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STUDIES ON GREEN MANURING IN THE PHILIPPINES

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FOREWORD

Green manure is plant material in the form of a growing crop which is plowed into the soil. Because a major objective of manuring is to increase the nitrogen supply, it is leguminous crops which are generally selected for use as green manures. This Bulletin discusses the use of green manures in the Philippines. Green manure crops include grain legumes such as cowpea, perennial legumes such as leucaena, and non-grain legumes such as sesbania. The contribution of various species to the nitrogen supply is discussed, and their effect on the yield of the subsequent crop.

In spite of the fact that green manuring improves the physical properties of soils as well as soil fertility, the practice has not been widely adopted by farmers in the region. The author discusses the reasons for this, and ways in which the various constraints might be overcome.

The paper on which this Bulletin is based was first presented by its author at an international seminar on "*The Use of Organic Fertilizer in Crop Production*", held in Suweon, Korea in June 1990, with the co-sponsorship of the Rural Development Agency of Korea. It is one of a series of five Extension Bulletins (EB 311-315 inclusive) being published by the Center this year on the use of organic materials as fertilizers for crop production.

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(Chinese Abstract)

摘　　要

本文主要討論在菲律賓各種不同型式綠肥的使用及對作物產量的影響，絕大部份綠肥來自木本豆科植物的切離葉片　在許多情形下，綠肥最好與化學肥料混合使用

將綠肥混入土壤中較撒佈作物行株間可以得到較好的效果　施用時期也是相當重要因素　本文也討論農民施用綠肥所遭遇的困難及施用綠肥未來發展性

(Japanese Abstract)

摘　　要

フィリピンで主に使用されている緑肥は潅木性マメ科の葉である。緑肥は化学肥料と共に施用した場合に効果が大きい。畝間に施用するよりも鋤込んだほうが効果は高い。但し施用時期を選ぶことが重要である。緑肥利用上の問題点と将来の見通しにも触れた。

(Korean Abstract)

초　　록

이 논문은 필리핀에 있는 여러가지 종류의 녹비중 1년생 작물의 재배와 수량증진을 위해 사용되고 있는 목질형콩과의 사용을 검토하였다. 많은 시험결과중 녹비를 화학비료와 혼합시용할 때 가장 좋은 결과를 보였고 또 녹비를 골사이의 표면에 흩어주는 것보다 토양속에 시용해 주는 것이 더 좋은 효과를 보였으며, 녹비의 사용시기도 하나의 중요요인으로 판명되었다. 녹비사용에 있어서 농가에서 직면하는 여러가지 어려움과 미래의 전망에 대해서도 논의하였다.

STUDIES ON GREEN MANURING IN THE PHILIPPINES

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ABSTRACT

This paper reviews the use of various types of green manure used in the Philippines, most of them the cut leaves of woody legumes, on the performance and yield of annual crops. In many cases, the best results were seen when green manures were combined with chemical fertilizers. Incorporating the green manure into the soil tended to give better results than spreading it on the soil surface between rows. The timing of application seemed to be an important factor. The various constraints faced by farmers in using green manures are discussed, and the future prospects.

INTRODUCTION

Green manure is a green or fresh plant material which is incorporated into the soil, usually at the stage when its nitrogen content is highest, and which is allowed to decompose to supply nitrogen to a standing crop or to a subsequent crop. Green manuring in crop production is recorded to have been practiced in China as early as 1134 B.C. (Joffee 1955). In developed countries, legumes are often grown up to near the bloom stage, and then plowed under to enrich the soil under fallow. In poorer countries it is known that the practice, though often recommended, has not gained wide acceptance, probably due to the opportunity lost in the use of the land, water and the food legume that could have been harvested instead of being plowed under.

However, with the introduction of non-food legumes as green manure, new options for farmers have been opened. The major advantages of green manure as an organic fertilizer are its high nitrogen content, low carbon-nitrogen ratio and easy decomposability. Most green manures are also easy to propagate, and the biomass produced is usually high. They can be grown in the same field as the principal crop, and later plowed under or grown as an intercrop of the main crop. Green manures are a suitable alternative source of nitrogen, especially for farmers on low incomes. Where extra labor is available, they are also a means of stretching the usefulness of the land, if a fallow period of one to two months is available before the main crop is planted.

TYPES OF GREEN MANURE

There are three general types of green manure, namely grain legumes, woody or perennial legumes, and non-grain legumes. Examples of each type which are commonly used as green manure are as follows (Manguiat 1988):

Grain legumes – cowpea (*Vigna sinensis*), mungbean, soybean, peanut and pigeon pea

Woody (perennial) legumes – *Leucaena leucocephala, Gliricidia sepium, Cajanus cajan, Calliandra calothyrsus* and *Cassia siamea*

Non-grain legumes – Crotolaria, Sesbania, Centrosema, Stylosanthes and Desmodium

The important general characteristics of a good leguminous green manure are (Manguiat 1988):

- Early establishment and good seedling vigor;
- Tolerance to drought, flooding, shading and adverse temperatures;
- Rapid growth, with a short duration until maturity;
- High biomass yield and nitrogen accumulation;
- Non-photoperiodic;

- Easy to incorporate into the soil;
- Resistant to pests and diseases;
- Seed germinates easily;
- Multipurpose; and
- High nitrogen-fixing ability

Grain legumes are highly suitable as catch crops in rainfed lowlands following the principal crop of rice, to exploit residual moisture and nutrients. They may also be used in rainfed upland, irrigated lowland and alley cropped upland. In developing countries, these legumes are grown for both food and green manure purposes, but more often for food. In practice, the grain is harvested first, and the stover is then plowed under.

The woody legumes are most suitable for alley cropping systems, in which they serve as more or less permanent barriers to runoff, besides providing green herbage as fertilizer for the main crop. In an alley cropping system, the wide spaces or alleys are planted in clean-tilled staples such as rice or corn, and the boundary rows are planted closely in leguminous trees. These trees are periodically pruned, and the leaves are applied to the principal crop as green manure. Tree legumes may also be grown in a pure stand, and the leaves are cut and carried to where they are used as green manure. This poses some difficulty in handling and transport because of the large bulk of material needed.

