Production of cabbage grown in pots containing legumes' root and shoot

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ABSTRACT

Roots effect is not generally considered in studies assessing the performance of crops in response to green manuring. However, such effect can contribute to a better understanding of crop rotation. The aim of this study was to assess the effect of root and shoot of two legumes on the production of cabbage. The experiment was conducted in pots of 10 liters containing substrate of 2:1 soil/sand. The experiment was arranged in a factorial scheme (2x3 + 2) in a randomized block design with five replicates using two legume species (*Crotalaria juncea* L. and *Canavalia ensiformis* L), three plant parts (root, shoot, or whole plant), and two additional treatments (mineral fertilization with 100% and 50% of the recommended dose of N for growing cabbage). Pots with legume treatments received mineral fertilizer with 50% of the recommended dose of N for growing cabbage. The experimental plot consisted of a pot containing one plant of cabbage. Legumes were grown in pots and harvested at 78 days. The root biomass was determined in extra pots. Production was assessed using head fresh and dry weight. The application of the whole plant of both legume species reduced cabbage production. However, root or shoot of both legume species was equivalent to 50% of mineral N fertilization required for the cultivation of cabbage.

Key words: green manure, nitrogen, *Crotalaria juncea* L., *Canavalia ensiformis* L., *Brassica oleracea* var. *capitata* L.

RESUMO

Produção de repolho cultivado em vasos, contendo raiz ou parte aérea de leguminosas

Em estudos de avaliação do desempenho de culturas em sequência à adubação verde, geralmente não se considera o efeito das raízes dos adubos verdes. Entretanto, tais efeitos podem contribuir para maior entendimento científico dessa modalidade de adubação. O objetivo deste trabalho foi avaliar os efeitos da raiz e da parte aérea de duas leguminosas sobre a produção do repolho. O trabalho foi conduzido em vasos de 10 L de solo/areia, na proporção de 2:1. O experimento foi instalado em esquema fatorial (2x3) + 2, sendo duas espécies de leguminosas (*Crotalaria juncea* L. e *Canavalia ensiformis* L.), três partes das plantas (raiz, parte aérea ou planta inteira) e dois tratamentos adicionais (adubação mineral, com 100 e 50% da dose recomendada de N para a cultura do repolho), em blocos casualizados, com cinco repetições. Os vasos com os tratamentos de leguminosas receberam adubação mineral com 50% da dose recomendada de N para a cultura do repolho. A unidade experimental constou de um vaso com uma planta. As leguminosas foram cultivadas nos vasos e cortadas aos 78 dias. A massa das raízes foi determinada em vasos extras. A produção foi avaliada pelas massas das matérias fresca e seca da cabeça de repolho. A aplicação da planta inteira de ambas as espécies de leguminosas diminui a produção de repolho. A aplicação de raiz ou de parte aérea de quaisquer das espécies de leguminosas foi equivalente a 50% da adubação com N-mineral requerida para a cultura do repolho.

Palavras-chave: adubação verde, nitrogênio, *Crotalaria juncea* L., *Canavalia ensiformis* L., *Brassica oleracea* var. *capitata* L.

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INTRODUCTION

Vegetables require high demand of nitrogen fertilizer in a short period of their growing cycle. Moreover, after harvesting, only a few crop residues remain within the cultivation area and the crop will use up the soil significantly (Nowacki, 2004). So, the intense and frequent use of nitrogen fertilizers raises economic and environmental concerns, as well as increase farmers' dependence on the industrial sector. Therefore, the use of green manure can reduce the need for the application of synthetic N in succeeding crops (Zotarelli, 2000).

