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Sunnhemp, a Green Manure on Chinese Cabbage Production on Guam

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Abstract—Sunnhemp, *Crotalaria juncea* L. cv. Tropic Sun, was evaluated as a green manure crop in the vegetable production system in Pulantat soil (clayey, montmorillonitic, isohyperthermic, shallow Udic Haplustalf) during 1993 to 1996. A split plot design with four replications was used having an application of inorganic N-urea fertilizers (224, 112, 56 and 0 kg ha^{-1}) as a main plot and green manuring as a sub-plot. Sunnhemp was grown until the flowering stage and then incorporated into soil. Chinese cabbage, *Brassica rapa* L. var. *chinensis* L. cv. Speedy 602 was either directly sown in the field or transplanted. Sweet corn, *Zea mays* L. cv. Summer Sweet was planted after harvesting Chinese cabbage in 1995 and 1996 to examine plant response to residual soil nutrients. In 1994 Chinese cabbage yield was increased by N fertilizer application but not with green manuring. In both 1995 and 1996 the Chinese cabbage yield was increased by both green manuring and N-fertilizer application. Plant tissue analyses in 1995 showed that both green manuring and N-fertilizer application increased nitrate-N in petiole sap, and the total N in leaf tissues was increased as the amount of N application increased.

Introduction

The use of green manure crops is a cultural practice to improve soil productivity frequently used in the tropics. Various legumes (Fabaceae) are used as green manure crops (NAS 1981, Evans et al. 1983, Yost & Evans 1988). Examples of such plants included *Cajanus cajan* (L.) Millsp., *Crotalaria juncea* L., *Lablab* spp., *Mucuna* spp., *Phaseolus calcaratus* Roxb., *Prophocarpus tetragonolobus* (L.) DC., *Sesbania* spp., and *Vigna* spp. Positive effects of green manuring with legumes were documented in the production of rice (John et al. 1989, Morris et al. 1986a, 1986b), grass crops (Reddy et al. 1986), and recently in tropical tomato production systems (Thonnissen et al. 2000).

Crotalaria juncea L., commonly called sunnhemp (subfamily: Papilionoideae) is one of the most common green manure crops in the tropics. It was a superior species in terms of biomass production in some soils of Guam (Marutani & Simpson 1994). The cultivar 'Tropic Sun' was released by the USDA-Soil Conservation Service, now Natural Resources and Conservation Service (NRCS) and the University of Hawaii in 1982 (USDA-SCS 1984). This fast growing legume has been grown to add nitrogen and organic matter to soil (Rotar & Joy 1983, Sharma & Mittra 1988, Lales & Mabbayad 1983, Koler & Grewal 1988, Singh et al. 1988) and to suppress reniform nematodes, *Rotylenchulus reniformis* Linforn & Oliveira (Caswell et al. 1991, DeFrank 1989). Phosphorus application is recommended before planting *C. juncea* in low phosphorous soil and the phosphorus applied to sunnhemp can also be used by succeeding vegetable crops (Rotar & Joy 1983). The effect of planting sunnhemp to increase phosphorous availability in subsequent potato cropping was noted in India (Sharma et al. 1988).

Although seeds of *C. juncea* have been available to vegetable growers, green manuring is not popular on Guam. Local information on the benefits of green manuring is needed in order to advance the usage of green manure crops. In earlier trials, a slight increase in canopy growth was observed for potato (*Solanum tuberosum* L. cv. Kennebec) with green manuring by sunnhemp, and head cabbage (*Brassica oleracea* L. var. *capitata* cv. KK Cross) yielded more with green manuring (M. Marutani, unpublished data). Those studies showed the potential use of sunnhemp on Guam, especially for leafy vegetables which appeared to have a greater response. The present study was initiated to determine the effect of sunnhemp as a green manure crop on subsequent plantings of Chinese cabbage (*Brassica rapa* L. var. *chinensis* L.).

