Experiment 3 .

Effect of Vegetable Soybean Biomass Decomposition on Yield of Kale

Objective

1. To monitor the quantity of NO_3^--N and NH_4^+-N release by the decomposition of vegetable soybean green manures.
2. To find out the appropriate quantity of vegetable soybean biomass incorporated and the uptake of nitrogen by kale.

Materials and Methods

Experimental design and plant growing

The vegetable soybean used as green manure for kale was grown in a randomized complete block design with four replications. The application of vegetable soybean biomass at 6 t/rai for treatment 4 derived from the results of the 2nd Experiment. The said outcome showed that the percentage of N-uptake in kale from vegetable soybean was 30.36% with the total average N at 3.1% comparing with 21.2 kgN/rai of chemical fertilizer. The biomass had been decreased to 4,856 kg/rai (25%) and 3,642 kg/rai (50%) for T_3 and T_2, respectively. Besides, T_1 was used as control while T_5 was used as chemical fertilizer. The chemical fertilizer was split application twice, using 20-10-10 (N-P_2O_5-K_2O) at the rate of 60 kg/rai. First application was applied at the rate of 30 kg/rai after the vegetable was transplanted and was top-dressed with the same rate plus urea (46%N) at 20 kg/rai at 20 days after the vegetable was transplanted (DAT). After the vegetable soybean residue was incorporated into the soil for two weeks, the kale

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was transplanted into a 1x0.5 m plot size at a spacing of 15x15 cm. This spacing resulted in 44.4 plants per square meter which is within the range of optimum yield for kale. The experiment was conducted in the experimental plot of the Faculty of Agriculture, Chiang Mai University during January 2006 to June 2006.

Plant sampling

Ten plants of kale were randomly harvested at 14, 21, 28, 35 and 42 days after planting (DAP) to determine weight accumulation in terms of fresh and dry weight. All plant samples were dried in hot-air oven at 70^0C for 48 hrs.

Plant analysis

RGR (Relative growth rate) $= \frac{1}{w} x \frac{dw}{dt}$

$$= \frac{(\text{Ln W2} - \text{Ln w1})}{(\text{T2} - \text{T1})}$$

Where

dW = the increase in plant biomass per unit of plant biomass (W)

dt. = the increase in plant biomass per unit of time (t)

(South *et al*, 1991)

Statistical analysis.

All collected data from the experiments were subjected to statistical analysis of variance (ANOVA) and means were compared using the least significant difference (LSD) at the 5% level of probability (P=0.05), followed SXW version 8.

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Results and Discussion

1. Nitrogen mineralization in soil

1.1. Inorganic-N mineralization in soil .

Inorganic-N mineralized (NH_4^+-N + NO_3^--N) in the soil showed a different pattern, depending on the biomass quantity of amended vegetable soybean plant and with or without root residue. Generally, a soil with root residue resulted in a significantly much more total mineralized N than without root residue due to a vast root biomass remaining in the soil. In the root residue, soil N –mineralization occurred in lower concentration in the first week of soil amendment (Fig.4).

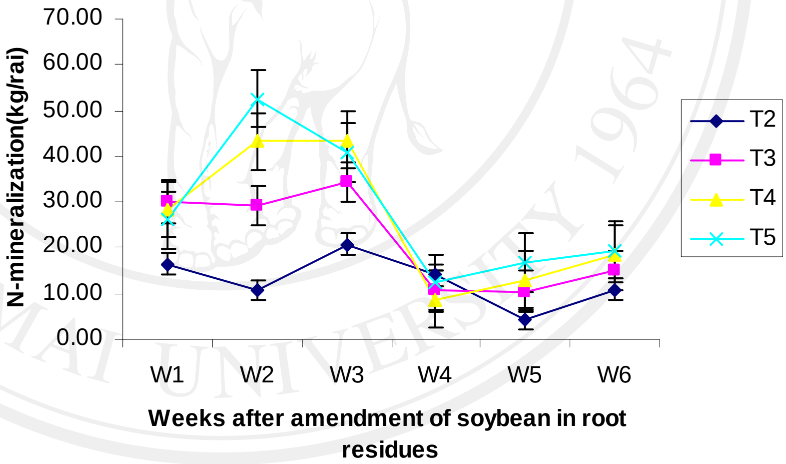

Figure 4 Quantity of inorganic-N mineralization in root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai) ;T5 = N fertilizer at the rate 21.2 kgN/rai.

