Use of Starter Nitrogen for Establishing Tropical Legume-Grass Pasture

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Tropical legumes are regarded to be an essential component for increasing pasture productivity throughout vast areas in the tropics and subtropics where N is an outstandingly deficient soil nutrient[5,8].

The beneficial role played by pasture legumes is to maintain or even enhance both quality and quantity of feed produced, and consequently to increase daily gain of grazing animals with minimum agricultural inputs.

It is usually observed, however, that the tropical legumes are very slow to achieve their full dry matter production, biological N_2-fixation, and possible transfer of the fixed N to associated grasses, and hence long time is required before the pastures enter into productive phase[10,14].

Quick pasture establishment which can increase pasture productivity in an establishing phase is the most important agricultural practice in areas of volcanic ash soil and steep slopes of southern Japan, since rainfall sometimes exceeds 100 mm per day during rainy or typhoon seasons, causing pasture erosions. Thus, application of starter N has been recommended in establishing tropical legume-grass mixtures, but published evidences to support this recommendation[8] are only few.

In this paper, therefore, the author attempts to show the beneficial effects of starter N application observed in some agro-physiological experiments in which a tropical legume *Desmodium intortum* cv. Greenleaf and tropical grasses *Setaria sphacelata* cv. Kazungula and S. *anceps* cv. Nandi were used.

Rates and methods of applying stater nitrogen

In contrast to P and K, when N was applied at heavy rates to a legume-grass pasture, the legume population tended to decrease and finally disappeared from the pasture, giving no legume effects for increasing pasture productivity. This is ascribed to the fact that as the grass shows better response to fertilizer N, it overtops legume canopy, and intercepts a large portion of light energy reaching the canopy, so that the associated legume can not receive enough light energy for its normal growth[2]. Dinitrogen fixation by nodulated legumes is also counteracted by higher soil N levels[1,6].

A field experiment was therefore conducted to determine rates and methods of N application which can enhance both legume and grass productivity without any limitation in biological N_2-fixation.

As shown in Fig. 1, total dry matter production was increased with higher rates of N application in the initial growth stage of the pasture mainly due to an increased growth of Kazungula, but the rate which did not induce significant setback in the Greenleaf component was up to 80 kg N/ha.

The increased dry matter by higher rates of N was clearly observed up to the second harvest in the establishing year, but thereafter the highest yield was recorded for 80 kg N/ha and the lowest for 160 kg N/ha. The increased dry matter in the former case might be introduced by a legume effect or by the

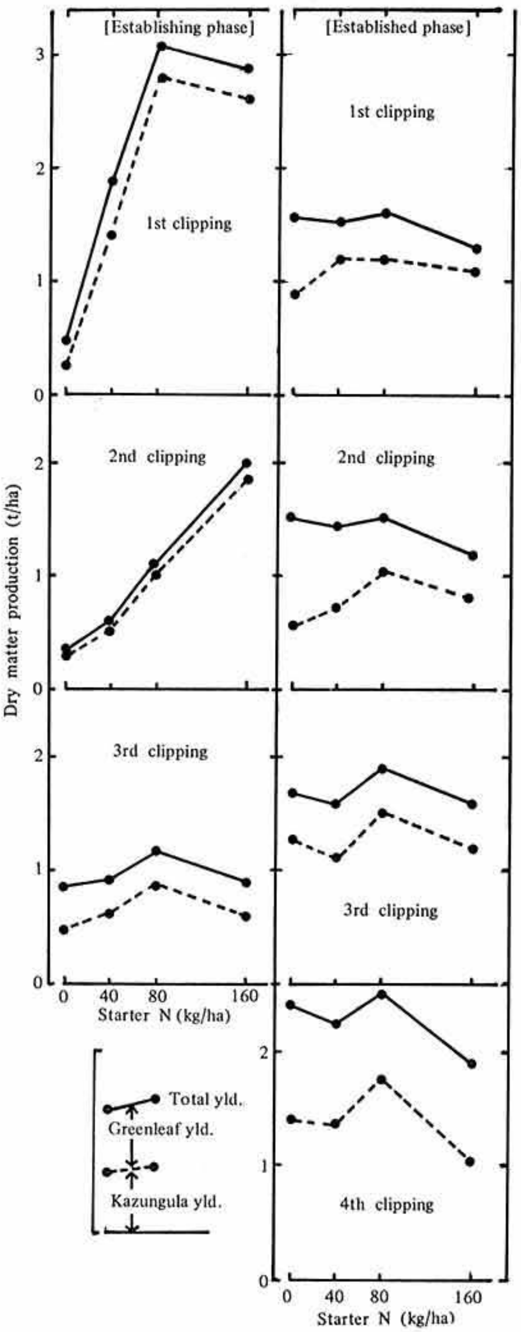

Fig. 1.. Dry matter production of Greenleaf-Kazungula mixture in the establishing year and the established year as affected by rates of starter N application (means of three methods of application).

residual effect of starter N[15]. At the same rate of N, basal dressing appeared to be more favorable for increasing dry matter than split application (Table 1).