Materials and Methods

Crotalaria juncea cv. Tropic Sun, was evaluated in a three-year crop rotation system starting in 1994. A split-plot design with four replications was used having an application of the N-urea fertilizers (224, 112, 56 and 0 kg ha^{-1}) at replanting of vegetable crops as a main plot, and with or without green manuring as a sub-plot. Prior to growing the green manure crop, corn (*Zea mays* L.) was grown in the entire experimental field of Pulantat soil (clayey, montmorillonitic, isohyperthermic, shallow Udic Haplustalf) at Barrigada for two months starting in 15 Oct 1993. This was done to reduce the effects of previous vegetation and soil nutrients in the experimental field. After removing all corn debris and other plant material including weeds from the entire field, plots were plowed and sunnhemp seeds were broadcast in green manuring subplots of 22m^2. The sunnhemp was cut at the flowering stage and incorporated into the soil by plowing.

Chinese cabbage, *Brassica rapa* L. var. *chinensis* L. cv Speedy 602 was directly sown in the field (in 1994) or transplanted (in 1995 and 1996) after four levels of N fertilizer were applied as the main plot treatment. A basal dressing of 56 kg P ha^{-1} and 56 kg K ha^{-1} was also applied to all treatments prior to planting Chinese cabbage. Each subplot consisted of four 3.6 m long rows. Each row contained 12 plants. The inter-row distance was 90 cm and the distance between plants within a row was 30 cm. Data were collected from 20 interior plants. A drip irrigation system was employed. Pest control was done by applying conventional pesticides as needed. Sweet corn, *Zea mays* L. cv. Summer Sweet was planted after harvesting Chinese cabbage and before planting sunnhemp in 1995 and 1996.

The response of Chinese cabbage to the different treatments was compared. Ten plants per sub-plot were sampled to determine the total fresh weight, which included leaf and root tissues at harvest. The percent dry matter was determined by drying ten individual leaf samples and ten entire root systems at 60ºC for 48 hrs. Approximately 0.1 g of dried leaf sample was digested with concentrated sulfuric acid with a catalyst on a hot plate at 224ºC for 4 hrs. Samples were then cooled and 10 mL of distilled water added. A micro-Kjeldahl distillation apparatus was used to transfer nitrogen as NH_4^+ to a boric acid-ethanol mixed indicator and to measure the amount of total-N by titration. The sap of ten leaf samples per sub-plot was combined and tested for the amount of nitrate-N using a compact Cardy ion meter (Spectrum Technologies, Inc. Plainfield, IL). For sweet corn, the biomass of entire plants per sub-plot was recorded to determine the residual effect of the fertilizer treatments on corn development. Analysis of variance and descriptive statistics were performed using StatView (SAS Institute 1998) and Super Anova (Abacus Concept Inc. 1991).

Results and Discussion

Chinese Cabbage

Effects of green manuring on plant development were clearly demonstrated for transplants in 1995 and 1996 experiments. However in 1994 direct-seeded Chinese cabbage plants in the field had irregular germination, and thus the wide range of plant development stages at harvest resulted in a great variation in plant size and sap nitrate-N level. Chinese cabbage plant grown from 7 Apr.–19 May, 1994 was positively influenced by applying N-fertilizer ($P<0.05$) (Table 1), but green manuring did not affect either the fresh weight of Chinese cabbage (Table 1) nor the concentration of petiole sap nitrate-N (Table 2). Likewise, neither N-fertilizer nor green manure had any effect on the percent dry matter of both leaf and root tissues (Marutani unpublished data). The great variation in plant growth rate among samples within a sub-plot seemed to be the primary cause to draw inconclusive results.

In 1995, the Chinese cabbage yield from the growing period of 11–31 Jan. was affected by both N fertilizer ($P<0.01$) and green manuring ($P<0.01$) (Table 1, Fig. 1). At all four N fertilizer levels, the fresh weight of Chinese cabbage was greater with green manuring than in plants grown in the field without manuring. The amount of nitrate-N of petiole sap at harvest was also greater with both green manuring ($P<0.05$) (Table 2) and the N fertilizer application ($P<0.001$). The highest concentration of nitrate-N (1198 mg L^{-1}) was detected from plants grown with green manuring plus the application of 224 kg N ha^{-1}. The total N of leaf tissues was increased as the amount of N application increased ($P<0.01$). However, the effect of green manuring on the total N of leaf tissue was not significant ($P=0.0612$).

