Revista Ceres
ISSN: 0034-737X
ceresonline@ufv.br
Universidade Federal de Viçosa
Brasil

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Revista Ceres, vol. 58, núm. 5, septiembre-octubre, 2011, pp. 645-650
Universidade Federal de Viçosa
Vicosa, Brasil

Broccoli yield in response to top-dressing fertilization with green manure and biofertilizer

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ABSTRACT

The objective of this work was to evaluate the productive performance of broccoli under different top-dressing organic fertilizations. The experiment was conducted under protected cultivation, in a completely randomized design with four replications, with two plants per experimental unit. Broccoli seedlings were produced in a commercial substrate in styrofoam trays. The seedlings were transplanted to plastic pots containing 10.0 L of substrate made up of subsoil and organic compost at the ratio of 3:1 (v/v), respectively, which is equivalent to about 20.0 t ha^{-1} of organic compost at planting. After seedling establishment, the top-dressing fertilization treatments were applied: gliricidia biomass associated or not with liquid biofertilizer of cattle manure to the soil and *bokashi*. Two control treatments were established: one with mineral fertilization recommended for the crop and the other without top-dressing fertilization. The broccoli production was evaluated (commercial standard). Plants that received mineral fertilizer were more productive, however, they were not significantly different (p>0.05), by Dunnet test, from the plants fertilized with 2.5 t ha^{-1} gliricidia biomass (dry mass) associated with liquid biofertilizer (2.0 L m^{-2}) applied to soil. Top-dressing fertilizations with only gliricidia, at 2.5 and 5.0 t ha^{-1} of biomass (dry mass), resulted in no significant increase in production of broccoli inflorescence. The use of *bokashi* in addition to gliricidia biomass and liquid biofertilizer reduced the efficiency of the fertilization compared with plants that received only gliricidia and liquid biofertilizer.

Key words: Organic horticulture, organic fertilization, *Gliricidia sepium* (Jacq.), biofertilizer; *Brassica oleracea* L. var. *italica.*

RESUMO

Resposta de brócolis à adubação de cobertura com biomassa de adubo verde e biofertilizante

O objetivo deste trabalho foi avaliar o desempenho produtivo de plantas de brócolis, submetidas a diferentes sistemas de adubação orgânica de cobertura. O experimento foi conduzido em ambiente protegido, em delineamento inteiramente casualizado, com quatro repetições e duas plantas por unidade experimental. Mudas de brócolis, produzidas em bandejas de isopor com substrato comercial, foram transplantadas para vasos plásticos, contendo 10,0 L de substrato formado pela mistura de terra de subsolo e composto orgânico, na proporção de 3:1 (v/v), respectivamente, adubação esta equivalente a cerca de 20,0 t ha^{-1} de composto, por ocasião do plantio. Após o pegamento das mudas, foram aplicados os tratamentos de adubação de cobertura, baseados na aplicação de biomassa de gliricídia, associada, ou não, à aplicação de biofertilizante líquido de esterco bovino, via solo e a *bokashi*. Houve dois tratamentos testemunhas: um, sem adubação de cobertura e, outro, com a adubação mineral de cobertura indicada para a cultura. Avaliou-

Recebido para publicação em 15/05/2009 e aprovado em 09/08/2011

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se a produção de inflorescências comerciais de brócolis. Plantas que receberam adubações de cobertura com adubos químicos apresentaram-se mais produtivas, entretanto, não diferiram (p>0,05), pelo teste de Dunnett, de plantas que receberam adubação de cobertura correspondente a 2,5 t ha^{-1} de biomassa seca de gliricídia , associada à aplicação de biofertilizante líquido de esterco bovino, via solo, na dose de 2,0 L m^{-2}. Adubações de cobertura apenas com biomassa de gliricídia, nas doses de 2,5 e 5,0 t ha^{-1} de biomassa seca, não proporcionaram aumentos significativos de produção de inflorescências de brócolis. O uso de *bokashi* reduziu a eficiência da adubação de cobertura com biomassa de gliricídia associada ao uso de biofertilizante líquido de esterco bovino.

