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Influence of *in situ* and *ex situ* Green Manures on the Productivity of Rice and Onions in the Mahaweli System C of Sri Lanka

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ABSTRACT. *The benefits of in situ mulching with Sesbania rostrata and the addition of loppings of Leucaena leucocephala as an ex situ manure to provide similar quantities of N were evaluated. The crops used were rice in the Maha (major) season and onion in the Yala (minor) season. The green manures were applied at the inception of both seasons. The usefulness of green manures in substituting all or part of the mineral fertilizer N requirement was also studied. In the Maha season, grain yield of rice obtained with 50% fertilizer N and Sesbania was similar to that of plots receiving the full component of fertilizers with or without green manures. However, application of ex situ green manure with 50% of the recommended rate of fertilizer N produced of lower rice grain yield than that with 100% of N fertilizer. Both green manuring methods could not substitute all of the mineral N, although the quantity of the N added by the organic matter was greater than supplied by fertilizer alone. The full component of mineral N was required to produce high yields of onion with or without green manures. The use of green manures enhanced its yields further. Substitution of part of mineral N requirements of onion by green manuring was not possible. Cost benefit ratios also highlight the usefulness of green manuring, especially in situ, for both crops. The added cost of procurement and application of ex situ green manuring was prohibitive, thus making it a non viable option.*

INTRODUCTION

The use of chemical fertilizer has been a primary factor for increasing rice production in Sri Lanka (Nagarajah, 1980). The most important nutrient contributing to this increase in production has been N.

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Thus, estimates (NFS, 1990) report the application of over 160000 MT of nitrogen fertilizer to rice in 1990, at a cost of Rs. 773 million.

Proper use of green manures leads to increased crop yields due to supply of nutrients, especially N and, long term improvement of physical and chemical properties of soil (Bouldin, 1986). Legumes are effective green manures as they contain high N contents and production of large quantity of biomass within a short period of time (Watanabe and Liu, 1992).

The intensive rice farming systems developed for the topics have not incorporated legumes green manures for maintaining soil fertility. This is primarily due to the inability of farmers to obtain green manures. However recent experiments (Buresh and Datta, 1991; Singh *et al.*, 1991) clearly demonstrate the practical feasibility of using legumes in intensive rice production systems. This is by utilizing the fallow periods between seasons for in situ planting of selected green manure crops.

The benefits of the two principle systems of green manuring on the productivity of rice based systems of new settlement areas of Sri Lanka have not been adequately studied. Thus field experiments was undertaken to identify the usefulness of green manuring on a rice farming systems in the 'system C' of the Mahaweli Development Programme of Sri Lanka. The objective was to study the influence of *in situ* and *ex situ* green manuring with legumes on the productivity of rice (*Maha*)-onion (*Yala*) system, recommended for the region. The possibility of reducing the dependence of inorganic N, on rice culture was also evaluated.

MATERIALS AND METHODS

The study was carried out during the *Maha* season of 1991/92 and *Yala* season of 1992, at the Regional Agricultural Research Centre, Girandurukotte, Sri Lanka. The soil of the site was a Alfisol with the following important characteristics: Texture-sandy loam, pH (1:1 H2O)-7.2, water soluble N 0.006%, Organic carbon-0.030%.

Climate

The rainfall received over the experimental period were as follows: *Maha* season 1152 mm, *Yala* season 365 mm, with 191 mm in the first

(September-October) and 143 mm in the second (March-May) intermonsoonal periods, which is available for green manure cultivation. The mean temperature over the seasons were 28.55 C (*Maha*) and 32.18 C (*Yala*).

