成熟ダイズの緑肥利用と硫安分施がソバの生育と窒素利用効率に及ぼす影響

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Influence of Split Ammonium Sulfate on Nitrogen Availability from ^{15}N-Labeled Matured Soybean as Green Manure for Buckwheat (*Fagopyrum esculentum* Moench)

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Abstract : A pot experiment was conducted at the Experimental Farm of Gifu University to study the effects of ^{15}N-labeled matured soybean as green manure, with and without splitted ammonium sulfate, on the growth and nitrogen (N) nutrition of buckwheat. Crop yield ranged between 0.7 to 2.8g/pot. Applying green manure together with ammonium sulfate split in a ratio of 2 : 1 : 1 enhanced higher dry matter yield and seed nitrogen content. The crop derived 5.3% N from green manure when applied alone, and between 7.4 to 13.4% N when applied in combination with split ammonium sulfate and basal P_2O_5 and K_2O. Nitrogen from green manure was most efficiently utilized by the crop when green manure was applied together with split ammonium sulphate at the ratio of 2 : 1 : 1. The "added nitrogen interaction" (ANI) was positive, indicating that the green manure did not furnish the crop with only N but also caused the effective utilization of soil resources as well.
Key words : Buckwheat, Matured soybean, ^{15}N utilization efficiency, Split ammonium sulfate.

成熟ダイズの緑肥利用と硫安分施がソバの生育と窒素利用効率に及ぼす影響 : ALLOTEY Daniel Francis Kpakpo・堀内孝次・宮川修一（岐阜大学大学院連合農学研究科）

要　旨 : ソバの生育に及ぼす若莢収穫後の緑肥ダイズ施用の影響と緑肥由来の窒素利用効率を化学肥料施用条件下でみるため，標識 ^{15}Nを吸収させた緑肥ダイズを用いてソバのポット栽培を岐阜大学研究圃場で行った．その結果，硫安分施の 2:1:1（基肥：第１回目追肥：第２回目追肥）の緑肥を併用した施肥区で乾物収量と子実窒素含量が増大した．緑肥由来窒素％は緑肥単独施肥区では 5.3%であったが，基肥として施用したP_2O_5 とK_2Oと硫安分施を伴った区では 7.4%～13.4%であった．窒素含量の最高値は 2:1:1 施肥区でみられた．付加的窒素作用（ANI）はプラスに働いており，この成育段階でのダイズの緑肥利用は単なる窒素供給のみならず土壌資源の効果的利用にもつながることが明らかになった．
キーワード : 成熟ダイズ，ソバ，^{15}N標識緑肥，^{16}N利用効率，硫安分施.

The utilization of leguminous plants as green manure is gaining popularity in recent years due to the rising cost of chemical fertilizers, their residual polluting effects on the environment[3] and growing concern for long-term soil productivity as well as ecological sustainability[36]. Though the immediate gains from green manuring may not compare favorably with chemical fertilizers, there are long-term advantages, such as improved physico-chemical properties of soil and better utilization of added nutrients[2,13,20,31].

Numerous studies have reported the beneficial effects[5,6,9,12,14,21,34] of green manures to successive crop. However, in most cases, the availability of N from plowed-in legume residues was examined indirectly ("difference method") through crop yields or total N of successive crops. Since the development of the "isotope dilution method"[11], ^{15}N-labeled plant materials have been used to study the fate of N from plant residue during decomposition and their subsequent uptake by such crops as wheat[1,6,7,16,18,19], barley[33], rice[2,4,22,25] and maize[6]. This method enabled researchers to clearly identify and quantify the various sources of N available to field crops from applied fertilizers (organic and inorganic). Unfortunately, the emphasis in these works had been on green manure application, either before or at flowering[1,18,20,29,35,37] with relatively little attention paid to the stage(s) after pod harvesting[28]. Investigations in these fields are important since farmers are bound to derive some income fromthe legume as well as the improvement of their soil resources.

Owing to the lower nutrient status of green manures, coupled with their slower release compared with chemical fertilizers, their utilization together with chemical fertilizers is imperative. However, judicious use of chemical fertilizer is vitally important. The efficiency of N fertilizer has been reported to be significantly affected by the method of application. Split application[32] and placement below soil surface[8] are recommended to prevent N loss through ammonium volatilization.