When assessing the role of green manure on the supplying of N to the production of organic broccoli, Diniz *et al*. (2007) found that the incorporation of 8.64 t ha^{-1} of dry mass of *Mucuna cinereum* L., at 15 days after transplanting, has replaced half the dose of organic or mineral fertilizer without reducing production. The previous cultivation of green manure allowed the production of commercial heads of cabbage with the application of 12.7 t ha^{-1} (*C. juncea*), 8.5 t ha^{-1} (*Mucuna aterrima* (Piper & Tracy) Holland) or 7.5 t ha^{-1} (*C. ensiformis*) (Fontanétti *et al*., 2006). These amounts can increase, if roots and shoots biomass nitrogen content is considered (Khan *et al*., 2002). The recovery of ^{15}N in maize from green manures *C. juncea* and *Mucuna* sp. was 30% of N from the sunnhemp shoot and less than 20% of N added by the roots of mucuna (Ambrosano, 1995). However, in most studies, green manure root effects are not usually taken into account. This occurs due to the difficulty of roots' collection and quantifying their N content (Khan *et al*., 2002). Thus, studies on the effects of different parts of legumes on crop production are expected to contribute to greater scientific understanding and future green manure management. The aim of this study was to assess the effects of root, shoot or whole plant of *Crotalaria juncea* and *Canavalia ensiformis* green manure on the growth and yield of cabbage grown in pots.

MATERIALS AND METHODS

Green manure production

The experiment was conducted in the experimental area of Agroecology, Departmento de Fitotecnia, Universidade Federal de Viçosa-MG, Brazil, from November 2007 to February 2008. Green manures were produced in 10-liter pots filled with soil and sand in a 2:1 ratio with the following chemical characteristics, after liming and simple superphosphate incorporation: pH in water (1:2.5) 5, 34, 56 mg dm^{-3} of P; 86 mg dm^{-3} of K; 2.45 $cmol_c$ dm^{-3} of Ca; 0.63 $cmol_c$ dm^{-3} of Mg; 0.0 $cmol_c$ dm^{-3} of Al, and 0.58 dag kg^{-1} of organic matter.

After legume seed inoculation with appropriate *Bradyrhizobium* strains, sunnhemp and jack-bean were sown nine seeds and six seeds per pot for sunnhemp and jack-bean, respectively. One week after the emergence, thinning was performed. Three plants of sunnhemp and two jack-bean per pot were maintained. Six treatments were determined for legumes (1) SSH, (2) SRO (3) SWP (4) JBSH (5) JBRO (6) JBWP. Treatments (1), (2) and (3) were made by sunnhemp (S) and three plant parts: shoot (SH), root (RO) or whole plant (WP); and treatments (4), (5) and (6) by jack-bean (JB) and three plant parts: shoot (SH), root (RO), or whole plant (WP). The green manure plants were cut close to the ground 78 days after planting, and weighed to determine the fresh weight. The removal of the shoot determined legume root (RO) treatment, which remained untouched in the soil. The removed shoot was applied in topdressing on another pot, which determined shoot treatment (SH) of legume. The cutting of shoot, without removing the aboveground biomass of the pot determined the whole plant (WP) treatment. The whole plant biomass was determined by summing up root and shoot biomass. Ten additional pots were used for each legume species, in order to quantify the legume plant shoot and root biomass, without interfering in the treatments. They were washed with deionized water, dried on paper towels, stored in paper bags, and dried in an oven at 65 °C, until a constant mass, then weighted to quantify dry matter.

The same procedure was performed for the legumes' roots. The material was stored and ground for later determination of macronutrients content. This procedure allowed us to establish the RO:SH ratio, and estimate the root biomass of the other pots. After quantifying legume shoot biomass, legumes were chopped using a paper cutter, reducing the effect of the absence of soil macrofauna in pots and then redistributed according to the treatments.

Mineral nutrients were extracted by nitric-perchloric or sulfur digestion, and the concentrations of P and K were determined by spectrophotometric colorimeter and flame photometer, respectively. Ca and Mg were determined by atomic absorption spectrophotometry and total nitrogen content was determined using the Kjeldahl distillation method. Biological nitrogen fixation (BNF) was also determined for sunnhemp and jack-beans using the ^{15}N natural abundance technique (Boddey *et al*., 1994), with a Finnigan MAT®, Delta Plus®, mass spectrometer, which estimated the $\delta^{15}N$ of samples of legumes, in order to estimate the percentage of N derived from BNF.