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Rapid significant increase of total mineralized N was observed at the second week after incorporation. In applied chemical fertilizer treatment, mineralized N was at the highest concentration (52.54 kg/rai) compared to the other treatments. This result indicated that applied chemical N fertilizer (urea) was easy to be mineralized to be inorganic N for plant growth. Significant N release in the second week was in the order of : N fertilizer > biomass 6.47 t/rai > biomass 4.86 t/rai> biomass 3.64 t/rai, at the amount of 52.54, 43.30, 29.05, and 10.69 kg/rai, respectively (Appendix Table4). Mineralization of urea dropped more rapidly in the third week whereas that of plant residue incorporated in soils was less in decreasing. Although chemical fertilizer and higher rate of biomass incorporation (6.47 and 4.86 t/rai) showed continuous decrease in N- mineralization in the fourth week, but the lower biomass treatment (3.64 t/rai) remained at the same level of the third week. However, the amounts of mineralized N in all treatments were not significantly different at the level of 8.73 to 14.03 kg/rai and remained until the sixth week.

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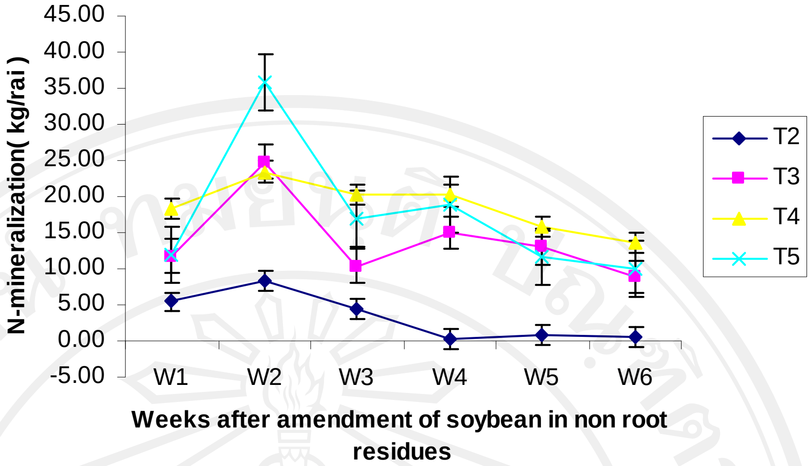

Figure 5 Quantity of inorganic- N mineralization in non root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks (T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai ; T5 = N fertilizer at the rate 21.2 kgN/rai).

In non-root residue soil (Fig.5), trends of N mineralization were similar as in root residue soil. Although in N-urea added soil, at the first week, mineralized N was lower than in 6.47 t/rai plant biomass incorporation treatment, but in the second week, it rose to be higher than the 3.64 t/rai treatment and dropped again in the third week. The amount of mineralized N in all treatments, except N-urea added soil, were dramatically lower since at the third week to the sixth week (Appendix Table 5). H9owever, the quantity of mineralized N in every treatment at all periods of observation were approximately 50% less than that in the root residue soil. This

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evidence might be because of the effect of large amount of underground soybean biomass residues which consisted of roots and leguminous nodules.

