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Effects of Legume Live-Mulch on Crop Performance, Soil Available Nitrogen and Crop N Status in Intensive Tropical Vegetable Production

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ABSTRACT

In an attempt to introduce legume green manure to intensive tropical vegetable production, we studied the effects of live-mulch. Soil nitrogen, crop-N status, and yields were closely monitored in a continuous, year-round vegetable sequence from *1992* to 1995 in the rice-based lowland environment of southern Taiwan. When live-mulch was newly established at high density, vegetable yields were negatively affected. With change in proportion and spatial arrangement, inter-specific competition was reduced. Besides direct competition between live-mulch and vegetable intercrops, incorporating legume biomass into the soil resulted in immobilization of available soil nitrogen. This effect was presumably conditioned by seasonal cool temperature. Short-term negative effects of live-mulch on vegetable production were offset in the longer term by a positive influence of previous year's biomass of legume clippings on vegetable yields in *1994/95*. No differences were found in mineralized soil nitrogen between no-mulch and live-mulch treatments, but there was indication that crop-N status was better in live-mulch plots. This might have resulted from a slow but sustained mineralization of soil organic nitrogen which was presumably improved by live-mulch application and was readily absorbed by vegetables. From a practical viewpoint, a live-mulch-vegetable system is probably too expensive and labour-intensive to implement for the minimal positive longer-term effects.

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INTRODUCTION

Sustained fast population growth in many tropical countries is a reason for an enormously increasing demand for food, but exposes arable land to irrevocable loss due to rapid urbanization (PCARRD, 1984). Further augmentation of agricultural land in highlands and marginal locations may not be tolerated because of a desire to preserve natural resources. Thus, new attempts to improve food production focus on promoting intensive peri-urban agriculture in tropical countries (Kleinhenz *et al.*, 1995). In vegetable production, intensified production is often associated with pollution of the environment through over-use of fertilizers and pesticides. Farmers frequently apply several times more mineral fertilizers than the recommended rates. Over-doses of fertilizers might be the main reason for soil acidification and salination in some of these areas (Huang *et al.*, 1989).

Recently, growers and researchers have developed some novel approaches to include soil improving crops in vegetable systems which maintain a high level of productivity, but protect natural resources from further degradation in spatially limited, highly specialized vegetable production (Sarrantonio, 1992). Amongst these options are the introduction of green manure crops into a vegetable cropping sequence as a pre- or succeeding crop, as a relay-intercrop, or as a full intercrop. Green manure may also be produced apart from the production area, and applied as a mulch (Yih, 1989), but generally the green manure is grown as a full crop within the field, or as a strip or alley besides the field (Sitompul *et al.*, 1992). Intercropping green manure crops as living mulches with the cash crop is particularly interesting where limitations to the cropping area drastically reduce the scope for rotations with green manure (Akobundu & Okigbo, 1984). Most such research has been done for field crops and few investigations have been conducted for vegetables. Usually, these studies detected significant competition between live-mulch and vegetable. Wiles *et al.* (1989) and Sarrantonio (1992) highlighted the need to suppress mulch growth to minimize competition with vegetables, and Lanini *et al.* (1989) found that possible positive effects of a live-mulch on reduced weed incidence are likely to be offset by direct competition.

In this study, we evaluated the use of permanent live-mulch in an intensive, continuous vegetable cropping sequence in the tropical lowland environment of Southern Taiwan from 1992 to 1995. The degree of interference between the regularly clipped mulch of several legume species and vegetable crops was determined as well as the short and longer-term influence of incorporated or surface-applied mulch biomass on available soil nitrogen, crop-N status, and yield.

MATERIALS AND METHODS

Site, systems, and crop management

From 1992 to 1995, the influence of legume live-mulch on the production of vegetables year-round was studied at the experimental farm of AVRDC, Shanhua in southern Taiwan (23° N latitude). Mean daily air temperature, mean daily soil temperature, and monthly sums of precipitation and evaporation were 27.6° C, 29.4° C, 302 mm, and 155 mm in the rainy season from May through September, and 21.0° C, 23.4° C, 22 mm, and 121 mm during the dry-season months. Soil at the experimental site was an alluvial sandy loam (0.5% total N, 18% clay, 27% silt, 55% sand). Permanent high beds (about 50 cm high) were constructed between continuously flooded furrows (2.0 m wide) with varying widths (in 1992: 2.00 m, 2.75 m, and 3.50 m wide; 1993—95: 2.0 m and 3.0 m wide). Beds were 40 m long, divided into 4-m-long experimental plots and replicated four times in a completely randomized block design. Besides live-mulch as the sub-plot treatment, the total experimental area included a width treatment in main plots, and a fertilization treatment in sub-sub-plots which are not discussed herein because no meaningful interactions were found between those treatments and live-mulch.