Planting of cabbage in the pots and treatment establishment

After cutting the legumes, the next step was planting 'Matsukaze' cabbage seedlings, on the same day, and on the same pots received legumes in a greenhouse. The experiment adopted eight treatments in a factorial design (2 x 3) + 2, with two legumes and three plant parts (root, shoot, and whole plant) previously mentioned, and two additional treatments (mineral fertilizer with 100% (MF100%) and 50% (MF50%) of recommended N dose for growing cabbage). The experiment was set in completely randomized blocks with five replicates, totaling 40 plots of one plant per pot.

The N doses used were 100 or 50 mg of N per kg of soil, referring to 100% or 50% of the recommended N dose. To reduce the interference of this nutrient in the process of decomposition of legume biomass and mineralization of the existent nutrients, mineral nitrogen was added immediately after transplantation on the side of the seedlings in the form of urea in a small hole to a depth of 1 cm, as described by Pereira (2007). Then, 70 mg of K per kg of soil in the form of potassium chloride were supplied. One gram of micronutrients complex (FTE BR-12) was supplied as well. Phosphorus (single superphosphate), calcium and magnesium (calcined dolomite) were applied in the substrate preparation before the sowing of legumes was performed.

Cabbage plants were grown in pots for 100 days. Production was assessed using head fresh and dry weight. Total fresh and dry weight of cabbage plants were determined by the sum of the head, leaves and stem. The head diameter was determined by a horizontal cut using a ruler. The analysis of variance was performed and the means of legumes treatments were compared with the additional control with mineral nitrogen, using the Dunnett test ($p<0.05$). Mean comparisons of treatments containing the different parts of legumes was determined using the Tukey test ($p<0.05$).

RESULTS AND DISCUSSION

Green manure production

Sunnhemp production of fresh and dry matter of the examined three parts was higher than jack-bean by 52% (Table 1). Sunnhemp and jack-bean whole plant N content was 1.56% and 2.50%, respectively. C/N ratio was higher in sunnhemp biomass, as it has low N concentration when compared to jack-bean. Dry matter (DM) content of green manure's shoots C. *juncea* (23.45%) and *C. ensiformis* (24.58%) were similar to those found by Oliveira *et al*., (2005) and Fontanétti *et al*., (2006). The higher values of DM content (62.45%) and C/N ratio (42.70%) and lower values of N content (0.96%) on sunnhemp roots occurred probably due to thin roots contamination by mineral fractions of the soil. Local conditions may not only favor some particular species if compared to others, but also may encourage production variations within the same species. In a study conducted in the Amazon, Fernandes *et al*. (2007) have found a production of jack-bean total dry matter, for plants grown in pots with 3.3 dm^3, of 19.30 g pot^{-1} which was higher than that obtained in this work, considering the volume of soil explored by plants.

The species showed different behavior in relation to the accumulation of macronutrients (Table 2). Jack-bean has accumulated less biomass, but its accumulation of K was similar to that of sunnhemp in the shoots (0.33 and 0.27 g/pot, respectively). Such differences, in the same soil fertility condition, can be due to genetic specificities. Mg and S accumulation (0.20 and 0.19 g/pot) was greater in sunnhemp plants. The amounts of P and Ca were similar in the shoots of both species. The highest accumulation of these nutrients was found in sunnhemp whole plant (0.14 and 0.57 g/pot), the higher N content was found in jack-bean plants (Table 1). However, the greatest N accumulation was found in sunnhemp due to its greater biomass production (Table 2).