Herbage Yield, Nitrogen Accumulation etc. of Green Manures

Of the leguminous trees, *Leucaena leucocephala* is the one which has been most thoroughly studied. It gained widespread recognition in the Philippines as a "green fertilizer" in the early 1970s. Some of the major features of leucaena (locally called "ipil-ipil") as a green manure are its rapid regrowth and high production of herbage, high nitrogen content, and the speed with which its leaves decompose after they are incorporated into the soil. Curran (1977) estimated that in a pure stand of leucaena drilled in rows and cut 1.5 m high every two months, about 120 mt/ha of green foliage could be harvested each year. This contains approximately 1,000 kg N, 200 kg P_2O_5 and 800 kg K_2O. The nutrient composition of the leaves is as follows: nitrogen, 2.0-4.0%; phosphorus, 0.2-0.3%; potassium, 1.3-4.0%; calcium, 0.75-2.0%; and magnesium, 0.6-10%. The pinnae and rachis of the leaflets contain only 6.5-33.5% crude fiber. The low fiber content and low C/N ratio of the leaves contribute to their rapid decomposition about two to three weeks after they are incorporated into the soil.

Stylosanthes is a perennial legume which is popularly used as a pasture crop, but because of its high nitrogen content it is also useful as a green manure. This legume is a native of South America and was therefore easily introduced into the Philippines, where there are similar climate conditions. Some of the desirable characteristics of stylo are:

- It grows well even in acidic soils, and is relatively tolerant of poor drainage conditions and low soil fertility. (One drawback, however, is that it is not shade tolerant, and is therefore difficult to grow under coconut trees).
- It competes well with cogon grass (*Imperata cylindrica*, a persistent weed) in native pastures, where it performs better than other legumes (Javier and Mendoza 1974).
- It is an efficient user of soil phosphorus, and is able to grow where phosphorus levels are so low that other legumes barely survive.
- It grows well even under a high rainfall level of 3,500 mm or more: at the other extreme, it can withstand prolonged dry weather or a dry climate with rainfall of only 900 mm per annum.

Stylo is an erect, sub-woody shrub which grows about 1.5 m high. It becomes too woody (and hence unsuitable as green manure) if it is allowed to grow too big, but remains leafy and succulent if it is kept short. Stylo can be propagated easily by seed sown at a rate of 3-4 kg/ha. In the phosphorus deficient, Aborlan soil of Palawan, Philippines, the Schofield variety of stylo was reported to produce 30 mt/ha of fresh herbage each year, even without fertilizer (Javier and Mendoza 1974). Under more favorable soil conditions, dry herbage yields may reach 2.5-10 mt/ha. This pasture legume contains about 18% protein, 29% fiber, 44% soluble carbohydrates, 4.3% CaO and 0.6% P_2O_5. Townsville stylo (*Stylosanthes humilis*, a relative of *Stylosanthes guyanensis*), has a nitrogen content of 4.5%.

A 10-year study revealed that Townsville stylo contributed as much as 240 kg/ha nitrogen to the top two inches of soil (Humphrey 1967). The plant tops contain 2.8% N and 0.22% P, while the roots have 2.42% N and 0.20% P.

Other pasture legumes which may have potential as green manures are *Centrosema pubescens*, Siratro (*Phaseolus atropurpureus*), *Desmodium intortum* and tropical Kudzer (*Pueraria phaseoloides*).

Crotolaria juncea L. is another green manure crop which is traditionally grown as a pasture crop. When raised in a pure stand, it can produce as much as 0.84-17.04 mt of fresh herbage per hectare in just 30 days, at a seeding rate of 30-90 kg/ha. This production is equivalent to 1.40 to 2.42 mt of dry matter, which has a nitrogen yield of 33 to 44 kg N/ha. When Manguiat *et al.* (1988) evaluated various green manures, they noted that *Crotolaria juncea* was still succulent six weeks after sowing. In their field trials, it produced the highest dry biomass (9.65 mt/ha) and had the highest level of accumulated N (196 kg N/ha) eight weeks after sowing. It also had the earliest flowering (46 days) and fastest growth rate. In his study, Lales (1983) found that when crotolaria was intercropped with corn and allowed to grow until hilling up (30 days after the corn was planted), 2.38-6.14 mt of fresh crotolaria herbage were produced, which contained 13.5 to 33.4 kg N/ha (Fig. 1). However, it was observed that crotolaria was adversely affected by being grown together with corn plants.

Sesbania is an aquatic tropical legume which is a nitrogen-fixer and which has the characteristics of high herbage yield and a high nitrogen content in its tissues. Some of the popularly grown species are *S. rostrata*, *S. aculeata*, *S. sesban*, *S. cannabina* and *S. speciosa*. Sesbania grows well under a varied range of agroclimatic conditions, and is resistant to drought, waterlogging and soil acidity and alkalinity. It is one of the most efficient nitrogen-fixing legumes, with values of more than 500 kg N/ha/year being reported. *Sesbania rostrata* can produce 15-22.5 mt of green herbage within six weeks, with nutrient yields of 82 kg N, 11-16 kg P_2O_5, and 23-34 kg K_2O. The N content of the various sesbania species ranges from 1.9 to 4.9%, with most of the species having a N content of 3.4 to 3.8%.

