ソバの生育と体内養分変動に及ぼす緑肥ダイズと微生物資材施用の影響

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Growth and Nutrient Dynamics of Buckwheat (*Fagopyrum esculentum* Moench) as Influenced by Different Applications of Green Soybean Manure and Bio-decomposer*

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Abstract : The growth and relative uptake of N. P, K, Ca and Mg of buckwheat was measured following the application of green manure from four growth stages of soybean with and without a bio-decomposer. The relative uptake rates (RURs) for all nutrient elements increased with the increasing relative growth rates (RGRs) of buckwheat. Although all RURs were linearly and positively correlated with RGRs, none of the homogeneity tests of the regression coefficients was significant. In absolute terms, all RURs were lower than RGRs with the exception of N with the bio-decomposer. There was a strong positve linear relationship between N and the coefficients of P, K, Ca and Mg during the green manure treatments both in the presence and absence of the bio-decomposer. Despite the reduced nutrient utilization efficiencies observed, the nutrient harvest indices of the crop were reasonably high. Applying soybean green manure from the first pod harvested stage together with a bio-decomposer proved to be a promising management alternative to that of application of manure from the flowering stage.
Key words : Green manure growth stages, Nutrient elements, Relative growth rate, Relative uptake rate.

ソバの生育と体内養分変動に及ぼす緑肥ダイズと微生物資材施用の影響 : アロティ ダニエル フランシス パポ・堀内孝次・宮川修一 (岐阜大学大学院連合農学研究科)

要 旨 : 異なる4生育段階の緑肥ダイズを微生物資材との併用条件下で施用した場合のソバの生育と栽培期間中の体内養分 (N, P, K, Ca, Mg) 変動について検討した. 相対養分吸収率 (RUR) は全ての栄養素で相対生長率 (RGR) と正の相関を示したが, 回帰係数間には有意差はなく, いずれのRURも微生物資材を併用したNの場合を除いてRGRより低かった. 微生物資材投与の有無に関係なくNとP, K, Ca, MgとのRUR間には高い正相関がみられた. また低い養分利用率に関わらず, 養分吸収指数は高かった. ソバの収量については微生物資材を併用したダイズ若莢収穫初期の莢収穫後個体の緑肥施用で開花時個体施用の場合と同様の収量が得られた.
キーワード : 基本栄養成分, 相対生長率, 相対養分吸収率, 緑肥の生育段階.

The application of leguminous green manure has been advanced as a critical factor in sustainable agriculture, especially where access to inorganic fertilizer is scarce. Knowledge of the kinetics of manure decomposition is crucial to maximize management techniques, such as the timing of green manure planting and incorporation into the soil.

Generally, the rate of decomposition of green manure is affected by the biological and chemical properties of soil, temperature, moisture and the nature and chemical composition of the green manure legume[23,24,36]. Additional properties essential in determining the rate of decomposition include residue particle size, carbohydrate content, levels of soluble and total N, and the presence of other mineral elements, lignins and polyphenols[12,32,34,35]. The age and/or growth stage of green manure is another important property.

There are numerous studies on the utilization of immature green manure legumes[6,15,30,32,34,36]. In contrast, relatively little information is available on the application of green manure after pod harvesting[6,25,26]. These studies are important since farmers are bound to derive some income from the legume itself as well as the improvement of soil fertility.

Studies on the nutritional value of green manures have focused mainly on N release and uptake by successive crops. The factor that seems to have received little recognition is the return of secondary nutrients (Ca and Mg) and micronutrients (Fe, Mn, B, etc.) to the soil[11]. Investigation in these areas is also important since they may directly or indirectly influence N-release from applied green manures.

Many discrepancies concerning the amount of N released from green manures to succes-

* Part of this work was presented at the 199th meeting of the Crop Science Society of Japan in April 1995.

sive crops were recognized. Most previous studies showed that N release is relatively slow and minimal[4,5]. This situation should be aggravated with the increasing age of the legume. Hence, the need for application of a bio-decomposer to enhance the rate of decomposition and subsequent nutrient release from mature green manures can not be over emphasized.

The efficacy of the bio-decomposer "Wara ace" on rice straw in two contrasting soils and water regimes has been reported[16]. Wara soil, a recent development and improvement over Wara ace, was used here to assess decomposition on green soybean, our chosen green manure source.