Sunnhemp shoot biomass proportion corresponded to 52% and the root to 48% of whole plant biomass. Jack-bean shoot biomass proportion accounted for 80% and the root for 20% of whole plant biomass. The root:shoot ratio of sunnhemp was 0.92, while 0.25 for jack-bean. Ambrosano *et al*. (1997), found root:shoot ratio of 0.24 for *M. aterrima* and of 0.14 for *C. juncea*, grown in pots containing 10 kg of soil, for 94 and 93 days using N labeled technique, respectively. According to the authors, sunnhemp showed little root growth as a result of high nitrogen fertilization. Moreover, roots were characterized by small nodulation.

Notably, green manuring is an effective supplier of N to vegetables because of legumes potential to fix biological N. It is noteworthy that, starting from the BNF process (Table 1), sunnhemp and jack-bean whole plants provided the soil with 61.64 and 82.00% of N from the air, respectively.

Besides N, legumes accumulated other nutrients (Table 2). Sunnhemp added the higher amounts of nutrients due to its larger biomass production. Results indicate that legumes species may differ markedly in biomass production and nutrient accumulation in the root fraction which may account for differences in their effects on the subsequent crops.

Cabbage production

Comparisons with MF100%

The fertilization of cabbage with 50% mineral nitrogen combined with root and shoot of both legumes resulted in head production similar to that of 100% MNF ($p<0.05$). Fertilization with 50% MNF with added whole plant of both legumes has reduced production, compared to 100% MNF (Table 3). Green manure nutrient release and the following recovery by vegetables depends on the synchrony between residue mineralization and crop nutrient demand (Diniz *et al.*, 2007).

Cabbage has a higher uptake rate and nutrient accumulation from 60 to 70 days after transplantion. In studies with *Mucuna cinereum*, it was found that 24 days after the addition of residue, 50% of the green manure nitrogen content was released (Diniz *et al*., 2007). In this present study, little synchrony between nutrient release from the whole plant of green manure and cabbage uptake was possible. Possibly, the low synchrony could be attributed to the surface application of GM biomass and water supply which may cause the fermentation of green manure roots, leading to a decline in the production of cabbage. Schroeder *et al*. (1998) found broccoli seedlings mortality after the incorporation of the cowpea biomass. The production of total fresh weight, as well as heads of cabbage within the whole plant treatments of green manure were lower than the other treatments (Table 3). The yield of cabbage ranged from 99.60 to 234.98 g/plant. The production may have been limited by the pot volume restricting root growth and consequently, resulting in low production despite fertilization.

Head fresh weight production was also negatively influenced by treatments with the root of both legume species (Table 3). In this treatment, the low production may result from the extraction of nutrients by the removed shoot. In the production of the total dry matter of cabbage, it was verified only the negative effect of the treatment with whole plant sunnhemp when compared with control 100% of recommended N (Table 3). The average horizontal diameter head was 7.37 cm, with no significant difference to the control (p>0.05).

Comparisons with MF50%

Cabbage plants grown in pots containing the roots, shoot and whole plant of any legume species resulted in yields similar to those grown with 50% of the recommended dose of N (Table 3).

When compared to the mass production of fresh and dry matter of cabbage plants with control 50% of the recommended dose of N, it was found that only plants fertilized with sunnhemp shoot were higher than the control. With the implementation of sunnhemp shoot, the N accumulated in the green manure biomass was higher by 58% compared to the N supplied by the roots. The N contained in sunnhemp shoot was higher than the N contained in shoots and roots of jack bean by 30% and 76%, respectively (Table 2). Moreover, in the treatments that consisted of roots of both legumes, the soil suffered a withdrawal of nutrients due to SH removal, thereby reducing its ability to nourish the cabbage grown in sequence. In this study, we chose not to use a control with zero nitrogen believing that the cabbage plants would present low productivity. According to studies conducted in Viçosa by Diniz *et al*., (2007), the low yield of broccoli when grown with zero nitrogen was confirmed.