Starter N also affects nodule formation directly or indirectly to different extents through plant competition for light and for soil nutrients between legume and grass: Starter N up to 40 kg/ha increased both number and weight of nodules formed in Greenleaf, whereas they were reduced to lower than the control by more than 80 kg N/ha. (Table 2). These adverse effects of application over 80 kg/ha disappeared in the final crop of the establishing year. At the same application rates, basal dressing seems to give better nodule formation of the final crop, similarly as in the case of dry matter production.

Thus, the starter N application up to 80 kg/ha was proved to be effective for accelerating pasture establishment and increasing pasture productivity in the establishing phase.

Factors influencing effects of starter nitrogen

In spite of the favorable effects of starter N application as recognized above, it can not be ignored that the effects may be influenced by various environmental factors such as light intensity, temperature, soil nutrient levels, etc.[1,3,4,7]. An attempt was therefore directed toward evaluating interactions between the effects of starter N and the environmental factors.

1) *Plant competition*

Effects of starter N on growth of legume associated with grass may be moderated through plant competition status which is retrogressively affected by starter N levels.

A pot experiment was conducted to evaluate the interaction between environmental factors and legume-grass competition, and its effect on growth and biological N_2-fixation of Greenleaf grown in association with Nandi.

By the treatment in which tops alone were exposed to the competition (hereafter referred to top competition treatment), growth of tops

Table 1. Dry matter yield and percent Greenleaf in Greenleaf-Kazungula mixture as affected by rates and methods of starter nitrogen application

Starter N rates	Total amount (kg/ha)	0	40				80				160
	Basal-Additional ratio (kg/ha)	0	1–3	2–2	4–0	mean	2–6	4–4	8–0	mean	mean
Establishing year	Total yield (t/ha)	1.69	3.33	3.30	3.59	3.41	4.18	4.85	5.23	4.75	5.60
	1st clipping (t/ha)	0.46	0.85	1.02	1.92	1.26	93	2.09	3.04	2.69	2.73
	Greenleaf %	37	17	18	20	18	12	12	11	11	7
Established year	Total yield (t/ha)	7.13	6.74	7.00	6.76	6.83	7.25	6.82	8.25	7.44	5.90
	Greenleaf %	42	39	36	37	37	28	29	24	27	27
Grand total		8.82	10.08	10.30	10.36	10.24	11.34	11.67	13.48	12.19	11.50
Greenleaf %		41	31	29	31	31	22	23	19	21	16

Table 2. Nodule formation 40 days after sowing as affected by rates of starter N application (A) and nodule formation at the final clipping in the establishing year as affected by methods of starter N application (B)

(A)

Rate of basal N (kg/ha)	0	10	20	40	80	160
No. of nodules/plant	24.7	25.3	25.0	27.8	12.5	8.6
Weight of one nodule (mg)	0.58	0.90	0.65	0.78	0.84	0.45

(B)

Rate of N (kg/ha)	40			80		
Ratio of basal-additional N (kg/ha)	10–30	20–20	40–0	20–60	40–40	80–0
No. of nodules per pot	89.9	96.2	105.5	95.6	104.0	106.0
Weight of nodules per plant (mg/g)	88.6	62.7	100.2	65.6	96.3	102.1
Weight of one nodule (mg)	0.99	0.65	0.95	0.67	0.67	0.96

and roots of Nandi was suppressed, while the top growth of Greenleaf was significantly increased, indicating that Greenleaf was more competitive for light than Nandi. But, Greenleaf showed reduced root growth, probably because its increased top growth must have consumed most of the available assimilates produced (Fig. 2).