Palavras-chave: Olericultura orgânica, adubação orgânica, *Gliricidia sepium* (Jacq.), biofertilizante; *Brassica oleracea* L. var. *italica.*

INTRODUCTION

Vegetable crops require large amounts of nutrients – broccoli, for example, extracts about 500.0 kg ha^{-1} of N throughout its production cycle. The high nutritional demands associated with the low investment capacity of family farmers have led to inappropriate plant nutrient management and hence low yields. Additionally, the imbalance in the supply of nutrients is a major problem affecting the sustainability of agricultural systems worldwide, both by the insufficient replacement and by the excessive nutrients applied (Vitousek *et al.* 2009). For this reason, it is important, in a broader view, to promote techniques that contribute to increased input of nutrients, their cycling in agroecosystems and the use of local resources. Alternative fertilization systems that allow the utilization of organic materials available or easily obtainable in the farms are needed to reduce the dependence on mineral fertilizers and increase the rate of organic matter input into areas of production.

The use of animal manure (Lupwayi & Haque, 1999, Whalen *et al*. 2001; van Kessel & Reeves, 2002) and green manure (Palm & Sanchez, 1991; Handayanto *et al*., 1997; Cobo *et al*., 2002) is an alternative to increasing the economic and environmental sustainability especially of small farms. Green manure, in addition to organic compost, can provide adequate amounts of nitrogen to crops, which in part derives from the biological fixation, through the symbiotic association between bacteria and legumes, and also allows the cycling of other nutrients essential to crops. Green manure also provides increased levels of soil organic matter, which makes an important contribution to the cation exchange capacity (CEC) of tropical soils (Raij, 1969), and incorporates organic matter into the soil, through the root systems of plants. Green manures provide soil cover and protection, helping to reduce erosion, and, finally, the plants can also be used as fodder for animal feed.

A study comparing the green manures sunnhemp (*Crotalaria juncea* L.), black-velvet bean (*Stizolobium aterrimum* Piper et Tracy) and jackbean (*Canavalia ensiformes* L. (DC)) with mineral fertilizer and incorporated spontaneous vegetation, in the production of cabbage and crisphead lettuce, showed no significant difference between green manuring and mineral fertilization for production of total fresh mass and commercial fresh mass of lettuce leaves (Fontanetti *et al.* 2006). But, sunnhemp was more efficient than jackbean or black-velvet bean in increasing the commercial weight of cabbage head with production similar to that obtained with the mineral fertilizer. However, the average weight of cabbage heads of all treatments ranged from 1,215.5 g and 1,960.0 g (Fontanetti *et al.*, 2006), meeting the Brazilian standard size (between 1,000.0 g and 1,500.0 g per head) (Lêdo *et al*., 2000). Oliveira *et al.* (2005) working with pre-plant incorporated sunnhemp also obtained average commercial weight of cabbage heads of 1,260.0 g.

Mesquita *et al*. (2007) reported positive effects of liquid bio-fertilizers applied to the soil on the yield and physico-chemical quality of papaya fruits cv. “Baixinho de Santa Amália”. Araujo *et al.* (2008) evaluated the effect of different rates and intervals of application of liquid biofertilizer to the soil on yellow passion fruit, and also reported higher growth rates and larger fruit production in plants that received the treatments.

The effect of unincorporated residues of sorghum, millet, sunnhemp and spontaneous vegetation on the production of broccoli inflorescences was evaluated in a no-tillage system (Silva, 2002). In the first year, plants that were covered with biomass of spontaneous vegetation produced smaller inflorescences than those covered with residues of sorghum, millet and sunnhemp. In the second year, it was evaluated the coverage by residues of sorghum, sorghum and sunnhemp, and spontaneous vegetation. In this evaluation, the biomass of sunnhemp, as well as the treatment that received sunnhemp and sorghum provided higher yields than the treatments with only sorghum and spontaneous vegetation (Silva, 2002).