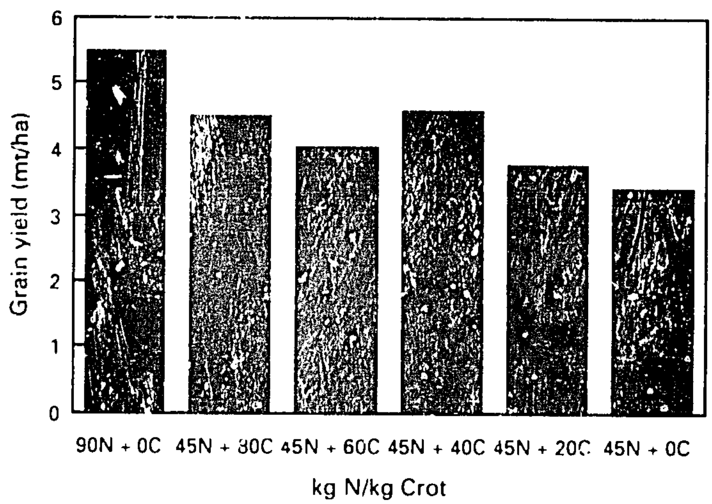

Fig. 1. Effect of increasing rate of crotolaria on corn yield
Source: Lales 1983

An analysis by Manguiat *et al.* (1988) showed that *S. rostrata*, which is 2 m tall, has a dry biomass of 5.6 mt/ha, 34% of which is leaves and 66% stalk. The N content of the leaves is 4.5%, and of the stems 0.77%. The total N accumulation was thus

84 kg N/ha from the leaves and 28.4 kg N/ha from the stems. Of the various kinds of green manure studied over a period of 45-60 days, Manguiat (1988) reported that the highest N accumulation was exhibited by *S. aculeata* (225 kg N/ha), and the lowest by *Cajanus cajan* (33 kg N/ha). In their studies, Furoc *et al.* (1985) cited three species of Sesbania – *Sesbania aculeata, Sesbania rostrata* and Sesbania "China type" – as particularly suitable for the green manuring of flooded rice, since all three were relatively resistant to waterlogging.

Garrity (1989) has stated that the feasibility of any green manure system is determined by the following agronomic issues: green manure stability, establishment methods, incorporation of the biomass, and seed production/seed technology problems. To these, Furoc and Manguiat (1989) have added the problems of photoperiodism, pest and diseases, and socio-economic factors. Garrity reported that drought reduced the N contribution of 45-day old *Sesbania rostrata* to 18 kg N/ha. With the onset of more favorable conditions in the wet season, sesbania contributed 65 kg N/ha. For good establishment of *Sesbania rostrata*, he suggested that to accumulate at least 80 kg N/ha in 40 days, 60 kg seed/ha should be broadcast onto a saturated soil subject to shallow surface flooding after the sesbania becomes established. With zero tillage, 15 kg/ha of seed can yield 95 kg N/ha in 60 days. Garrity pointed out that sesbania may easily be incorporated into the soil, provided the stand is not too dense and the crop is not too old. Incorporation of sesbania takes place after 30-70 days, and the stand may then exceed 20 mt/ha fresh weight. Furoc and Manguiat (1989) suggested that sesbania and crotolaria should be incorporated 45 days after seeding, when the biomass is still succulent and soft. IRRI has developed power tillers which cut and incorporate green manure biomass in one pass, while an animal-drawn implement with a similar action is being used by farmers in the Cagayan Valley, Philippines. Garrity has stated that the following seed production techniques for the on-farm seed production of sesbania have been tested: intercropping with rice; seeding or transplanting along paddy bunds; and planting as an upland crop in vacant areas. However, he says that in intercropping, the population of sesbania must be kept low to avoid competition with rice, while planting on bunds may cause the shading of nearby rows of rice.

Manguiat *et al.* (1988) reported that in rainfed lowland rice fields, 56-day-old *Sesbania rostrata* incorporated into the soil before rice was transplanted accumulated more than 6 mt/ha of biomass and about 160 kg N/ha. It improved rice yield by 1.8 mt/ha over the control, and was equal to an application of 60 kg N/ha of inorganic fertilizer. The authors also indicated that *Sesbania rostrata* grown in the field during the dry season needs rhizobial inoculation, and that stem-inoculated *S. rostrata* could substitute effectively for an application of 45 kg/ha of inorganic N. Inoculating the root, the stem, or both, increased the N uptake of sesbania by up to 69%. Root and stem nodulation, biomass production, N uptake and N fixation was higher in sesbania grown on Sariaya sandy loam (pH 6.6) than in sesbania grown on Antipolo clay (pH 5.5).

The studies of Manguiat *et al.* (1988) further showed that net mineralization occurred two weeks after sesbania had been incorporated into the soil, and that green manuring with the leaves alone was more effective than using the whole plant in increasing the number of tillers in upland rice. The peak of N availability from *S. rostrata* appears to be four weeks after incorporation (Fig. 2). Pre-sowing *S. rostrata* and incorporating it 55 days afterwards gave better results than intercropping it with corn.

Grain legumes such as mungbean and cowpea (*Vigna sinensis*), although more popularly used as food, may in some cases be useful as a green manure (Fig. 3). Meelu *et al.* (1985) reported that mungbean can attain a herbage yield of 2.5 mt/ha (dry) in 60 days, giving an accumulation of 50 kg N/ha. An even higher N yield of 86 kg N/ha in just 40 days was noted by Morris *et al.* (1984). Gonzales (1962) observed fresh biomass yields of 9 mt/ha in the wet season, and 13 mt/ha in the dry season, for mungbean grown for 40-50 days. Rajbhandari (1984) observed a fresh biomass yield of 13.3 mt/ha for 48-day old cowpea (1.8 mt/ha dry). With a nitrogen content of 1.91%, the N yield of the harvested cowpea was 32 kg N/ha.