Much of the research effort has been directed toward identifying the appropriate types of green manure and inorganic fertilizer combinations for both upland and paddy[23,27] crops[1,15,20,28,29,30]. However, research focusing on combinations of green manures and split inorganic fertilizer are lacking.

Buckwheat, a member of the family *Polygonaceae* and genus *Fagopyrum*, is growing in popularity not only because of its high protein and highly balanced amino acid content, but also because of its potential as a possible cure for hypertension[17]. Good management of the crop is therefore important in order to realize its full potential for the benefit of mankind. Although some soil fertility and nutritional research has been done on the crop, not much has been reported on the aspect of green manuring and split N fertilizer application. Hence, the need to undertake such a studies to improve upon the yields and nutritive value of the crop with minimum environmental pollution cannot be over emphasized.

Our objectives were therefore to study : 1) the effects of pod harvested green soybean as green manure, with or without chemical fertilizer, on the growth and N nutrition of the buckwheat, 2) quantify the exact amount of N available to the buckwheat using ^{15}N and 3) identify the appropriate combination of green manure and ammonium sulfate splitting conducive to the growth and development of the crop.

Materials and Methods

A pot experiment using ^{15}N-labeled (50.5% atom abundance) pod-harvested green soybean (*Glycine max.* Merr., cv. Ezomidori) as green manure and split ammonium sulfate as fertilizer sources, with buckwheat (cv. Botan soba) as test crop was carried out at the Crop Science Dept., Gifu University, from 5 August to 27 November, 1994.

1. ^{15}N-labeled sources

The green soybean was grown in pots containing 60 kg/ha labeled ammonium sul fate (50.5% ^{15}N atom abundance), 30 kg P_2O_5 and 30 kg K_2O as single super phosphate and muriate of potash, respectively. The matured soybean was harvested at green stage and the stover was used as the green manure source. The chemical composition of the pod-harvested green soybean used for this study is shown in Table 1.

2. Experimental setup

Freshly harvested stover, including roots of the above ^{15}N-labeled pod harvested green soybean, was chopped into pieces and applied to Yanagido soil ; a sandy loam with pH 6.36, total C 3.33%, total N 0.019%, and available P, K, Ca, and Mg of 20.66 mg/100g, 10.00 mg/100g, 3.4 mg/100g and 2.8 mg/100g dry soil, respectively. The rate of application of the green manure was 3 t/ha (3.2 gN/pot). The ammonium sulfate (AS) was split-applied at 24 kg N/ha (1.5 g N/pot) as basal dressing, and top dressing (4 and 8 weeks after planting) at 4 different split ratios. The amount of ammonium sulfate used was 45% less than

Table 1. Chemical content of the pod harvested soybean applied as green manure.

Percent of dry matter					
Total N	3.6	Lignin	15.8	*C/N	7.1
^{15}N atom excess	22.6	Cellulose	26.3	*Lignin/N	4.4
Carbon	25.6	Hemicellulose	29.3		
Water soluble material	25.3	Ash	3.3		

*Absolute values.

Table 2. Details of treatments.

1. T_0-Absolute control	2. T_1-Standard $N+P_2O_5+K_2O$
3. T_2-Green manure (GM) alone	4. T_3-GM+N(0 : 0 : 0)*$+P_2O_5+K_2O$
5. T_4-GM+N(0 : 1 : 1)$+P_2O_5+K_2O$	6. T_5-GM+N(2 : 1 : 1)$+P_2O_5+K_2O$
7. T_6-GM+N(1 : 2 : 1)$+P_2O_5+K_2O$	8. T_7-GM+N(1 : 1 : 2)$+P_2O_5+K_2O$

*Values in bracket show ammonium sulfate split ratios. For T_4, T_5, T_6 and T_7, 1.5 gN/pot was split applied as basal, 4 WAP and 8 WAP. The standard N was 2.2 gN/pot and was applied as basal.

that recommended for the crop. This rate was based on results from our previous experiment on ^{15}N labeled soybean indicating that 32-45% of the nitrogen content was mineralized within 4 months. Basal 16 kg P_2O_5/ha and 49 kg K_2O/ha as single superphoshate and muriate of potash were also applied to all other green manure pots, apart from the sole green manure treatment. An absolute control (no fertilizer) and standard fertilization treatments of the crop [36 kg N/ha (2.2 g N/pot) : 16 kg P_2O_5/ha : 49 kg K_2O/ha] were also included to serve as checks. Details of the treatments are shown in Table 2.