The green soybean, a popular summer delicacy, was selected because its succulent stover after pod harvesting could serve as a good green manure material for the minor season buckwheat crop. Buckwheat, although a minor crop in most countries, is currently ganining substantial nutritional recognition because of its effectiveness in the treatment of hypertension, diabetes and cardiovascular diseases[27,28]. Good management of the crop is therefore important to utilize its potential.

Recently, numerous attempts have been made by plant nutritionists to relate the growth rate of plants to their nutrient uptake[1,2,3,10,19,20]. For lower plant species such as plankton, the Droop and other related equations[8,9] have been used extensively. Ågren[2] proposed a single formula that relates growth to the concentration of several nutrient elements for many plant species. A modification of this formula led to the so-called "steady state nutrient concept"[21,22]. This concept has provided theoretically derived and testable predictions about nutrient balance and plant growth. When plants have adjusted to nutrients in soils, the concept states that : i) their relative growth rates and relative uptake rates are equal (i. e. RGR=RUR) and ii) relative growth rates of their different parts (organs) should also be equal. Deviations from these predictions would indicate a stress situation to which the plant can adapt by changing its growth prttern.

Unfortunately, most of these studies were conducted with nutrient solutions under controlled environments. The extent to which these results are relevant to green manures in soils under normal environmental conditions is uncertain.

Our aims were 1) to compare N-release from four growth stages of green soybean manure and its upake by buckwheat in the presence and absence of a bio-decomposer (Wara soil), 2) to assess the extent to which some secondary nutrient elements affect N availability, uptake and general nutrition of buckwheat, and 3) to determine if the nutrients released are synchronized with the crop's demand using the "steady state nutrition concept"[22].

Materials and Methods

A pot experiment which comprised of 2×5 factorial randomized complete block design was conducted from Sept. 2, 1994 to Dec. 2 1994 at the Crop Science Department, Gifu University. The sandy loam soil used for the study had an initial pH of 6.36, total C 3.33%, total N 0.019%, CEC of 8.2 me/100g, available P, K, Ca and Mg of 20.66mg/100g, 10.00mg/100g, 3.4me/100g, and 2.8me/100g respectively, and water-holding capacity of 6.68.

The treatments used were an absolute control and 4 different growth stages of green soybean (*Glycine max*. Merr. cv. Ezo midori) with and without a bio-decomposer (Wara soil : produced and distributed by Asahi Sangyo Co. Gifu, Japan). The chemical and biological composition of the green soybean (green munure material) and bio-decomposer are presented in Tables 1a and 1b.

The green manure and the bio-decomposer were applied at the rates of 560kg/ha (dry weight basis) and 300kg/ha, respectively, on Aug. 19, 1994. Planting of the buckwheat (cv. Botan soba) was on Sept. 2, 1994. Fifteen pots each containing three plants per treatment were used for the study. Details of the treatments are as follows :

T_0 Control (Neither green manure nor bio-decomposer applied)

F Green manure applied at flowering stage (July 19, 1994)

H_1 Green manure applied after lst pod harvest (Aug. 5, 1994)

H_2 Green manure applied after 2nd pod harvest (Aug. 12, 1994)

H_3 Green manure applied after 3rd pod harvest (Aug. 19, 1994)

BT_0 T_0 with bio-decomposer

Table 1a. Composition of the bio-decomposer.

Nutrient elements	Amount	Micro-organisms
Total N (%)	1.6	*Bacillus, Clostridium,*
P_2O_5 (%)	4.9	*Pseudomonas, Penincillium,*
K_2O (%)	0.6	*Aspagillium.*
Zn (mg/kg)	1250	
Cu (mg/kg)	360	

Table 1b. Nutrient content of the green soybean applied.

Nutrient	Growth stage			
elements	F	H_1	H_2	H_3
Total N (%)	4.7	3.6	3.6	3.7
P (mg/100 g)	339	340	339	338
K (mg/100 g)	523	512	525	520
Ca (mg/100 g)	77.0	77.2	80.8	77.7
Mg (mg/100 g)	55.9	57.4	57.6	56.5
C : N	5.3	7.1	7.2	7.2
Lignin (%)	25.5	25.8	26.2	27.0
Cellulose (%)	22.1	23.3	23.7	24.2
Hemicellulose (%)	26.9	27.3	27.8	28.1

BF F with bio-decomposer
BH_1 H_1 with bio-decomposer
BH_2 H_2 with bio-decomposer
BH_3 H_3 with bio-decomposer

1. Soil sampling and chemical analysis

The nutrient status of the soil was determined at the beginning of the experiment. Soil pH was measured in 1 : 2.5 mixture of soil and distilled water. Total N was determined by the Kjeldahl method[7], while total carbon was determined following the method of Parr and Papendick[33] as the ignition loss at 550°C. The CEC, exchangeable K, Ca and Mg in soil were measured on the atomic absorption spectrophotometer after extraction in 1N ammonium acetate (pH 7.0). P was determined colorimetrically by spectrophotometer after reaction with $(NH_4)_2M_0O_4$ and $SnCl_2$.