Therefore, this study was conducted to compare different forms of organic fertilization by top-dressing in broccoli cultivation, using low-cost inputs which are generally available or easily obtainable in small farms, such as poultry litter, compost, legume biomass, liquid bio-fertilizer made from fresh cattle manure and *Bokashi*.

MATERIALS AND METHODS

The experiment was conducted in a protected environment, the Sector of Fruit Crops, Federal University of Viçosa (UFV).

Broccoli seedlings, cv. Ramoso Santana, were produced in a commercial substrate in polystyrene trays. The seedlings (5 cm tall) were transplanted to plastic pots containing 10.0 L of substrate made up of subsoil and organic compost at the ratio of 3:1 (v/v), which is equivalent to about 20.0 t ha^{-1} of organic compost at planting, and supplemented with simple superphosphate (5 kg/m^3 substrate). The compost was produced in piles, using mature napier grass clippings and poultry litter with wood shavings at the ratio of 3.5:1 (v/v). Table 1 shows the nutrient levels in the poultry litter and the compost. Nutrient contents in the soil used to make the substrate were: P = 2.7 mg dm^{-3}, K = 8 mg dm^{-3}, Ca^{2+} = 0.6 $cmol_c$ dm^{-3}; Mg^{2+} = 0.3 $cmol_c$ dm^{-3} and Al^{3+} = 0.5 $cmol_c$ dm^{-3}, with pH (H_2O) = 5.6. The nutrient contents were determined by the following methods: Ca, Mg and Al using the extractor 1mol.L^{-1} KCl; P and K with the Mehlich I; extractable acidity (H + Al) with the extractor SMP; and the pH in water at the ratio 1:2.5 (soil: water).

After seedling establishment, the top-dressing fertilization treatments were applied as follows: T1 (no top-dressing); T2 (mineral fertilization corresponding to 150.0 kg ha^{-1} N, 240.0 kg ha^{-1} K_2O and 400.0 kg ha^{-1} P_2O_5 in three applications at 30, 45 and 60 days after transplanting); T3 (green manure equivalent to 5.0 t ha^{-1} gliricidia biomass (dry matter - DM) applied on the soil surface (without incorporation) at 10 days after transplanting); T4 (2.5 t ha^{-1} gliricidia biomass (DM) applied at 10 days after transplanting); T5 (2.5 t ha^{-1} gliricidia biomass (DM) applied at 10 days after transplanting + application of liquid biofertilizer of cattle manure diluted in water at the ratio of 1:1 corresponding to 2.0 L m^{-2} applied at 30, 37, 45, 52 and 60 days after transplanting); T6 (2.5 t ha^{-1} gliricidia biomass (DM) applied at 10 days after transplanting + surface application of *Bokashi* corresponding to 150 g m^{-2}); T7 (2.5 t ha^{-1} gliricidia biomass (DM) applied at 10 days after transplanting + 2.0 L m^{-2} of liquid biofertilizer of cattle manure diluted in water at the ratio of 1:1 applied at 30, 37, 45, 52 and 60 days after transplanting + 150 g m^{-2} *Bokashi*); and T8 (planting substrate made of subsoil + raw poultry litter (non composted) at the ratio of 3:1 (v/v), supplemented with simple superphosphate at 5 kg m^{-3} substrate). Treatment T8 differed from the others by replacing the organic compost by the non-composted poultry litter in the substrate, which is the form commonly used by farmers in fertilization, because composting of poultry litter is a labor-and time-consuming process. The experiment was arranged in a completely randomized design with eight treatments, four replications and two plants per experimental unit.

Table 1 shows the nutrient contents found in the poultry litter, liquid bio-fertilizer of cattle manure, *Bokashi* and the organic compost used in the experiment. Gliricidia biomass was obtained from adult plants grown from live stakes, in the Sector of Fruit Crops of UFV. Gliciridia dry matter content was determined by drying samples at 65 °C in an oven to a constant weight (about 72 h). The liquid biofertilizer of cattle manure was produced in a 200 L plastic drum by mixing 90 L of fresh cattle manure with 90 L of water. The drum was kept sealed tightly for 60 days. A vent system was adapted to the drum lid (a hose coming out of the drum lid with the lower end immersed in a container with water) to allow the methane gas produced during the fermentation to exit the drum, without the entry of oxygen (anaerobic fermentation).