The green manure was applied on 5 August, and the test crop buckwheat was planted on 19 August. The mode of application used was mixing the fertilizer to the entire volume of soil and ringing for the basal application and the various top dressings, respectively.

3. Harvesting and analysis of samples

Random sampling of 5 pots containing 3 plants each was done at 4 weeks after planting (WAP), 8 WAP and harvest. Plant samples were separated into seeds and stover, oven dried at 78°C for 2 days and weighed. Total N content of both the buckwheat and the pod harvested green soybean (before application) were determined by the Kjeldhal method. The ^{15}N content in each subsample was determined by concentrating the distillate from the Kjeldhal analysis to about 5 m*l* after acidifying with a few drops of 0.1N H_2SO_4 and analysis by the mass spectrophotometer. The water soluble material, lignin, cellulose and hemicellulose of the green manure (pod harvested green soybean) were determined by following the extraction and gravimetric method of Harper and Lynch[10]. The carbon content of the soybean material was determined following the method of Parr Papendick[26]. Ten grams of the soybean material was ignited overnight at 550°C and its C content calculated as 45% of the ignition loss.

4. Agronomic studies

In addition to the yield and yield components, plant height and the chorophyll content of leaf were also measured. The chlorophyll content was monitored by SPAD 501 (Minolta instrument, Japan).

5. Method of calculation

The N recoveries of each sample, which represent the total N in buckwheat originally from the pod-harvested green soybean residue, were calculated by way of two different metnods, namely, the "isotope dilution"[11] and "difference" methods. The isotope dilution method was done by adjusting the total ^{15}N excess in the buckwheat in relation to the ^{15}N atom excess in the green soybean applied as green manure. The equations used for the calculations were as follows :

Isotopic dilution method :

$^{15}NRF = YpNP/YfNF$ .... (1)

Difference method :

$ARF = (NP\text{-}NP_0)/NF$ .... (2)

$\%\ ^{15}NDfGM = (^{15}NRF \times NP) \times 100$ ...... (3)

$GMNUE = (^{15}NDfGM \times NP)/NF$ .... (4)

NF = green manure (green soybean) N applied

ARF = apparent recoveries fraction

$^{15}NRF = {}^{15}N$ recovery fraction

NP_0 = N uptake in absolute control treatment

NP = N uptake in fertilized treatments

Yp, Yf = atom percent excess ^{15}N in the plant and the green manure, respectively.

$^{15}NDfGM = {}^{15}N$ derived from green manure

GMNUE = Green manure ^{15}N utilization efficiency

The so-called "priming effect", or added N interaction (ANI) indicated[9,16], is equivalent to the difference between N recoveries calculated by the difference and isotopic dilution method.

6. Statistical analysis

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

Results and Discussion

1. Plant height and extent of branching

The changes in plant height as presented on Fig. 1 clearly showed the superiority of the ammonium fertilizer (T_1) over any other treatments. Green manure application either alone (T_2) or in combination with the split ammonium sulfate (T_4, T_5, T_6 and T_7) significantly increased both plant height and the extent of branching of the crop. With regard to the green manure and ammonium sulfate combined treatments, splitting at 2 : 1 : 1 (T_5)

Table 3. Yield and yield components as influenced by green manure and split ammonium sulfate.

Treatments	Cluster No./Plant	Cluster No./branch	Seed No./ Cluster	Seed No. per plant	% filled seeds	1000seeds wt(g)	Relative grain yield(%)
T_0	7.2 e	2.2 c	3.0 d	25.0 g	43.5 d	9.5 d	25.0 g
T_1	25.2 a	7.2 b	8.2 a	226.4 a	91.2 a	54.7 a	100.0 a
T_2	13.5 d	7.1 b	4.8 c	64.8 f	72.7 c	19.3 c	64.3 f
T_3	14.8 cd	6.6 b	5.2 c	81.2 e	77.9 c	20.2 b	71.4 e
T_4	19.8 b	7.1 b	6.5 c	127.8 d	83.8 b	23.4 b	82.1 d
T_5	24.8 a	7.6 b	7.3 a	195.2 b	86.8 b	24.1 a	92.9 b
T_6	23.3 a	7.5 b	7.2 a	173.8 c	86.6 b	24.3 a	89.3 bc
T_7	23.2 a	8.3 a	7.0 a	164.3 c	85.9 b	23.8 a	85.7 cd

Means with the same alphabets are not signifficantly different by Duncan's multiple range test ($P<0.05$).