2. Plant sampling and analysis

Fifteen plants from 5 pots per treatment were randomly sampled at 4 weeks after planting (WAP), 8 WAP and at harvest. These were oven-dried at 78°C for 48h and their nutrient contents were determined. Total N was determined by the Kjeldahl method ; P colorimetrically by the Vanado-molybdate method ; K, Ca and Mg were measured by the atomic absorption spectrophotometer after digestion in a concentrated acid mixture from 75m*l* HNO_3, 15m*l* H_2SO_4 and 30m*l* $HClO_4$. The ignition loss overnight at 550°C of each sample was also determined and the C content calculated as 45% of the ignition loss[33]. The lignin, cellulose and hemicellulose content was determined following the procedure of Harper and Lynch[14].

3. Calculatioins and statistics

The relative growth and uptake rates of the crop were calculated as shown below :

$$RGR = (\ln W_2 - \ln W_1) \ / \ (t_2 - t_1) \quad \cdots\cdots (1)$$

$$RUR = (\ln U_2 - \ln U_1) \ / \ (t_2 - t_1) \quad \cdots\cdots\cdots (2)$$

where,
RGR = relative growth rate,
RUR = relative uptake rate,
W = dry weight of plant or its parts (organs),
U = nutrient uptake or content of plant or its parts (organs), and
t = time.

All data were statistically analyzed following standard procedures for analysis of variance (ANOVA) and the differences between means were tested by the Duncan Waller test, using the SAS system (Statistical Analysis System Inc., Raleigh, N. C., U.S.A). Differences reported were significant at $P < 0.05$.

The homogeneity test of the coefficient of regeression was performed following the procedure and explanation in the "Statistical Procedures for Agricultural Research"[13].

Results

1. Relative growth rate, dry matter yield and yield components

The growth rate of plant parts represented as the slopes of the curves in Fig. 1, generally, showed linear increases during the period. Initially, leaf growth of the buckwheat due to the soybean green manure treatments without the addition of bio-decomposer was linear but slightly peaked up between 8 weeks after planting (WAP) and harvest. On the other hand, leaf growth of the crop from the bio-decoimposer amended green soybean munure treatment showed a linear growth trend until harvest. Green soybean application as flowering stage (F) enhanced the growth of plant parts (organs) and total biomass of the crop both in the presence and absence of the bio-decomposer over the pod harvest stage ones. Highest growth rates of plant parts and total biomass was obtained from the application of the first pod-harvest stage (H_1) green soybean manure than the other two satges, both in the presence and absence of the bio-decomposer. However, the results were only significant between the first pod-harvest stage (H_1) and the third (H_3). The total biomass of the crop varied between 822mg (T_0) and 8886 mg (BF).

There was a closely linear relationship between the relative growth rates of plant parts (PRGR) and whole plant (RGR) (Fig. 2). The higher the relative growth rates of leaves and roots were, the faster the total growth of the crop. Root growth was the most rapid. The homogeneity test of the regression coefficients of plant parts from the green manure treatments with and without a bio-decomposer were not significant (Table 2) and generally lower than the PRGR=RGR line (Fig. 2). There was the tendency of growth to increase when the green soybean manure was applied together with a bio-decomposer. The green manure from the flowering stage (F), however, produced the most outstanding effects on the buckwheat compared to that from other growth stages

