Jpn. J. Crop Sci. 63(1) : 137—143 (1994)

Effect of Sunn Hemp and Peanut Incorporated as Green Manures on Growth and Nitrogen Uptake of the Succeeding Wheat*

Katsuya YANO**, Hiroyuki DAIMON*** and Hironori MIMOTO
(*College of Agriculture, University of Osaka Prefecture, Sakai 593, Japan*)
Received July 31, 1993

Abstract : Effect of summer legumes incorporated as green manures, sunn hemp (cv. Kobutoriso) and peanut (cv. Chiba-handachi), was examined for nitrogen contribution to the succeeding wheat (cv. Norin 61). The dry weight of sunn hemp, of which the stem occupies the largest proportion, was higher than that of peanut at time of incorporation. Total nitrogen content was higher in peanut compared with sunn hemp. The amount of nitrogen fixed by each legume was estimated by the 'difference method' with non-nodulating peanut (cv. Tarapoto) as a reference crop. In peanut, 18 g N per m^2 was calculated as the amount of nitrogen fixed at the late maturity stage. The percentage of nitrogen fixed to the total nitrogen was 60-70% in both legumes. On the yield and nitrogen uptake of the succeeding wheat, the peanut plot was superior to the sunn hemp plot. The percentage contribution of nitrogen accumulated by each legume to total nitrogen of the succeding wheat was 11.2% on the peanut plot and 9.4% on the sunn hemp plot. In peanut, the C-N ratio was approximately 20 at time of incorporation. In sunn hemp, it was 40, and the decomposition rate was found to be slower than that of peanut by a modified method using glass fiber filter papers. The results indicated that peanut crop contributed more nitrogen to the succeeding wheat compared with sunn hemp.
Key words : C-N ratio, Green manure, Nitrogen fixation, Nitrogen mineralization, Peanut, Sunn hemp, Wheat.

緑肥として施用したサンヘンプならびにラッカセイが後作コムギの生長および窒素吸収に及ぼす影響：矢野勝也・大門弘幸・三本弘乗（大阪府立大学農学部）

要　旨：夏作マメ科作物のサンヘンプ（品種：コブトリソウ）およびラッカセイ（品種：千葉半立）を緑肥としてすき込み，後作コムギ（品種：農林 61 号）の生長ならびに窒素吸収について比較検討した．すき込み時における緑肥作物の乾物生産量は，サンヘンプがラッカセイよりも優った．一方，全窒素含有量はラッカセイがサンヘンプよりも優った．すき込み時のC-N率はラッカセイにおいて約 20 であったのに対してサンヘンプでは約 40 と高く，全乾物重に占める茎の割合が著しく高かった．両マメ科作物の固定窒素量を根粒非着生ラッカセイ（品種：タラポト）を対照作物とした差引法によって算出した結果，ラッカセイで高く，18 g m^{-2} であった．全吸収窒素に対する固定窒素の割合は何れのマメ科作物ともに 60-70%であった．後作コムギの収量ならびに窒素吸収量は，ラッカセイ区がサンヘンプ区よりも優った．各々のマメ科作物が後作コムギの吸収窒素に寄与した割合は，サンヘンプ区で 9.4%，ラッカセイ区で 11.2%であった．ガラス繊維濾紙法を用いて評価した分解速度においてC-N率の高いサンヘンプの分解が遅いことが示された．以上のように，両マメ科作物を緑肥としてすき込んだ場合，後作コムギへの窒素供給作物としてはラッカセイがサンヘンプよりも優った．
キーワード：コムギ，サンヘンプ，C-N率，窒素固定，窒素の無機化，ラッカセイ，緑肥．

In recent years, concerns for sustainable soil productivity in relation to ecological sustainability have emerged in various crop production systems[11,12,13,15]. Leguminous crops, which have an ability to symbiotically fix nitrogen with root nodule bacteria, have been widely used as a nitrogen contributing crop[3,8,14]. Crop rotations, including legumes, have increased in importance because of their potential to reduce chemical nitrogen fertilizer inputs. Sunn hemp (*Crotalaria juncea* L.), which is an annual legume used as a fiber crop and rarely as a forage crop in tropical regions, has been recently recognized as an antagonistic plant to nematodes[6,9,10]. As this plant species, moreover, has high dry-matter production potential and grows vigorously on poor soil, it is expected to be introduced as a green manure crop[8,12]. Peanut (*Arachis hypogaea* L.), which is produced all round the world in warm temperate and tropical regions, is also reported as an antagonistic plant[10].