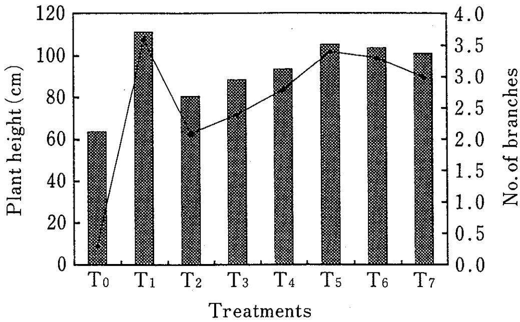

Fig. 1. Effects of green manure and split ammonium sulfate on plant height adn branching. ▩ Plant height, —◆— No. of branches

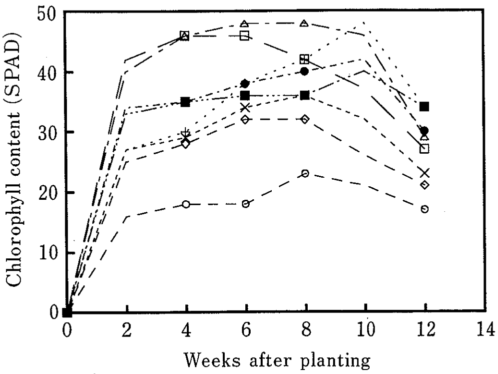

Fig. 2. Chlorophyll content of buckwheat as influenced by green manure and ammonium sulfate.

—⊖- - T_0 ; —⊟ - T_1 ; —◇- - T_2 ; - -✕- - T_3 ; · · +· · T_4 ; —△- - T_5 ; - -●- - T_6 ; —■- - T_7.

produced both taller and higher number of branches. Applying the green manure together with basal P_2O_5 and K_2O (T_3) is important for good plant height as well as branching. All results were significantly better than the absolute control (T_0). Plant heights in the combined treatments compared to the standard (T_1) showed a reduction ranging from 5.2 to 15.3%. Since the susceptibility of a plant to lodging normally increases with increasing plant height, the heights obtained by the combined treatments were considered to be preferable to that of the sole ammonium sulfate treatment (standard : T_1).

2. Chlorophyll content

The chlorophyll content in the absolute control (T_0) was the lowest and those in all other treatments were significantly higher (Fig. 2). The standard treatment (T_1), though initially the highest, declined after 4 WAP, while that of T_5 exceeded and maintained its upward trend around 8 WAP. The combined green manure and the split ammonium sulfate treatments (T_4, T_5, T_6 and T_7), although initially lower than the standard (T_1) did maintain their chlorophyll content over a longer time (up to 10 WAP) before declining. Applying the green manure together with basal P_2O_5 and K_2O also gave higher chlorophyll content in the plant than when the green manure was applied alone.

3. Yield any yield components

The number of clusters per plant was high at T_1, but it was not significantly different from T_5, T_6 and T_7 (Table 3). All other treatments were significantly different however, and higher than the control (T_0), T_2 and T_3 (Table 3). Similar trends and levels of significance as observed on the number of clusters per plant were also observed on the number of seeds per clusters. Interestingly, the number of cluster per branch for all the combined treatments except T_4 were significantly

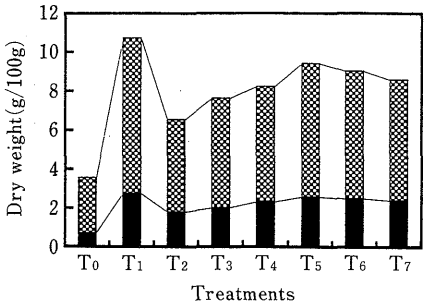

Fig. 3. Dry matter yield of buckwheat as affected by green manure and split ammonium sulphate.