The treatments

The treatments were structured with *Sesbania rostrata* grown *in situ* at density of 600,000 or 400,000 pl/ha before rice and onion crops respectively, and adding *Leucaena leucocephala* quantities required to supply the N added by *Sesbania* plant biomass. The full complement, 50% or 0% of the recommended N fertilizer for rice (80 kg N/ha) and onion (60 kg N/ha) and the recommended P2O5 (28.5 and 45.0 kg/ha for rice and onions respectively) were combined green manure treatments. A control treatment was also included with both sources of N. Thus total N received by the rice crop was equivalent to 180.3, 140.3, 100.3, 80.0 kg or 0 /ha with uniform levels of 28.5 kg P2O5 and 38.4 kg K2O/ha in the *Maha* season. The onion crop received either 125.5, 95.5, 63.5, 60 or 0 N/ha with uniform levels of 45 kg of both P2O5 and K2O per ha.

The technique

The experiment was laid out as a randomized complete block design with 3 replicates. The individual plot size was 5 x 5 m. At the onset of pre-monsoon rains in October, 1991, and April, 1992 the land was tilled once, and pre-germinated seeds of *Sesbania* (mean germination 92.1%, was broadcast sown onto selected plots, to obtain densities equivalent to 660,000 and 400,000 plants/ha respectively for both crops. At 45, the biomass and N content of the *Sesbania* were determined. The plant material was incorporated into the soil. At the same time, *Leucaena* leaves and small twigs were also incorporated to selected plots to provide the same quantity of N added by *Sesbania*.

After seven days, (mid November and May), plots were flooded, levelled and 14 day and 35 day old uniform seedlings of rice and onions were transplanted at a spacing of 20 x 15 cm and 10 x 10 cm, respectively as recommended by the Department of Agriculture (1988 and 1991). The crops were managed as per local recommendations, along with fertilizer application. The rice crop was harvested at full maturity (late february) and

grain yield per plot measured and corrected to 14% seed moisture. Irrigation was provided for onion in the dry season, along with the recommended prophylactic fungicidal treatments. The crop was harvested at maturity (September) to determine total and marketable bulb (> 3 cm in diameter) yield.

The economic potential of the system was calculated by the technique described by Garrity and Flinn (1988), and the biomass data subjected to statistical analysis to determine the significance of treatment differences.

RESULTS AND DISCUSSION

Green Manures

The lower quantum of rainfall received in the intermonsoonal season beginning in April, which is characteristic of this region and the higher mean temperatures have not affected establishment and early growth of *Sesbania*. Thus,the required plant populations of *Sesbania* could easily be obtained in both intermonsoonal seasons, which is an asset in the adoption of this technology in the region.

The N content of *Sesbania* biomass (both shoots and roots) was 3.12% $\pm$ 0.26%. Thus the quantum of mineral N added by 3400 and 2100 kg of *Sesbania* dry matter was equivalent to 100.3 kg and 65.5 kg N/ha in the intermonsoonal seasons beginning in October and April respectively. The N content supplied by *Leucaena* leaves added from external sources was also similar. Thus, the requirements of *Leucaena* leaves (3.63% N) from external sources for the two incorporations in October and April were 2765 kg and 1804 kg/ha respectively.

Crop performance

The lowest yield of rice was produced when no fertilizer was added (Table 1), indicating the requirement of external sources of N for high yields of rice variety BG 94-1. Incorporation of organic matter from external sources (*Leucaena*) showed a lower increase in yield (200 kg/ha) than when similar quantities of N were added from *Sesbania* grown *in situ* without fertilizer N. This signifies a beneficial effect of *in situ* green manuring. While this requires clarification, it confirms earlier reports (*eg.* Meelu and

Morris, 1988; Becker *et al.*, 1990) of the benefits of *in situ* green manuring with legumes, especially with *Sesbania*. This could be attributed to the biologically fixed nitrogen by the legume in such systems (Roger and Ladha, 1992). Addition of fertilizer nitrogen with organic matter nullifies this benefit, and produces similar yields, which are greater than plots receiving only organic matter or fertilizer nitrogen. The use of the full complement or 50% of the rate of mineral nitrogen with *Sesbania* produced similar yields. This suggests that the application of *in situ* mulch with *Sesbania* could reduce the mineral N requirement by 50%, in the *Maha* season in this region.