In case of root competition, Nandi was much more competitive than Greenleaf, showing greater growth of tops, roots, and leaf area. Nandi roots were able to obtain sufficient N and other nutrients to develop a large leaf area, which in turn supplies sufficient assimilates to the growth of roots. On the contrary, Greenleaf showed severely depressed top growth and leaf area even though root growth was similar to the control. It can be concluded that Greenleaf roots were not able to compete against Nandi roots for nutrients.

When competition occurred with both tops and roots (top and root competition which expresses normal situation in pastures), top growth of Nandi was further stimulated, although the plants were somewhat etiolated, while root growth was restricted due to the shading effect of surrounding plants and increased consumption of assimilates by stems and leaves.

On the other hand, growth of Greenleaf tops and roots was severely depressed. As the depression of the top growth of Greenleaf

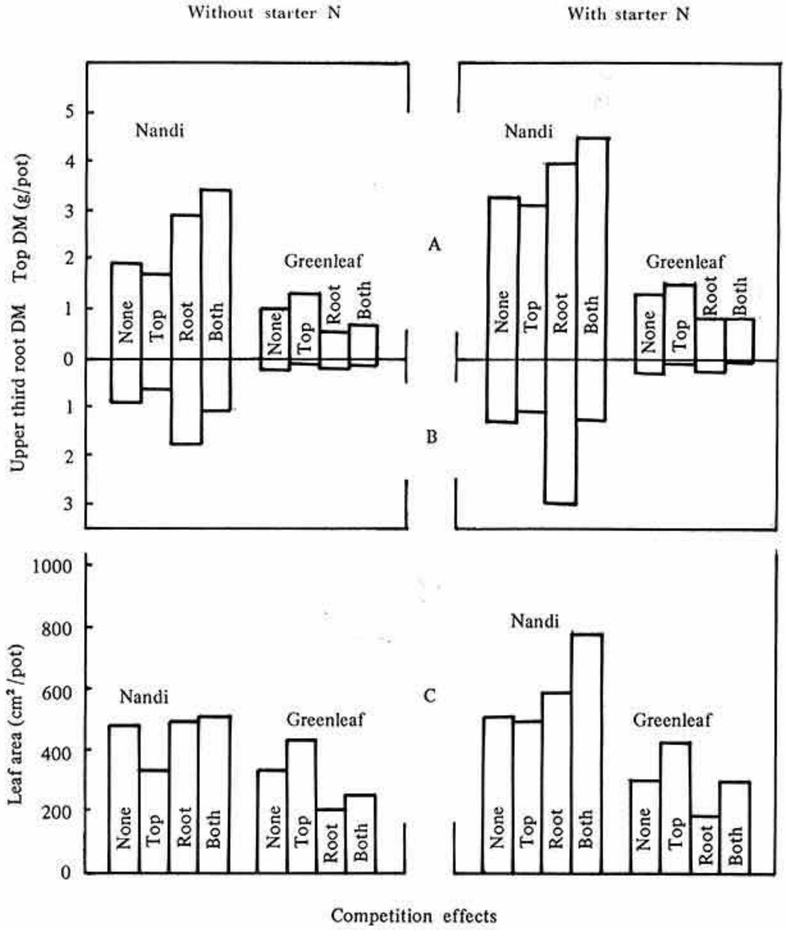

Fig. 2. Influence of plant competition and starter N application on dry matter yield (top and root) and on leaf area of Greenleaf and Nandi mixture

None = control (no competition)
Top = top competition treatment
Root = root competition treatment
Both = top and root competition treatment

was similar to that observed in the root competition treatment, competition for nutrients might be the main factor limiting Greenleaf yields.

Nodulation of Greenleaf was reduced by the top and root competition, but the reduced number of nodules was found to be compensated by an increased specific activity of nodules, after they had been fully developed (Kitamura et al.: *Agron, J.* In press).

As already mentioned, Greenleaf was more competitive than Nandi for light, but it showed more restricted root development than Nandi by the top competition treatment. This result suggests that Greenleaf may probably require, at least, moderate solar radiation levels and lenient management regime to avoid depletion of root reserves and subsequent further reduction in root ability to compete with an associated grass. Thus, starter N application should be limited within 80 kg/ha as indicated before.