■ Seed wt. ▩ Stover wt.

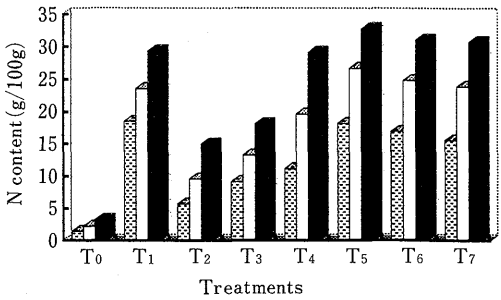

Fig. 4. Changes in N uptake of buckwheat as influenced by green manure and split ammonium sulfate.

▩ 4 WAP □ 8 WAP ■ Harvest

superior (6.0-16.5%) to T_1. Seed number per plant was also significantly superior at T_1 with T_5 the best among the combined treatments. The seed filled percentage for the standard (T_1) and all green manure treatments were significantly higher than the control, with T_1 the highest. No significant difference was observed between T_2 and T_3, but both were significantly lower than the green manure and split ammonium sulfate combined treatments. The 1000 seed weight of the crop in the standard (T_1) and all green manure treatments were likewise significantly improved over the control Although T_1 was the highest, it was not significantly different from T_5, T_6 and T_7 but significantly different from T_2, T_3 and T_4. Ammonium sulfate applied alone or in combination with the green manure also significantly enhanced the yield of the crop (Table 3). Seed (expressed as relative and absolute values in Table 3 and Fig. 3, respectively) and stover yields were also significantly higher in all green manure and split ammonium sulfate treatments than observed in the control, with the ammonium sulfate treatment (standard : T_1) the highest. Applying the green manure together with the split ammonium sulfate in the ratio 2 : 1 : 1 (T_5), was the best splitting alternative. The highest seed yield obtained at T_5 could be due to the longer leaf area duration as depicted by its ability to maintain its chlorophyll content over a comparatively longer period (Fig. 2). The reduction in seed yield in the combined treatments could have been caused by their lower seed number. This would suggest that either high floral abortion or poor fertilization might had occurred.

4. Nitrogen uptake and utilization efficiencies ("Difference method")

Nitrogen uptake by the crop generally, increased from 4 WAP through to harvesting for all treatments (Fig. 4). Although uptake by the crop due to T_4 at 4 WAP was significantly lower than all split ammonium sulfate applied treatments, its value rose tremendously through 8 WAP and attained values not significantly different from T_6 and T_7 at harvest. The N uptake by the crop under the combined treatments was higher than the sole ammonium sulfate treatment (T_1). These results would imply that N was efficiently utilized by the crop when the green manure was combined with the ammonium sulfate. This result corroborates with the majority reported elsewhere[1,16,20].

The top N content of the crop at harvest, ranged between 3.9 to 32.7 g/100 g (Table 4). With the exception of T_4, the ammonium sulfate split treatments were comparatively higher than T_1, the standard. With regard to the seed N, no significant differences were observed among the split ammonium sulfate treatments (T_4, T_5, T_6 and T_7) and the standard (T_1), however all were significantly higher than the control (T_0), T_2 and T_3. On the other hand, the green manure, together with the basal single supersulfate and muriate of patash (T_3), were better than the sole green manure treatment (T_2). The lower N uptake observed at T_1 compared to those in the green manure and sulfate of ammonium combined treatments could probably be due to high volatile N losses from the sole ammonium sulfate treatment. This area needs further

Table 4. Top dry weight, N concentration, nitrogen harvest index (NHI), nitrogen utilization eficiency (NUE) and agronomic efficiency (AE) as influenced by green manure and split ammonium sulfate.