Table 1. Mean values of the production of fresh and dry matter (FM and DM), dry matter (DM) and N content, % N from biological nitrogen fixation (BNF) and C:N ratio of the root (RO), shoot (SH) and whole plant (WP) of sunnhemp (S) and jack-bean (JB) at 78 days after planting in pots

Treatments	FM	DM	DM	N	BNF	C:N
	(g/pot)		(%)			
SRO	69.86	43.63	62.45	0.96	31.93	42.70
SSH	202.10	47.39	23.45	2.11	88.99	19.43
SWP	271.96	91.02	33.47	1.56	61.64	26.28
JBRO	25.81	9.71	37.62	2.48	31.62	16.53
JBSH	155.08	38.12	24.58	2.51	94.83	16.33
JBWP	180.89	47.83	26.44	2.50	82.00	16.40

Table 2. Mean values of nutrient accumulation in the root (RO), shoot (SH) and whole plant (WP) of sunnhemp (S) and jack-bean (JB)

Treatments	N	P	K	Ca	Mg	S
	(g/pot)					
SRO	0.42	0.05	0.16	0.11	0.05	0.10
SSH	1.00	0.09	0.27	0.46	0.15	0.09
SWP	1.42	0.14	0.43	0.57	0.20	0.19
JBRO	0.24	0.02	0.08	0.05	0.02	0.02
JBSH	0.70	0.07	0.33	0.42	0.07	0.04
JBWP	0.94	0.09	0.41	0.47	0.09	0.06

Comparisons between legume parts

Legume species had no effect on the examined variables. However, legume parts had a significant effect on these variables. The application of legume shoots or roots provided an increase in yields of fresh and dry matter of cabbage heads when compared with the application of the whole plant (Table 4). The effect of fertilization using roots did not differ from that of shoots. The lower results obtained with the application of legumes whole plant showed a clear negative effect on the production when the root and shoot are provided together. Individually, the roots of legumes showed similar results to the application of legume shoots, even with the removal of nutrients by removing plant shoots. However, the application of the whole plant has possibly injured the crop due to the fermentation of green mass.

Table 3. Mean values of the production of fresh and dry matter of cabbage heads (FMH and DMH) and fresh and dry matter of total shoot (FMTOTAL and DMTOTAL), 100 days after transplant

Treatments	FMH	DMH	MFTOTAL	DMTOTAL
	(g/pot)			
MF100	219.58	24.78	527.22	76.00
MF50	170.84	18.06	414.10	60.26
SRO MF50	175.96	19.32	438.68 a	68.96
SSH MF50	234.98	25.66	547.72 b	81.54 b
SWP MF50	99.60 a	10.28 a	380.62 a	58.82 a
JBRO MF50	171.52	18.98	427.26 a	65.96
JBSH MF50	190.04	21.92	471.88	71.52
JBWP MF50	124.98 a	12.82 a	402.76 a	61.32
CV (%)	26.50	32.26	11.29	14.67
LSD	71.47	9.52	79.22	15.52

In the columns, means followed by (a) differ from the control 100% or (b) from the control 50% of N-fertilizer by Dunnett test ($p<0.05$); CV= coefficient of variation; LSD= least significant difference.

Table 4. Mean values of fresh and dry matter of cabbage heads (FMH and DMH), total fresh and dry matter of cabbage (FMTOTAL and DMTOTAL) plants and horizontal diameter of cabbage heads (DIAM) fertilized with root (RO), shoot (SH) and whole plant (WP) of legumes

Parts	FMH	DMH	FMTOTAL	DMTOTAL	DIAM
	(g/plant)				cm
SH	212.51 a	23.79 a	509.80 a	76.53 a	7.85 a
RO	173.74 a	19.15 a	432.97 b	67.46 Ab	7.31 Ab
WP	112.29 b	11.55 b	391.69 b	60.07 b	6.80 b
CV (%)	26.50	32.26	11.29	14.67	10.90

In each column, means followed by different letters differ by the Tukey test ($p<0.05$); CV= coefficient of variation.

CONCLUSION

The application of the whole plant of both species of legumes reduces the head production of cabbage grown in pots.

In pot cultivation, the application of root or shoot of any species of legumes can reduce mineral N supply by 50% with no production losses.

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