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GREEN MANURE CROPS IN TAIWAN

By

H. F. Chu

TAIPEI, TAIWAN, CHINA

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Green Manure Crops in Taiwan

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I. Green Manure Crops and Their Effects on the Soil and Plant Growth

Green manure crops imply those crop-plants which, while still growing and usually blooming, are plowed into the soil for the purpose of improving soil texture as well as of increasing soil fertility. Most of the green manures are leguminous crops having nodules on roots enabling them to supply plant nutrient by absorbing free nitrogen from air. A cover crop is a prostrating plant grown to cover the soil surface for protection against soil erosion caused by heavy rain or strong wind. Although the objectives of growing cover crop are usually different from those of planting green manure, some cover crops can serve simultaneously as green manure crops. For example, Mucuna capitata, a leguminous plant grown in the banana orchard in the hilly regions of Taichung and Nantou Prefectures, covers the land in summer during the raining season for erosion control and is plowed into the soil in autumn as green manure.

The effects of green manure crops on soil and plant growth can be briefly stated as follows:

A. Replenishment of organic matter and nitrogen in the soil

Organic matter in the soil of Taiwan, under tropical and subtropical climate, is quite easily decomposed, especially in Central and Southern Taiwan. The long period of warm and dry season during winter and spring often causes a serious deficit of humus in the soil. Green manure will replenish a great deal of organic matter thus lost. On supplying nitrogenous nutrient, while taking one-third of its total nitrogen from the soil, green manure fixes the other two-thirds from air. According to the unpublished data of the Taiwan Agricultural Research Institute, the amount of nitrogen

fixed by the principal green manure crops in Taiwan is as follows:

Green manure crop	Nitrogen fixation (kgs./ha.)
Pea (*Pisum Sativum*)	35.35
Blue soybean (*Glycine max*)	36.14
Sesbania (*Sesbania sesban*)	91.67
Crotalaria (*Crotalaria juncea*)	88.84
Cowpea (*Vigna sinensis*)	34.10
Mucuna (*Mucuna capitata*)	104.39
Tephrosia (*Tephrosia candida*)	48.48
Broad bean (*Vicia faba*)	26.54

B. Conservation of soil fertility and soil moisture

Both cover crops and green manure crops are able to conserve the soil fertility and its water content as well as to control erosion. Nitrate in soil is most easily washed away by rain. The presence of a green manure or cover crop will reduce such a loss by absorption of the nitrate-form nitrogen through its roots. The deep-rooting green manure crop serves also as a transferring medium by absorbing those nutrients available in the subsoil and leaving it in top soil when plowed in. The turning in of green manure crop will also increase the organic acid content in soil, which, by dissolving those insoluble elements such as Ca, P, K, and Mg, converts them into available plant food. Furthermore green manures are the most powerful plants in absorption of soil phosphorus to transform it into organic phosphorus compound which will then be taken up by other principal crops. Therefore green manure crops will not only increase carbon, hydrogen, oxygen and nitrogen content of soil, but also will replenish other necessary mineral elements.

C. Promotion of the activity of soil micro-organism

Green manure, being rich in nitrogen, when plowed into soil will immediately expedite the multiplication of micro-organisms, and thus hasten the nitrification and ammonification in soil to improve its fertility.

D. Improvement on the physical property of soil

The physical property of soil will be improved greatly by continued application of green manure, such as in the case with heavy clay or too-sandy soils. Soil in the bottom layer can also be ameliorated by planting of deep-rooted green manure crops.

E. Illustrative cases in rice and sugarcane

According to the experimental result of the Taiwan Agricultural Research Institute, the rates of absorption of nitrogen by paddy rice from different green manure crops, ammonium sulphate, and farmyard manure are tabulated as follows:

Green manure or fertilizer	1st rice crop	2nd rice crop	Total	No. of year of experiment
Blue soybean (*Glycine max*)	65.5%	8.4% (RE)*	73.9%	4
Black soybean (*Glycine max*)	9.8 (RE)*	49.8	59.6	3
Raphanus (*Raphanus sativus*)	57.5	7.9 (RE)*	65.4	4
Sesbania (*Sesbania sesban*)	6.2 (RE)*	20.9	27.1	3
Pea (*Pisum sativum*)	56.4	14.0 (RE)*	70.4	2
Cowpea (*Vigna sinensis*)	9.8 (RE)*	49.4	59.2	2
Ammonium sulphate	47.7	4.9 (RE)*	52.6	3
Farmyard manure	12.0 (RE)*	9.1	21.1	3

* Residual effect

As can be seen from the above table, the absorption rates of nitrogen by paddy rice from all green manure crops except sesbania are far better than from ammonium sulphate. The average data of a 7-year experiment on the increased production of rice by green manure conducted by the said Institute are as follows:

Fertilizer treatment	Index of yield	
	1st crop	2nd crop
No fertilizer	100	100
Application of green manure equivalent to N 40 kgs/ha.	118	112
Application of green manure equivalent to N 80 kgs/ha.	130	121
Application of green manure equivalent to N 120 kgs/ha.	141	127
Application of ammonium sulphate equivalent to N 40 kgs/ha.	118	114
Application of ammonium sulphate equivalent to N 80 kgs/ha.	127	121
Application of ammonium sulphate equivalent to N 120 kgs/ha.	132	132

Note : Green manure used for 1st rice crop is blue soybean; and for 2nd crop, sesbania.

Therefore, the effect of green manure application on the increase of rice yield is about the same as or even higher than that of ammonium sulphate application.

Trials conducted by the Taiwan Sugar Experiment Station have shown that the application of green manure will not only increase the nitrogenous nutrient and organic matter in soil, but also will change the non-available potash in the soil into available forms, thus boosting the cane yield.