* An outline of this paper was presented in the 194th meeting of the Crop Science Society of Japan, Kumamoto, 1992.

** Present address : School of Agriculture, Nagoya University, Chikusa-ku, Nagoya 464, Japan.

*** To whom correspondence should be addressed.

This plant with green leaves containing high nitrogen content at the maturity stage may also be useful as a green manure.

In order to apply these plants as green manure legumes efficiently, it is essential to estimate the amounts of nitrogen fixed symbiotically and released from incorporated materials. However, there has been little information on traits of nitrogen fixation and utilization as a nitrogen contributor in crop rotation including both legumes.

The study reported herein was conducted to : 1) estimate the amounts of nitrogen fixed by sunn hemp and peanut, and : 2) determine the effect of both legumes incorporated as green manure on growth and the nitrogen uptake of the succeeding wheats.

Materials and Methods

1. Field experiment

The experiment was carried out in 1991 and 1992 on the Experiment Farm at University of Osaka Prefecture, Sakai. Soil at the site was a silty loam (a gray lowland soil ; Haplaquept) with a pH (H_2O) of 5.5, 0.58% T-C, 0.07% T-N and a EC of 27 μs cm^{-1}. Sunn hemp (*Crotalaria juncea* L.), cv. Kobutoriso, and peanut (*Arachis hypogaea* L.), cv. Chiba-handachi, were sown on May 27 in 1991. A non-nodulating peanut line (*A. hypogaea* L.), cv. Tarapoto, was sown as a non-N_2-fixing reference crop for quantifying N_2 fixation by the 'difference method'[4]. Each plot was 2.1 × 1.8 m in area with 5 rows spaced at 0.36 m intervals for sunn hemp and with 4 rows at 0.45 m for both peanut cultivars. The experiments were conducted in a completely randomized method with two replications. Basal fertilizer was applied to all plots except fallow just prior to sowing : N 3 g m^{-2}, P_2O_5 10 g m^{-2} and K_2O 10 g m^{-2}. Each strain of *Bradyrhizobium*, USDA3024 for sunn hemp and A2R1 for peanut, was inoculated just after sowing.

At 3 and 5 months after sowing, five uniform plants from each of the duplicate plots were sampled to measure dry weights, nitrogen contents and C-N ratios of leaves, stems, pods and roots. Each sample was ground and analyzed for total nitrogen and carbon contents with a Sumigraph Model NC 80 N. C-Analyzer (Sumitomo Chem. Inc., Osaka, Japan).

Plants not sampled in each plot were incorporated after cutting into 5-10 cm in length on Nov. 8 in 1991. Prior to sowing the succeeding crop, (*Triticum aestivum* L.), cv. Norin 61, fertilizer was applied to all plots including fallow plot : P_2O_5 10 g m^{-2} and K_2O 10 g m^{-2}, but no N fertilizer was applied for clarifying nitrogen contribution from incorporated green manures. On Nov. 8, wheat was sown by row seeding at rate of 6 g m^{-2} with 5 rows spaced at 0.36 m intervals.

On May 29 1992, wheat plants were harvested from each of the duplicate plots. After air drying for 10 days under glasshouse conditions, dry matter production and yield components of wheat samples were determined. Total nitrogen contents of the samples were analyzed by the method described adove.