NH_4^+-N mineralization in soil

The total mineralized N content in the soil from vegetable soybean residues is defined as the sum of NH_4^+-N and NO_3^--N contents. NH_4^+-N is derived from organic nitrogen in the soil by ammonification process of soil microorganisms. In root residue soil, incorporation of organic N, urea and soybean plant generated NH_4^+-N in the same pattern of total mineralized N. At initial determination, first week, non significant difference of NH_4^+-N was found in all treatments. At the second week, NH_4^+-N was significantly increased especially in urea-N and 6.47 kg/rai soybean biomass treatments which was generated as high as double of the first week, from approximately 20 kg/rai to be 40 kg/rai (Appendix Table 6). An increase and decrease pattern of NH_4^+-N concentration in urea-N was closely related to the treatment of incorporation with 6.47 kg/rai plant biomass. This indicated that soybean plant residue at the high rate was able to release NH_4^+-N equivalent to urea-N. However, NH_4^+-N concentration of all organic N incorporation treatments were lowered down to 6.46 and 2.69 kg/rai at the fourth week and remained at this quantity until the end of experiment (Fiqure 6).

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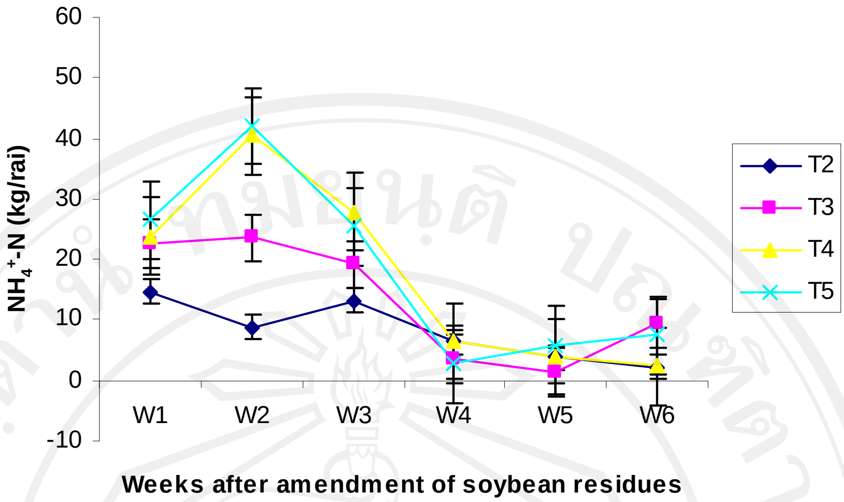

Figure 6 Quantity of NH_4^+- N- mineralization in root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks(T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai ;T5 = N fertilizer at the rate 21.2 kgN/rai).

In non root residue soil, significant low level of NH_4^+-N was observed in every treatment compared to root residue soil. Release of NH_4^+-N at the first and second week depended on the amount of soybean biomass, higher biomass was able to release higher NH_4^+-N. NH_4^+-N was increased to the highest peak in the second week and progressively decreased to below 10 kg/rai at the 3rd to 6th week (Fiqure 7, Appendix Table 7).

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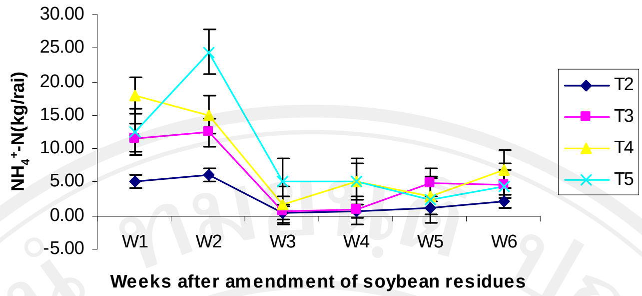

Figure 7 Quantity of NH_4^+-N-mineralization in non root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks (T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai ; T5 = N fertilizer at the rate 21.2 kgN/rai).

1.3 NO_3^--N mineralization in soil .

NO_3^--N was derived from nitrification process of nitrifing bacteria in an aerable soil.