Table 1. Nutrient contents** in the organic fertilizers used in the experiment

Fertilizer*	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu
	dag kg^{-1}						mg kg^{-1}			
GB	4.23	0.19	2.20	1.09	0.24	0.18	19	156	34	5
BK	0.74	0.24	0.47	1.35	0.24	0.69	58	3004	432	24
BCM	0.41	0.02	0.21	0.21	0.05	0.02	2.	22	7	1
PL	2.81	8.28	3.82	2.21	1.05	1.29	10	21	12	2
CO	1.68	4.58	1.81	4.67	0.83	0.63	5	0.000	15	1

* GB - Gliricidia biomass; BK - *Bokashi*; BCM - Biofertilizer of cattle manure; PL – Poultry litter (non-composted); CO – Compost of poultry litter and napier grass.** N concentration was determined after sulfuric digestion by the Kjedahl method. Contents of P, K, Ca, Mg and S were determined after nitric-perchloric digestion. P was determined based on the formation of a complex between phosphate and sodium molybdate in the presence of ascorbic acid as the reducing agent. K was determined by flame photometry and Ca and Mg by atomic absorption spectrophotometry.

Bokashi was produced from a mixture of 60 L of forest humus (litter), 120 L of cattle manure, 120 L of rice husk, 60 L charcoal dust, 30 kg of wheat meal, 2.0 kg of molasses and 50 L of water (enough to the mixture reached about 50% moisture). The materials were mixed using shovels and hoes, forming a small heap that was covered with burlap sacks. The fermentation process was controlled by monitoring the temperature inside the mixture and by turning it when the temperature reached 50 ºC (Adapted from Trivellato, 2002).

The production of commercial broccoli inflorescences (t ha^{-1}) was evaluated for each treatment. Data were subjected to analysis of variance by F test and means were compared by Dunnett's test at 5% probability ($P < 0.05$).

RESULTS AND DISCUSSION

Only the treatment T5 (2.5 t ha^{-1} gliricidia biomass (DM) + 2.0 L m^{-2} biofertilizer at 50%, applied at 30, 37, 45, 52 and 60 days after transplanting) provided yield of commercial inflorescences higher than the control treatment T1 (20 t ha^{-1} of organic compost at planting) (Figure 1).

Plants that received the treatment T5 (2.5 t ha^{-1} gliricidia biomass (DM) at 10 days after transplanting + 2.0 L m^{-2} biofertilizer at 50%) also had yields ($P < 0.05$) similar to those that received mineral fertilizers (Figure 2). The other organic fertilization treatments provided yields lower than the chemical fertilization.

The superiority of the treatment T5 over the other organic fertilizations can be related to the combined use of legume biomass with the liquid biofertilizer of cattle manure. In this case, the gliricidia biomass would release nutrients gradually, while the biofertilizer, considered an organic fertilizer with nutrients readily available, would supplement the plants. The application of biofertilizers to the soil for the production of yellow passion fruit and papaya also provided positive effects on production and fruit quality (Mesquita *et al*., 2007; Araújo *et al*., 2008).