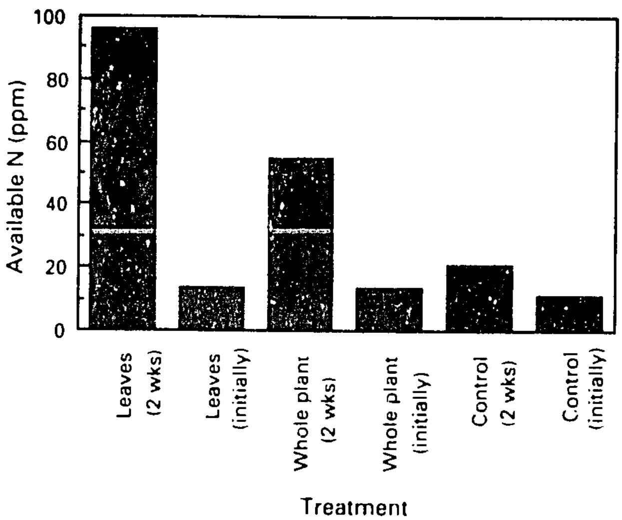

Fig. 2.
N content of soil 2 weeks after incorporation of *Sesbania rostrata*
Source: Manguiat 1988

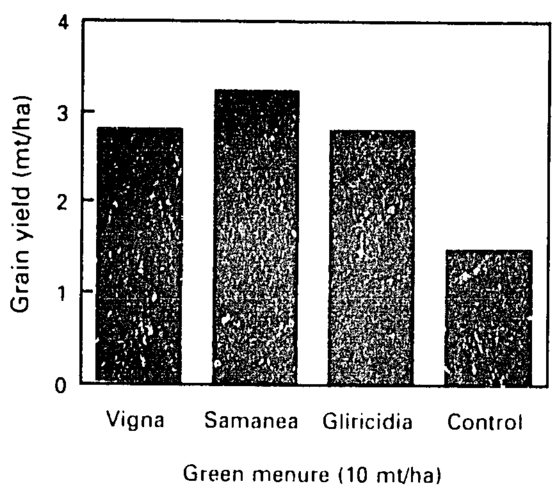

Fig. 3. Effect of various green manures on rice yield
Source: Hernandez *et al* 1958

GREEN MANURES: SOME RECENT EXPERIMENTAL RESULTS

Use of Leucaena as Green Manure

The following are highlights of research findings on the use of leucaena as a green manure for various crops. Unless otherwise stated, all experiments were carried out in the Philippines.

Paddy Rice

■ Rice plants fertilized with enough leucaena to provide 60 kg/ha N produced about 3 mt/ha more grain than unfertilized plants, under both flooded and non-flooded conditions. There was no statistically significant difference between the yield of rice fertilized with leucaena and that given ammonium sulfate, either at 60 kg N or 120 kg N per hectare. This means that the organic N fertilizer was as good as the inorganic fertilizer as a nitrogen fertilizer for rice (Alferez 1978).

■ In Zamboanga del Sur in Mindanao, Alama (1983) showed in a field trial that the grain yield and nitrogen uptake of rice fertilized with leucaena were similar to those of rice fertilized with urea applied by deep placement. Yield components such as the percentage of filled spikelets and the number of panicles per hill were also comparable (Fig. 4)

■ When Lacuesta and Laranang (1983) compared various tree legumes as a green manure for rice, they observed higher yields, more productive tillers and greater 1,000 grain weight in IR50 fertilized with leaves from leucaena, acacia (Samanea), madre de cacao or *Gliricidia sepium* (kakawate) than in the control plots. The highest return per dollar invested was estimated to be from the use of leucaena leaves as green manure.

■ In his doctoral thesis, Lao-lao (1980) further confirmed the effectiveness of leucaena as a green manure for lowland rice. His field experiment on Maahas clay showed that at either 60 or 120 kg N/ha, rice yields and nutrient uptake of rice were about the same, regardless of whether the nitrogen source was leucaena leaves or ammonium sulfate. Rice

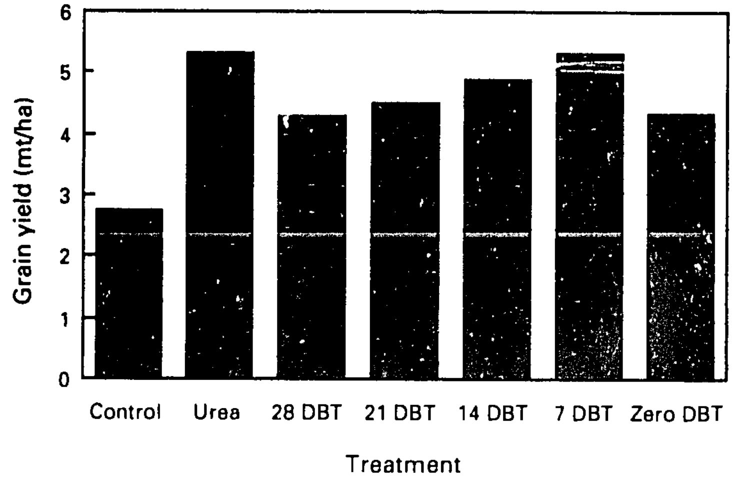

Fig. 4. Effect of timing of incorporation of leucaena leaves on rice yield
DBT = Days before transplanting
Source: Alama 1983

growth, the percentage of filled spikelets, and the number of panicles per hill, were also comparable in plants which received green manure and those given ammonium sulfate. Soil chemical properties such as pH, organic matter content, available phosphorus, exchangeable potassium and calcium were not affected by the application of either organic or inorganic fertilizer. However, the amount of ammonium nitrogen and nitrate nitrogen increased by four to six times between the 3rd-5th and the 10th week after leucaena leaves were incorporated into the soil. The time at which the green manure was incorporated, whether this was done once or split between three weeks before transplanting and three weeks after transplanting, did not significantly affect grain yield, nutrient uptake or chemical properties of soil. This indicates the ready availability of nutrients from the green manure. Essentially, the same results (Fig. 5) were obtained as in earlier tests (Lao-lao *et al.* 1978). In 1980, San Valentin and Perez reported the same effect from leucaena leaves used as a green manure for lowland rice. Grain yields were the same in rice to which either leucaena leaves and urea had been applied. No significant effect was noted from either the rate or the timing of nitrogen application.