During 1992 two vegetable crops, namely Chinese cabbage *(Brassica pekinensis* Lour. Rupr.; cv. "ASVEG No. I", AVRDC) and tomato *(Lycopersicon* Mill. *lycopersicum (L.);* line "CL 5915-93D4-1-0-3", AVRDC) were cultivated either without live-mulch or intercropped with one row of legume live-mulch per row of vegetable (2.00-m-wide bed: 2 rows, 2.75-m-wide bed: 3 rows, 3.50-m-wide bed: 4 rows; Figure 1). Legume species were: alyce clover *(Alysicarpus vaginalis (L.)* DC), desmodium *(Desmodium intortum* (Mill.) Urb.), indigofera *(Indigofera tinctoria L.),* and soyabean *(Glycine max. (L.)* Merr). After reconstruction and adjustment of high-bed width in Spring 1993, the vegetable crop sequence was changed to Chinese cabbage, chili *(Capsicum annuum* L.; cv. "Hot Beauty", Known You Seed Co.), carrot *(Daucus carota* L.; *cv.* "Red Judy", Known You Seed Co. (1994) and cv. "Parano", Nunhems (1995)), and vegetable soyabean *(Glycine max. (L.)* Merr; cv. "AGS 292", AVRDC). Live-mulch was relocated to the steep edges of the permanent high beds with two rows of live-mulch per four vegetable crop rows on the 2.0 m wide bed, and two rows of live-mulch per six vegetable rows on the 3.0 m wide bed (Figure 1). Legume species were: alyce clover, centrosema *(Centrosema pubescens* Benth.), desmodium, and siratro *(Macroptilium atropurpureum DC.).* Live-mulch was directly sown in 1992, but transplanted from a greenhouse (40 cm interplant distance) in Winter 1993 and 1994. The legumes were usually clipped after final harvest of

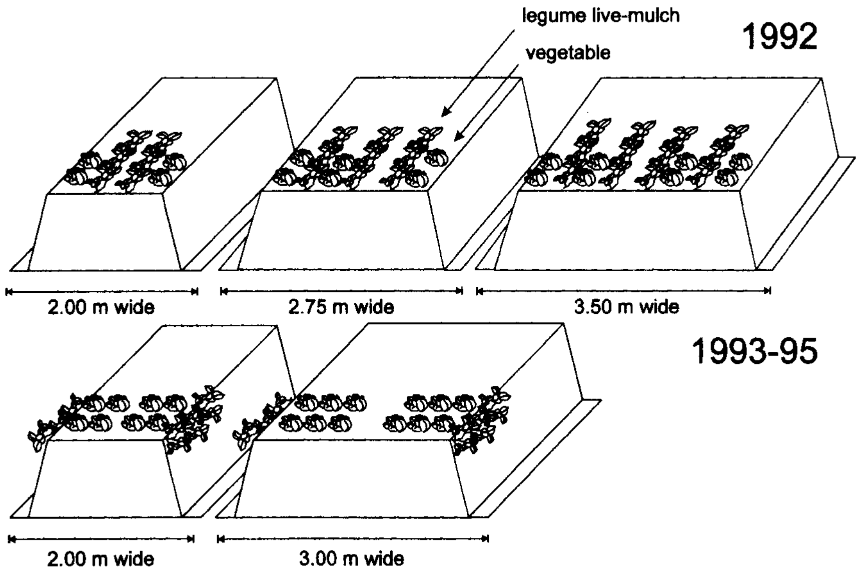

FIGURE 1. Row arrangement of vegetables and legume live-mulch on permanent high beds with varying widths in 1992 *(top)* and from 1993 to 1995 *(bottom)*.

vegetable crops, chopped into 10-cm pieces and either spread evenly on the soil surface as a mulch (1992 and 1993), or rototilled into the soil (1994). Additionally, live-mulch was clipped and mulched during vegetable cultivation as needed. After heavy flooding caused by torrential rains in August 1994, all live-mulch died and was not re-established afterwards. In 1995, one live-mulch treatment (alyce clover) was discarded. Crop yields were recorded for bordered areas from individual rows with distinct distance from the live-mulch strips (1992: 40 and 80 cm; 1993—95: 40, 80, 120 cm). Plant protection and other crop management practices followed AVRDC recommendations.

Soil and plant nitrogen analysis

Soil mineralized nitrogen was measured by sampling soil 0 to 30-cm-deep (three samples per plot) with a 2.0-cm-diameter punch tube at weekly intervals in one treatment without live-mulch, and in two live-mulch treatments (centrosema and desmodium) with two replications in 3.0-m-wide beds (12 plots). During crops of carrot and vegetable soyabean in 1995, samples were analyzed from all 48 plots. Extracted 1:2 by volume in 0.8% KCI water solution, samples were analyzed for NO_3 and NH_4 using

Merck's RQflex reflectometer and Reflectoquant nitrate (5–225 ppm), and Reflectoquant ammonium (0.2–7.0 ppm) analytical test strips. All readings were converted from concentrations to contents (kg ha-').