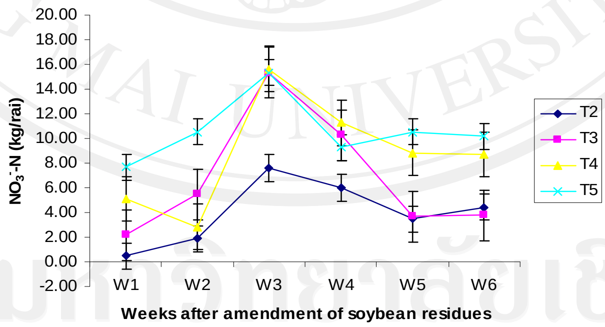

Figure 8 Quantity of NO_3^--N-mineralization in root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks (T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai ;T5 = N fertilizer at the rate 21.2 kgN/rai).

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In root residue soil (Fig.8), NO_3^--N mineralization was not significantly different in different treatments of added organic N, at all observation dates. Lower amount of NO_3^--N was determined at the initial week, then progressively increased to optimal level at the third week in the approximate amount of 7.61 to 15.63 kg/rai. After the third week, the quantity of NO_3^--N remained fairly constant until the end of observation. However, lower soybean biomass incorporation soil seemed to be lower in NO_3^--N (Appendix Table 8). Although similar trend of NO_3^--N increasing was also found in non root residue soil at the first to the third week but it was relatively decreased after the third week of incorporation (Appendix Table 9, Fig.9) while in the root residue soil constantly remained so. Moreover, in this soil condition, it was also found that mineralization was slow in the first two weeks and rapidly reduced in the last two weeks.

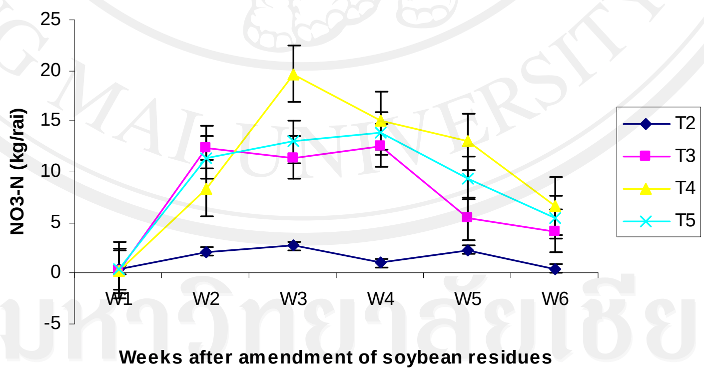

Figure 9 Quantity of NO_3^--N-mineralization in non root residue soil incorporated with vegetable soybean plant biomass at different rates during 1-6 weeks (T2 = soybean residue incorporation at 3.64 t/rai ; T3 = soybean residue incorporation at 4.86 t/rai ; T4 = soybean residue incorporation at 6.47 t/rai ;T5 = N fertilizer at the rate 21.2 kgN/rai).

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2. Yield of kale

Growth of kale in the first two weeks after transplanting did not seem to be dependent on N mineralization because their fresh weights were not correlated with applied plant biomass and urea-N in both root residue soil and non root residue soil.

In root residue soil, responses of kale to mineralized N was initially significantly different at the first and third week (2,4 weeks after sowing). At this growth stage, application of urea-N gave the highest vegetable biomass at 475.73 kg/rai, followed by that of 6.47 t/rai soybean biomass incorporated treatment (279.08 kg/rai). Nevertheless, different levels of soybean plant biomass incorporation did not significantly affect plant growth. Similar growth performance was also observed in the fourth week of growth stage of kale. At harvest stage, five weeks after transplanting, the organic N incorporation treatments showed significant difference on kale yields and they were significantly higher when compared with control. However, yield increment was found when comparing increasing percentage with the control treatment (Table 8).

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Table 8 Comparison of kale fresh weight as affected by different levels of application rate of soybean biomass with root and urea fertilizer (kg/rai).