The field experiment conducted by the Hsinying Sugarcane Improvement Station on the study of various green manure shows that if the effectiveness of ammonium sulphate on cane production is 100, the comparative effects of different parts of crotalaria plant when plowed into soil are: leaves 178; stem 2; root 13; and whole plant 83. The same for sesbania are: leaves 187; stem 2; root 13; and whole plant 180.

Average data of three crop-seasons of sugarcane showed that interplanting of cane field with Crotalaria juncea increases the sugar yield of both the spring and autumn planting cane crops by 14.2% and 5.7% respectively.

II. Green Manure Crops and Green Manuring

A. Green Manure Crops for Paddy-field

The acreages of paddy field and green manure crops under cultivation

were 789,074 ha. and 176,865 ha. respectively according to the Taiwan Agricultural Year Book of 1952. Green manure crops were 22.4% of the total rice acreage. Green manures planted can be classified into two groups, basing on cultural method:

a. Single-seeding—acreage amounted to 153,085.6 ha. or 86.5% of total

b. Mixed seeding—acreage amounted to 23,779.6 ha. or 13.5% of total

So-called "single-seeding" is when only one kind of green manure crop, such as sesbania, pea, soybean, etc., is planted on a parcel of land, while the "mixed seeding" means that two kinds of green manure crops, e. g., radish and pea, or radish and soybean, are planted simultaneously in one tract of land.

The breakdown of acreage of single-seeding green manure for rice on crop basis is as follows:

Kind of green manure	Cultivated acreage(ha.)	Locality
Sesbania (*Sesbania sesban*)	73,607	Mostly in Southern Taiwan: Pingtung, first; Tainan, Yunlin, Chiayi and Kaohsiung follow en suite.
Soybean (*Glycine max*)	31,539	Mostly in Southern Taiwan: Pingtung, first ;Chiayi, Changhwa, Hwalien, and Kaohsiung follow en suite.
Radish (*Raphanus sativus*)	27,747	Distributed in Northern and Central Taiwan: Miaoli, first; Hsinchu, Taichung, and Taoyuan follow en suite.
Pea (*Pisum sativum*)	7,577	Mostly in Central Taiwan: Changhwa first; Taichung and Yunlin follow en suite.
Rapeseed (*Brassica campestris*)	2,199	Central Taiwan: Yunlin, Changhwa, etc.
Green bean (*Phaseolus radiatus*)	1,494	Southern Taiwan: Tainan.
Cowpea (*Vigna sinensis*)	1,405	Southern Taiwan: Tainan.
Peanut (*Arachis hypogaea*)	1,333	Central Taiwan: Yunlin.

It can be seen from the above table that principal green manure for the rice crop in Southern Taiwan are sesbania and soybean; and in the 3-year rotation areas of Tainan, Yunlin and Chiayi, sesbania, soybean, green bean and cowpea; while Northern Taiwan, the principal green manure is radish; in Central Taiwan, pea. Among the crops, the acreage under cultivation of sesbania was the biggest, and soybean and radish the next. Recently, at the Hsinchu Agricultural Improvement Station, broadbean has been planted for trial as green manure for rice with good result, and is now recommended for farmers' adoption.

The purpose of mixed seeding is to ensure a better harvest as well as to get an increase of both organic matter and nitrogenous nutrient. Taking the practice of mixed seeding of radish and pea in Taichung and Changhwa areas for example, the former is a cruciferous plant capable of replenishing organic matter only, while the latter and other legumes will furnish nitrogenous nutrient. Another illustration is the mixed planting of sesbania and soybean as green manure in Southern Taiwan to minimize loss of harvesting in either one of the two if and when suffered from insect or weather damage. Crops most commonly used as in mixed seeding are sesbania and soybean in Kaohsiung and Pingtung districts; sesbania and cowpea or green bean rank next and are quite popular in Chiayi and Tainan districts. Radish and pea or soybean mixed seeding is also a common practice in Taichung and Changhwa districts.

The acreage and yield of green manure crop for rice and its geographical distribution are shown in Appendix I.

Sesbania sesban, an annual erect plant with vigorous root system and nodules, well adapted to moist and moderately hot climate, is generally grown in Taichung and Southern Taiwan. Its seed is strongly water-resistant, and thus can be planted in moist sandy soil, loam, or clayey loam. Its growth at early stage is rather slow, but becomes vigorous toward the later period. In Pingtung and Kaohsiung areas, it is extensively used as green manure for the first rice crop, and usually planted with soybean, pea, etc., as mixed seeding. It can also be used for second rice crop as single seeding in Southern Taiwan where rainy days prevail right after the harvest of the first rice crop when no other green manure crop but sesbania can be favorably grown. The seeding rate is 30-40 kgs/ha. It is done by broadcast or row planting either before or after the harvest of the rice crop. It should

be noted, however, that for better manuring, sesbania must be plowed into the soil when its leaves and stems are still tender enough.

Glycine max, an annual erect plant with a strong root system, has stem of 60-90 cm. in height, three oval leaflets forming a compound leaf, and small butterfly-shaped white or purple flower on the leaf-axil. There are four varieties commonly grown, which are differentiated from each other by the color of seed:

a. Blue soybean —small seed of bluish green color, most extensively grown in this Island.
b. Black soybean —small seed of greyish black color.
c. Pearl soybean —yellow seed and white flower.
d. White soybean—seed of light green color and light purplish flower.