2. Measurement of decomposition rate of green manure

To investigate the difference in the decomposition rate of incorporated materials between sunn hemp cv. Kobutoriso and peanut cv. Chiba-handachi, pot experiment using a modified glass fiber filter method[5] was conducted. Whole plant samples of sunn hemp and peanut (C-N ratio : 17 and 16 respectively), and stem of sunn hmp (C-N ratio : 50) were used as incorporated materials. Both legumes were grown under glasshouse conditions during 3 months after sowing on Dec. 1 1991. Plant materials sampled on March 2 1992 were dried at 70°C for 48 hours and cut into small pieces. One gram of the material weighed accurately was confined in a pair of glass fiber filters (70 mm in diameter, Advantec Inc. Tokyo, Japan), and then put into 300 ml pot filled with soil of the experimental field. At the start of the experiment, the pots were moistened to reach a maximum water holding capacity and incubated at 23°C under dark conditions. The experiment was conducted with three replications.

Dry weight, total nitrogen and C-N ratio of sample were determined at weekly intervals from zero to 4 weeks after the start of incubation.

Results

1. Dry matter production and amounts of nitrogen fixed by preceding green manure legumes

Fig. 1 shows the dry weights of green manure crops at 3 and 5 months after sowing.

No significant difference in total dry weight between sunn hemp and peanut was found at the first sampling time. At 5 months after sowing, when the plant materials were harvested and incorporated into each plot, the total dry weight of sunn hemp was significantly higher than that of peanut. The rise in the dry weight during 2 months was mostly caused by increase in stems in sunn hemp and in pods in nodulating peanut. Of non-nodulating peanut used as a reference crop for N_2 fixation, the total dry weight was significantly lower than that of each legume.

Fig. 2 shows nitrogen contents of green manure crops at 3 and 5 months after sowing. At both sampling times, total nitrogen content was significantly higher in peanut compared with sunn hemp. At 5 months after sowing, the stem fraction included about 50% of total nitrogen content in sunn hemp. Non-nodulating peanut exhibited extremely lower nitrogen content.

Table 1 shows C-N ratios in green manure crops at 3 and 5 months after sowing. The values were significantly higher in sunn hemp compared with peanut at the both sampling times.

Table 2 shows the amounts of nitrogen fixed in green manure legumes calculated by the 'difference method' with a non-nodulating peanut. Peanut had higher total amounts of nitrogen due to N_2 fixation at 12.8 g m^{-2} at the first sampling time and 18.1 g m^{-2} at the second, as compared with 6.2 g m^{-2} and 12.5 g m^{-2} for sunn hemp respectively. The proportion of nitrogen fixed to the total nitrogen in

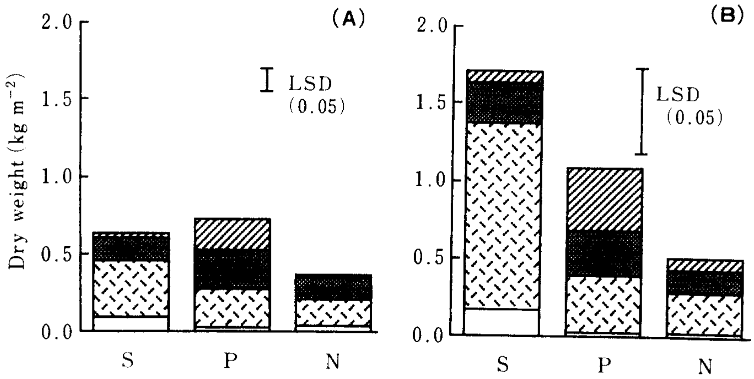

Fig. 1. Dry matter production of green manure crops at 3 (A) and 5 (B) months after sowing. Vertical bars indicate LSD (P=0.05).
S : Sunn hemp. P : Peanut. N : Non-nodulating peanut.
□ Roots, Stems, Leaves, Pods