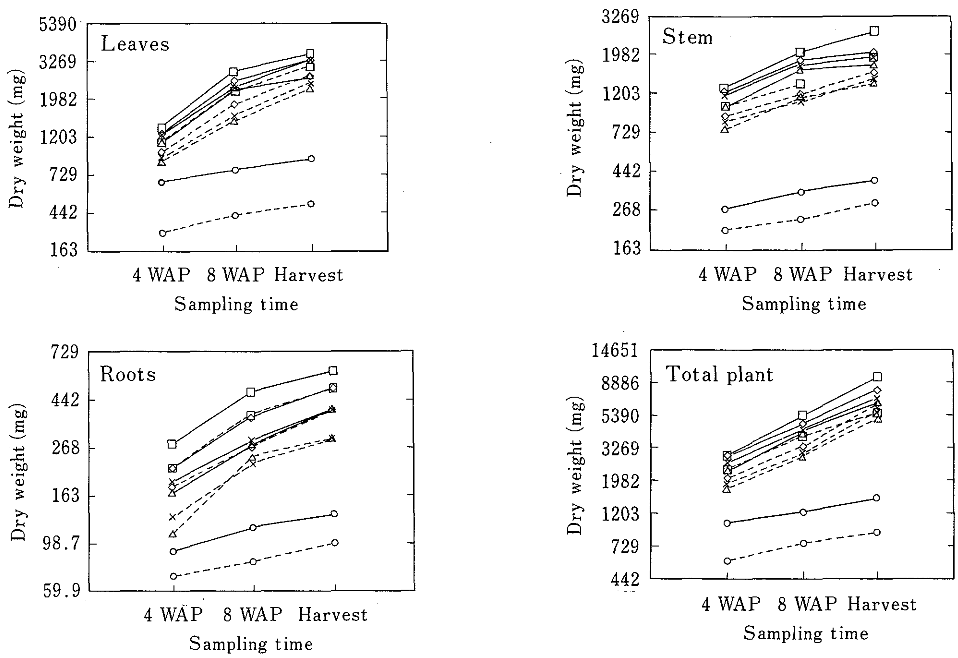

Fig. 1. Growth curves for leaves, stem, roots and biomass in logarithmic scale.

T_0; F; H_1; H_3; H_2; } Bio-decomposer absent;
BT_0; BF; BH_1; BH_2; BH_3; } Bio-decomposer present.

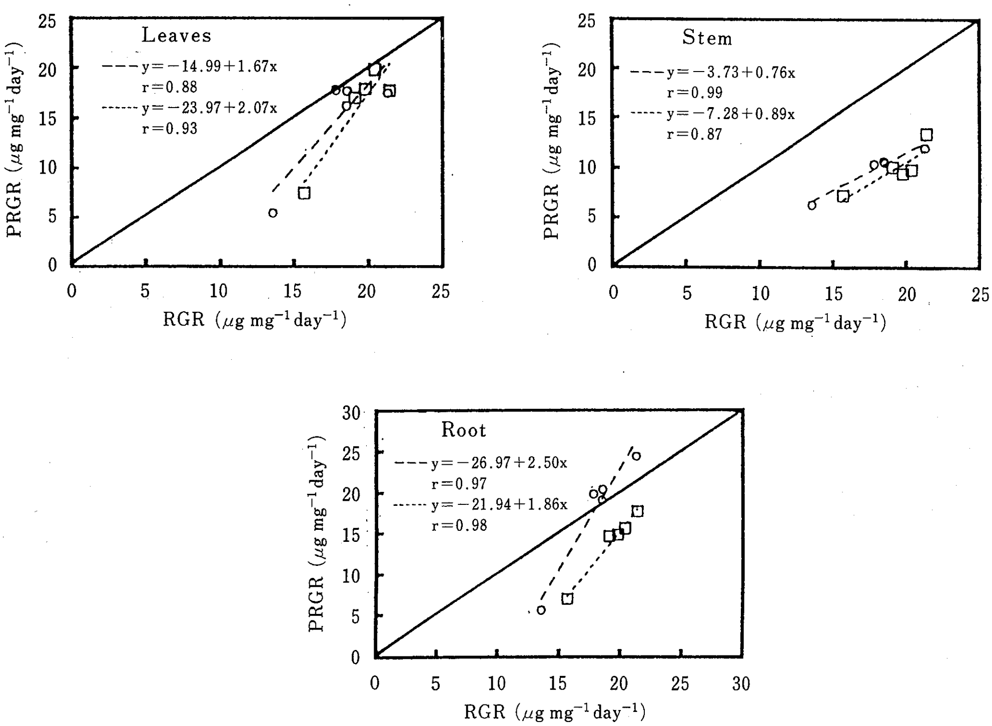

Fig. 2. Relative growth rates of leaves, stem and roots (PRGR) versus relative growth rates of whole palnt (RGR). The diagonal shows that RGR is equal to PRGR.
— — □ — — Bio-decomposer absent ; — — ○ — — Bio-decomposer present.