Since nutrient concentrations decline most quickly in rapidly expanding tissues, and the petiole acts as a storage and transport organ for nitrate-N, the petiole of recently matured leaves is a sensitive indicator for plant N status and N nutrition (Prasad & Spiers, 1984). Petioles were collected from eight newly expanded leaves per plot for vegetable soyabean and carrot, twenty complete leaves per plot for chili, and five midribs of recently matured leaves per plot for Chinese cabbage. Plant sap was expressed with a garlic press and diluted with deionized water to fit the range of the test strips for NO_3-N analysis. Live-mulch clippings were analyzed for nitrogen concentrations by the Kjeldahl distillation method of material dried at 60° C for 48 h.

Study of live-mulch application on soil mineralized nitrogen

To study the influence of live-mulch application on soil mineralized nitrogen, chopped fresh legume material (siratro from an adjacent area) equivalent to 60 kg N ha-' (based on 20% dry/fresh weight ratio and 3% N/dry weight) and 60 kg N ha-' applied as ammonium sulphate was rototilled into the soil on high bed plots with two replications and on three dates: 11 January, 23 March, and 13 June 1995. Plots rototilled with ammonium sulphate alone were considered controls. Both NH_4-N and NO_3-N were measured daily in samples taken from the 0 to 30-cm soil layer for up to 15 days. Soil nitrogen before mulch and fertilizer application was subtracted from measured concentrations.

Data analysis

Vegetable yields were analyzed with split-plot ANOVA (four replications) with live-mulch treatments regarded as sub-plots. Comparison of the no-live-mulch treatment with all other live-mulch treatments was done with orthogonal contrasts. ANOVA, linear and quadratic regressions, and standard errors were calculated with appropriate procedures using SAS Version 6.04 (SAS Institute Inc., 1989).

RESULTS

Live-mulch biomass production

During 1992, live-mulch biomass of individual legume species was not greater than in a similar period of time in 1993 although population density was greater (Figure 2 a). Biomass from soyabean was negligible because the annual legume had to be re-sown after the clipping in early June. Biomass production in 1993 exceeded biomass in 1994, but biomass was similar among species. All legume species died in August 1994. Siratro and desmodium performed better in the warm, but dry spring (March to May 1993, Figure 2 *b),* but alyce clover and centrosema appeared to be more tolerant to hot and wet summer conditions (May to September 1993, Figure 2 *b).* Since all species were clipped in intervals of 2 to 4 months, only young plant material with similar dry/fresh-weight ratios and N-contents (Table 1) was added to the soil.

Vegetable yield

Marketable yield of Chinese cabbage in Spring 1992 was not affected by live-mulch since the vegetable was transplanted one month before legumes were sown and harvested shortly afterwards (Table 2). No more than a total of 1.2 kg m^{-2} fresh live-mulch biomass was clipped before trans-planting tomato in October 1992 and after the final harvest in February 1993 (Figure 2a). Live-mulch treatments in which the greatest biomass was produced (alyce clover and indigofera) did not significantly affect tomato yield, although the orthogonal contrast of the no-mulch treatment versus all mulch treatments was almost significant (Table 2). For this and the two succeeding crops, Chinese cabbage and chili, no-mulch outyielded mulch

TABLE 1

Dry/fresh weight ratio and N content of live-mulch clippings from 1992 to 1994[a]

Live-mulch species	Fresh/dry weight ratio (%)	N content (% N/dry weight)
Alyce clover	25.7 ± 4.10	2.89 ± 0.11
Centrosema	19.0 ± 1.11	3.17 ± 0.32
Desmodium	20.0 ± 3.70	3.12 ± 0.03
Indigofera	24.0 ± 3.77	3.16 ± 0.07
Siratro	19.2 ± 1.05	3.11 ± 0.06
Soyabean	26.1 ± 6.00	3.25 ± 0.40

Mean ± standard error of two to eight determinations.