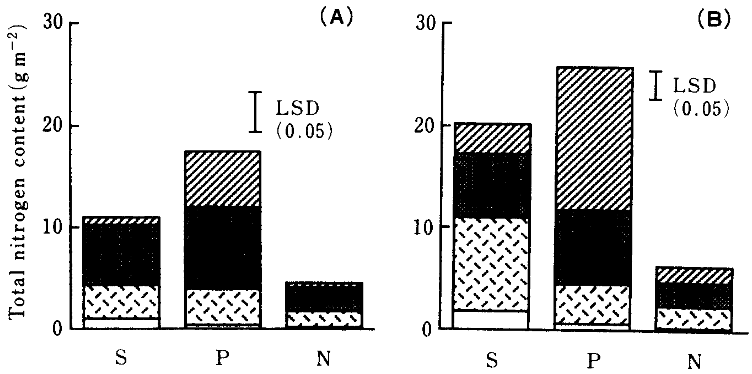

Fig. 2. Total nitrogen accumulation of green manure crops at 3 (A) and 5 (B) months after sowing. Vertical bars indicate LSD (P=0.05).
S : Sunn hemp. P : Peanut. N : Non-nodulating peanut.
□ Roots, Stems, Leaves, Pods

Table 1. Mean C-N ratios of green manure legumes at 3 and 5 months after sowing.

Crops	Months after sowing 3	5
Sunn hemp	25.8	39.3
Peanut	18.7	20.8
Non-nodulating peanut	31.6	27.2
LSD (0.05)	2.5	4.9

both legumes was 56.9-61.6% for sunn hemp and 73.1-69.9% for peanut.

2. Growth and nitrogen uptake of the succeeding wheat

Fig. 3 shows wheat plants at the internode elongation stage growing on each plot incorporated green manure. The difference in top growth among 4 treatments was found. The leaf color of wheat plant, which is the most sensitive indicator of the status receiving nitrogen, was deep green on the nodulating peanut plot and the sunn hemp plot and pale to yellowish green on the non-nodulating peanut

Table 2. The amounts of nitrogen accumulated by each legume for 3 and 5 months after sowing.

Crops	Months after sowing	Total N (g/m^2)	Fixed N[1)] (g/m^2)	Fixed N[2)] (%)
Sunn hemp	3	10.9	6.2	56.9
	5	20.3	12.5	61.6
Peanut	3	17.5	12.8	73.1
	5	25.9	18.1	69.9
Non-nodulatig peanut	3	4.7	—	—
	5	7.8	—	—

1) Fixed N (g/m^2) = Total N of each legume − Total N of non-nodulating peanut.

2) Fixed N (%) $= \frac{\text{Fixed N}(g/m^2)}{\text{Total N}(g/m^2)} \times 100$