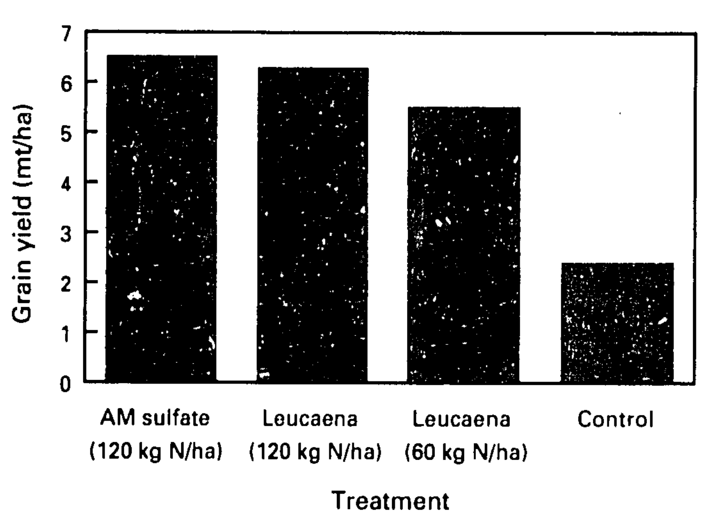

Fig. 5.
Response of rice to leucaena
Source: Laolao *et al.* 1978

Upland Rice

Even in upland rice, Hardjosuwignjo (1980) demonstrated in a field experiment that grain yield of IR36 rice variety fertilized with 10 mt/ha of leucaena leaves was comparable to that of rice fertilized with inorganic fertilizer at a rate of 80-30-30. This effect was noted whether leucaena was applied 25 days before seeding or split, with half at seeding and half 25 days after seeding, implying the ready availability of nitrogen from the green manure. The other beneficial effects observed from the green manure were:

a. reduction of bulk density of the soil;
b. increase in soil organic matter content, cation exchange capacity, available phosphorus and exchangeable potassium at maximum tillering stage; *and*
c. increase in the soil population of bacteria and actinomycetes when the rice was ready for harvest.

Corn

▪ As an interrow crop and mulch for corn, Dofeliz and Nesbitt (1984) found that leucaena leaves applied at a rate of 7-10 mt/ha/crop increased corn production by up to 300%. The leaves were applied alongside the corn rows as a mulch before hilling up, and again when the corn reached the tasseling stage. The leaves of leucaena were cut from hedges growing within the corn crop, or hauled from a nearby source.

▪ In his Ph.D. dissertation, Herrera (1980) reported that corn fertilized with leucaena leaves, and corn which received ammonium sulfate, had a comparable yield of both dry matter and ears of marketable corn. The effect of green manure was the same whether it was applied as a mulch, or mixed in the furrow between the corn plants. The peak of ammonium nitrogen released by the decomposition of leucaena leaves occurred during the third week after application.

▪ In Zamboanga del Sur, Magana (1980) observed in wet and dry season tests that grain yields of corn were better after the combined application of leucaena and inorganic fertilizer, than from organic fertilizer alone. Green manure alone gave a higher yield than that of the control. Leucaena leaves were applied air-dried, at a rate of 2,564 kg/ha in the wet season, and 1,935 kg/ha in the dry season. The rate of inorganic fertilizer used was 60-40-60. The best combination appeared to be 2/3 inorganic fertilizer plus 1/3 of leucaena leaves. This combination, and the treatment using inorganic fertilizer alone, were found to be the most profitable.

▪ In his green manuring trials in areas cleared by logging, Manguiat (1988) reported a cumulative increase in the grain yield of corn with the application of green leucaena leaves. In the first year (1985), the yield increment over control plots was +8.3%; in the second year, +15.1% and in the third year, +27.2%. Green manure was applied at a rate which supplied the equivalent of 45 kg N/ha. The corn yield from the application of ammonium sulfate was markedly superior to that from leucaena in the first year, but in the third year the yields from the inorganic and organic fertilizers were nearly the same (Fig. 6).

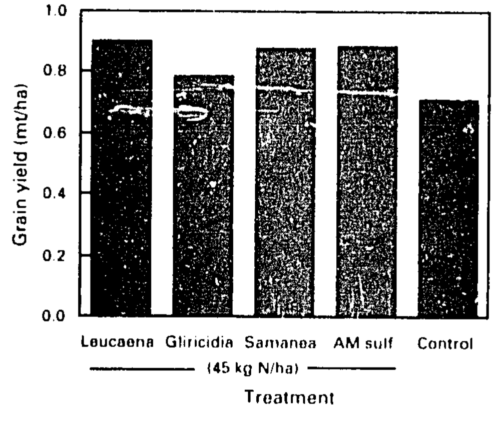

Fig. 6. Effect of various types of green manure on corn yield, 1987 WS
Source: Manguiat 1988

▪ Mabbayad (1981) reported in his study on methods of applying leucaena leaves on corn that both incorporating the leaves into the soil and furrow placement gave consistently better results than surface application, in terms of grain yield, nitrogen uptake and recovery by corn plants.

▪ Results of early experiments in Hawaii in 1976 showed that the use of leucaena leaves as a green manure produced 3.5 mt/ha/year of corn. Corn intercropped with leucaena gave a 23% higher yield than the control plots, although the efficiency of leucaena compared to urea was only 38%. It was also found that when the legume tree was cut to a height of 1 m from the ground at three-month intervals, the total yield was 500-600 kg/ha/year of green manure (Guevarra 1976 and cited by Moomaw *et al.*)

Sorghum

▪ In experiments on sorghum (*Andropegon sorghum* (L.) Brot.) Mendoza (1969) found that a combined application of leucaena leaves and ammonium sulfate significantly increased grain and stover yields. However, green manure did not affect other agronomic characteristics of the sorghum plants, nor did it appear to change the physical and chemical properties of the soil. This study, it must be noted, was conducted over only a single cropping season.

▪ In a later experiment, Quilang (1981) reported that incorporating enough leucaena leaves into the soil ten days before planting to supply 75 kg N/ha gave yields comparable to applications of ammonium sulfate at the same nitrogen rate. Grain yields fell when green manure was incorporated too early i.e. 20-30 days before planting.