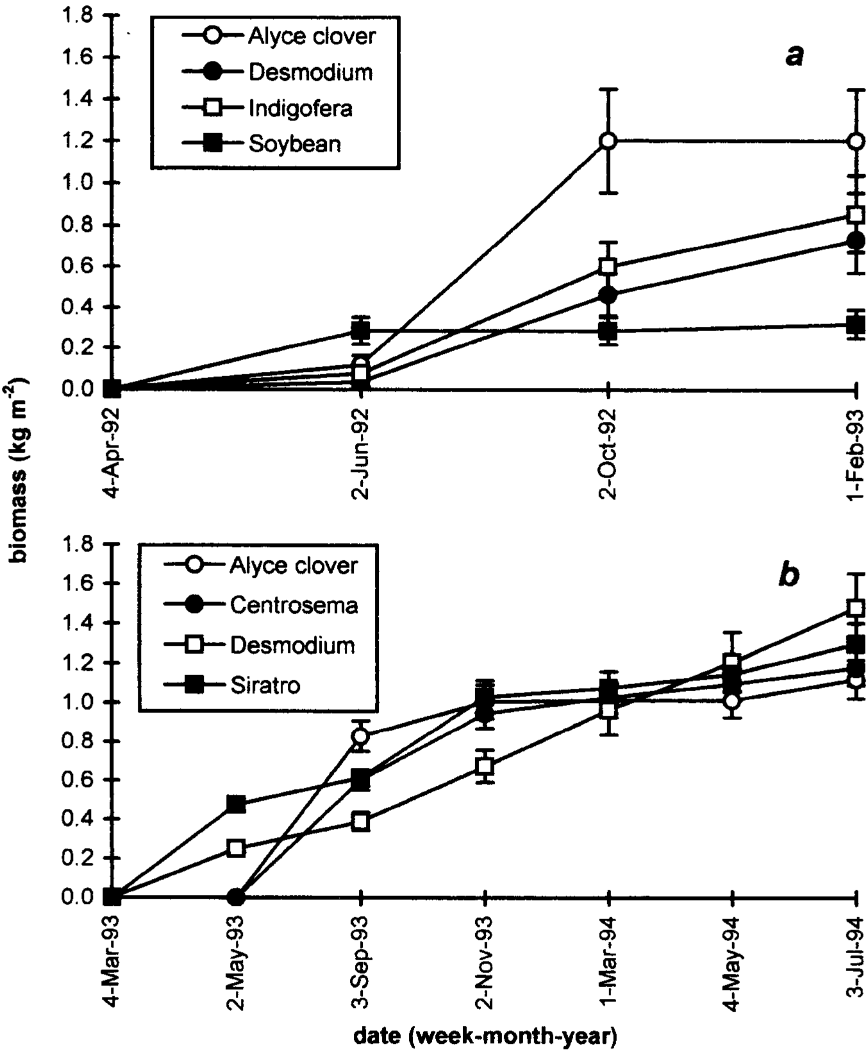

FIGURE 2. Cumulative live-mulch biomass production of different legume species in (a) 1992, and (b) 1993 and 1994. Vertical bars indicate standard errors.

TABLE 2

Marketable yield of vegetables as influenced by live-mulch from 1992 to 1995'.

Cultivation period (week-month-year) Vegetable Live-mulch	4 Mar-1 May 1992 Chinese cabbage (kg m-^{2})	2 Oct-4 Jan 1992/93 Tomato (kg m-^{2})	Vegetable Live-mulch	I May-3 Jun 1993 Chinese cabbage (kg m-^{2})	3 June-3 Dec 1993 Chili (kg m-^{2})	1 Dec-4Feb 1993/94 Carrot (kg m^{-2})
Alyce clover	1.53 a	4.86 ab	Alyce clover	2.14 a	0.53 b	1.04 a
Desmodium	1.46 a	4.41 bc	Centrosema	2.18 a	0.47 b	1.24 a
Indigofera	1.48 a	4.49 abc	Desmodium	2.17 a	0.59 ab	1.01 a
Soyabean	1.44 a	4.09 c	Siratro	1.92 b	0.59 ab	1.17 a
No live-mulch	1.44 a	4.88 a	No live-mulch	2.19 a	0.69 a	1.19 a
Contrast P-value mulch-no mulch	0.69	0.06		*0.17*	*<0.01*	*0.51*

Cultivation period (week-month-year) Vegetable Live-mulch	2 Mar-4 May 1994 Vegetable soyabean (kg m-^{2})	4 May-3 Jul 1994 Chinese cabbage (kg m-^{2})	4 Jul-3 Dec 1994 Chili (kg m-^{2})	2 Jan-4 Apr 1995b Carrot (kg m-^{2})	1 May-3 Jul 1995 Vegetable soyabean (kg m-^{2})	1 Aug-3 Sep 1995 Chinese cabbage (kg m-^{2})
Alyce clover	1.11 a	1.41 c	0.36 a			
Centrosema	1.13 a	1.66 abc	0.32 a	3.12 a	1.31 a	2.60 a
Desmodium	1.02 a	1.92 a	0.35 a	3.11 a	1.30 a	2.75 a
Siratro	1.04 a	1.70 ab	0.32 a	3.22 a	1.29 a	2.64 a
No live-mulch	1.09 a	1.59 bc	0.29 a	2.99 a	1.28 a	2.79 a
Contrast P-value mulch-no mulch	*0.72*	*0.54*	*0.15*	*0.07*	*0.70*	*0.25*

[a]Means in each column followed by the same letter are not significantly ($p \leq 5\%$) different.
[b]In 1995 only three live-mulch treatments continued from previous years.

treatments. After reconstruction of high beds in early 1993, Chinese cabbage yield was significantly reduced only by siratro live-mulch. Total yields of chili in the second half of 1993 were negatively influenced by the live-mulch treatment and the comparison no-mulch versus mulch was highly significant (Table 2). After the middle of 1994 yields in live-mulch plots surpassed those in the no-mulch treatment. In the carrot crop early 1995 this comparison almost reached significance (Table 2). Thereafter, vegetables were not affected by treatments.