Table 2. Linear regression summaries for relative growth rates of plant parts and relative uptake rates as related to total relative growth rates of whole plant.

Parameter	Intercept	t-test	Regression coefficient	Homogeneity test	r^2
Leaf DM	−24.0	NS	2.1	NS	0.98
Leaf DM bi-odecomposr	−14.9	NS	1.7	NS	0.98
Stem DM	−7.3	NS	0.9	NS	0.98
Stem DM bio-decomposer	−3.7	NS	0.7	NS	1.00
Root DM	−21.9	*	1.9	NS	1.00
Root DM bio-deomposer	−27.0	NS	2.5	NS	1.00
N	−2.3	NS	0.9	NS	0.86
N bio-decomposer	5.8	*	0.7	NS	0.84
P	−7.4	*	0.8	NS	0.97
P bio-decomposer	−8.2	*	1.1	NS	0.63
K	−2.7	*	0.8	NS	0.88
K bio-decomposer	−0.1	*	0.9	NS	0.77
Ca	−10.9	*	1.0	NS	0.81
Ca bio-decomposer	−12.6	*	1.2	NS	0.82
Mg	−10.4	*	0.9	NS	0.86
Mg bio-decomposer	−9.5	*	1.0	NS	0.7

Columns show intercept and its t-test, regression coefficient and the homogeneity test for the various parameters.
*Significant at $P<0.05$; NS : Not significant.

applied.

Total dry matter yield and yield components were also significantly influenced by the green soybean manure and the addition of bio-decomposer (Table 3). The yield and yield components of buckwheat were highest on the green manure treatments from the flowering stage (F) than the pod harvested ones. Dry matter yield from the first pod-harvest stage green manure (H_1) treatment was highest among the pod-harvest applied treatments.

2. Nutrient uptake and its relationship with growth rate and yield

The nutrient content of buckwheat at harvest, indicating the total nutrient uptake during the growth period of the buckwheat under the treatments applied followed the same trends as those presented earlier for the biomass yield of the crop (Table 4). The relationship between uptake of the selected nutrient elements (Fig. 3) on N content was highly positive and linear. One Hundred milligarms of N was estimated to be released together with 18.9mg P, 26.8mg K, 3.2mg Ca and 1.3mg Mg from the green manure without a bio-decomposer. With regard to the bio-decomposer, 20.7mg P, 29.3mg K, 3.4mg Ca and 1.5mg Mg was estimated to be released.

3. Relative growth and nutrient uptake rates

All the linear regression lines between RUR and RGR (Fig. 4) for all other nutrient elements except N under the bio-decomposer treatment, were signficantly lower than that expressed by the equality (RUR=RGR, i.e.

Table 3. Yield and yield components of buckwheat as affected by growth stages of green manure and bio-decomposer.

Treatment	Cluster per plant	Seeds per cluster	Seeds per plant	% Ripened seeds	1000 seeds weight (g)	Relative yield (%)	Relative total wt. (%)
T_0	7.0 e	3.1 d	29 e	40.7 g	0.9 d	8.0 f	14.5 h
F	13.4 a	4.3 b	58 b	69.1 bc	2.1 b	72.0 bc	82.3 b
H_1	12.7 b	4.0 bc	54 bc	67.8 c	1.9 bc	64.0 d	65.6 d
H_2	12.3 b	3.9 bc	48 c	60.2 e	1.7 c	52.0 e	59.4 e
H_3	11.0 c	3.6 c	42 c	59.7 e	1.7 c	44.0 e	54.2 f
BT_0	8.7 d	3.3 cd	37 d	52.2 f	1.0 d	28.0 f	22.9 g
BF	13.7 a	5.0 a	69 a	74.2 a	2.4 a	100.0 a	100.0 a
BH_1	13.0 a	4.3 b	52 bc	69.6 b	2.1 b	80.0 b	83.3 b
BH_2	12.6 b	4.3 b	49 c	68.1 c	1.9 bc	72.0 bc	74.0 c
BH_3	12.5 b	3.9 bc	46 c	63.9 d	1.8 c	64.0 d	67.7 d

Means with same alphabets within columns are not significantly different at $P<0.05$ (DMRT).

Table 4. Nutrient content of buckwheat at harvest.