Vegetables

▪ Deanon (1983) stated that leucaena could be a promising fertilizer for tomato plants. In one trial, he obtained a tomato yield of 22-24 mt/ha after applying 12 kg of leucaena leaves per 5 square meter plot (equivalent to 24 mt/ha of leaves). These results are comparable to those using inorganic fertilizer at a rate of 120-90-90. The amount of leucaena applied, 24 mt/ha, seems very large, but an economic analysis showed that the green manure, which cost ₱1,200/ha, gave a gross income of ₱11,110-120,090/ha. The leucaena had the lowest production costs, in terms of fertilizer application, and the highest returns compared to the other treatments. Furthermore, it was demonstrated in two experiments that infection with bacterial wilt in all tomato cultivars used was reduced in the treatments in which leucaena leaves alone were applied.

▪ Villanueva and Briones (1983) also reported a good response in another vegetable, Chinese cabbage, to the application of leucaena and *Gliricidia sepium* as green manures. An application rate of 5 mt/ha of green manure gave the best cabbage growth and yield. Applications of leucaena at a rate of 5 mt/ha also gave the highest return per dollar invested.

▪ In experiments using cucumber, Villegas (1982) reported that a combination of fresh leucaena leaves, chicken manure and urea gave the highest yield and greatest number of laterals. This combination also increased the soil pH, available phosphorus, potassium and calcium. Leucaena leaves applied alone gave a higher percentage germination and better yields than either chicken manure or urea applied separately.

▪ As an intercrop of cassava, leucaena appeared to compete intensely with the principal crop for light and space (Escalada 1981). The formation and development of cassava tubers seemed to be inhibited as a result of the rapid growth and development of the periodically pruned leucaena trees. For better tuber yields, a planting distance of at least 3 m x 15 cm for the leucaena was suggested.

▪ Urdaneta and Javier (1980) found that sweet potato plants fertilized with ammonium sulfate gave higher tuber yields than those fertilized with leucaena at the same nitrogen rate. Nevertheless, when enough leucaena was applied to give 60 kg N/ha, the tuber yield was 3 mt/ha, which was higher than in the unfertilized plots.

Tobacco

▪ Ramirez (1984) reported from his studies in Isabela in the Northern Philippines that leucaena leaves, applied alone or combined with inorganic fertilizer, gave a significant increase in leaf length, lamina-midrib ratio, specific leaf weight, cured leaf yield and the quality index of cigar-filler tobacco. These results were noted at a rate of 120-90-50 kg/ha inorganic fertilizer, and at 100-120 kg N/ha from leucaena leaves (with or without phosphorus or potassium). The results also indicated that the best time to apply the fertilizer seemed to be 14 days before transplanting, since this produced the highest cured leaf yield of 2.06 mt/ha.

▪ Tattao has reported from another experiment that leucaena leaves used as fertilizer on Virginia tobacco had effects comparable to those of inorganic fertilizer, in terms of the size, color, texture, burning rate and chemical properties of flue-cured tobacco leaves. It seemed to make little difference whether the green manure, applied at a rate of 500-1,500 kg/ha, was applied on the soil between the rows, or incorporated into the soil.

Sugarcane

■ In 1984, Saliendra, Mendoza and Rosario reported perhaps the first attempt to integrate leucaena culture into sugarcane production. The objectives of the study were to determine the proper spacing between the sugarcane and the leucaena, and to discover the best way of establishing leucaena along with sugarcane. The spacing found to be adequate was two rows of leucaena spaced at 0.5 m, and then four rows of sugarcane 0.75 m apart, with an interval of 4 m before the next two rows of leucaena. With this system, about 1.2 mt/ha of dried leucaena leaf was produced which contributed 53 kg/ha of nitrogen to the sugarcane.

Response of Crops to Sesbania

Sesbania is another green manure which appears to be a promising organic fertilizer substitute or supplement for some crops. The following are highlights of some studies on the use of sesbania on crops:

Paddy Rice

■ One of the early attempts to study the potential of sesbania was an experiment conducted by Bronson (1983) in a field trial on paddy rice at the IRRI farm. The results showed that green manuring with *Sesbania rostrata* and cowpea significantly improved all rice parameters except the number of productive tillers. Rice yield following the incorporation of sesbania was 3.59 mt/ha, while that of cowpea was 4.01 mt/ha. Nitrogen yields were 30.9 kg N/ha from the cowpea, and 18.4 kg N/ha from the sesbania. From a regression analysis, Bronson concluded that cowpea, sesbania and corn were similar in efficiency when used as green manure. Nineteen kg of rice grain were produced per kg green manure, against 17 kg grain per kg of inorganic N fertilizer.

■ In his M.Sc. thesis, Rajbhandari (1984) found that *Sesbania aculeata* and cowpea (*Vigna unguiculata* L. Waly) used as green manure for paddy rice gave 20.6% and 14.4% higher yields, respectively, than the control (Figs. 7 and 8). The yield response of rice to cowpea and sesbania incorporated 48 days after seeding was equivalent to the grain yield produced by applying 85.4 and 97.7 kg N, respectively. The rice yield following the incorporation of sesbania was 3.5 mt/ha, while the yield after cowpea was only 3.3 mt/ha. The green manure crops were incorporated into the soil two days before the rice was transplanted.

■ In his assessment of various kinds of green manure used for rice, Singh (1984) stated that of the green manures cultivated *in situ*, sesbania has been found most suitable for rice in numerous trials. He reported that incorporating sesbania into the soil one day before planting rice has yielded as much as 90 kg N/ha.