Effect of live-mulch biomass on vegetable yield

Since differences in vegetable yields in this study were also attributable to experimental factors other than live-mulch, regressions of yield on live-mulch clipping biomass were regarded as meaningful when all parameters in the equation were significant at the 5% level even when r^2-values were relatively low. Live-mulch data were separated into (1) clippings which were made before or soon after establishing vegetables (pre-crop biomass), and (2) biomass which accumulated during the crop growth period (intercrop biomass). Table 3 illustrates the live-mulch effect on vegetable performance as an intercrop, and as a preceding crop. Interspecific competition and residual effects of live-mulch were severe in the first year of experimentation and explained up to 34% of variation in vegetable yields. In 1994, live-mulch biomass production and decomposition did not

TABLE 3

Effect of clipping application of live-mulch on vegetable yield[a].

Vegetable and year	Live-mulch biomass	Regression equation Intercept	Slope	r^2-value
Chinese cabbage '92	intercrop biomass	1.81*	-0.79*	0.23
Tomato '92	pre-crop biomass	4.96*	-2.29*	0.20
	intercrop biomass	4.52*	-6.05*	0.34
Chinese cabbage '93	pre-crop biomass	2.37*	-0.90*	0.33
	intercrop biomass	2.05*	0.11	0.03
Chili '93	pre-crop biomass	0.60*	-0.12	0.05
	intercrop biomass	0.63*	-0.28*	0.07
Carrot '94	pre-crop biomass	1.14*	-0.08	0.00
	intercrop biomass	1.15*	0.12	0.00
Vegetable soyabean '94	pre-crop biomass	1.07*	-0.13	0.03
	intercrop biomass	1.09*	-0.10	0.03
Chinese cabbage '94	pre-crop biomass	1.60*	1.39	0.04
	intercrop biomass	1.43*	1.84*	0.13
Chili '94	pre-crop biomass	0.35*	-0.02	0.00

[a]Parameters followed by (*) are significant ($p \leq 5\%$).

negatively affect vegetable yield and a significantly positive relationship was found between Chinese cabbage yield and live-mulch-intercrop biomass (Table 3). When live-mulch biomass was summed up for the whole year 1993, significantly positive regressions were found between this biomass and vegetable yields after May 1994 (Table 4).

Differences in yield reduction in vegetables due to direct interspecific competition between 1992 and succeeding years could partly be explained by spatial arrangement and relative population density of live-mulch and vegetable. When tomato was intercropped with one row of live-mulch per row of vegetable in 1992 (Figure 3 a), plant biomass (yields were not determined for individual rows) was significantly reduced in all positions within beds. When live-mulch was relocated to the edges of high beds with one row live-mulch per three rows vegetable on the 3.0-m-wide high bed, total chili yield in 1993 was significantly reduced only in the row close to the live-mulch (Figure 3 b).

Effect of live-mulch on soil mineralized nitrogen and vegetable crop N status

Biological oxidation of ammonium to nitrate follows Michaelis-Menten reaction kinetics (Richter, 1987). Hyperbolic-type decreases in ammonium and increases in soil nitrate were approximated with quadratic regressions in Figure 4. When 60 kg N ha-' as ammonium sulphate was applied in combination with 1 kg $^{m-2}$ green manure (siratro), soil NO_3-N contents decreased about 30 kg N ha^{-1} one day after application in the cool dry season (Figure 4 a). Within 14 days soil nitrate approached the level recorded for the no-mulch treatment. Decreases in soil-ammonium did not differ between treatments. In the warm and dry spring, no treatment

TABLE 4

Effect of total live-mulch biomass application 1993 on vegetable yield 1994/95'

Vegetable and year	Regression equation		
	Intercept	Slope	r^2-value
Carrot '94	1.24*	-0.12	0.02
Vegetable soyabean '94	1.10*	-0.02	0.01
Chinese cabbage '94	1.31*	0.35*	0.05
Chili '94	0.24*	0.10*	0.16
Carrot '95	3.00*	0.18*	0.09
Vegetable soyabean '95	1.16*	0.17*	0.21

[a]Parameters followed by (*) are significant (p ≤ 5%).