These grow well in sandy loam or loam of good drainage, but not in extra heavy clay of poor drainage. As green manure for frist rice crop, planting should be done 2-3 weeks before the harvest of the second rice crop (1-2 days before the paddy field is to be drained off). After one day's soaking in the field from which water should then be drained off, it germinates in about 2-3 days. In case of paddy field of poor drainage and in those localities with too much rain, either hill planting or row planting is practiced after the harvest of rice crop and the plowing of the soil. The seeding rate is 80-100 kgs/ha. The proper time of turning it into soil is from February to March. For multiplication purpose, it is best to plant it in April-May on dry-land, and the crop will be ready for harvest in September-October.

Raphanus sativus, a cruciferae with white flower, is easily grown even in acid red-earth, but imparts less fertility to the soil than leguminous crops. It is planted after the harvest of second rice crop at a rate of 10 kgs/ha., or mix-seeded with pea or blue soybean, and plowed into soil as green manure for the first rice crop in February-March of the next year.

Pisum sativum — Pea grows well in sandy loam or loam of good drainage, but not in clay soil of poor drainage or in land receiving too much rain. It blooms with reddish purple or white flowers. As green manure for the first rice crop, it is planted after the harvest of the second rice crop, and plowed into soil the following spring before rice transplanting. The seeding rate is 60-80 kgs/ha.

B. Green Manure Crops for Sugarcane

Green manure crops are extensively grown in the Taiwan Sugar Corporation's (TSC) farms, and occupied 19,216.9 ha. out of the total planting acreage of 100,000 ha. for sugarcane in the year 1953. Almost all TSC farms have been planted with green manure crops. For the 1952/53 sugarcane crop the planted acreages of various green manures on TSC's farms are:

Kind of green manure	Acreage for green manuring sugar-cane field (ha.)	Acreage for seed multiplication (ha.)
Mucuna (*Mucuna capitata*)	8,167.39	328.72
Sesbania (*Sesbania sesban*)	5,227.40	288.36
Crotalaria (*Crotalaria juncea*)	4,592.18	237.36
Poona pea (*Vigna sinensis*)	28.96	60.24
Others	256.06	30.28
Total:	18,271.99	944.96

No data are available of the planting acreage of green manures on contract farms. According to the Taiwan Agricultural Year Book of 1952, the acreage under cultivation of dryland green manure crops totals 26,083 ha. (Appendix II). As very few green manure has been grown for crops other than sugarcane, the acreage of green manure crops cultivated on the contract farms is estimated to be 5,000-6,000 ha. The principal green manures for sugarcane are mucuna, sesbania, crotalaria and Poona pea, and those of less importance include peanut, soybean, lupine, green bean, radish, etc,.

Mucuna, an annual prostrated plant with big compound leaf consisting of three leaflets and butterfly-shaped blossom, has deep but not vigorous root together with nodules. Vine length is about 30 cms. The pods have a size like that of broadbeans, black when mature. Its seed is white in color dotted with greyish spots or grey with black spots and larger than broadbean in size. It grows well in sandy loam or loam of good drainage, and covers the land well to protect against soil erosion. In March-April each year, after the harvest of sugarcane and land preparation, it is planted in hills 50-60 cms. apart at a seed rate of 20-30 kgs/ha. with a furrow distance of 120-125 cms.; and its being plowed into soil as green manure takes place in July-August. Weight of green stuff accrued is about 20,000-30,000 kgs/ha.,

which decomposes about 7-10 days after being turned into soil. For multiplication purpose it is better grown in hill-land, to be harvested in December-January, and will yield 300-500 kgs. of seed per hectare.

Sesbania is usually planted in March-April each year after the harvest of sugarcane with a seeding rate of about 40 kgs/ha., and plowed into soil three months afterwards when or before blooming. It decomposes in soil within 3 weeks. Sesbania is tolerant of damp and saline soils, so it grows well in coastal and riverside land. For multiplication, it is harvested in September and gives a yield of seeds around 900 kgs/ha.

Crotalaria, a good green manure for sugarcane, is an annual erect plant with deep and vigorous root system and a height of 1-1½ meter. It is planted in March-April each year after the harvest of sugarcane at a seeding rate of 30-50 kgs/ha., and plowed into soil in June-July. For multiplication, it is planted in July-August, and harvested in middle or late December. Its seed usually suffers from insect damage, resulting in a lower yield of 250-350 kgs/ha.

Poona pea was introduced into Taiwan in 1937 from Australia. It grows rather quickly and can be harvested in two months' time. It is good as green manure as well as cover crop for fallow land after harvest of sugarcane or for interplanting with young cane. Similar to the native variety of cowpea, called "Mie-tou", the plant has alternative leaves of three small leaflets forming a compound leaf, and butterfly-shaped greyish purple flowers. The pod, 7-13 cms. in length, has 4-12 seeds in oval shape. Its main root is more vigorous than the side-root, both of which are deep-growing and have spherical nodules on it. It prefers hot climate, though can be planted any time from February to August. The growth of this erect plant at early stage is rather slow, but becomes vigorous at later period of growth to reach a height of 100-130 cms. As green manure it can be plowed into soil 50-70 days after planting. For multiplication, it may be either planted in January-February and harvested in May, or planted in August and harvested in November. When planted in March-April, it often suffers from insect damage and gives less harvest than that of sesbania or crotalaria, while if planted in September-October, it yields more than any other green manure crops. Seeding rate is 15 kgs/ha. for multiplication, and 20-30 kgs/ha. for green manure. It grows well in sandy soil or sandy loam, but not in clay soil.