In the treatment T7 (2.5 t ha^{-1} gliricidia (DM) + 2.0 L m^{-2} biofertilizer at 50% + 150 g m^{-2} *Bokashi*), the addition of *Bokashi* to the treatment T5 resulted in lower yield. It is likely that the use of forest humus (leaf litter) in the production of *Bokashi* influenced negatively the broccoli production by immobilization of nutrients. *Bokashi* consists of a diverse and active microflora, because it is produced using inoculants based on efficient microbes (EM's) or forest soil. However, when it is made from forest soil, there is no guarantee that the microbial flora is effective for the target crop and environment. Della Bruna *et al*. (1991) showed that the addition of leaf litter can increase about five times the biological activity in soils. Assis Júnior *et al*. (2003) evaluated the non-instantaneous biological activity by the total amount of CO_2 released during the decomposition of organic matter in the field. The systems native forest (559.37 mg m^{-2} h^{-1} CO_2), pasture

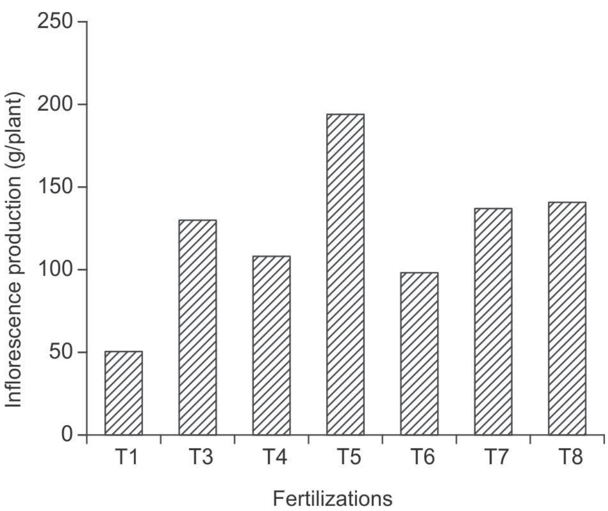

Figure 1. Comparison of means of the production of commercial broccoli inflorescences under top-dressing of different organic fertilizations.

Top-dressing fertilizations: T1 (no top-dressing); T3 (5.0 t ha^{-1} gliricidia biomass - DM); T4 (2.5 t ha^{-1} gliricidia biomass - DM); T5 (2.5 t ha^{-1} gliricidia biomass - DM + 2.0 L m^{-2} of biofertilizers at 50%); T6 (2.5 t ha^{-1} gliricidia biomass - DM + 150 g m^{-2} *Bokashi*); T7 (2.5 t ha^{-1} gliricidia biomass - DM + 2.0 L m^{-2} of biofertilizer at 50% + 150 g m^{-2} *Bokashi*) and T8 (only raw poultry litter at planting). Means with letters different from the treatment T1 are significantly different by the Dunnett's test at 1% probability level.

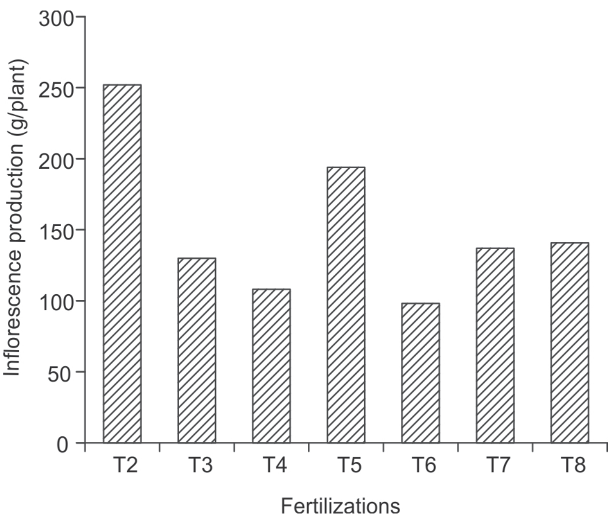

Figure 2. Comparison of production means of commercial broccoli inflorescences under top-dressing of different organic fertilizations.