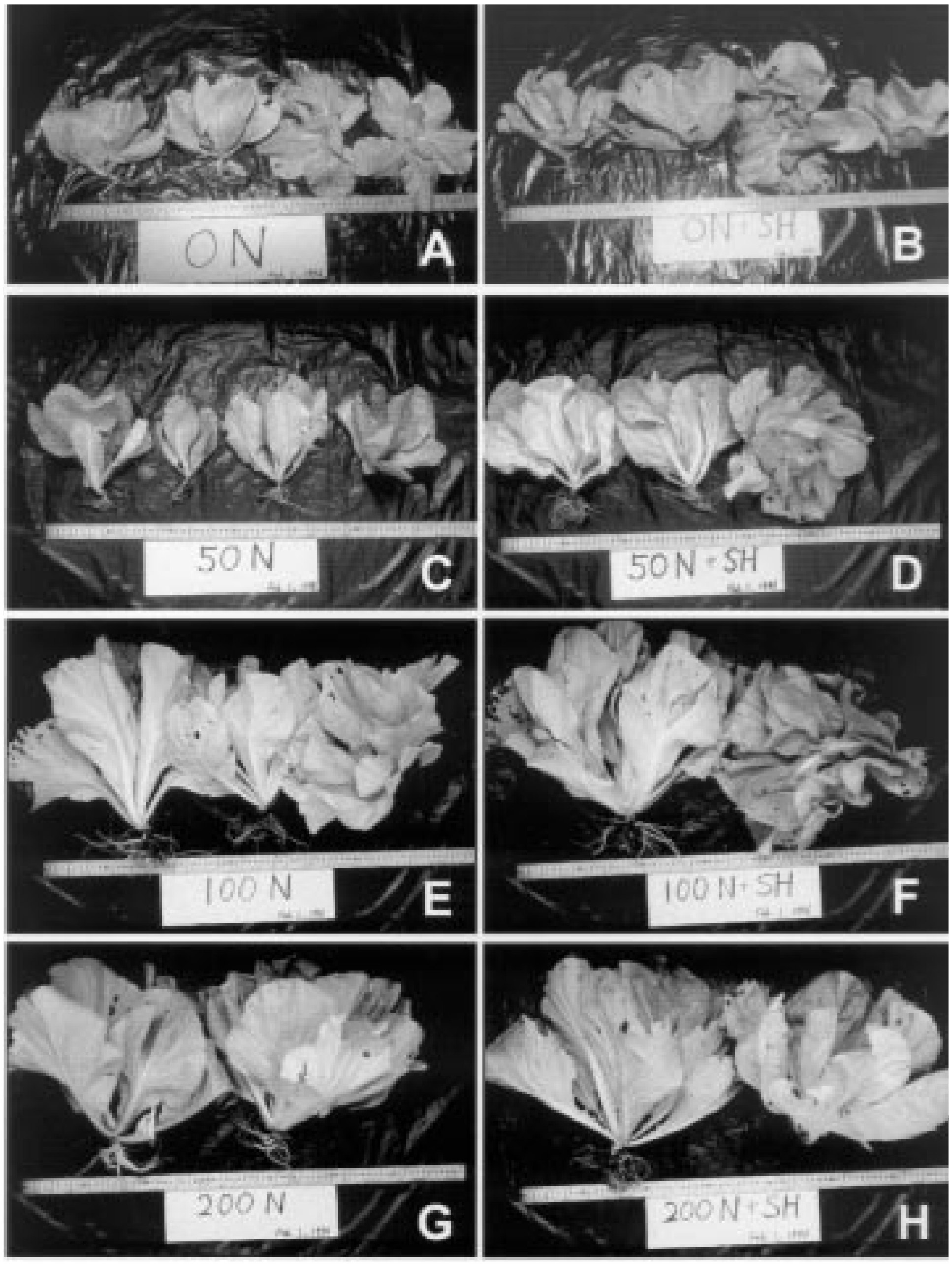

Figure 1. Effects of green manuring and N-urea fertilizer application on the growth of Chinese cabbage (*Brassica rapa* L. var. *chinenis* L. cv. Speedy 602). Chinese cabbage was transplanted in the field on 12 Jan 1995 and harvested on 31 Jan 1995. Photographs were taken on 1 Feb 1995. 0 N = 0 kg ha^{-1} N-fertilizer; 50 N = 56 kg ha^{-1} N-fertilizer; 100 N = 112 kg ha^{-1} N-fertilizer; 200 N = 224 kg ha^{-1} N-fertilizer; SH = sunnhemp application.

Table 1. N-fertilizer x green manure treatment interaction mean (±SE) for plant weight of Chinese cabbage (*Brassica rapa* var. *chinensis*) cv. Speedy grown in 1994, 1995 and 1996.

Treatment		Fresh weight of plant (leaves+roots)		
N-fertilizer	Green Manure	1994	1995	1996
kg ha^{-1}		g plant^{-1}		
0	With	45.4 ± 22.7	123.0 ± 8.6	55.9 ± 14.4
	Without	28.5 ± 6.2	63.5 ± 6.3	33.4 ± 4.0
56	With	48.2 ± 9.7	170.1 ± 9.8	79.5 ± 10.5
	Without	68.0 ± 12.2	129.4 ± 9.7	41.6 ± 9.1
112	With	118.5 ± 53.8	118.2 ± 8.1	73.5 ± 22.3
	Without	79.4 ± 23.5	94.5 ±18.9	41.9 ± 8.2
224	With	114.8 ± 41.8	116.5 ± 9.5	122.3 ± 2.9
	Without	96.4 ± 23.4	89.6 ±20.3	120.6 ± 11.6
Source of Variation		Analysis of Variance		
		$P > F$		
N fertilizer (N)		0.0349	0.0062	0.0005
Green manure (G)		0.4240	0.0036	0.0056
N x G		0.6547	0.2549	0.4444

Because the measurements of sap nitrate-N were much less in 1995 compared to the data obtained in 1994, the amount of nitrate-N of 1995 data was verified by using a Lachat Quick Chem Automated Ion analyzer (Lachat Instruments Milwaukee, WI). It was found that the nitrate levels recorded by a Cady Ion meter were linearly related with the nitrate-N measured by the