Treatments \ Weeks	2nd week 14 DAP	3rd week 21 DAP	4th week 28 DAP	5th week 35 DAP	6th week 42 DAP	% increase from control at 6th week (at harvest)
control	34.57 b	54.22	182.80 c	629.06 c	1152.69 b	0
Biomass3.64 t/rai	43.43 a	56.03	208.48 bc	897.37 b	1385.54 ab	20.20
Biomass4.86 t/rai	32.88 b	63.98	254.80 bc	1025.64 b	1389.55 ab	20.55
Biomass6.47 t/rai	38.33 ab	64.33	279.08 b	1115.93 b	1532.20 ab	32.92
Urea 21.2 kgN/rai	41.52 a	66.26	475.73 a	1549.54 a	1645.47 a	42.75
$LSD_{0.05}$	5.61	ns	90.94	244.17	389.91	
CV(%)	7.82	23.45	17.24	12.43	14.57	

Means with the same letter are not significantly different at alpha level =0.05

The increasing percentage of kale yield was estimated at 20.2, 20.5, 32.9 and 42..7 in 3.64 , 4.86, 6.47 t/rai of soybean plant residue incorporation and application of urea-N at 21.2 kgN/rai treatments, repectively. This result indicated that soybean plant residue can be used as a green manure to improve crop yield of kale, even at lower quantity (3.64 t/rai). Although at the higher rate of soybean plant residue utilization, it seemed to affect yield of kale but it was not significantly different when comparing to chemical-N fertilizer.

In non-root residue soil, responses of kale yield to soybean plant residues and chemical-N treatments were similar to root residue soil. Significant difference on growth of kale as determined by fresh weight was found at the third week after

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transplanting. In the first two weeks (2,3 weeks after sowing), growth of kale seemed to be in the initial growth stage because there were variations among treatments and they were not significantly different at all. However, growth of kale in every treatment dramatically increased along with growing stages. At the third, fourth and fifth week (4,5 and 6 weeks after sowing) after transplanting, there were significant differences in fresh weight among the treatments. Incorporation of soybean plant residues at higher rate produced higher yield, especially at 6.47 t/rai which gave vegetable fresh weight at the same level of urea-N treatment. Comparison in percentage increasing over control showed linear increase at 49.60, 66.16, 89.80 and 102.88% in the treatments of 3.64, 4.86, 6.47 t/rai incorporated soybean plant residue and 21.2 kgN/rai, respectively (Table 9).

In non-root residue soil, crop yield responses were found at the 4thweek after transplanting of kale. Although application of urea-N seemed to produce higher yield but there were generally no significant differences with all soybean plant residue incorporation treatments, especially at the 5th and 6th week of growth stage. However, lower rate of plant residue treatments showed lower yield production. At the 6th week stage, application of soybean plant residue produced kale yield at equivalent level to urea-N treatment, (Table 9). Yield responses of this experiment differed from the root residue soil in lower kale yield production.

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Table 9 Comparison of kale fresh weight as affected by different levels of application rate of soybean biomass without root and urea fertilizer (kg/rai).

Weeks / Treatments	2^{nd}week 14 DAP	3^{rd}week 21DAP	4^{th}week 28 DAP	5^{th}week 35 DAP	6^{th}week 42 DAP	% increase
control	41.19	58.02	191.14 b	302.22 b	568.00 b	
Biomass3.64 t/rai	39.29	60.63	179.24 b	568.89 ab	849.73 ab	49.60
Biomass4.86 t/rai	33.02	83.66	278.74 ab	623.59 ab	943.77 ab	66.16
Biomass6.47 t/rai	33.20	79.75	302.99 ab	732.99 a	1078.06 a	89.80
Urea 21.2 kgN/rai	52.75	84.51	422.51 a	702.91 ab	1152.34 a	102.88
$LSD_{0.05}$	ns	ns	187.67	408.85	498.63	
CV(%)	26.70	28.72	36.26	37.05	28.84	

Means with the same letter are not significantly different at alpha level =0.05

The highest yield was at 1,152.34 and 1,078.06 kg/rai in the treatments 21.2 kgN/rai of urea and 6.47 t/rai of soybean plant residue, followed by application of 4.86 and 3.64 t/rai of plant residue treatments which provided 943.77 and 849.73 kg/rai fresh weight of kale, respectively. However, the increasing potential was rather high when compared with those in root residue soil. Similar responses of kale on organic N application was also found in dry biomass (Table 10). At harvest stage, increasing of dry weight was related to plant nutrient sources. The responses to lower soybean biomass application were lower than that of the higher rate. Nevertheless, N source from urea showed higher kale biomass than the soybean plant residue treatment. This

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could be concluded that organic materials from the soybean residue act as an easily decomposable C source for microorganisms and cause immobilization of N so that the available N in residue incorporation treatments became less than that of urea-N.