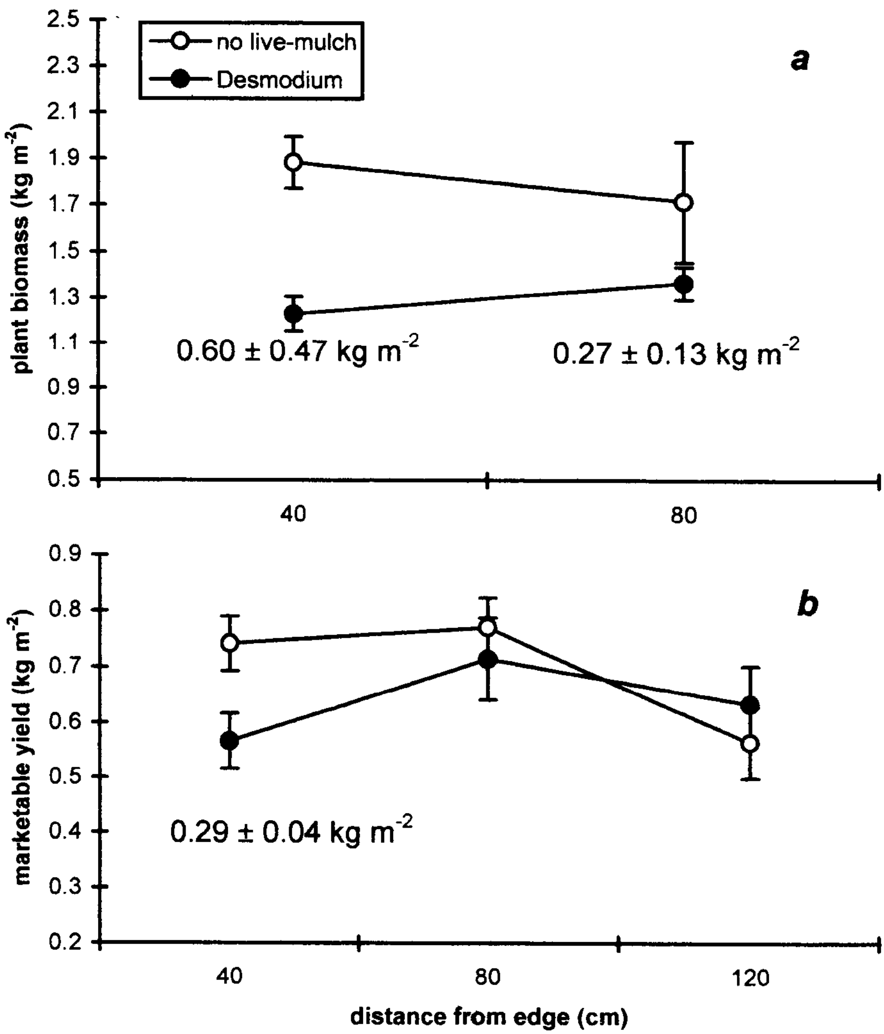

FIGURE 3. Plant biomass production of (a) tomato in 1992 and total marketable yield of (b) chili in 1993 as influenced by crop-row position within 3.50-m-wide high beds (1992) and 3.00-m-wide high beds (1993), and spatial arrangement of live-mulch (desmodium) strips. Values (± standard error) indicate biomass production of intercropped live-mulch strips. Vertical bars indicate standard errors.

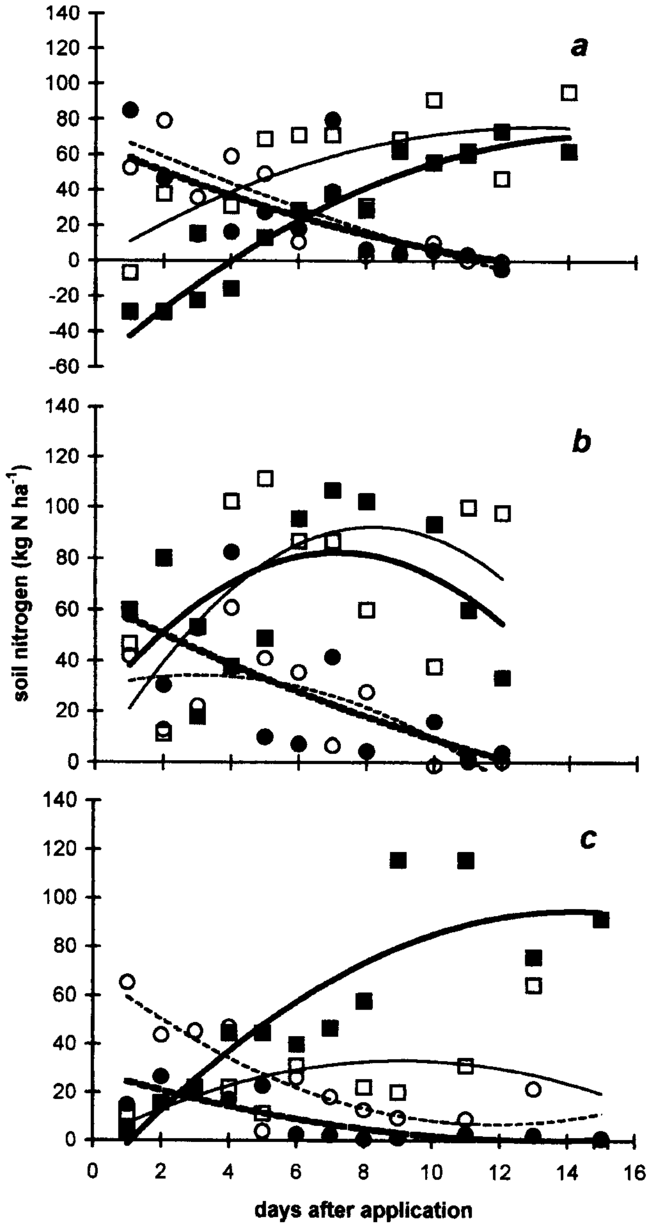

FIGURE 4. Influence of live-mulch application (60 kg N ha-' as siratro) in combination with mineral N-fertilizer (60 kg N ha-' as ammonium sulphate) on soil mineralized nitrogen on *(a)* 1I January, *(b) 23* March, and (c) 13 June 1995. Solid lines indicate soil nitrate-N contents, dotted lines soil ammonium-N contents. Thin lines: without live-mulch; thick lines: with siratro live-mulch. (See Methods for details).

differences were obvious (Figure 4 *b).* In the hot, wet summer (Figure 4 c), soil NHs-contents decreased to zero within 6 days after combined application of fertilizer and green manure and soil nitrate-N contents increased rapidly.