Lachet Ion analyzer (r^2=0.935), confirming the reading by the Cady Ion meter to be reliable. Several factors may have contributed to the variation in sap analyses between 1994 and 1995. First, Chinese cabbage in 1994 was directly seeded in the field while in 1995 seedlings were transplanted. The growing period was also different. In 1994 Chinese cabbage was grown at the end of the dry season (April–May) while in 1995 plants were planted in the beginning of the dry season in January. Nitrate-N measurements from petiole sap may also be influenced by the sampling time of day and the irrigation schedule. Available soil-nitrogen levels were determined by not only the amount of nitrogen added to the field but also by the amount of available soil water. In the earlier study Coltman (1987) found that a continuous supply of nitrogen by drip irrigation gave a high yield in tomato but lower levels of sap nitrate than when plants received the conventional fewer, split applications of nitrogen.

The yield of Chinese cabbage grown from 28 Dec. 1995 to 1 Feb. 1996 again showed the positive effects of both green manuring (P<0.01) and N fertilizer application (P<0.001) (Table 1). The highest mean plant weight of 122.3 g was obtained from the treatment of green manuring plus an application of 244 kg N ha^{-1}. The data indicated that sunnhemp as green manure crop contributed to better plant growth of Chinese cabbage.

Table 2. N-fertilizer x green manure treatment interaction mean (±SE) for petiole sap NO_3 -N (ppm) of Chinese cabbage cv. Speedy (*Brassica rapa* var. *chinensis*) in 1994 & 1995 at harvest, and for the total N (g kg^{-1}) of leaf tissues in 1995 at harvest.