Table 10 Comparison of kale dry weight as affected by different levels of application rate of soybean biomass with root and urea fertilizer. (kg/rai)

Weeks / Treatments	2nd week 14 DAP	3rd week 21 DAP	4th week 28 DAP	5th week 35 DAP	6th week 42 DAP	% increase
control	4.34 bc	9.97	27.17 b	95.36 b	329.83 c	
Biomass3.64 t/rai	5.22 a	9.72	21.97 b	115.07 b	486.96 bc	47.64
Biomass4.86 t/rai	3.90 c	7.88	26.15 b	129.84 b	499.07 bc	51.31
Biomass6.47 t/rai	4.52 b	7.53	23.72 b	125.21 b	554.47 b	68.11
Fer.21.2 kgN/rai	4.74 ab	7.57	86.65 a	227.23 a	906.72 a	174.91
$LSD_{0.05}$	0.51	ns	10.46	59.07	169.36	
CV(%)	5.90	23.92	14.96	22.65	16.20	

Means with the same letter are not significantly different at alpha level =0.05

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Table 11 Comparison of kale dry weight as affected by different levels of application rate of soybean biomass without root and urea fertilizer. (kg/rai)

Weeks / Treatments	2nd week 14 DAP	3rd week 21 DAP	4th week 28 DAP	5th week 35 DAP	6th week 42 DAP	% increase
control	5.42	7.39	19.51	91.55	182.86 c	
Biomass3.64 t/rai	5.10	7.40	19.47	89.44	297.17 b	62.51
Biomass4.86 t/rai	4.19	9.79	25.55	127.09	314.98 b	72.25
Biomass6.47 t/rai	4.14	9.61	29.28	139.01	349.45 ab	91.10
Fer.21.2 kgN/rai	6.65	10.10	37.21	183.70	431.29 a	135.86
$LSD_{0.05}$	ns	ns	ns	ns	111.25	
CV(%)	22.15	28.78	30.54	37.37	18.75	

Means with the same letter are not significantly different at alpha level =0.05

3. **Relative growth rate (RGR).** Generally, growth performances of kale in terms of fresh biomass were simultaneously increased by different rates of soybean residue and urea-N application (Fig10) and the impact was further enhanced by fertilizers, soybean manure and urea-N. RGR of all treatments, except control, increased rapidly from the second to the fourth week, then declined one week later (at the fifth week). RGR in urea-N treatment declined faster than the other treatments. However, RGR of urea-N was of the greatest average value while the control was the lowest. This result indicated that RGR was correlated with soil fertilities derived from manures and urea-N. Similar trend of plant growth was found in non-root residue soil but the RGR was significantly lower than the root residue soil. However, Agren (1985) said that RGR is directly controlled by the concentration of N within the plant while Robin *et al.*(2000).

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studied on responses of lettuce growth rate to nitrogen supply by varying % total N from1 to 6 and found that RGR of lettuce was increased from 0.04 to 0.16 $gg^{-1}day^{-1}$