Treatment	N	P	K (mg/100 g)	Ca	Mg
T_0	34.4 g	17.0 c	17.4 f	2.1 d	1.7 e
F	501.7 e	137.1 a	183.0 b	21.3 ab	10.3 b
H_1	501.7 e	128.8 ab	137.6 cd	17.7 c	6.9 d
H_2	465.3 ef	126.6 b	127.9 de	15.8 c	6.8 d
H_3	439.5 f	124.2 b	118.2 e	15.1 c	6.7 d
BT_0	70.7 g	18.4 c	37.4 f	2.4 d	2.2 e
BF	649.8 a	147.1 a	228.1 a	24.3 a	12.7 a
BH_1	608.7 b	142.1 a	159.3 c	22.5 a	8.9 bc
BH_2	568.7 c	138.4 a	146.8 c	21.0 ab	8.4 c
BH_3	539.3 d	136.6 a	145.2 c	19.4 b	8.4 c

Means followed by same letters within column are not significantly different at $P<0.05$ (DMRT).

the diagonal). Furthermore, none of their regression lines was parallel to the equality line, hence their non-significant homogeneity test values (Table 2). Nitrogen uptake was, however, tremendously raised by the application of the bio-decomposer. Despite the high K uptake (except for the H_3 treatment) by the crop compared to P (Table 4), its line deviated most from the equality line than any other macro-elements. Although the addition of bio-decomposer improved the situation a little, values obtained were still far below the equality line. Despite the lower RUR observed, the nutrient uptake rates of the crop generally showed significant increases with increasing RGR, but deviated significantly from equality with growth.

4. Nutrient utilization efficiency (NUE) and Nutrient harvest index (NuHI)

The nutrient utilization efficiencies of the crop as shown in Table 5 were generally low. The highest nutrient utilization efficiency was obtained from N followed by P, K, Ca and Mg in descending order. Differences between the various growth stages of the green soybean manure applications were also observed. The NUE of buckwheat from the flowering stage soybean green manure treatment was the highest and the third pod-harvest stage the lowest. The addition of the bio-decomposer also improved upon the uptake of the various nutrient elements of the crop.

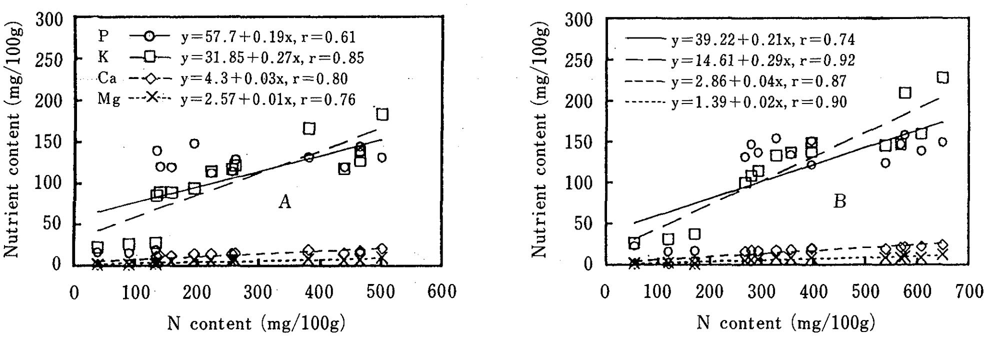

Fig. 3. Relationship between the selected nutrient elements and N content of buckwheat. A : Bio-decomposer absent ; B : Bio-decomposer present.