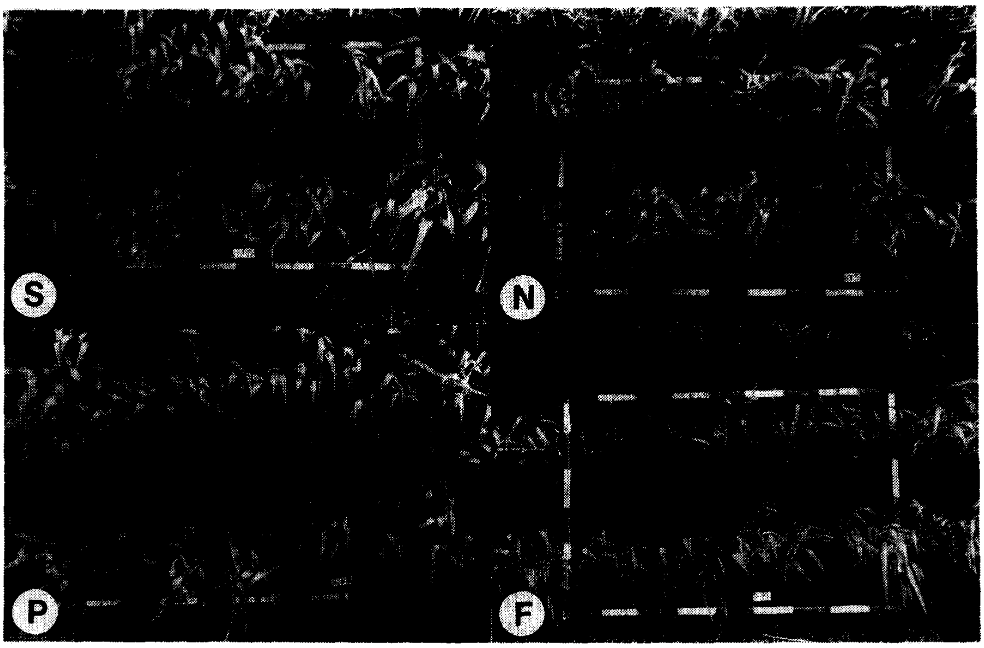

Fig. 3. Wheat plants at the internode elongation stage growing on each plot. S : Sunn hemp plot. P : Peanut plot. N : Non-nodulating peanut plot. F : Fallow plot.

Table 3. Effect of green manure legumes on yields and nitrogen contents of the succeeding wheats.

Preceding green manure crops	No. of ears (/m²)	No. of grains (/ear)	1000 grains weight (g)	Grain yield (g/m²)	Top dry weight (g/m²)	Top N content (g/m²)
Sunn hemp	186	28.1	36.2	189	455	3.6
Peanut	212	29.1	37.8	233	587	4.6
Non-nodulating peanut	107	25.8	37.0	102	273	2.8
Fallow	101	21.0	35.8	76	167	1.7
LSD (0.05)	26	2.5	2.5	23	78	0.8

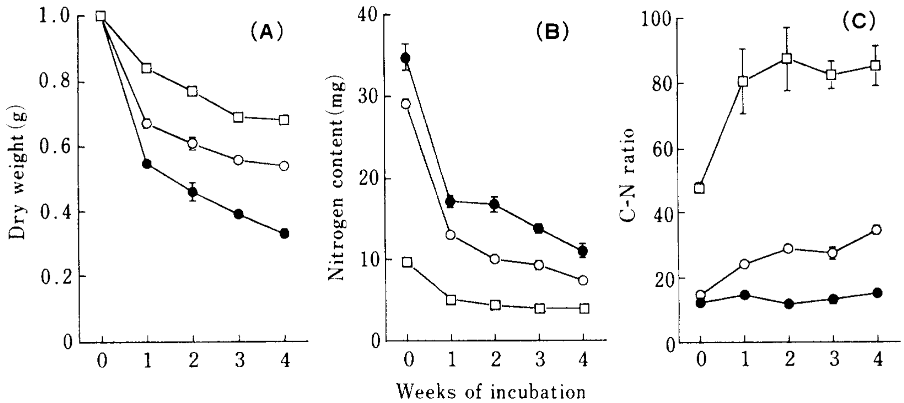

Fig. 4. Changes in dry weights (A), nitrogen contents (B) and C-N ratios of incorporated plant materials (C). Vertical bars indicate standard errors of the mean (n=3).
—○— whole plant of sunn hemp.
—●— whole plant of peanut.
—□— Stem of sunn hemp.

plot and the fallow plot.

Table 3 shows the grain yields and their components, and the total nitrogen contents of the succeeding wheats. The highest grain yield was obtained on the peanut plot and followed by the sunn hemp plot. Nitrogen contents of above ground parts were significantly higher on the peanut plot compared with the sunn hemp plot. In each plot of non-nodulating peanut and fallow, the nitrogen content was extremely low.

3. Decomposition rates of incorporated plant materials

Fig. 4 shows changes of dry weights, nitrogen contents and C-N ratios of incorporated whole plants of sunn hemp and peanut, and stems of sunn hemp. The reductions of dry weight and nitrogen content were found in all of incorporated plant materials during 4 weeks after the start of incubation. At 7 days after incubation, the amount of initial dry weight remaining was the lowest for peanut and highest for sunn hemp stems. The amounts of nitrogen reduction in the whole plants of sunn hemp and peanut were greatly higher than those of sunn hemp stems. The C-N ratio in sunn hemp stems remarkably increased by the lst sampling time and thereafter it remained constant whereas in the whole plant of sunn hemp it slightly increased by the final sampling time. The C-N ratio in peanut was found to be almost constant during 4 weeks.