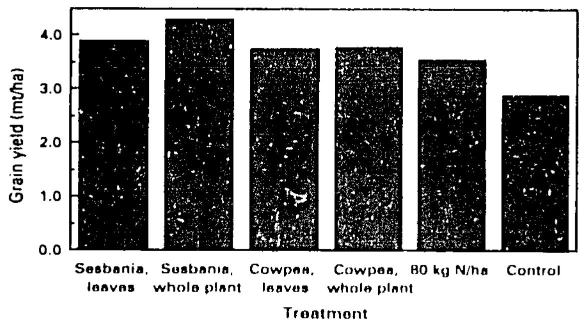

Fig. 7. Effect of cowpea and sesbania on rice yield
Source: Rajbhandari 1984

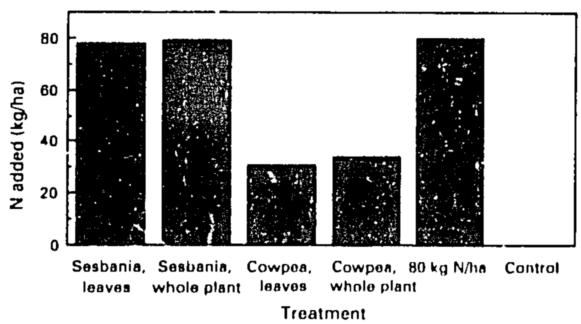

Fig. 8. Effect of cowpea and sesbania on N added
Source: Rajbhandari 1984

▪ In a recent experiment at IRRI, Furoc *et al.* (1986) indicated that the incorporation of *Sesbania rostrata* into paddy soil increased the grain yield, total dry matter and nitrogen yields significantly, compared to surface application of the green manure. The highest rice yields were obtained when the green manure was applied at rates of 7-14 mt/ha of fresh herbage, regardless of the application method used. Their results indicate that the higher yields when the sesbania was incorporated was more than enough to pay for the higher labor cost of plowing the green manure into the soil.

▪ In earlier experiments, Furoc *et al.* (1985) noted that the N substitution effect of 60-day-old sesbania is about 60 kg N/ha, in terms of rice yield. The same result was observed in farmers' fields. These workers also reported that 60-day-old sesbania yielded significantly more N than 45-day-old sesbania. Although sesbania is generally considered to be tolerant of waterlogging, flooding reduced the total dry matter yield and nitrogen accumulation by about 20%.

▪ More recent experiments at IRRI by Furoc *et al.* (1989) have indicated that intercropping cowpea and sesbania with rice can be profitable (Fig. 9). A combination of cowpea and sesbania rows, in the proportion of 3:1, resulted in a net profit of US$593/ha. This is nearly twice the income gained by using inorganic nitrogen fertilizer at 120 kg N/ha, which gave a net profit of US$330/ha. The marginal rate of return from green manuring was US$0.24, while that from inorganic N fertilization was only US$0.12.

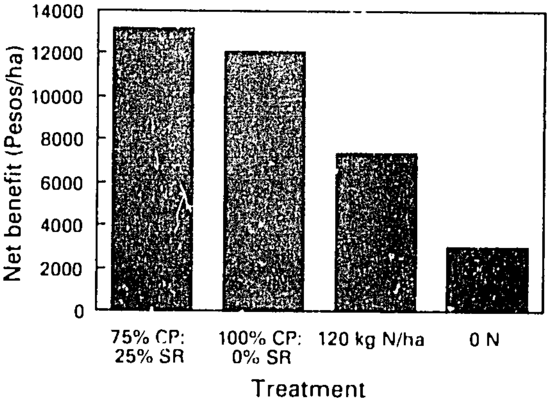

Fig. 9. Net benefit from use of green manure on rice
Source: Furoc and Manguiat 1989
Note: 1 US$ = 21 Philippine Pesos

▪ Another very recent report by Becker and Ladha (1989) indicated that the yield of rice (IR 64/66) fertilized with sesbania or *Aeschynomene afrasfena* was comparable to, or even slightly better than, that of rice fertilized with prilled urea at a rate of 60 kg N/ha. The same results were obtained in two sites, when green manure was used 6 and 8 weeks after sowing (Fig. 10).

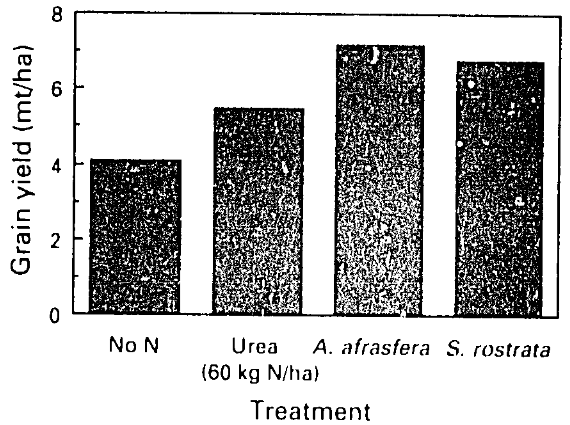

Fig. 10. Effect of two green manures on rice yield
Source: Becker and Ladha 1989

▪ Another experiment showing that sesbania gives results comparable to those from inorganic fertilizer is that conducted by Ventura *et al.* (1987). Sesbania applied at a rate of about 3 mt/ha gave rice yields in three croppings which were the same as, or even slightly higher than, those from rice plants which had received urea (Fig. 11). Plants treated with sesbania also exhibited higher nitrogen recovery than those fertilized with urea.

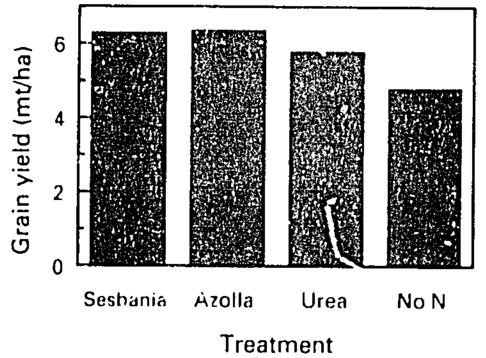

Fig. 11. Effect of two green manures and urea on rice yield
Source: Ventura 1987

Upland Rice

■ With regard to upland rice, Manguiat (1988) reported that the stem-nodulating *Sesbania rostrata* gives better results than *Sesbania sesban*. In terms of rice yield, incorporating *S. rostrata* into the soil was equivalent to applying 60 kg N/ha (Fig. 12), while the same amount of *S. sesban* was equivalent to only 30 kg N/ha. A combination of *S. rostrata* and inorganic N gave better results than the application of inorganic N alone.