The following shows the advantages and disadvantages of the above-mentioned green manure crops:—

	Advantages	Disadvantages
Mucuna	(1) Good yield when the growth period is long.	(1) Slow growth in early stage, so less yield if the growth period is short.
	(2) Easily decomposed in soil, even within one week's time.	(2) Not suitable for interplanting.
	(3) Well covers the land and prevents soil erosion and weed growth.	(3) The crop season is rather long: planted in March-April and seeds not harvested until November-December.
	(4) Easily grown.	
Sesbania	(1) Good yield when the growth period is long.	(1) Slow growth in early stage, so less yield if the growth period is short.
	(2) Easily grown.	(2) Although better yield is obtained when turned under more than 100 days after planting, the lower part of the stem becomes lignified.
	(3) Suitable for interplanting.	
	(4) Resistant to water or rain.	
Crotalaria	(1) Good yield when the growth period is long.	(1) Poor growth under excessive rain.
	(2) Regenerative.	(2) Slow growth in early stage, so less yield if the growth period is short.
	(3) Being erect, capable to be interplanted with sugarcane.	
	(4) Good for cattle feed.	
Poona pea	(1) Short period of growth; could be plowed into soil 50-70 days after planting.	(1) Hard to obtain seeds during rainy season, seeds are apt to ferment or germinate on pod.
	(2) Could be interplanted with sugarcane.	(2) Seed is easily damaged by granary weevils, so its storage presents quite a problem.
	(3) Seed edible.	
	(4) Strong resistance to drought and water.	

C. Green Manure Crop for Tea Garden

Among the total 42,000 ha. of tea plantation in Taiwan, 13,000 ha. are located in those red table lands in Taipei, Taoyuan, Miaoli, and Hsinchu. This red earth is strongly acid, lacks organic matter and is low in fertility. Lupinus luteus had been tried out as green manure for this particular region. Before 1949 the acreage planted with lupine was only 800 ha. Since then, through the assistance of the Joint Commission on Rural Reconstruction (JCRR), effort was made by the Provincial Department of Agriculture and Forestry (PDAF) to expand the planting acreage at 2,000 ha. annually and, up to 1953, the total acreage has reached 5,000 ha. The effectiveness of growing lupine and its cultural methods are now quite familiar to tea growers. Lupine is an autumn green manure crop, prefers moist and warm climate, and grows well in sandy loam, even in acidic soil. It is planted from late September to late October at a seeding rate of 25 kgs. per hectare between the rows of tea and is plowed into the soil in March of the following year when blooming. For multiplication purpose, the seeds can be harvested as late as May when the pods turn black with an average yield of 200 kgs/ha. As a good starting practice it is recommended to bring in some soil from the tea garden already grown with lupine in previous year to mix with seeds when planting, as the plant will not grow well if in deficit of nodule bacteria. For 25 kgs. of lupine seed to be planted in 1 ha. of land, 40-50 kgs. of old soil should be mixed and inoculated to the new field. In case of poor growth of lupine thus treated in the first year, the practice should be continued for another year. Lupine needs phosphatic fertilizer. Application of calcium superphosphate or fused phosphate at about 100 kgs/ha. will give good results. Lupine grows well in Northern Taiwan. In the Hsinchu area it has been used as green manure for the spring-planted sugarcane. In Hsinchu and Taoyuan areas, farmers plant lupine in tea garden or in other land, then cut it in February-March when blooming, and apply it to paddy field as green manuring for rice.

D. Green Manure Crops for Fruit Orchard

Soil erosion is serious in those banana orchards of mountainous

slope in Central Taiwan. Demonstration on planting mucuna as green manure for banana crop has been carried out by the Taichung Vegetable and Fruit Marketing Cooperative through the assistance of JCRR. In 1951, 200 ha. had been contracted for demonstration purpose; in 1952, 400 ha.; and in 1953, 1,000 ha. Mucuna is easily grown and thrifty. It is planted in February-March at a seeding rate of 20 kgs. per ha., 2-3 seeds for each hill with a distance of 3 ft. between rows and of 1.5 ft. between hills (Two rows of mucuna may be planted between the rows of banana). The plant will grow to cover the whole ground in June-July and is adequate in preventing soil erosion; however, its only defect is that its vines climb onto the banana plants and bind the banana leaves together. This often hinders the unfolding of the young leaves. Therefore, the banana growers have to cut off the vines every 2-3 weeks, leaving a vacant space of 1-2 ft. around the banana plant. According to the investigation made by the Taichung Vegetable and Fruit Marketing Cooperative, an increase of more than 10% of the yield of banana can be obtained if mucuna is intercropped as green manure; that is, 5,500 kilograms of banana per hectare against a yield of 5,000 kilograms from those orchards without planting mucuna. The productivity of banana orchard without intercropping mucuna as green manure will be reduced after five years, while that with mucuna will maintain its productivity for ten years. The labor cost of growing mucuna including vine-cutting could be offset by part of the profit realized from the increased yield.

Pineapple is cultivated on the hill-land of red earth in Central and Southern Taiwan. The plantations are located mostly on the steep slope and there soil erosion is rather serious. Subsidy has been granted by JCRR to the Taiwan Pineapple Corporation for conducting demonstration on planting green manure crops for pineapple. Thirty ha. have been contracted for the purpose in 1952, and hundred ha. in 1953. Mucuna and Tephrosia (*Tephrosia candida*) are the two green manure crops employed for demonstration. Pineapple growers were not at all accustomed to planting green manure crops so that even in the fifth year of the growing cycle of pineapple when old pineapple plants should be taken out and land should be fallowed for one green manure crop before another new crop of pineapple is planted, no attempt has been made to grow green manure crop on fallow