2) Temperature and light intensity

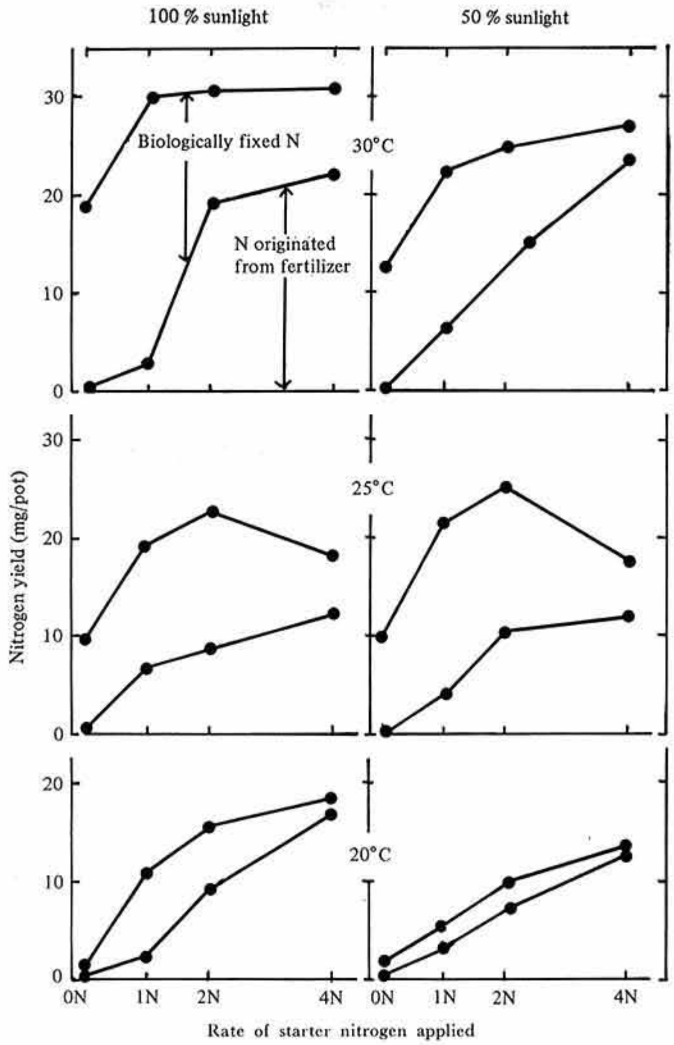

Fig. 3. Nitrogen originated from fertilizer-N and biologically fixed N at various rates of starter N application as affected by growing temperatures and light intensities; Greenleaf (*Desmodium*).

Within a limited level of starter N application, environmental factors might not cause much differences in relative plant growth and N_2-fixation between mono and mixed cultured legume. Therefore, influence of light intensity and temperature on the effects of starter N was examined using the results obtained from the mono-cultured Greenleaf.

Although the plant growth was increased by higher temperature at any rate of starter N application, it was limited by lower light intensities except at lower rates of N at 25°C. Although the total N yield was almost parallel to plant growth, biological N_2-fixation and recovery of starter N were influenced differently by temperature and light intensity. (Fig. 3).

Biological N_2-fixation was increased with lower rates of starter N, but not with heavy application, indicating an favorable effect of the lower rates on biological N_2-fixation.

Nitrogen derived from starter N was

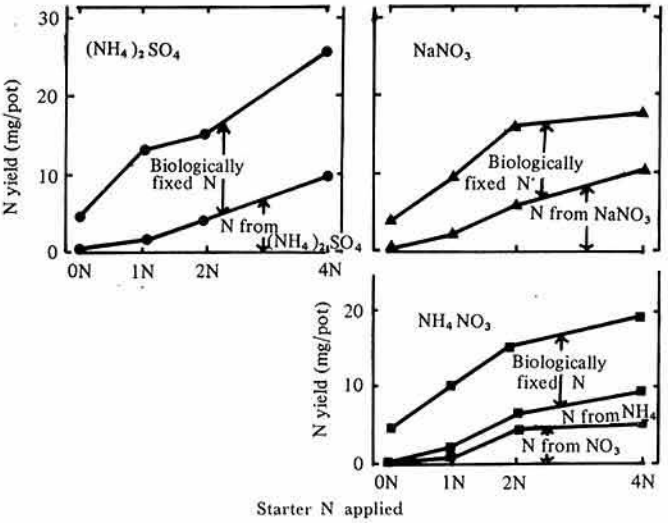

Fig. 4. Nitrogen originated from starter N and biologically fixed N in Greenleaf (*Desmodium*) as affected by rates and forms of starter N applied.
0N: no N
1N: ca. 20 kg N/ha
2N: twice of 1N
4N: 4 times of 1N

increased linearly with the increased rate of starter N almost similar at any temperature and light intensity, suggesting that mineral N assimilation is more or less stable regardless environmental conditions.