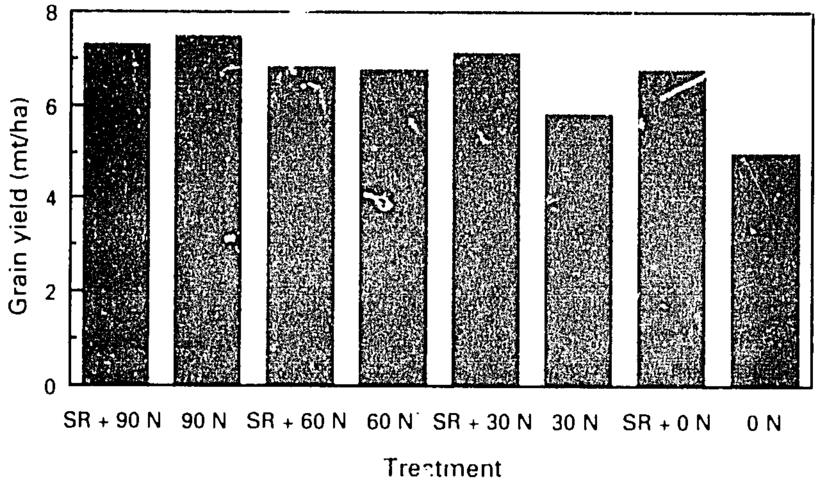

Fig. 12.
Effect of sesbania on rice yield
Source: Manguiat 1988

Corn

■ With regard to corn, Manguiat *et al.* (1988) found that inoculated *S. rostrata* can substitute for up to 45 kg N/ha (Fig. 13), and increase grain yield by more than 650 kg/ha over uninoculated *S. rostrata*. Field experiments also showed that either *S. rostrata* or *Phaseolus calcaratus* (rice bean) significantly increased the yield of grain, stover, cob and total dry matter compared to the control. Substantial yield increments were also obtained when green manure was combined with inorganic nitrogen fertilizer. Green manuring with *S. rostrata* increased the fresh weight of marketable ears by 90% compared to the control, and with *P. calcaratus* by 130%.

GREEN MANURES: FUTURE PROSPECTS

Green manuring improves soil fertility as well as the physical properties of soils. Thus, it offers a good alternative to chemical fertilizers, in terms of sustained soil productivity. The use of green manure has not yet been widely adopted by farmers, especially in developing countries, due to the constraints mentioned above. Nevertheless, numerous studies have already shown that it is a technically and economically feasible technology. What is needed is a more aggressive educational and promotional campaign, so that more farmers become aware of the practice and are prepared to accept it.

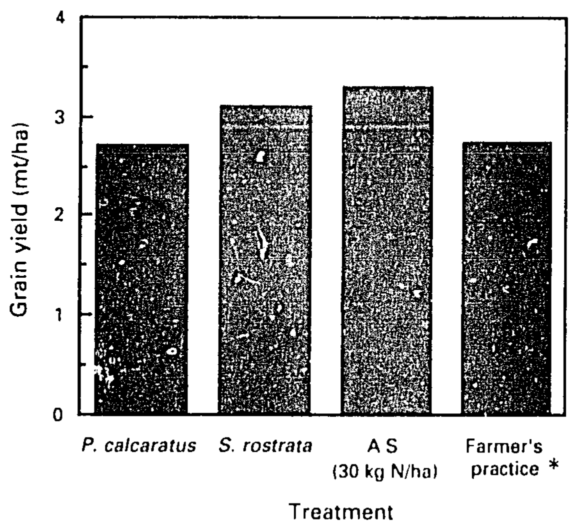

Fig. 13. Effect of green manures on corn yield 1988-89

*45 kg/N applied but minimal management
Source: Manguiat 1988

There may still be some gaps in the technology, but many of the major questions have already been answered. The other areas that need further research are:

- Evaluation of various green manure crops in terms of their adaptation to different climatic and soil conditions;
- Determination of various combinations of green manures, and also of green manures and inorganic fertilizers, for optimum crop production;
- Determination of the best methods and timing of application;
- Determination of the long-term effect of green manure on soil fertility and soil physical properties;
- Determination of the most economical and practical green manuring technology.

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DISCUSSION

Q. (A.S. Karama)
When sesbania was used in corn production, was it grown in a pure stand or as an intercrop? When you compared the effects of chemical and organic fertilizers, what was your basis of comparison: was it the amount of N per hectare?

A. The use of sesbania with corn was not my experiment, but I seem to remember that it was used as an intercrop. Yes, the basis of comparison was the level of N, assuming that the sesbania contained 4% N.

Q. (J. Bay-Petersen)
Green manuring seems to be more common where farmers use machinery for land preparation. I wonder if there may be some difficulty in using draft animals to plow under the green manure. In the Philippine experiments, were draft animals or tractors used?

A. Water buffalo were used to heap up the soil and plow under the green manure. Sesbania is not a woody plant, and it can easily be cut by either draft animals or machines. If green legumes are allowed to grow too old, they may become woody and difficult to cut.

Q. (K. Abdul-Raffir)
When you plant green manures as an intercrop etc., how do you determine the percentage of the area to be planted in green manure: do you assume 10% or 20%, for example? Or is the area calculated on the basis of the nutrient requirements of the crop and the N production of the green manure? Some cropland will be lost to the green manure: what percentage is it?

A. Generally, the crop is planted according to its regular spacing before the green manure is planted as an intercrop. Some experiments, such as that with sugarcane, recommend a modification of two rows of green manure in place of the crop, but usually the plant population of the main crop is much the same as if no green manure is used. There is not much loss of cropping area, especially since the green manure may be grown for only 40 days.