land. Now, farmers are being taught to have a rotation system of 5-year pineapple followed by 1-year green manure for the purpose of maintaining soil fertility. It is also a good practice to plant tephrosia between the rows of pineapple in March-April of the second year when the pineapple plant is still small (7-month's growth), to be pulled out in August-September and laid among the pineapple plants as mulching material. Rice straw is often used as mulching material but is rather expensive. The per hectare amount of 5,000 kgs. costs at present NT$900 in Central Taiwan and NT$500 in Southern Taiwan. The yield of tephrosia is 10,400-13,000 kgs/ha. in fresh weight or 3,400-4,300 kgs/ha. in dry weight which would save 1/2-2/3 of the cost of straw for mulching. In addition, it has the advantages of being able of:- (1) Controlling soil erosion; (2) replenishing organic matter and nitrogenous nutrient in the soil; and (3) conserving soil moisture. It is also worthwhile to plant tephrosia on the walkway of pineapple plantation and on both sides of drainage ditches. Up to the present, farmers are not yet fully aware of the value of tephrosia cultivation; further extension teachings are indeed needed.

Tephrosia, a tropical perennial legume shrub of 3-4 ft. high and having featherlike compound leaves, grows luxuriantly on all types of soil. Its pod is 9 cm. in length and contains 10-12 seeds. It is usually planted in March-April at a seeding rate of 25 kgs/ha., and harvested in August-September to be used for mulching by pulling out the plant. Otherwise, it may be cut at a distance of two feet from the ground at blooming season for green manure. Cutting can also be done at every three months, i.e., 2-3 times annually, to be continued until the third or fourth year.

III. Problems in Growing Green Manure Crops

A. Green manure for rice

1. Northern Taiwan

No green manure crops are grown by rice growers in Taipei, Ilan and Taoyuan at the interval when the paddy field is fallowed after the harvest of the second crop and before the transplanting of first crop. The reasons are firstly, too frequent and too much rainfall in winter which is

unfavorable to the growth of green manure crops; secondly, the heavy clay soil soaked with water because of poor drainage which makes the growing of green manure crops impossible; and thirdly, late harvest of second rice crop leaving too short a period of fallow. Demonstrations on the green manure for rice crop have been conducted by the Taiwan Agricultural Research Institute and National Bureau of Agricultural Research under the subsidy of JCRR. The 2-year demonstration in Ilan Hsien revealed that blue soybean was the one best adapted because the soil in that district is relatively sandy. The project was carried out in ten townships. After 78 days the soybean plant grew to an average bush height of 35.7 cms. and the total weight of the green stuff harvested was 12,145 kgs/ha. This is approximately equivalent to an application of 330 kgs. of ammonium sulphate per hectare. However, two main difficulties will be encountered if the program were to be expanded:

a. In that area too frequent rain during the summer makes the seed multiplication of blue soybean almostly impossible. Seeds have to be purchased from Hwalien, a neighboring Hsien, about 240 km. apart from Ilan.

b. The acreage for growing blue soybean as green manure crop is greatly limited by its poor drainage system, under which condition most of the paddy field under fallow is flooded during the winter rainy season.

At present, no green manure has yet been found suitable in this area for rice crop; therefore, more efforts should be made toward solving this particular problem.

2. Places other than Northern Taiwan

Defects found generally in farmers' field where green manure is grown are too less attention being paid by the farmer in tending the crops and low seeding rate, resulting in a thrifty growth of weeds and much damage being caused by insect and disease. Most of the farmers do not apply chemical fertilizer. A better yield of rice could be reached indirectly if calcium superphosphate is used for the green manures. Demonstration and education work for farmers on improved methods of planting green

manure crop for rice should therefore be emphasized.

B. Green manure for sugarcane

Of sugarcane, only the Taiwan Sugar Corporation farms are extensively cultivated with green manures, but very few farmers carrying on the same practice in their cane fields. Farmers generally choose to plant sweet potato or peanut in their cane-fields in the early period of growth of the sugarcane instead of green manure for either their own consumption or more immediate cash income as they lack foresight of the benefit derived from soil improvement and eventually the increase of cane-yield by growing green manure. Hence, it is worthwhile to teach farmers to plant an edible legume crop or peanut as a previous crop for cane-field or intercropping with sugarcane for soil improvement and increase their cash income as well as to improve their nutrition by introducing high protein substance to their diet.

Efforts should be made for the control of pests attacking legumes. Army-cutworms (*Prodenia litura Fab.*), attacking the young plant of sesbania, and weevils (*Callosobruchus spp.*), eating up the seeds of crotalaria, are common insects found in the sugarcane field. The low yield of seeds due to insect damage makes the price of seed unreasonably high and farmers cannot afford to buy such high-priced seeds for green manuring purposes. In the seed multiplication fields pesticides should be applied in order to ensure good yield.

C. Green manure for crops other than rice and sugarcane

After four years of JCRR assistance in demonstration of the value of lupine as green manure for tea plantation, the green manuring system for tea plantation has been established. However, during the course of extension teaching, some difficulties have been encountered and remain to be solved. Firstly, in its first year planting, lupine growth is always poor due to lack of nodule-bacteria inoculation. Secondly, climatic fluctuation exerts a great effect on lupine growth. Dry weather at seeding time and much rain in the flowering stage will cause poor growth and poor seed-setting of the crop. Thirdly, in some localities where deficiency of phos-

phorus prevails as in the lateritic soils, lupine growth is usually very poor. Fourthly, in those Assam tea plantations in Central Taiwan near Sun-Moon Lake, lupine has never grown well owing to the dry season prevailing in winter. A suitable legume adaptable to that particular area should be sought.

In the rainy season extending from May to September, soil erosion in tea plantations, especially of the hilly regions, is very severe. Proper measures for controlling soil erosion, such as introducing suitable cover crop, should be studied.