Table 1. Influence of *in situ* and *ex situ* green manures and fertilizer nitrogen on rice yields (t/ha).

Treatments	Yield (t/ha)
Sesbania + 100% fertilizer N	07.4 a
Sesbania + 50% fertilizer N	07.0 ab
Sesbania + 0% fertilizer N	06.0 ab
Leucaena + 100% fertilizer N	07.3 a
Leucaena + 50% fertilizer N	06.3 ab
Leucaena + 0% fertilizer N	05.8 b
100% fertilizer N alone	06.9 ab
No organic matter or n fertilizer	03.7 c
Significance (P = 0.05)	*
CV%	11.4

Means within a column followed by the same letter are not significantly different (DMRT P = 0.05)

The yields obtained in plots receiving *ex situ* green manure with fertilizers were lower. The application of 50% of the recommended rate of fertilizer N with *Leucaena* reduced yields by 1000 kg/ha when compared with plots receiving the full complement of fertilizers. This suggests that combinations of external sources of *Leucaena* and reduced mineral N cannot produce rice yields similar to that obtained with the full complement of fertilizers, and the same quantity of organic matter. This again confirms the benefits *in situ* mulching with legumes, which can add greater quantities of

N than measured in the biomass, by biological N fixation (George *et al.*, 1992).

Application of fertilizer N increased total yields of onions significantly, irrespective of the presence of organic matter (Table 2), demonstrating the requirement of the full compliment of fertilizer N for high yields in this region. However, the use of organic matter from either source with the full complement of fertilizer N enhanced yields further, which highlight the usefulness of this practice in onion production in the dry season. This phenomenon can be related to the multitude of benefits of adding organic matter to highland agriculture, especially in the dry seasons (Sanchez and Salina, 1981). The presence or absence of organic matter did not have any impact on the percentage of marketable yield. The percentage of large bulbs suitable for marketing when taken as a proportion of the total yield was 75% except in the control plot which did not receive any N. This indicates that in the absence of fertilizer N, organic matter alone could increase the number of large bulbs, thus making the cultivation more profitable, although total yields were reduced. This requires further investigation.

Table 2. Effect of *in situ* and *ex situ* green manures and fertilizer nitrogen on total and marketable yields (t/ha) and their ratio in onion.

Treatments	Total yield t/ha	Marketable yield t/ha	Ratio t/ha
Sesbania + 100% fertilizer N	12.7 a	9.3 a	0.73
Sesbania + 50% fertilizer N	11.5 ab	8.7 a	0.75
Sesbania + 0% fertilizer N	5.1 c	3.7 b	0.72
Leucaena + 100% fertilizer N	12.0 a	9.4 a	0.77
Leucaena + 50% fertilizer N	11.4 ab	8.8 a	0.76
Leucaena + 0% fertilizer N	5.1 c	3.6 b	0.70
100% fertilizer N alone	12.3 a	9.1 a	0.73
NO organic matter or fertilizer N	6.1 bc	3.7 a	0.59
Significance (P=0.05)	*	*	
CV%	22.40	5.59	

Means within a column followed by the same letter are not significantly different (DMRTP=0.05).

Cost benefit ratio

The cost of production in situ green manure was lower than addition of similar quantities from external sources (Table 3). This again signifies the usefulness of *in situ* green manuring, especially for a rice crop, at a time when the fields are idle, rather than importing organic matter. This would also reduce the N requirement by 50% to obtain similar yields (Table 3).

Table 3. Estimates of cost:benefits ratio of green manure application for rice.