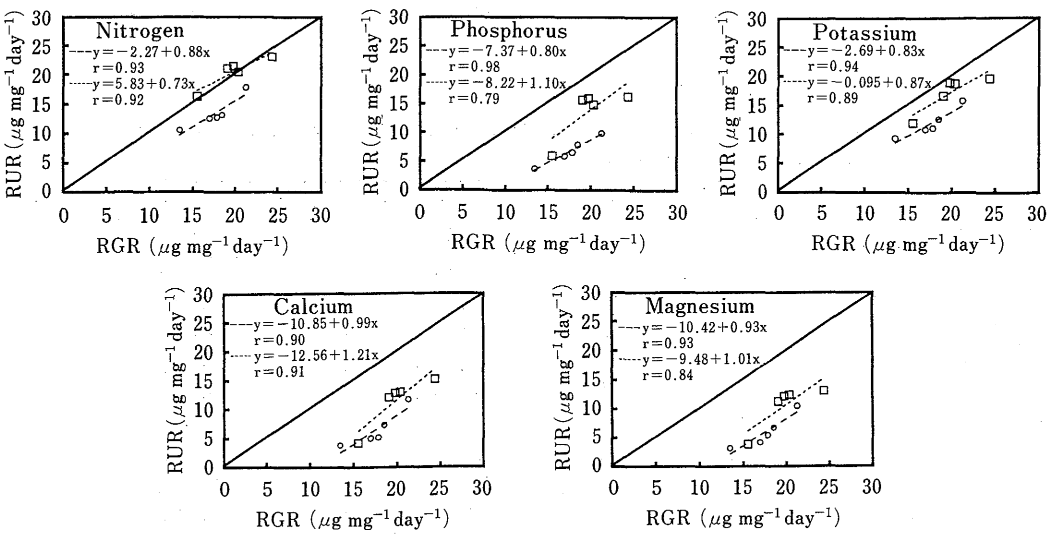

Fig. 4. Relative uptake rates (RUR) of nutrient elements versus relative growth rates (RGR) of buckwheat. The diagonal shows that RUR is equal to RGR.

– – ○ – – Bio-decomposer absent ; – – □ – – Bio-decomposer present.

The proportion of the nutrient in plant than has been partitioned for seed development is indicated as the nutrient harvest index (NuHI). The NuHI (Table 6) of the buckwhear also followed a decreasing order as the NUE but the values were comparataively higher. Significant differences or relatiomship were also observed (in most cases) between growth stage of green soybean manure treatments on buckwheat both in the presence and absence of the bio-decomposer.

Discussion

The buckwheat showed a considerable variation in its dry matter porduction under the various green manure treatments, with and without the bio-decomposer (Fig. 1). Dry matter yield was higher in all bio-decomposer applications than in the non-treated green manure applications regardless of the growth stage at which they were applied. Production by the crop was highest under the flowering stage green manure (F) both in the presence and absence of the bio-decomposer. The fact that the first pod-harvest stage green manure amended with the bio-decomposer (BH_1) gave results quite similar to F (Table 3) implies that it could be a good substitute to that of the flowering (F).

The amount of nutrient element taken up by a crop from an applied green manure may reflect the demand for that particular nutrient element. Usually the amount of N supplied by green manure plants is taken as a basis for

Table 5. Nutrients utilization efficiencies of buckwheat.

Treatments	N	P	K (%)	Ca	Mg
T_0	—	—	—	—	—
F	42.7 d	16.2 b	22.7 b	11.1 ab	7.5 b
H_1	42.7 d	15.2 c	17.0 c	9.2 bc	5.0 d
H_2	39.6 e	14.9 cd	15.8 d	8.2 c	4.9 e
H_3	37.4 f	14.7 d	14.6 d	7.8 c	4.9 e
BT_0	—	—	—	—	—
BF	55.3 a	17.4 a	28.2 a	12.6 a	9.2 a
BH_1	51.8 b	16.8 ab	19.7 c	11.7 ab	6.5 bc
BH_2	48.4 c	16.3 b	18.2 c	10.9 b	6.1 c
BH_3	45.9 c	16.1 b	18.0 c	10.1 b	6.1 c

Means followed by same alphabets within column are not significantly different at $P<0.05$ (DMRT).

Table 6. Nutrient harvest index (NuHI) as affected by growth stages of green manure and bio-decomposer.

Treatments	Nutrient elements				
	N	P	K	Ca	Mg
T_0	51.3 c	58.2 b	60.1 b	59.0 c	57.3 c
F	76.4 ab	72.4 a	76.8 a	68.4 ab	66.3 ab
H_1	71.1 ab	68.9 ab	70.1 ab	64.2 b	61.7 b
H_2	67.2 b	68.6 ab	70.1 ab	63.3 b	60.0 b
H_3	69.1 b	67.1 ab	69.4 ab	63.1 b	59.4 bc
BT_0	55.2 bc	58.6 b	67.7 ab	61.8 b	60.1 bc
BF	85.4 a	75.3 a	79.2 a	71.8 a	70.4 a
BH_1	72.3 ab	73.7 a	78.8 a	67.8 ab	65.3 ab
BH_2	72.1 ab	71.9 a	78.2 a	65.1 b	63.7 b
BH_3	71.4 ab	71.8 a	77.6 a	64.8 b	63.4 b

Means with same alphabets within columns are not significantly different at $P<0.05$ (DMRT).

determining their value in agricultural systems[25,26,29]. Our results (Table 4) showed that, although N uptake was comparatively higher, the total production as observed could not be attributed solely to it. This is evident from the significant positive correlation between N and the other nutrient elements both in the presence or absence of the bio-decomposer as shown in Figure 3. The non-significant homogeneity test of of their regression coefficients (Table 2) which implies an interacting situation[13] further supports this point. These facts indicate the primary importance of N[25,26,29] in addition to the other nutrient elements in influencing the nutrition of the crop.