Differences in plant-sap-nitrate concentrations (Figure 5 *b)* reflected differences in soil nitrate contents (Figure 5 a) between treatments, but differences between live-mulch and no-mulch treatments were not clear. When more plots were analyzed for soil nitrate and petiole-sap NO_3 on one occasion in the cultivation period of carrot and vegetable soyabean (Table 5), no significant differences were found in soil nitrate between live-mulch and no-mulch treatments. The low averages of sap-nitrate concentrations in carrot at this time can be attributed to the sampling date which was shortly before crop harvest. Plant-sap NO_3 decreased with crop age and this is due to translocation of N from vegetative plant parts to the storage organ (Maynard *et al.*, 1976). Plant-nitrate concentrations were significantly higher in live-mulch treatments as indicated by contrast p-values. These concentrations were, at the same time, slightly higher in the treatment in which more legume biomass (desmodium) was produced during 1993 and 1994.

DISCUSSION

In this study, legume species with similar biomass characteristics (dry/ fresh weight ratio, N content) were used as live-mulch. Therefore, effects of live-mulch on vegetable performance were expected to be due only to differences in biomass production. Growth and yield of crops grown in association with green manure species are affected by factors including:

TABLE 5

Soil nitrate-nitrogen content and plant petiole sap concentration in two vegetable crops (carrot and vegetable soyabean) as influenced by live-mulch (two species) in 1995 (n = 48)[a]

Vegetable	Carrot				Vegetable soyabean			
Live-mulch	Soil nitrate (kg NOR-N ha-')		Plant sap nitrate (ppm)		Soil nitrate (kg NO_3-N ha-')		Plant sap nitrate (ppm)	
Centrosema	59.0	a	2385	a	21.2	a	469	a
Desmodium	43.4	a	2423	a	24.6	a	479	a
No live-mulch	48.7	a	2139	a	22.6	a	405	a
Contrast P-value mulch-no mulch	*0.46*		*0.04*		*0.92*		< *0.05*	

'Means in each column followed by the same letter are not significantly ($p \leq 5\%$) different.

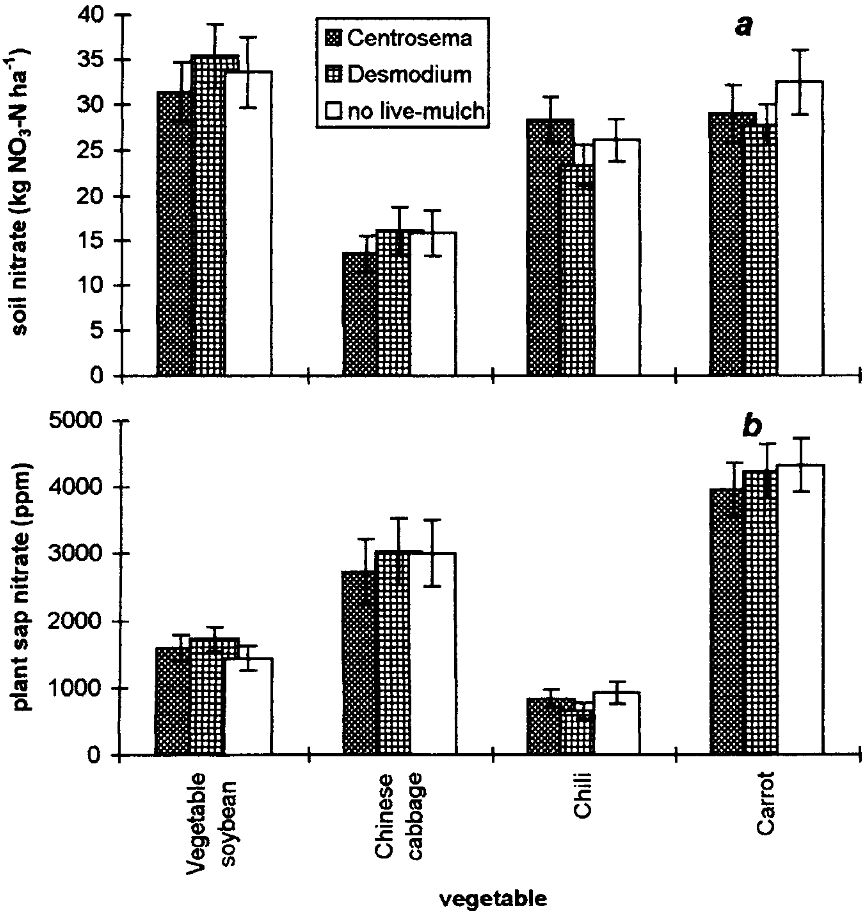

FIGURE 5. Influence of live-mulch treatments (two species) on average (a) soil contents of mineralized nitrogen and (b) crop N-status during the cultivation period of four vegetable crops in 1994/95. Vertical bars indicate standard errors.