Biological N_2-fixation, on the other hand, was much influenced by environmental factors than the mineral-N assimilation: It increased at higher temperature but was somewhat limited with lower light intensity, particularly at lower temperature.

These changes in amount of biological N_2-fixation were partly explained by the changes in nodule formation caused by temperature and light conditions (data not presented).

These results indicate that although biological N_2-fixation was easily affected by environmental factors, the plant growth and total N yield were stabilized or even enhanced by mineral-N application, so that starter N application is an effective way to increase legume production in an early spring of lower temperature and as a result to maximize pasture productivity under hot summer climates. It was also concluded that a limited shading by an associated grass will not severely reduce biological N_2-fixation except under lower temperature conditions.

3) Form of starter nitrogen

The effects of starter N may vary with the form and rate of N applied or by interactions with environmental parameters such as temperature, light intensity, etc.[1,4,10]. Intensity of root hair infection, and nodule initiation, development, and activity are affected by the form of N applied[11], rate of mineral-N-uptake by plant[13], and carbohydrate level available for biological N_2-fixation[3]. Biochemical pathway of assimilating mineral-N is also different depending on the form of N applied.[9]

Thus, the effects of different forms of starter N on the efficiency of biological N_2-fixation, starter N assimilation and plant growth of Greenleaf were investigated using three forms of tagged N.

Although dry matter production was not much different with different forms of starter N, the total N yield varied with the forms of N, showing the highest yield with NH_4-N (Fig. 4).

Uptake of the starter N increased linearly with increasing rates of N, especially when NO_3-N was applied.

Biologically fixed N increased with increasing NH_4-N rates, but with NO_3-N, it showed an increase only up to the rate of 2N, beyond which it decreased. When NH_4NO_3 was applied, it increased only at the rate of 1N and was relatively constant at the higher rates.

Thus, the effects of N forms were more apparent at higher rates of application: NH_4-N stimulated nodule formation and biological N_2-fixation, whereas NO_3-N inhibited both, and NH_4NO_3 was intermediate between these two. NO_3-N was reported to have a negative effect on the early stage of nodule formation, affecting the infiltration process of *rhizobia* into host plants, nodule initiation, and nodule development[11].

Thus, NH_4-N was recognized to be suitable for the starter N. However, NH_4-N tends to lower soil pH[7], shows some negative effects on plant growth[12], and in some cases induces plant disorders.[13]

These adverse effects of NH_4-N may not occur at lower levels of application used in this experiment. Thus, it is suggested that NH_4-N is better than NO_3-N for the use as starter fertilizers for pasture legumes.

Mechanism underlying the positive effects of starter nitrogen

The essential role of starter N in the legume-grass mixture was shown to maintain or even enhance plant growth and biological N_2-fixation of the legume, but not the grass.

In order to know a physiological mechanism underlying positive effects of starter N on the legume growth, time course of leaf area expansion, nodule formation, and tissue N increase derived from starter N or from biological N_2-fixation (using tagged N) were traced.

The mechanism appeared as follows: At the early stage of plant growth when N_2-fixation was not yet active, a rapid plant growth and leaf expansion were induced by starter N application, and which caused an increased translocation of photosynthate to root systems. This, in turn, enhanced nodule formation and N_2-fixation by supplying photosynthate to the nodules. A rapid assimilation of N in the nodules mitigates an inhibitory effect of soil N on nodule initiation and formation.

Summary and conclusion

Starter N applied at less than 80 kg/ha as basal dressing increased the dry matter production of Greenleaf-Kazungula mixture without any setback in the production of legume component, Greenleaf.

Although Greenleaf was more competitive for light than the grass, its roots were not able to compete against the grass roots for soil nutrients. This disadvantage was overcome by the application of starter N at a moderate rate, less than 80 kg/ha.

Uptake of starter N by Greenleaf was more stable under various light intensity $\times$ temperature combination than biological N_2-fixation. Of different forms of N, NH_4-N was most suitable for the starter.

Application of starter NH_4-N at the rates less than 80 kg/ha as a basal dressing is expected to achieve quick pasture establishment and increased levels of the first year's pasture production without causing any retarded growth of the legume component. This will be effective to minimize soil erosion in the establishing phase of pasture. In addition, an increased pasture productivity is expected in the following established phase.

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