Treatments	Top wt. (g)	Top N g/100g	Seed N g/100g	NHI (%)	NUE (%)	AE (%)
T_0	3.6 g	3.9 e	2.1 d	54.7 e	—	—
T_1	10.7 a	29.3 b	25.0 a	85.2 a	74.7 a	67.2 a
T_2	6.6 f	15.0 d	10.5 c	70.5 d	24.0 f	17.8 c
T_3	7.7 e	18.1 c	13.1 b	72.7 c	30.3 e	23.3 d
T_4	8.3 d	29.1 b	24.1 a	82.8 ab	39.1 d	46.6 c
T_5	9.4 b	32.7 a	25.8 a	78.8 b	61.8 b	50.1 b
T_6	9.1 bc	31.0 ab	25.1 a	81.0 ab	57.5 bc	48.7 b
T_7	8.6 cd	30.7 b	25.0 a	81.5 ab	56.2 c	48.5 b

Means with the same alphabets are not significantly different by Duncan's multiple range test ($P<0.05$)

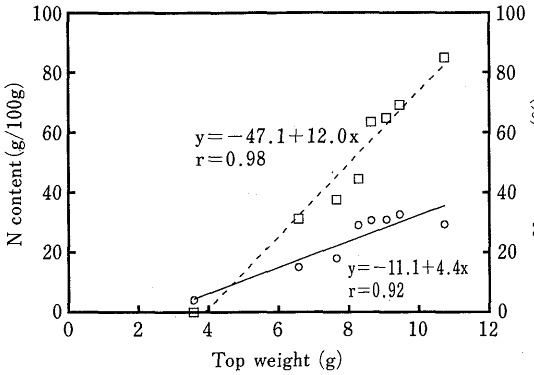

Fig. 5. Relationships between top dry weight and top N content or percent recovery.

—o— N content (g/100g) ; - -□- - % N recovery.

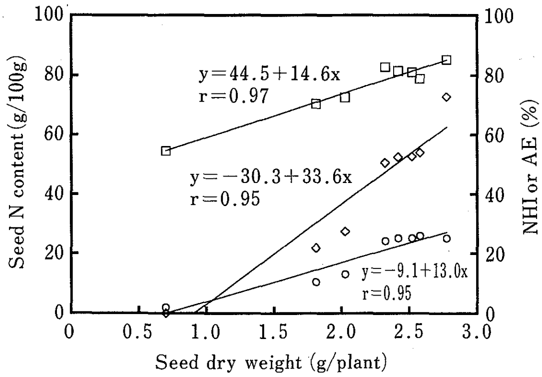

Fig. 6. Relationships between seed yield and N content, N harvest index (NHI) or agronomic efficiency (AE).

—o— Seed N content (g/100g), —□— NHI, —◇— AE.

research to elucidate the problem.

The partitioning efficiency of N reflected as the nitrogen harvest index (NHI), is the proportion of plant N recovered in seed. Contrary to our expectations, T_4, T_6 and T_7 were better than T_5 (Table 4). This shows that N was efficiently partitioned for seed development in these treatments than T_5. This would suggest that higher rates as topdressing are favorable for better seed N content and protein as a whole. Percent N utilization efficiency (NUE) of the crop as calculated by the 'difference method' (Table 4) followed similar trends as observed on most of the parameters discussed so far. The higher recovery by the crop on T_5, despite its lower observed NHI, is a clear demonstration of efficient utilization of N during the vegetative growth stage by the crop as could be deduced from Fig. 4. The higher NUE at T_1 on the other hand, indicates the superiority of inorganic fertilizer as a readily available source compared to the green manure, which is relatively slower. However, the higher NHI and the lower percent of NUE observed in the combined treatments could mean that N release was not well synchronized with the crop's demand.

The agronomic efficiency (AE) defined as 1) the increase in yield per amount of nutrient applied (expressed as kilogram of yield due to fertilizer per kilogram of nutrient aplied), or 2) the proportion of nutrient taken up by the crop (expressed as percent of nutrient taken up per unit nutrient applied). The agronomic efficiency depends upon the native fertility of soil. The lower the native fertility of the soil, the higher the value. Our results in Table 4 also support the fact that splitting the ammo-

Table 5. Percent ^{15}N derived from green manure (NDfGM), N utilization efficiency (NUE) and added N interaction (ANI) as affected by split ammonium sulfate.