Top-dressing fertilizations: T2 (150.0 kg ha^{-1} N; 240.0 kg ha^{-1} K_2O and 400.0 kg ha^{-1} P_2O_5); T3 (5.0 t ha^{-1} gliricidia biomass - DM); T4 (2.5 t ha^{-1} gliricidia biomass - DM); T5 (2.5 t ha^{-1} gliricidia biomass - DM + 2.0 L m^{-2} of biofertilizers at 50%); T6 (2.5 t ha^{-1} gliricidia biomass - DM + 150 g m^{-2} *Bokashi*); T7 (2.5 t ha^{-1} gliricidia biomass - DM + 2.0 L m^{-2} of biofertilizer at 50% + 150 g m^{-2} *Bokashi*) and T8 (only raw poultry litter at planting). Means with letters different from the treatment T2 are significantly different by the Dunnett's test at 5% probability level.

in monoculture (538.25 mg m^{-2} h^{-1} CO_2) and pasture associated with eucalyptus (488.81 mg m^{-2} h^{-1} CO_2) had higher biological activity, whereas the lowest values were recorded in rice (202.82 mg m^{-2} h^{-1} CO_2) and deforested areas (165.16 mg m^{-2} h^{-1} CO_2).

In a microbiological analysis of *Bokashi*, Magrini *et al*. (2009) found that yeasts were the most representative group, followed by bacteria and fungi. The fungi identified in the final stage of maturation of the compost belonged to different genera, especially *Aspergillus* sp., *Dactylium* sp. and *Rhizopus* sp.. Factors such as diversity of microbiota, availability of organic carbon sources and parameters such as the C/N/P and the lignocellulosic index affect soil biological activity (Assis Júnior *et al*., 2003).

Plants that received only Gliricidia biomass as top-dressing, regardless of the rate tested (T3 and T4), had lower yields than those fertilized with mineral fertilizers. Salcedo & Menezes (2007) also reported lack of effect for addition of gliricidia to corn production, using rates equivalent to those in this experiment. Although the gliricidia biomass has a low C/N ratio, it takes some time for mineralizing nutrients and making them available to the crop (Marin *et al*., 2006). Therefore, its surface application, in a short cycle crop such as broccoli, has certainly not been enough to release the amount of nutrients necessary for the development of the crop.

Plants from the treatment T8 (substrate made of subsoil + raw poultry litter at the ratio of 3:1 (v/v), without top-dressing) also had lower yields than those fertilized with mineral fertilizers (Figure 2). This result showed that the replacement of the organic compost by poultry litter at planting did not reduce the need for top-dressing fertilization, since this treatment did not achieve the yields provided by T2 (mineral fertilization) or T5 (gliricidia biomass + liquid biofertilizer), which were 4.7 t ha^{-1} and 3.6 t ha^{-1} respectively. The use of biofertilizer applied to the soil in addition to cattle manure increased the production of peppers in comparison with the treatment that received only cattle manure (Araújo *et al*., 2007). Different rates of organic compost (5-25 t ha^{-1}) used in the production of broccoli provided yields from 6.67 to 12.5 t ha^{-1} (Diniz *et al*., 2008). Top-dressing of velvet bean, at the rates 0-12 t ha^{-1}, in addition to 12.5 t ha^{-1} of organic compost provided broccoli yields between 8.8 t ha^{-1} and 13.8 t ha^{-1} (Siqueira *et al*., 2009). The yield obtained in this study was lower than those achieved in these studies, which were conducted in the field, whereas this experiment was conducted in pots, which certainly restricted the volume of soil being explored by the plant root system. Besides, the fertilizer rates used in this experiment were lower, because the objective was a qualitative assessment, comparing the different types of organic fertilizers.

CONCLUSIONS

Organic fertilization at planting corresponding to 20 t ha^{-1} of organic compost of poultry litter is not enough to provide good production yields of commercial broccoli inflorescences.

Organic fertilization top-dressing with Gliricidia biomass associated with liquid biofertilizer of cattle manure applied to the soil result in production of broccoli inflorescences similar to those obtained by plants fertilized with mineral fertilizers.

The use of *Bokashi* made with forest topsoil in the production of broccoli reduce the efficiency of top-dressing with Gliricidia biomass associated with liquid biofertilizer of cattle manure.

Top-dressing with only gliricidia biomass at the rates of 2.5 t ha^{-1} and 5.0 t ha^{-1} (DM) do not provide significant increases in the production of commercial broccoli inflorescences.

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