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Performance of lettuce in sole cropping and intercropping with green manures

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ABSTRACT

The performance of lettuce in sole and intercropped with green manures was assessed under different establishment times. The lettuce fresh and dry weight, number of leaves per plant, diameter and length of head, and fresh and dry weight of green manure were evaluated. The intercropping design was additive and both cash and cover crops were planted in rows. The experimental design was of randomized complete blocks in split plot scheme, with six replicates. The plots represented the green manure sowing days (0, 20, 40 and 60 before transplanting of lettuce), and the sub-plots were assigned by cropping systems (lettuce in sole crop and intercropped with black oat, cowpea or white lupin). Simultaneous planting in the intercropping did not affect the lettuce performance. However, when the green manures were sown before lettuce, they influenced it in a negative way. Among the green manures, cowpea increased biomass and had a higher negative effect on lettuce performance compared to white lupin, which appeared to produce less competition. The sole crop and the intercropping with simultaneous planting of the green manures resulted in a better lettuce performance.

Keywords: *Avena strigosa*, *Lactuca sativa*, *Lupinus albus*, *Vigna unguiculata*, polycultures.

RESUMO

Desempenho de alface em cultivo solteiro e consorciado com adubos verdes

Foi avaliado o efeito de adubos verdes semeados em diferentes épocas, sobre o desempenho da alface consorciada. Avaliou-se os pesos fresco e seco, número de folhas por planta, diâmetro e comprimento da cabeça da alface. Dos adubos verdes avaliaram-se o peso fresco e seco. O consórcio foi implantado em esquema aditivo e tanto alface quanto os adubos verdes foram plantados em linha. Utilizou-se delineamento experimental de blocos ao acaso, com parcelas subdivididas e seis repetições. As parcelas foram representadas pelo tempo de semeadura dos adubos verdes em relação ao transplante da alface (0, 20, 40 e 60 dias) e as subparcelas foram representadas pelos sistemas de cultivo (alface solteira, e alface consorciada com aveia-preta, caupi ou tremoço-branco). O plantio simultâneo não influenciou o desempenho da alface. No entanto, quando os adubos verdes foram semeados antes do estabelecimento do consórcio, estes influenciaram negativamente o desempenho da hortaliça. Entre os adubos verdes, o caupi teve maior biomassa e maior efeito negativo no desempenho da alface do que o tremoço-branco que se mostrou menos competidor. O cultivo solteiro e o cultivo consorciado com plantio simultâneo dos adubos verdes resulta em melhor desempenho da alface.

Palavras-chave: *Avena strigosa*, *Lactuca sativa*, *Lupinus albus*, *Vigna unguiculata*, policultivos.

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Lettuce cultivation is often intensive and made by small farmers (Costa & Sala, 2005). To maintain and improve the system's fertility at a low price, low energy cost and high resource use efficiency is a difficult task for agroecological farmers. The use of green manures is an alternative, though this technique normally implies cultivating a non-cash crop during part of the season. In this context, the intercropping of green manures with the cash crop should be an alternative.

White lupin (*Lupinus albus*) and black oat (*Avena strigosa*) are successfully cultivated in Southern Brazil as green manures, cover crops and forage (Costa *et al*., 1992). Cowpea (*Vigna unguiculata*) is commonly cultivated as a crop and vegetable in Northeastern Brazil and often cultivated in intercropping in Africa (Fery, 2002). Therefore, the potentialities of intercropping and green manuring together should include benefits from both practices, such as, improve the use of resources (water, land and nutrients); increase soil fertility; transfer of nutrients; soil protection; weed and pest control; biodiversity enhancement, and others (Costa *et al*., 1992; Liebman & Dyck, 1993; Trenbath, 1993; Mitchell *et al*., 2002; Oliveira *et al*., 2005; Salgado *et al*., 2006).

Some authors have been reporting the success of intercropping lettuce with other vegetables, such as carrot and peruvian carrot (Negreiros *et al*., 2002; Vieira *et al*., 2003). However, intercropping systems can pose serious challenges, such as competition, mainly for light, with negative effects on performance and morphological development of the dominated crop (Cecílio Filho & May, 2002; Oliveira *et al*., 2005; Santos *et al*., 2002; Rezende *et al*., 2005a). According to Wilson (1988), the advantage of intercropping

depends on the extent to which species do not compete with one another, and plants grown together frequently do compete, primarily for solar radiation. In terms of competition, besides species, varieties, planting time, planting density, planting date and spatial arrangement of the intercropped system also play an important role.