Lupine extension has been successful because farmers can multiply lupine seeds in their own tea garden. But for planting green manure for banana and pineapple, the farmers will encounter difficulty in supplying their own seeds for the next crop. Tephrosia grown on the pineapple field will exert shading effect on and compete with the growth of pineapple with which it is intercropped, if it is allowed to remain in the field until seeds are harvested. It is also impossible to harvest seeds from mucuna when grown on hilly banana field, because its vine has to be cut off in order to avoid its hindrance to banana growth. Farmers are willing to plant tephrosia or mucuna for green manuring but they have no separate land to grow these crops for seed multiplication. Therefore, some agencies should be responsible for multiplication of these legume seeds and distribute or sell them to the banana and pineapple growers every year. Citrus crops are mostly cultivated in those hilly lands in northern Taiwan. The growers are not accustomed to planting green manure or cover crops to prevent soil erosion. It is necessary to introduce some green manure crop for this purpose.

IV. Appendixes

Appendix 1

Acreage and Yield of Green Manure Crop for Rice in Each Hsien or City (1951)

Hsien/City	Acreage under cultivation of single-seeding crop	Yield of green stuff	Acreage under cultivation of mixed-seeding crop	Yield of green stuff
	(ha.)	(m.t.)	(ha.)	(m.t.)
Taipei Hsien	1,858.90	17,338.9	3.50	35.0
Ilan Hsien	494.00	8,670.1	0.50	3.5
Taoyuan Hsien	4,100.30	29,956.8	—	—
Hsinchu Hsien	5,612.50	23,501.2	150.30	614.3
Miaoli Hsien	11,795.10	100,490.0	766.75	3,457.4
Taichung Hsien	8,298.32	65,661.8	1,892.70	10,535.4
Changhwa Hsien	14,339.98	117,153.4	5,083.12	35,826.9
Nantou Hsien	4,343.00	38,478.1	110.00	423.2
Yunlin Hsien	19,253.50	185,088.4	3,857.40	39,127.1
Chiayi Hsien	13,846.20	144,962.7	3,646.70	39,176.9
Tainan Hsien	17,361.51	178,845.4	3,938.73	43,653.6
Kaohsiung Hsien	10,344.62	100,827.1	1,620.80	10,989.0
Pingtung Hsien	32,954.97	320,200.5	1,521.95	16,883.3
Taitung Hsien	2,650.00	17,827.3	456.00	3,293.6
Hwalien Hsien	3,912.08	34,957.0	650.45	7,167.0
Taipei City	8.40	48.1	—	—
Keelung City	12.30	96.2	—	—
Taichung City	718.58	6,679.7	18.00	178.4
Tainan City	1,118.79	11,485.8	62.70	368.6
Kaohsiung City	40.00	360.0	—	—
Yangmingshan Adm.	22.60	127.3	—	—
Total:	153,085.65	1,402,755.8	23,779.60	211,733.2

Source: Taiwan Agricultural Year Book 1952 Edition

Appendix 2

Acreage and Yield of Green Manures for Dry Land Crop in Each Hsien or City (1951)

Hsien/City	Single-seeding crop		Mixed seeding crop	
	Acreage under cultivation	Yield of green stuff	Acreage under cultivation	Yield of green stuff
	(ha.)	(m.t.)	(ha.)	(m.t.)
Taipei Hsien	813.6	8,670.1	8.0	80.0
Ilan Hsien	9.2	75.4	—	—
Taoyuan Hsien	402.0	2,396.0	—	—
Hsinchu Hsien	599.4	2,331.3	3.0	23.0
Miaoli Hsien	379.0	3,237.4	—	—
Taichung Hsien	93.8	873.6	44.0	340.0
Changhwa Hsien	4,387.1	39,547.3	769.3	1,729.6
Nantou Hsien	862.0	5,978.0	14.0	115.2
Yunlin Hsien	2,358.1	16,976.1	147.0	1,414.0
Chiayi Hsien	1,181.7	9,202.6	260.8	3,055.8
Tainan Hsien	3,109.0	26,876.5	224.9	1,860.1
Kaohsiung Hsien	2,367.1	26,066.6	134.0	1,225.0
Pingtung Hsien	5,279.9	56,649.0	486.6	5,469.0
Taitung Hsien	113.3	624.3	—	—
Hwalien Hsien	1,274.0	3,100.0	—	—
Taipei City	9.0	65.8	—	—
Keelung City	2.8	28.0	—	—
Taichung City	61.9	471.3	—	—
Tainan City	432.3	3,315.9	34.3	181.2
Kaohsiung City	221.6	3,570.4	—	—
Yangmingshan Adm.	—	—		
Total:	23,956.8	210,055.6	2,125.9	15,492.9

Source: Taiwan Agricultural Year Book, 1952 Edition

Appendix 3

The Yield of Green Stuff and the NPK Content in the Principal Green Manure Crops Grown in Taiwan

Green manure crop	Yield of green stuff	N%	P_2O_5%	K_2O%
	(Kg/ha.)			
Arachis hypogaea (Peanut)	-	0.48	0.10	0.48
Crotalaria juncea (Sun-hemp)	20,000-30,000	0.37	0.08	0.14
Glycine max (Black soybean)	7,700-15,500	0.70	0.13	0.52
Glycine max (Blue soybean)	7,700-15,500	0.62	0.09	0.32
Lupinus leteus (Lupine)	20,000-30,000	0.37	0.14	0.28
Mucuna capitata (Tiger-paw bean)	20,000-30,000	0.81	0.12	0.40
Phaseolus radiatus (Green bean)	7,700-15,500	0.63	0.15	0.04
Pisum sativum (Pea)	7,700-15,500	0.45	0.10	0.35
Raphanus sativus (Radish)	7,700-15,500	0.27	0.09	0.56
Sesbania sesban (Sesbania)	7,700-15,500	0.47	0.12	0.42
Tephrosia candida (Tephrosia)	20,000-30,000	0.72	0.12	0.39
Vicia faba (Broadbean)	8,000-10,000	0.33	0.12	0.57
Vigna sinensis (Cowpea)	15,000-20,000	0.43	0.08	0.05
Vigna sinensis (Poona pea)	15,000-20,000	0.51	0.38	0.12