Operation	100% N with Sesbania	50% N with Sesbania	0% N with Sesbania	100% N with Leucaena	50% N with Leucaena	0% N with Leucaena
Cost (Rs) – in situ						
Land preparation	750	0	750	750	–	–
Seeding – Seeds	625	625	625	–	–	–
Labour	550	550	550	–	–	–
– ex situ						
Picking	–	–	–	2340	2340	2340
Transport	–	–	–	300	300	300
Application	–	–	–	325	325	325
Total Cost	1925	1925	1925	2965	2965	2965
Benefits						
Savings – fertilizer	–	976.80	1954.70	–	976.80	1954.70
Changes in income in relation to plots with 100% N alone	3325	875	– 5125	2687.5	– 3250	– 6375
Carry over effect (5% of cost)	96.25	96.25	96.25	136.75	136.75	136.75
Total Benefits	3421.25	1948	– 3074	2824.25	– 2136.45	– 4283.55
Cost Benefit Ratio	1.77	1.01	– 1.58	0.95	– 0.72	– 4.44

The cost benefit ratios of using the *Sesbania* green manure with the full or 50% of recommended N fertilizer were above 1.0, thus illustrating the usefulness of its adoption for rice culture.

Similar cost benefit ratios for onion cultivation (Table 4) also illustrate the advantage of using both methods of green manuring with the full complement of fertilizer N, due to an increase in yields. This again suggests the usefulness of green manuring, to onions, although the benefit was greater when organic matter was added from external sources, in contrast of rice.

Table 4. Estimates of cost:benefit ratio of green manure application to onion.

Operation	100% N with Sesbania	50% N with Sesbania	0% N with Sesbania	100% N with Leucaena	50% N with Leucaena	0% N with Leucaena
Cost (Rs) – in situ						
Land preparation	750	750	750	–	–	–
Seeding – Seeds	425	425	425	–	–	–
Labour	550	550	550	–	–	–
– ex situ						
Picking	–	–	–	1383.50	1383.50	1382.50
Transport	–	–	–	200	200	200
Application	–	–	–	250	250	250
Total Cost	1725	1725	1725	1833.50	1833.50	1833.50
Benefits						
Savings – fertilizer	–	723.60	1465.30	–	732.60	1465.30
Changes in income in relation to plots with 100% N alone	4000	– 8000	– 1,08000	6000	– 4000	– 1,10000
Carry over effect (5% of cost)	86.25	86.25	86.25	91.67	91.67	91.67
Total Benefits	4086.25	– 7181.75	– 106'*	6091.67	– 3175.73	108'*
Cost Benefit Ratio	2.36	– 4.16	– 61.70	3.32	– 1.73	– 59.1

* = x 1000

CONCLUSION

Farmers cultivate rice along with the addition of some organic matter, brought from the neighboring highlands, to maintain fertility of the soil. The practice of using *in situ* green manuring is not prevalent, although its use is well established in many Asian region, including Sri Lanka. This study, however extended this concept further, to evaluate the effects of *in situ* and *ex situ* green manuring on two crops, rice and onions recommended for 'system C' of the Mahaweli region of Sri Lanka. The study demonstrated that 50% of N fertilizer for rice (variety BG 94-1) could be met by growing *in situ* green manure of stem nodulating *Sesbania* at a density of 660,000 plants/ha, which supplies 100.3 kg N. This treatment was not evident when the same quantity of N was applied by *Leucaena* brought from an external source. Thus *in situ* green manuring with *Sesbania* could reduce mineral N. However, both sources of green manure increased yields over control with only fertilizer N, which confirms the ideology of this traditional farmer practice in rice culture.

The impact of green manuring was less evident in onions, which is cultivated in the *Yala* season. This crop required all of the mineral N with organic matter, either *in situ* or *ex situ*, to produce high yields. The impact of organic matter was most evident in the percentage marketable yield. Cost benefit ratios also indicate the usefulness of incorporating the green manures, both in rice and onions. Thus application of *Sesbania* green manure with 100 and 50% of the present N fertilizer recommendation of rice and incorporation of *Sesbania* and *Leucaena* with 100% of the present N fertilizer of large onions can be considered a suitable alternative for present recommendation, although it requires further clarification and testing prior to recommendation to the farmers of the region.

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