Nutrient release from green manure may be controlled by the difference between mineralization and various losses, such as leaching, volatilization and immobilization[36]. This phenomenon together with the inherently lower and slower nutrient release status of the green manure may account for the lower dry matter production and nutrient utilization efficiency of the crop observer. It is therefore necessary to investigate the relationship between buckwheat production from these green manure growth stages and various factors, such as immobilization, denitrification, volatilization and some edaphic factors so as to clearly identify the main cause of the lower yield and nutrition of the crop.

As indicated in Table 4, the buckwheat displayed different abilities to absorb different quantities of each nutrient element during its growth from the green soybean manure with and without the bio-decomposer. The adsorption of N and P were high compared with other nutrient elements. These trends actually show that N and P are more important for the growth of the crop, although other nutrient elements are also vital. The finding that biomass yield and nutrient uptake from the bio-decomposer added at first pod-harvest stage of green soybean manure gave results (Table 4) similar to that of flowering stage is also a clear demonstration that, this stage could be a substitute for the flowering stage.

Under steady state conditions, the retlative growth rate among plant parts should be equal[19,21,22]. With the exception of roots, all the correlation lines between the relative growth rate of plant parts (PRGR) and relative growth rate (RGR) of whole plant, fell below that predicted by the equality line (i. e. PRGR=RGR) (Fig. 2). Thus steady state conditions were not achieved. Furthermore, under extreme nitrogen stress conditions, the bulk of resources, mineral nutrients as well as carbohydrates are distributed to the roots[17,18]. This could partly explain the high relative growth rates of roots of the crop as observed in the study. Our results are quite similar to the majority reported on beech[18,31] and birch[10]. Hence the plant reacted to the nutritional stress situation by the development of larger root biomass. The non-significant calculated homogeneity test values obtained indicate (Table 2) an interaction between the relative growth rate of the individual plant part and that of the whole plant.

The availability of a nutrient element to a crop without excessive uptake (optimum nutrition) may be attained when relative uptake rates (RUR) is more or equal to relative growth rate (RGR). Any situation in which relative uptake rate is less than relative growth rate (RUR$<$RGR) is a nutrient-limited situation[2,20,22]. Normal growth when observed under such nutritional stress condition could be due to greater accumulation of carbohydrates than nutrient elements.

Our results showed that all the nutrient elements except N under the bio-decomposer treatments clearly deviated from the equality line (Fig. 4) and were lower than it. This could suggest a nutrient stress conditions as a result of an imbalance between nutrient released from the green manure treatments and uptake by the crop. Hence nutrients releasedwere not well synchronized with the crop's demand. Since our C : N ratio (Table 2a) was within tolerable limits, the lower nutrient availability observed could not be attributed to N immobilization but most probably to the binding action of nutrient elements by polyphenols, as reported by some authors[11,12]. This observation needs further investigations with more sensitive determination methods, so as to produce conclusive results. The minimum deviation of N from the equality line under the bio-decomposer treatment indicates the positive role of the bio-decomposer in making N readily available to the plant. The mechanisms by which the bio-decomposer acts under adverse nutritional conditions such as these need an urgent attention.

Despite the lower nutrient utilization efficiencies (Table 5) observed for the crop due to treatments, its NuHI (Table 6) was reasonably high. Hence sink potential was not limiting but rather sink size as shown by the number of seeds (Table 3). The high foral abortion, which is known to be an inherent problem with the crop was further aggravated by the nutritional stress, hence the lower seed set observed during the reproductive period of the buckwheat.

From the results obtained and the discussions made so far, we could conclude that although the N level is important so far as the quality of green manure is concerned, due consideration must also be given to the role of other microelements since they are also necessary for the quality of the green manure in general. Applying the green manure after pod harvesting, especially as first harvesting stage is a promising management alternative to that of flowering. Addition of a bio-decomposer could give superb results, provided some of the limiting factors that might mitigate against their effectiveness are identified and addressed.

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