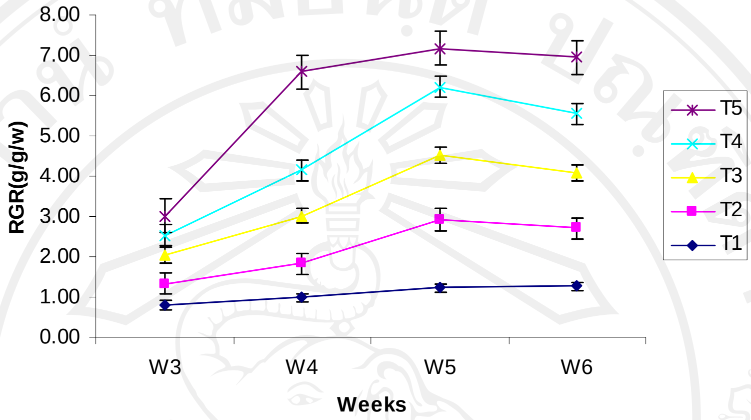

Figure 10 Relative growth rate of kale as affected by different treatments of organic N application grown in root residue soil

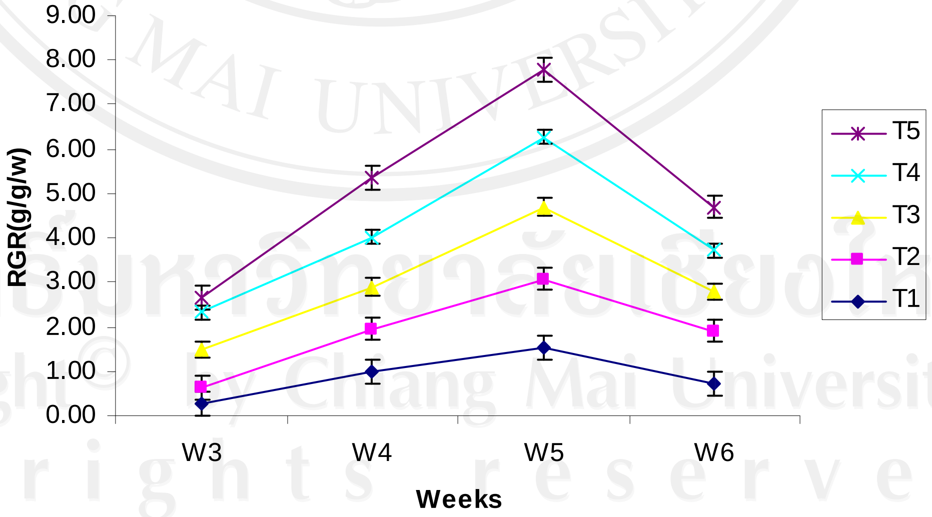

Figure11 Relative growth rate of kale driy weight as affected by different levels of soybean biomass without root and urea fertilizer

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GENERAL CONCLUSIONS

The use of N-fixation from soybean is one choice for soil conservation and decreases the use of chemical fertilizer, not only to protect soil from chemical fertilizer but also for sale of fresh pods. In this study, soybean (*Glycine max* Merr.) No. 75 was selected because it can produce a lot of yield.

In the present study, it was found that number and dry weight of nodules were significantly different when nitrogen fertilizer was used at different rates. Excessive nitrogen fertilizer application decreased number and weight of nodules whereas economic yield and biological yield significantly increased. To understand N-uptake efficiency of kale from soybean nitrogen, soybean was labelled with ^{15}N for plot experiment. Plots (metal frames 25 by 50 by 40 cm, length by width by height) were grown with ^{15}N labelled soybean by using nitrogen fertilizer at the rate, ranged from 0, 16, 32 and 48 kg N/rai and used Mass spectrometer to detect nitrogen from each part of soybean. It was found that total N was contributed from three different sources, i.e , atmosphere 50.01% (19.36 kgN/rai) , fertilizer 16.57% (6.52 kgN/rai) and soil 33.42 (12.98 kgN/rai).