Intercropping systems involving vegetable crops and green manures are relatively uninvestigated, so limited information about this technique is available. Thus, the goal of this study was to evaluate the agronomic performance of lettuce intercropped with three different green manure species (black oat, cowpea and white lupin) in four different sowing times.

MATERIAL AND METHODS

The experiment was carried out at the "Polo Regional Centro Sul" from the "Agência Paulista de Tecnologia dos Agronegócios (APTA)" in Piracicaba, São Paulo State, Brazil (22°42'S, 47°38'W; altitude 560 m above sea level) between July and November 2005. The soil on the site is classified as a Pauleudalf, with the following chemical characteristics (0-20 cm): medium pH (5.35); low Al^{+3} (0.0 mmolc dm^{-3}); high in organic matter (34.75 g dm^{-3}), medium in K (5.5 mmolc dm^{-3}); medium in P (25.50 mg dm^{-3}); high SB (85.8); high in Ca (55.25 mmolc dm^{-3}); high in Mg (25.0 mmolc dm^{-3}); low in S (3.75 mmolc dm^{-3}); medium in Cu (4.5 mg dm^{-3}); medium in B (0.42 mg dm^{-3}); high in Fe (51.0 mg dm^{-3}); high in Zn (3.1 mg dm^{-3}); and high in Mn (45.0 mg dm^{-3}). Total rainfall during the experimental period was 436 mm and temperature ranged from minimum 11.4°C to maximum 30.4°C.

The species used in the study were lettuce (*Lactuca sativa*) cv. PiraRoxa, black oat (*Avena strigosa*), cowpea (*Vigna unguiculata*) cv. IPA-206 and white lupin (*Lupinus albus*). The experimental design was randomized complete blocks in split plot scheme, with six replicates, where plots represented the green manures sowing days (0, 20, 40 and 60 before transplanting of lettuce), and the sub-plots, which measured 1.80 x 1.2 m, were represented by the cropping systems (lettuce in sole crop and intercropped with black oat, cowpea or white lupin).

Field plots were established on July 22, 2005, when the first green manures were sown (60 days before lettuce transplanting). Lettuce seedlings were sown in polyethylene trays and after 28 days transplanted to the field plots. Lettuce was planted with a spacing of 0.30 x 0.30 m and the green manures were sown in rows spaced 0.30 m of each other with sowing densities of 68 seeds m^{-1} for black oat (1.5 cm apart), 15 seeds m^{-1} for cowpea (6.6 cm apart) and 15 seeds m^{-1} for white lupin (6.6 cm apart). The intercroppings were planted with lettuce in alternate rows between the green manures. Sowing densities were 68 seeds m^{-1} for black oat (1.5 cm apart), 15 seeds m^{-1} for cowpea (6.6 cm apart) and 15 seeds m^{-1} for white lupin (6.6 cm apart) and the rows were also spaced in 0.30 m.

To avoid shading of lettuce plants and consequently sunlight competition, which according to Portes (1984) is the main biotic factor in intercropping systems, the green manures were periodically moved at 0.20 m above soil. The moved fresh mass was weighed and 10% of this material was dried in a forced-air oven at 65°C for 72 h for dry weight determination. The remaining fresh mass was laid on the soil surface as mulching. The only green manure plots that were moved before the lettuce transplanting were the 60 DBT treatments (sown 60 days before), to avoid excessive shading of the vegetable seedlings by the green manure's huge amount of biomass.

Automatic drip irrigation was used twice a day before the lettuce transplant (for irrigating the 20, 40 and 60 DBT treatments) and three times a day after the transplant for the rest of the growth cycle. The experimental area was weeded periodically. There was no other fertilizer application besides the green manures mulching.

Lettuce plants were harvested 49 days after transplanting at September 2005. Four central lettuce plants were harvested per plot. The measured parameters were fresh weight, dry weight, number of leaves per plant, diameter and height of head. Of the four lettuce plants harvested, two of them were dried in a forced-air oven at 65°C for 72 h for dry weight determination. The parameters measured in green manures were fresh and dry weight (this measurement was done after each moving).

Statistical analyses were performed using "Sanest" (Zonta *et al*., 1986) and treatment means were compared by Tukey test ($p<0.05$). Response curves were fitted to the parameters in function of the green manures sowing dates.