Discussion

In this study, as one of the most important features for affecting the amount of nitrogen supplied to the succeeding crop, the amount of nitrogen fixed by two legumes was assumed by the 'difference method'. In estimating the amount of nitrogen fixed by comparing the nitrogen content of a nitrogen-fixing legume with that of a non-fixing reference crop, the results will obviously depend on the choice of a reference crop. Therefore, isogenic lines of the legumes with nearly identical traits in relation to growth patterns and root morphology especially to nitrogen uptake profiles should be used. Since non-nodulating mutant genotype of tested cultivars in sunn hemp and peanut, however, have not been produced, a non-nodulating peanut isoline of cv. Tarapoto was used. As a result of subtracting the amount of nitrogen absorbed in the non-nodulating line from that of each legume, peanut had higher amounts of nitrogen fixed at 12.8 g m^{-2} at the early pod filling stage (3 months after sowing) and 18.1 g m^{-2} at the late maturity stage (5 months after sowing) as compared with sunn hemp at each sampling time. Percentage nitrogen derived from fixation in peanut ranged from 73% to 69%. These values estimated here were essentially similar to the values by a ^{15}N isotope dilution method reported previously[16]. Whereas there has been little information for estimating those values in sunn hemp, further studies for the estimation should be conducted using a pertinent reference crop.

In the present study, the highest grain yields and nitrogen contents of the succeeding wheats were obtained on the peanut plot and followed by the sunn hemp plot. The difference in nitrogen content between both legume plots may be mainly caused by the amount of nitrogen of green manure incorporated into each plot. In fact, nitrogen content was higher in peanut at time of incorporation compared with sunn hemp (sunn hemp : 20.3 g m^{-2}, peanut : 25.9 g m^{-2}), although the total dry weight of sunn hemp was higher than that of peanut (sunn hemp : 1704 g m^{-2}, peanut : 1112 g m^{-2}).

On the other hand, green manure features determining decomposition and nitrogen mineralization include C-N ratio, which is determined by plant species, ages and plant parts. Plant materials with high C-N ratios are usually considered to decompose more slowly than those with low C-N ratios[2,7]. In particular, C-N ratio that is greater than about 25-30 might be critical for rapid decomposition[1]. In the field experiment, the C-N ratio in sunn hemp at time of incorporation was approximately 40, although it was 20 in peanut, and this may be also a factor for the lower nitrogen uptake of the succeeding wheat on the sunn hemp plot. Actually, the amount of initial dry weight remaining was highest for sunn hemp stems with a high C-N ratio in pot experiment using a modified glass fiber filter method.

Furthermore, the dry weight of sunn hemp occupied a high proportion in the fibrous stems in the field experiment. The ratio of the cell wall constituents such as lignin, cellulose and hemicellulose are known to be important for decomposition rate[1,7]. Nevertheless the C-N ratios of whole plant in sunn hemp and peanut were nearly equivalent in the pot experiment, while the differences in rates of reduction in dry weight and changes of C-N ratios during 4 weeks between both materials were found. The constituent elements in carbohydrates might be dissimilar between both materials. It is also substantial to obtain some index of nitrogen mineralization based on cell wall constituents/carbohydrates ratio

Table 4. Contribution of nitrogen accumulated by green manure legumes to nitrogen uptake of the succeeding wheats.

Preceding legumes	Total N of legume (g/m^2)	Total N of wheat (g/m^2)	Recovery of N[1] (%)
Sunn hemp	20.3	3.6	9.4
Peanut	25.9	4.6	11.2
Fallow	–	1.7	–

1) $\frac{\text{Wheat total N in legume plot} - \text{Wheat total N in fallow plot}}{\text{Legume total N}} \times 100$

in incorporated plant materials.