The soybean green manure was incorporated manually into the soil. Green manure application increased soil total N, NH_4^+-N and NO_3^--N contents. Total N reached highest level in 2 weeks at 14.11 kg N/rai and dramatically decreased until to 0.18 kg N/rai in 6 weeks, relative with NH_4^+-N that increased in first week to 2.52 kgN/rai and slightly decreased until 0.12 kgN/rai and NO_3^--N reached highest level in 2 weeks at 11.45kgN/rai and decreased until 0.17 kgN/rai in 6 weeks. Two weeks after

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incorporating soybean green manure into soil, kale seedlings(14 days after sowing) were transplanted into each plot. Soybean green manure ^{15}N recoveries in kale were determined. After 14 days (DAP), determination of fresh weight and dry weight was carried out every week until 48 days. From vegetable soybean biomass of 2.4 t/rai, highest fresh weight of kale about 1,345.79 kg/rai,was produced and when using vegetable soybean biomass of 2.3 t/rai , 2.0 t/rai and control, fresh weights of about 1,262.11, 1,194.87 and 995.10 kg/rai were produced, respectively. Nitrogen uptake by kale was measured by the different rates of ^{15}N fertilizers in vegetable soybean that was incorporated as green manure into the soil. From this experiment, it was found that soybean ^{15}N recovery in kale was about 31.01, 30.48 and 29.59% or 12.53, 12.39 and 10.70 kgN /rai of total N in vegetable soybean that used ^{15}N fertilizer at rate of vegetable soybean biomass 2.4, 2.3 and 2.0 t /rai, respectively.

Calculated biomass of soybean green manure by using percent of ^{15}N uptake in kale to compare among 5 treatments : first, not used biomass(control), used soybean biomass less than received from calculate 50%(3.64 t/rai) (suggestion from Department of Agriculture; N=21.2 kg N/rai), used biomass 25%(4.86 t/rai) less than suggestion, used biomass by suggestion and last method, used chemical fertilizer 21.2 kgN /rai. Experiments were run simultaneously on two fields, each with different soybean green manure system: mixed with roots and non root. In location that was incorporated with soybean roots, highest yield of 1645.47 kg/rai, was found in application of chemical N fertilizer 21.2 kgN/rai but when reduced biomass to 6,474, 4,856 and 3,642 kg/rai, yields of 1,532.20, 1,389.55 and 1,385.54 kg/rai were received, respectively. The

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effect of soybean green manure in location with non root was similar to that incorporated with root where the use of chemical fertilizer 21.2 kgN /rai produced highest yield about 1152.34 kg/rai but when reduced biomass to 6474, 4856 and 3642 kg/rai would receive yield of 1,078.06, 943.77and 849.73 kg/rai, respectively. Control plot produced lowest yield of kale only 568 kg/rai.

Suggestion for fertilizer application

N in vegetable soybean comes from the atmosphere about 50.01% by fixation, N-uptake from application of chemical fertilizer 16.57% and 33.42% from soil and residues of fertilizer in soil . More application of nitrogen fertilizer reduced nitrogen fixation of rhizobium whereas biomass and yield of soybean had increased, significantly different in fertilizer rates of 16, 32 and 48 kg/rai. However, inoculation with rhizobium and the use of N 16 kg/rai resulted in highest nitrogen fixation, highest number of nodules and nodule dry weight.

N-uptake (%) in kale was not significantly different when using soybean green manure in different rates but an increase of soybean biomass had increased yield of kale. In this experiment, incorporated biomass into soil with no fertilizer was not sufficient for the requirement of kale.

% FUE in kale was not significantly different when using soybean green manure in different rates and the highest %FUE averaged 36.24% by using vegetable soybean biomass of 6.47 t/rai. However, soybean biomass with 2.0 t/rai gave the lowest fertilizer use efficiency (FUE) averaged 32.73%.

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Suggestion for green manure application

It was found that the use of chemical fertilizer at the rate of 21.2 kgN/rai and the use of 6,474 kg/rai biomass at two locations were not significantly different in yield of kale. The problem found in this experiment was that one rai of vegetable soybean at two locations produced only 1,310 kg/rai biomass (exept pods). So one rai of vegetable soybean biomass can support only 1/5 rai of kale.

From this study, it could be suggested that after incorporating vegetable soybean stover with root amended in soil about 2 weeks, it should be suitable for planting the next crop because decomposition rates and the peak of total-N release was highest.

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