Source of the material : Taiwan Agricultural Research Institute

Appendix 4

A Guide to Growing Green Manures for Different Crops

Kind of green manure crop	Time of sowing	Method of sowing	Seeding rate	Usage
			(Kg/ha)	
Crotalaria juncea (Sun-hemp)	Mar.-Apr.	Drilling or dibbling	30-50	For green manuring of sugarcane
Glycine max (Blue or black soybean)	Oct.-Nov.	Broadcasting, drilling or dibbling	80-100	For green manuring of the first rice crop
Lupinus leteus (Lupine)	Sept.-Oct.	Drilling or dibbling	25-30	For green manuring of tea
Mucuna capitata (Tiger-paw bean)	Mar.-Apr.	Dibbling	20-30	For green manuring of sugarcane, pine-apple and banana
Pisum sativum (Pea)	Oct.-Nov.	Dibbling	60-80	For green manuring of the first rice crop
Raphanus sativus (Radish or rape seed)	Nov.	Broadcasting or dibbling	10-15	- do -
Sesbania sesban (Sesbania)	May-June Oct.-Nov.	Broadcasting	30-40	Both for green manuring of first and second crop of rice
	Mar.-Apr.	Broadcasting	30-40	For green manuring of sugarcane
Tephrosia candida (Tephrosia)	Mar.-Apr.	Drilling or dibbling	25-30	For green manuring of pineapple
Vigna sinensis (Poona pea)	Mar.-Apr. Sept.-Oct.	Drilling or dibbling	20-30	For green manuring of sugarcane

Appendix 5

A List of Green Manure Crops Already Under Test in Taiwan

The following is a name list of green manure crops which have been tested or are under testing at present by various experimental stations.

Scientific names	Common names
Alysicarpus vaginalis	Alyceclover
Astragulus sinicus	Milk vetch
Cajanus cajan	Pigeon pea
Calopogonium mucunoides	—
Canavalia ensiformis	Jack bean
Cassia occidentalis	—
Cassia tora	Sickle senna
Centrosema plumieri	—
Clitoria ternatea	—
Crotalaria usaramoensis	—
Crotalaria striata	—
Crotalaria anagyroides	—
Dolichos lablab	Hyacinth-bean
Indigofera endecaphylla	Creeping indigo
Indigofera suffruticosa	—
Lespedeza striata	Kobe lespedeza
Lespedeza stipulacea	Korean lespedeza
Leucaena glauca	White-popinag
Lupinus albus	White lupine
Lupinus angustifolius	Blue lupine
Medicago denticulata	Bur clover
Medicago hispida	California bur clover
Medicago lupulina	Black medic
Medicogo sativa	Purple alfalfa
Melieotus alba	White sweet clover
Mimosa pudica	Sensitive plant
Phaseolus vulgaris	Kidney bean
Pueraria phaseoloides	Tropical kudzu
Stizolobium	Velvet bean
Tephrosia noctiflora	—
Trifolium hybridum	Alsike clover
Trifolium pratense	Red clover
Trifolium repens	White clover
Vicia sativa	Common vetch
Vicia villosa	Hairy vetch

Appendix 6

Memorandum of JCRR Program on the Demonstration and Extension of Green Manure Crop (From Plant Industry Division, JCRR):

A. Memorandum TC-1079: Demonstration on green manure seeds for rice in Ilan Hsien
B. Memorandum TC-866: Demonstration on green manuring for banana plantation in Taichung area
C. Memorandum TC-851: Demonstration of green manure crops in pineapple fields
D. Memorandum TC-1444: Extension of green manure crop seeds (lupine) for tea plantation in 1954

A. Memorandum TC-1079 (October 6, 1952)

Subject: Continuation of demonstration on green manure seeds for rice in Ilan Hsien

The main content of this project is excerpted as follows:

1. Number of demonstrations: 160 demonstrations will be conducted in the ten townships of Ilan Hsien. In each demonstration, 0.5 ha. of paddy field will be planted to blue soybean crop after the second crop of rice in 1952 is harvested.

2. Amount of seeds required: A total of 12,000 Taiwan catties of soybean seeds is needed for planting 80 ha. of demonstration fields, at the seeding rate of 150 T.C./ha.

3. Selection of demonstration fields. Four demonstration fields in each township will be carefully selected in accordance with the following conditions:

a. Where the communication is convenient.
b. That the demonstration fields be evenly distributed in the township.
c. Where the drainage condition is good.
d. That two ha. of land be used for each demonstration.

e. That the demonstration farmer in the last year be not selected again.

f. That the demonstration farmer should be enthusiastic and interested in demonstration work and willing to receive any technical supervision rendered by the National Bureau of Agricultural Research.

4. Method of management:

a. Seeding date: November first to November tenth, 1952.

b. Seeding rate: 150 T.C./ha.

c. Method of seeding: Broadcast.

d. Plowing and leveling: Before planting the crop the demonstration field should be plowed and leveled. Necessary drainage ditches should be made.

e. In the different stages of plant growth, field records should be taken regularly.

f. A field day should be held in each township before the green manure crop is plowed under, so that the method of cultivation of this crop and its effectiveness may be extensively publicized to the farmers.

