine how to apply organic fertilizer effectively during organic production of onions while, at the same time, enhancing the nutrient efficiency, soil fertility and microbes.

2. Materials and methods

2.1. Field experiment

The field experiment was conducted at the experimental farm of the Onion Research Institute, Changnyeong district, Korea (35°55′N latitude and 128°47′E longitude) from 2005 to 2006. The experimental site had been under continuous cultivation by a double cropping system of rice followed by bulb onion (*Allium cepa* L.) and managed organically without the use of any chemicals for 3 years before starting this experiment. The topsoil was a silty loam with organic matter (OM) content of 14.9 g kg^{-1}, NO_3-N of 5.3 mg kg^{-1} and pH 6.7. Seeds of onion cv. *Superball* (a F1 hybrid cultivar for fall transplanting) were sown on August 9 and transplanted on November 7 with a spacing of 15 cm × 20 cm in 6 rows. Harvesting was conducted after 80% top fall-down on June 7 to estimate the marketable yield, bulb size and nutrient uptake. The amounts of organic fertilizer and chemical fertilizer applied to the onion field are shown in Table 1. The mixed organic fertilizer was made of organic materials like sesame oil cake, rice bran and molasses and minerals like illite as well as mountainous soil by a fermenting process. The solid organic fertilizer for basal application contained N, P, K, OM of 40, 13, 18, 461 g kg^{-1}, respectively, and the fertilizer for topdressing contained N, P, K of 35, 9, 23 g kg^{-1}, respectively. The latter was liquefied with a 10-fold volume of water for 10 days for producing liquid fertilizer. The nutrient components in liquid fertilizer were 1154 mg N kg^{-1}, 32 mg P kg^{-1}, 324 mg K kg^{-1}. The four organic treatments, which all had the same basal fertilization by solid OF, were different in the topdressing as follows: (1) solid OF without mulch (OF/OFnM), (2) liquid organic fertilizer without mulch (OF/LOFnM), (3) liquid organic fertilizer under mulch (OF/LOFuM) and (4) liquid organic fertilizer over mulch (OF/LOFoM). Chemical fertilizer (CF) and no fertilizer (NF) were treated as controls. The solid organic fertilizer rate was 2.0 ton ha^{-1} for the basal application (Table 1). It was incorporated by hand raking into the soil of the plots which had already been set up. The treatments were replicated three times in a randomized complete block design using 1.2 m × 14 m individual plots. For topdressing, the solid organic fertilizer was applied at the rate of 4.6 ton ha^{-1} on the surface soil with mulch, twice separately in the middle of February and March. The liquid fertilizer was supplied at the rate of 133.2 ton ha^{-1}, which was divided into 6 applications with each occurring every 10 days from February through March. The OF/LOFuM treatment was fertigated in one line under the mulch and the OF/LOFoM treatment was sprayed over the mulch using a power supply. Onion crops in all plots had 20.0 ton of cow manure compost applied and were cultivated under conditions of no herbicides or pesticides. Weeds in onion field were controlled by hand weeding 3 times from early March to late April. In mulch, weeds were removed through the planting holes of onion stand by hand weeding hoe in early spring. And then transparent plastic film was covered with the soil collected from furrow to hinder sunlight penetrate through the film into soil. In no mulch, weeds grew slower and rarer than in mulch, so it was effective enough to remove weeds by hand weeding hoe 3 times. As the previous crop, rice was transplanted mechanically and not applied with any fertilizers and pesticides. Weeds were controlled by rice-duck farming method. The yield was produced approximately 4.0 ton ha^{-1}. We cultivated rice crop without applying any fertilizer to sequester the residual nutrients in soil after onion harvest. The straw was cut, spread and incorporated into soil at rice harvest.

Table 1
Amounts of organic fertilizer and chemical fertilizer applied to the onion fields.

Treatments	Basal fertilization (N–P–K, kg ha^{-1})	Topdressing (N–P–K, kg ha^{-1})	Total rate (N–P–K, kg ha^{-1})
NF	–	–	
CF	(80–34–48)	(160–0–80)	(240–34–128)
OF/OFnM	2,000 (80–20–27)	4,570 (160–27–103)	(240–47–130)
OF/LOFnM	2,000 (80–20–27)	132,000 (160–4–43)	(240–24–69)
OF/LOFuM	2,000 (80–20–27)	132,000 (160–4–43)	(240–24–69)
OF/LOFoM	2,000 (80–20–27)	132,000 (160–4–43)	(240–24–69)

NF, no fertilizer; CF, chemical fertilizer; OF/OFnM, basal application of organic fertilizer (OF) and topdressing of solid OF without mulch; OF/LOFnM, basal application of OF and topdressing of liquid OF without mulch; OF/LOFuM, basal application of OF and topdressing of liquid OF under mulch; OF/LOFoM, basal application of OF and topdressing of liquid OF over mulch.

2.2. Plant and soil sampling

Crop plants were sampled at the 98th, 112th, 126th, 147th, 161st, 177th, 189th and 212th day after transplanting with 10 plants per replicate. The soil samples for soil chemical and microbiological analysis were collected from the surface layer (0–15 cm) at plant sampling points, with additional sampling at the 17th day before transplanting and at one day after basal fertilizer and compost application.

2.3. Plant growth and nutrient uptake analysis

After measuring plant height and bulb diameter, the onion plants were separated into the bulb and green leaves so that the