RESULTS AND DISCUSSION

The fresh and dry mass of the aboveground portion of green manures varied significantly among species. Cowpea produced a significantly higher fresh and dry mass than black oat and white lupin. The fresh and dry weight of green manures species changed significantly depending on the intercropping planting time. A quadratic effect was observed ($p>0.01$) of black oat on fresh weight ($\hat{Y} = 9.53 + 1.6056x - 0.016023x^2$; $R^2 = 1.00$). There was a linear effect ($p<0.01$) of white lupin sowing dates on fresh weight ($\hat{Y} = 14.29 + 0.7962x$; $R^2 = 0.95$) and cowpea ($\hat{Y} = 32.86 + 1.1516x$; $R^2 = 0.97$). There was a quadratic effect ($p<0.05$) of black oat on dry mass ($\hat{Y} = 5.43 + 0.4072x - 0.002587x^2$[; $R^2 = 0.99$), sowing time with the maximum estimated at 79 DBT. A linear effect was observed ($p<0.01$) ($\hat{Y} = 5.30 + 0.2823x$; $R^2 = 0.95$) of white lupin and ($\hat{Y} = 11.68 + 0.3991x$; $R^2 = 0.97$), of cowpea.

These green manures biomass influenced the lettuce fresh yield which varied according to the associated green manure and its sowing time (Table 1). Under simultaneous intercropping planting the average fresh weight of lettuce head was 182.98 g, which suggests that the competition between the component crops was not evident or was rather very weak because there was no difference between the sole crop and the intercroppings. However, when planting was not done simultaneously the intercropped lettuce reached a lower fresh yield compared to the sole

Table 1. Lettuce fresh and dry weight in sole crop and intercropped with green manures (peso fresco e seco de alface em cultivo solteiro e consorciada com adubos verdes). Piracicaba, ESALQ, 2005.

Days before transplant (DBT)[a]	Lettuce sole crop	Lettuce and black oat	Lettuce and white lupin	Lettuce and cowpea	Mean
	fresh weight (g plant^{-1})				
0	194.51 a	199.59 a	180.15 a	157.76 a	182.98
20	216.87 a	139.87 b	161.95 b	137.31 b	164.00
40	209.66 a	106.67 c	164.17 b	92.96 c	143.37
60	222.54 a	164.12 b	149.62 b	148.03 b	171.08
Mean	210.89	152.55	163.97	134.01	
CV%(a)	16.70				
CV%(b)	17.96				
F[1]					
Linear effect	ns	ns	ns	ns	
Quadratic effect	ns	*	ns	ns	
Cubic effect	ns	ns	ns	ns	
	dry weight (g plant^{-1})				
0	12.49	10.54	10.03	8.72	10.45
20	11.78	7.92	9.29	7.50	9.12
40	11.29	6.68	9.13	5.36	8.11
60	12.87	8.33	8.72	8.36	9.57
Mean	12.11 a	8.37 bc	9.29 b	7.48 c	
CV%(a)	11.64				
CV%(b)	16.30				
F[1]					
Linear effect	----	----	----	ns	
Quadratic effect	----	----	----	**	
Cubic effect	ns	ns	ns	ns	

Means followed by the same letters in rows are not significantly different (p>0.05) by Tukey test; [1]F* = (p<0.05); ** = (p<0.01); ns= not significant (p>0.05); [a]Sowing days of green manures before lettuce transplanting (médias seguidas de mesmas letras minusculas nas linhas, não diferem entre si pelo teste de Tukey (p>0,05); [1]F* = (p≤ 0,05); ** = (p≤0,01); ns = não significativo; [a]Número de dias de semeadura dos adubos verdes antes do transplante das alfaces).

vegetables. Under 20 and 60 DBT there were no significant differences in lettuce fresh weight between the different species of green manures. However, in the 40 DBT treatment, the different green manures species had different effects in the main crop. The lettuce plants intercropped with white lupin had a smaller decrease of fresh mass (26%) compared to the ones intercropped with cowpea (58%) and black oat (42%). These results are consistent with a similar study made by Hussain (2003) who reported that lettuce intercropped with peas had a 68.4% yield loss compared to the single crop. According to Muller-Sumann (1994), yield decreases are expected when green manures are intercropped with the food crop.

Lettuce fresh weight showed a quadratic response ($p<0.05$) to black oat sowing dates ($\hat{Y} = 202.73 – 5.0882x + 0.073188x^2$; $R^2 = 0.95$), with minimum value of production estimated at 35 DBT. The probable reason for this behavior is that the 40 DBT treatments were the most competitive in the early stages of the lettuce development because its biomass was not moved before the transplant of the vegetable seedlings like in the 60 DBT treatment. Thus, this treatment resulted in more shade and consequently more competition between crops.