Treatment		Petiole sap NO_3 -N		Total N of leaf (Dry weight basis)
N-fertilizer	Green Manure	1994	1995	1995
kg ha^{-1}		- - - - - - - - - - - mg L^{-1} - - - - - - - - - - -		g kg^{-1}
0	With	1870 ± 754	171 ± 36	2.69 ± 0.07
	Without	1029 ± 157	91 ± 22	2.15 ± 0.09
56	With	844 ± 206	258 ± 62	2.70 ± 0.18
	Without	759 ± 133	63 ± 14	2.81 ± 0.34
112	With	1175 ± 266	949 ± 118	3.55 ± 0.18
	Without	1396 ± 509	514 ± 158	3.29 ± 0.03
224	With	2563 ± 782	1198 ± 235	3.37 ± 0.39
	Without	2055 ± 807	892 ± 87	3.45 ± 0.07
Source of Variation		Analysis of Variance		
		- - - - - - - - - - - - - - - *P* > *F* - - - - - - - - - - - - - - -		
N fertilizer (N)		0.2083	0.0001	0.0052
Green manure (G)		0.4733	0.0063	0.0612
N x G		0.7692	0.4343	0.7584

SWEET CORN

Sweet corn was planted after Chinese cabbage harvest in 1995 and 1996 to examine the residual effect of main plot and sub-plot treatments. In both years, no significant effects on the total fresh biomass of corn were detected with either green manuring or N fertilizer treatments (Table 3). Corn is a good indicator plant for testing N-nutrient residues in soils (Thonnissen et al. 2000). The lack of difference in corn biomass production in response to experimental treatments indicated a possible loss of soil nutrients in the interval from Chinese cabbage harvest to the subsequent corn planting. This interval was 71 days and 54 days for 1995 and 1996, respectively. During this time the field was maintained as weed-free as possible. The decline in soil nutrients appeared to have already occurred prior to corn planting through the leaching essential elements required for plant growth.

Conclusions

Chinese cabbage yield responded to both green manuring and N-urea fertilization, when transplanted. The concentration of petiole sap nitrate -N was also increased by green manuring and application of N-urea fertilizers. Transplants had well-established root systems capable of absorbing available soil nutrients immediately after planting. When plants received the same amount of N-urea fer-

Table 3. N-fertilizer x green manure treatment interaction mean (±SE) for biomass of sweet corn (*Zea mays*) cv. Summer sweet in 1995 and 1996. Seeds were sown in field on 12 Apr 1995 and 26 Mar 1996 after Chinese cabbage harvest on 31 Jan 1995 and 1 Feb 1996, respectively.

Treatment		Plant Biomass (fresh whole plants)	
N-fertilizer	Green Manure	1995	1996
kg ha^{-1}		- - - - - t ha^{-1} - - - - -	
0	With	2.49 ± 0.16	3.42 ± 0.33
	Without	2.37 ± 0.16	3.28 ± 0.77
56	With	2.48 ± 0.75	3.55 ± 0.43
	Without	2.10 ± 0.16	3.55 ± 0.43
112	With	2.78 ± 0.26	4.05 ± 0.77
	Without	2.26 ± 0.33	2.30 ± 0.34
224	With	2.63 ± 0.46	3.13 ± 0.57
	Without	2.46 ± 0.38	3.70 ± 0.29
Source of Variation		Analysis of Variance	
		- - - - - $P > F$ - - - - -	
N fertilizer (N)		0.8430	0.7948
Green manure (G)		0.1133	0.4127
N x G		0.7914	0.2349

tilizers, Chinese cabbage yield and the content of sap nitrate-N were greater with green manuring. Green manuring improved soil productivity probably by adding organic matter and mineralized nutrient elements from sunnhemp. Residual effects of soil fertility after Chinese cabbage harvest were not clearly demonstrated in this study. Corn should be planted soon after Chinese cabbage harvest to benefit from such residual effects. We recommend further studies to examine the decomposition rate of sunnhemp and the nutrient holding capacity of the soil.

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