Treatments	% NDfGM	% NDfGM increase over T_2	% NDfGM increase over T_3	% NUE	% ANI
T_0	—	—	—	—	—
T_1	—	—	—	—	—
T_2	5.3 d	—	—	1.7 e	22.3 f
T_3	7.4 cd	39.6 d	—	2.8 d	27.5 e
T_4	12.0 c	126.4 c	62.1 c	7.4 c	31.7 d
T_5	13.4 a	152.8 a	81.1 a	9.3 a	52.6 a
T_6	12.7 b	138.6 b	71.6 ab	8.3 b	49.0 b
T_7	12.3 bc	132.1 bc	66.2 bc	8.0 b	48.2 b

Means with the same alphabets are not significantly different by Duncan's multiple range test ($P<0.05$).

nium sulfate together with the green manure enhanced the better seed weight. Splitting at 2 : 1 : 1 (T_5) gave the highest results among the green manure and ammonium sulfate combination treatment.

The regression of percent N recovery, and top N content on top weight showed a highly significant and positive correlation (Fig. 5). These results illustrate that green manure application together with split ammonium sulfate is important for good seed and N content of the crop. Likewise, the relationships between the seed yield, N content, N harvest indices and the agronomic efficiencies (Fig. 6) were also highly positive. This implies that there is a great potential for this management technology provided some of the bottle necks that might show up are well identified and duly corrected.

N derived from green manure and its efficiency ("isotope method")

The importance of the quality of organic residues added to soil on N dynamics in natural and managed ecosystems has long been recognized [9,24,25,30,31,37]. There is a general consensus that net N mineralization occurs if N concentration of the residue is above 2.0% and immobilization occurs below that concentration. It has also been shown that it is the form of N[3,13,32], C and the C : N ratio of the residue that is important. The % lignin or lignin : N ratio is yet another vital parameter[22]. High polyphenolic contents in the material may give rise to lower N mineralization through the process of nitrosation and the formation of stable polymers between the polyphenols and amino acid groups thereby rendering N unavailable to subsequent plants[25,31].

Our ^{15}N isotope results (Table 5) revealed that the buckwheat derived 5.3% of its N from the green manure (%NDfGM) when applied alone (T_2). When basal P_2O_5 and K_2O were added (T_3), the %NDfGM was increased to 7.4%, an improvemnt of 39.6% over T_2. Improvements due to ammonium sulfate splitting ranged from 62.1 and 81.1%, over T_3. Among the split ammonium sulfate application plants, the highest recovery was obtained when the fertilizer was applied as 2 : 1 : 1, with 1 : 2 :1, 1 : 1 : 2 and 0 : 1 : 1 mixtures following in that order. Improvemnts realized were 152.8%, 139.6%, 132.15% and 126.4% over T_2, respectively. Although these results were lower than most reported previously[1,4,13], they essentially suggest that basal N application in addition to basal P_2O_5 and K_2O is vital for the effective decomposition of the pod harvested green soybean and its consequent N releases for utilization by buckwheat. Since the total N content of our material was 3.6%, and therefore higher than the critical value of 2.0%, we expected net N mineralization and the consequent uptake from the green manure to be high. Therefore, the lower N releases and the lower utilization efficiency observed could be attributed to the high lignin content of the material rather than the C : N ratio of the material. We could not say whether or not the presence of polyphenolic components contributed to the above mentioned results. Studies are therefore urgently needed to prove the existence and contribution of the polyphenols during the decomposition of this selected green manure.

The nitrogen utilization efficiencies (NUE) although low, followed the same trends, more or less. These ^{15}N isotope results clearly show that our NUE as calculated by the 'difference method' was over estimated. The difference between these two nitrogen utilization efficiencies termed as the added N interaction (ANI) as presented in the same table gave positive values. The positive ANI indicates that, in addition to its role as a direct source of plant available N, the green manure improved crop productivity through an enhanced availability of soil N and therefore affected the dynamics of the mineralization-immobilization process[15,16].

From the results obtained and the discussions made so far, it could be concluded that the green soybean as green manure can rather be a supplement than a substitute to inorganic fertilizer (ammonium sulfate) in buckwheat production. Basal P_2O_5 (single supersulfate) and K_2O (muriate of potash) are important for effective utilization of the green manure. Finally, splitting the ammonium sulfate at 2 : 1 : 1 is a promising combination with the green manure for good yields and higher N contents. Urgent studies are therefore needed to determine if polyphenols were released during the decomposition of the pod harvested soybean.

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