In terms of dry weight, as well as for fresh weight, the single lettuces performed better (Table 1). Among the green manure treatments were found only differences between lettuce intercropped with white lupin and cowpea, which yielded 77% and 62% of the single ones, respectively. There was a quadratic response ($p<0.01$) of lettuce dry yield regarding the cowpea sowing dates ($\hat{Y} = 10.55 – 0.1224x + 0.001737x^2$; $R^2 = 0.92$), with the minimum yield estimated at 35 DBT as well, showing a higher level of competition related to the 40 DBT treatment. Cowpea is a fast growing plant and a good competitor as observed by Ofori & Gamedoagbao (2005). In fact, cowpea planting time relative to the associated crop has been reported to be important to cotton, millet, cassava and scarlet eggplant (Ofori & Gamedoagbao, 2005).

As observed in the present experiment, Sudo *et al*. (1997) found that there was no yield penalty when lettuce was

Table 2. Number of leaves per plant, diameter and length of lettuce head in sole crop and intercropped with green manures (número de folhas por planta, diâmetro e comprimento da cabeça de alface em cultivo solteiro e consorciada com adubos verdes). Piracicaba, ESALQ, 2005.

Days before transplant (DBT)[a]	Lettuce sole crop	Lettuce and black oat	Lettuce and white lupin	Lettuce and cowpea	Mean
	number of leaves per plant				
0	27.83 a	28.29 a	26.00 ab	23.62 b	26.44
20	27.58 a	21.21 bc	23.25 b	19.21 c	22.81
40	28.21 a	18.32 c	22.92 b	16.83 c	21.57
60	29.04 a	23.17 b	22.75 b	20.67 b	23.91
Mean	28.17	22.75	23.73	20.08	
CV%(a)	8.07				
CV%(b)	9.28				
F[1]					
Linear effect	ns	*	ns	ns	
Quadratic effect	ns	**	ns	*	
Cubic effect	ns	ns	ns	ns	
	diameter of head (cm)				
0	24.77 a	24.95 a	26.06 a	25.02 a	25.20
20	26.64 a	24.58 ab	24.27 ab	24.10 b	24.90
40	25.48 a	24.77 ab	22.64 bc	21.82 c	23.68
60	25.43 a	25.12 a	24.25 a	24.91 a	24.93
Mean	25.58	24.33	24.84	23.96	
CV% (a)	4.68				
CV% (b)	6.83				
F[1]					
Linear effect	ns	ns	ns	ns	
Quadratic effect	ns	ns	ns	*	
Cubic effect	ns	ns	ns	ns	
	length of head (cm)				
0	18.29 ab	19.33 a	19.00 ab	17.60 b	18.55
20	18.77 a	17.12 b	17.14 b	16.79 b	17.46
40	18.25 a	16.21 bc	16.98 ab	14.96 c	16.60
60	18.89 a	18.17 ab	17.56 ab	16.87 b	17.87
Mean	18.55	17.71	17.67	16.55	
CV%(a)	6.23				
CV%(b)	5.60				
F[1]					
Linear Effect	ns	ns	ns	ns	
Quadratic Effect	ns	*	ns	ns	
Cubic Effect	ns	ns	ns	ns	

Means followed by the same letters in rows are not significantly different (p>0.05) by Tukey test; [1]F* = (p<0.05); ** = (p<0.01); ns = not significant (p>0.05); [a]Sowing days of green manures before lettuce transplanting (médias seguidas de mesmas letras nas linhas, não diferem entre si pelo teste de Tukey (p>0,05); [1]F* = (p≤0,05); ** = (p≤0,01); ns= não significativo; [a]Dias de semeadura dos adubos verdes antes do transplante das alfaces).

intercropped with carrot in simultaneous planting. These intercropping schemes are probably successful due to the canopy height and accumulated biomass of the green manures, which were not enough to offer competition to the vegetable crops. The establishment time of the intercropping has been shown to influence the companion crops performance (Cecílio Filho *et al*., 2008; Rezende *et al*., 2005a). In a tomato/lettuce intercropping at different transplanting dates, when lettuce transplanting was late, both fresh and dry mass and also the number of leaves

were lower due to light competition between the companion crops. Paula (2005) reported the same result for an onion/lettuce intercropping.