On the basis of the amount of nitrogen accumulated, we calculated the percentage of nitrogen contribution from both legumes in the succeeding wheat. Table 4 shows the amount and the percentage recovery of nitrogen in the succeeding wheat. The results showed that the percentage contribution in wheat on the peanut plot (11.2%) was higher than that on the sunn hemp plot (9.4%). It can be seen from these values that peanut would readily contribute to the succeeding wheats in regard to the supply of nitrogen.

Acknowledgements

We thank Dr. T. Gamo, National Institute of Agrobiological Resources, and Dr. H. Nakano, Tropical Agriculture Research Center, for supplying the root nodule bacteria for sunn hemp and peanut. We are also grateful to the Chiba Prefectural Agricultural Experiment Station and the Shiga Prefectural Agricultural Experiment Station for supplying the seeds of peanut and wheat, and to Mr. T. Yamada, University of Osaka Prefecture, for technical assistance.

References

1. Allison, F.E. 1966. The fate of nitrogen applied to soils. Adv. Agron. 18 : 219—258.
2. Aulakh, M.S., J.W. Doran, D.T. Walters, A.R. Moiser and D.D. Francis 1991. Crop residue type and placement effects on denitrification and mineralization. Soil Sci. Soc. Am. J. 55 : 1020—1025.
3. Hargrove, W.L. 1986. Winter legumes as a nitrogen source for no-till grain sorghum. Agron. J. 78 : 70—74.
4. LaRue, T.A. and T.G. Patterson 1981. How much nitrogen do legumes fix? Adv. Agron. 34 : 15—36.
5. Maeda, K. and Y. Onikura 1977. Method of measurement for decomposition rate of organic matter under field condition. Jpn. J. Soil Sci. Plant Nutr. 48 : 567—568*.
6. Ohbayashi, N. 1990. Control of plant parasitic nematode by antagonistic plants. J. Agric. Sci. 45 : 450—454**.
7. Ranells, N.N. and M.G. Wagger 1992. Nitrogen release from crimson clover in relation to plant growth stage and composition. Agron. J. 84 : 424—430.
8. Reddy, K.C. and G.M. Prine 1986. Tropical legums for green manure. I. Nitrogen production and the effect on succeeding crop yields. Agron. J. 78 : 1—4.
9. ————, A.R. Soffes, G.M. Prine and R.A. Dunn 1986. Tropical legumes for green manure. II. Nematode population and their effect on succeeding crop yields. Agron. J. 78 : 5—10.
10. Sano, Z and K, Nakasono 1986. Histological responses of three leguminous enemy plants to the penetration and development of *Meloidogyne incognita*. Jpn. J. Nematol. 16 : 48—55***.
11. Sharma, A.R. and B.N. Mittra 1988. Effect of green manuring and mineral fertilizer on growth and yield of crops in rice-based cropping on acid lateritic soil. J. Agric. Sci. Camb. 110 : 605—608.
12. Shioya, T., K. Kogano and J. Itoh 1990. Improvement of soil properties by planting tropical leguminous green crops in ill-drained clay paddy fields. I. Sesbania, Crotalaria : Characteristics of growth and effect on soil physical properties. Jpn. J. Farm Work Res. 25 : 59—68***.
13. Touchton, J.T., W.A. Gardner, W.L. Hargrove and R.R. Duncan 1982. Reseeding crimson clover as a N source for no-tillage grain sorghum production. Agron. J. 74 : 283—287.
14. Willson, D.O. and W.L. Hargrove 1986. Release of nitrogen from crimson clover residue under two tillage systems. Soil Sci. Soc. Am. J. 48 : 1143—1146.
15. Yamada, M. 1991. Significance of multiple cropping systems on intensive material use agriculture. J. Agric. Sci. 46 : 441—445**.
16. Yashiki, T., Y. Takahashi, N. Kiho and M. Shibuya 1991. Partitioning of fertilizer nitrogen and its contribution to total nitrogen accumulation in peanut plants. Bull. Chiba Agric. Exp. Stn. 32 : 91—97***.

* In Japanese.
** Translated from Japanese by the present authors.
*** In Japanese with English summary.