inter-row spacing, timing of clipping, and placement method (Kang *et al.*, 1990). Sarrantonio (1992) discussed possible relay-intercropping schemes of vegetables and green manure crops to minimize interspecific competition, emphasizing that timing of sowing is crucial to avoid competition with the crop. When legume live-mulch was sown into Chinese cabbage in 1992, reductions in yield were avoided presumably because the maturing vegetable inhibited legume growth. Compared with subsequent years, inter-specific competition was severe in the tomato 1992 crop although only little live-mulch biomass (0.03 to 0.07 kg m^{-2}) was produced. This could be attributed to differences in proportion and spatial arrangement of live-mulch and vegetable (Radosevich & Wagner, 1986). In 1992, the pro-portion of live-mulch to vegetable was 1:1 row, but subsequently only 1:3 rows (3.0-m-wide bed). Arrangement of live-mulch on the edges of high beds limited competition to the border row of vegetables (Figure 3 b). Growing the live-mulch strip in between vegetable rows would have probably resulted in more severe competition between live-mulch and vegetable after 1992.

Incorporation of legumes before vegetables were established did not improve performance of crops (pre-crop biomass, Table 3). Although it is often anticipated that a short-term nitrogen flush after incorporation may favour the yield of a succeeding cash crop, nutrients in the green manure biomass may not mineralize in time to become available to the following crop. Green manure may even immobilize soil nutrients that were available before application (Yamoah & Mayfield, 1990) through the buildup of soil microbes stimulated by the application of decomposable plant material. This process has been observed with green manure and legume crop residues in some rice-based environments (AVRDC, 1992; AVRDC, 1995) and shows that immobilization can be significant even when high-nitrogencontaining material is added to soil (Stojanovic & Broadbent, 1956). The effect of green manure application on soil mineralized nitrogen in this study was obviously determined by season: incorporation in the cool season resulted in initial immobilization of soil nitrate and virtually no release (Figure 4 *a).* Similar negative effects of green manure application were observed in poorly aerated rice soils and particularly when temperatures were cool by Patrick *et al.* (1964). In the hot season release of nitrate was more pronounced (Figure 4 c).

We did not evaluate the influence of live-mulch application without additional fertilizer application because it was shown that nitrogen deficiencies can develop in crops after legume application when nitrogen is not applied (Wilson *et al.,* 1986). Poorer vegetable crop performance after legume incorporation was, however, also observed when fertilizer was added (AVRDC, 1992).

Live-mulch biomass in vegetable production was usually negatively correlated with crop yields in the short term (Nicholson & Wien, 1983; Wiles *et al.,* 1989), and Mulongoy & Akobundu (1992) stated that competition takes place between intercrops in newly established live-mulch plots. Therefore, no benefit can be expected when the establishing cover crop reduces growth and yield of associated crops. Slow but steady improvement in crop yield has, however, been recorded by Balasubramanian & Sekayange (1991) after the first year of establishing a legume hedgerow system. Warman (1990) attributed a positive yield response in tomato to residual fertility of a previous year's cauliflower-live-mulch system, and Mulongoy & Akobundu (1992) found sustained maize yield after a lag of two years from the time of cover-crop establishment. This study in part confirms these results for intensive vegetable production in tropical lowlands. Soon after establishment of cover crops in 1992 and 1993, vegetable yields were inhibited, but biomass of live-mulch clippings in 1993 improved vegetable yields in the following year (Table 4). The findings that positive effects of a legume cover crop may not last for more than a year after incorporation (Utomo *et al.,* 1992) were confirmed since live-mulch significantly improved vegetable yields only for one crop (Table 2).

Positive longer-term effects of green manure or cover crops were often associated with improvements in soil chemical and physical properties (Lal *et al.,* 1978). In intensive vegetable cultivation, Gysi & Keller (1983) found that loss of organic matter was significantly inhibited by a green-manure intercrop. In our study, soil analyses were confined to measurements of available nitrogen and did not include detailed measurements of chemical and physical properties. Effects of live-mulch on available soil nitrogen could not be detected, but there was an indication that plant nutritional status was improved in live-mulch treatments (Table 5). This might have resulted from slow, but sustained mineralization of organic nitrogen which was improved by the live-mulch biomass application in previous years. This nitrogen was obviously readily absorbed by vegetable crops.

The practical significance of a live-mulch-vegetable system in intensive tropical vegetable production, characteristic to many peri-urban areas in Asia, appears, however, minimal. Management of such a system is too expensive and labor-intensive (Kelly, 1990), negative effects may be obvious in the short term, and positive longer-term effects, if any, may not be recognized by farmers.

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