The number of leaves decreased even at simultaneous planting in the intercropping with cowpea (Table 2). For the other sowing times (20, 40 and 60 DBT) the sole crop resulted in greater number of lettuce leaves compared to all intercropping treatments. The number of leaves goes along with lettuce development, thus observing the lettuce fresh weight at simultaneous planting (0 DBT treatment) (Table 1), even though the results are statistically similar, the yield under cowpea influence was lower. Thus a plausible reason for the lower number of leaves in lettuce intercropped with cowpea even at simultaneous sowing, is the competition effect due to the green manure biomass that probably caused shade and competed for light. There was a quadratic effect ($p<0.01$) of black oat sowing time on lettuce number of leaves ($\hat{Y} = 28.47 – 0.5381x + 0.007447x^2$; $R^2 = 0.99$) with minimum number of leaves production estimated when black oat was sown at 36 DBT of lettuce, and for cowpea ($p<0.05$) ($\hat{Y} = 23.83 – 0.3656x + 0.005156x^2$; $R^2 = 0.96$) the minimum was estimated in 35 DBT. This quadratic effect indicates that the 40 DBT treatment posed the greatest level of competition among plants, with consequent shading of lettuce that resulted in a decrease in the number of leaves. This effect tended to decrease as the green manures sowing time changed to 0, 20 and 60 DBT, resulting in a higher number of leaves per head of lettuce.

According to Sala & Costa (2005), lettuce cv. PiraRoxa has around 28 leaves at the harvest time, which is supposed to occur between 35 and 45 days after transplanting. At the harvest time of this experiment, only the single lettuces had reached an average of 28.17 leaves per head (Table 2). Thus it is possible to deduce that lettuce plants suffered an extension of their cropping cycles due to an intercropping competition effect, with exception of the simultaneous planting with black oat and white lupin.

The intercroppings established at 0 and 60 DBT did not affect the diameter of head (Table 2). However, the lettuces intercropped with cowpea presented 90% of the diameter of the sole crop in the 20 DBT treatment and 89 and 86%, respectively to white lupin and cowpea in the 40 DBT treatment. There was a quadratic effect ($p<0.05$) of cowpea sowing dates on lettuce diameter ($\hat{Y} = 25.35 – 0.1631x + 0.002503x^2$; $R^2 = 0.65$) (Table 2) with the minimum diameter of head estimated at 33 DBT.

In close agreement with this study, Cecílio Filho *et al*. (2008) and Negreiros *et al*. (2002) observed that in a lettuce/tomato and lettuce/carrot intercropping there was a diameter decrease and fewer leaves compared to the sole lettuce cultivation due to sunlight competition imposed by the companion plants. Rezende *et al*. *(*2006) also found that the companion species interfere differently in the number of leaves and diameter reached by lettuce. In their case, cabbage influenced negatively and rocket did not.

The length of lettuce head in response to intercropped green manures species changed significantly depending on the intercropping planting time (Table 2). A quadratic effect was observed ($p<0.05$) ($\hat{Y} = 19.14 – 0.1785x + 0.002610x^2$; $R^2 = 0.98$), of black oat sowing time with the minimum length of lettuce heads estimated at 35 DBT. In accordance with this, Cecílio Filho & May (2002) reported that there was a reduction in radish plants height when intercropped with lettuce. On the other hand, in the present experiment lettuce was dominated by the green manures, having its morphological characteristics depreciated.

White lupin is an erect plant and offers much less competition to a companion crop than black oat and cowpea cv. IPA 206 (which is prostrated) because there is more sunlight penetration through its branches. Plant architecture is an important consideration to maximize sunlight utilization in intercropping. In this way, the results obtained for lettuce/white lupin intercropping agree with a previous experiment done by Ofori & Gamedoagbao (2005), who tested an erect and a semi-spreading variety of cowpea in intercropping with scarlet eggplant. Similar to the present study, the authors found that the erect green manure offered less competition to the vegetable, which obtained a better performance.

There were neither nutritional deficiency nor drought stress symptoms on the lettuce plants under the different treatments, thus it is assumed that the main source of competition was sunlight. In fact, cv. PiraRoxa depends on light to develop its hallmark purple color and, once it grows under shade, it tends to present greenish leaf coloration. The lettuces under intense intercropping competition in this study showed greenish leaves due to lack of sunlight. However, within 3 days of moving the green manures with the consequent decrease of shade, the leaves of lettuce reverted to its characteristic purple.

In this intercropping system, except for the simultaneous planting, for most analyzed parameters the growing cycle overlapped, causing competition between crops and domination of lettuce by the green manures, which are taller and, consequently, intercept more sunlight. In this way, under the conditions of this experiment, a better performance of lettuce would be obtained under sole cultivation or under intercropping with simultaneous planting of the main crop and the green manures.

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