B. Memorandum TC-866 (January 4, 1952)

Subject: Continuation of demonstration on green manuring for banana plantation in Taichung area

1. Purpose

"Tiger-paw" bean is planted in the banana plantation as a cover crop as well as a green manuring crop. It serves a dual purpose: to minimize soil erosion in the hilly region and to supply plant nutrient for banana growth.

2. Method of cultivation

The green manure crop seeds are sown in February or March when the weeding of banana groves is performed. Two to three seeds are sown in each hill, 5-10 cm. in depth, with a space of 50 cm. between hills. After two to three months, its leaves would cover all the surface of hilly

ground, and thus the seriousness of soil erosion in the rainy season can be reduced. In August to September it can be plowed under as green manuring for banana plantations. It is estimated that by seeding 20 kg. per hectare of seeds, 15,000-30,000 kg. of fresh leaves and vines can be produced. After turning in and decayed the green manure crop will enrich the organic matter content in soils and improve soil fertility.

3. Procedures to be carried out

   a. A total of 8,000 kg. of the green manure crop seeds will be collected and purchased in January, 1952.
   b. In February, 1952, they will be allocated to the banana growers in different localities. At the rate of 20 kg. of seeds in each hectare, a total of 400 ha. will be included in the demonstration.
   c. Advice will be given regarding the proper seeding time and sowing method.
   d. Advice will be given regarding cutting off the vines and turning in the whole plant.
   e. 20% of the demonstrative fields will be reserved for propagation of seeds. After harvest, the same amount of seeds allocated to the demonstration farmers will be collected by the Vegetable and Fruit Marketing Cooperative for the continuation of this project in the next year.

C. Memorandum TC-851 (December 11, 1951)

Subject: A request for approval of a project on demonstration of green manure crops in pineapple fields

This Division has recently received a request submitted by the Taiwan Pineapple Corporation on a project of demonstration of green manure crops in pineapple fields. The purpose of the project is to increase soil organic matter and improve soil fertility for pineapple growth and to establish a green manure crop system in these plantations.

Since chemical fertilizers are still in shortage at present in Taiwan and have depended largely on importation from other countries, a development of green manure crops in the hilly lands of gravel clay loam or sandy loam

soils is most important. According to the report of the said Corporation, several green manure crops were introduced to the pineapple fields before the War, such as *Mucuna capitata* for fallow land, and *Tephrosia candida* for interplanting purpose. The growth of the plants was very promising. However, due to declination of the pineapple industry in war time, the extension work of green manure crops was not developed.

The main idea of the present project is as follows:

1. Purpose of the program
   a. To plant green manure crops in the pineapple fields between intercycle period or in the lanes between beds of the first year plantings in order to increase soil fertility and prevent soil erosion in slope areas.
   b. To use the leaves and stems of green manure crops as mulching material in order to preserve soil moisture for root growth.
   c. To establish a self-support system of green manure crop seeds production among pineapple growers.
2. General outline of the program
   a. Thirty hectares of land with ninety contracted farmers will be selected as demonstration centers. It must be either land being fallowed and planned to be planted with pineapple in the succeeding season, or land of first year plantings with enough space for raising green manure crops.
   b. Land should be with a gentle slope not more than twenty degrees and close to communication line (within one mile of the highway).
   c. Acreage for each individual farm should be limited to 0.20 to 0.50 ha.
   d. The selection of green manure crops will depend upon types of land and sources of seeds. *Mucuna capitata* is the main crop for fallow land. Others, such as Sesbania and Tephrosia, will be used as interplanting crops.
   e. Green manure seeds will be distributed to farmers on loan basis.
   f. Each contracted farmer should keep one-tenth of green manure

crops for seeds. After harvesting, equal amount of seeds loaned should be paid back to sponsor agencies for further extension. The remainder will be kept by farmers for the next growing season.

g. Distribution of work:

District (Hsien)	Acreage (ha.)	No. of contracted farmers	Sponsor agency
Changhwa	6	18	Changhwa Farm
Nantou	5	15	Changhwa Farm
Yunlin	4	12	Dou Liu Farm
Chiayi	3	9	Chiayi Farm
Tainan	6	18	Kwan Miao Farm
Kaohsiung	5	15	Chiu Chu Tang Farm
Pingtung	1	3	Lao Pei Farm
Total	30	90	

h. The sponsoring agency of this project is the Taiwan Pineapple Corporation and the manager of the Corporation is the person in charge. JCRR will act as supervisor.

3. Procedures to be carried out:

a. Selection of contracted farmers — Ninety contracted farmers, each with an acreage of about 0.2-0.5 ha. of pineapple field, will be selected in January, 1952 by all the relevant workers of the Taiwan Pineapple Corporation.

b. Collection and distribution of seeds—Due to limitation of seed supply, the sponsor might obtain their seeds from local markets, but a germination test is required before delivery to farmers at the end of February, 1952.

c. Supervision of planting — The green manure crop seeds will be sown in March, 1952. Technical persons will be delegated by the Taiwan Pineapple Corporation to supervise land preparation and methods of planting.

d. Inspection of plant growth — The condition of crop growth in the demonstration field will be inspected by the local agricultural supervisors of the seven sponsoring agencies once every month.

e. Usage of green manure crops — All the green manure crops should be plowed under or cut for mulching in August, 1952, except those (1/10 of the crops) for seeds.

D. Memorandum TC-1444 (May 19, 1954)

Subject: Continuation of extension of green manure crop seeds (lupine) for tea plantation in 1954

After four years of JCRR subsidy in extension of lupine seeds for tea plantation, the green manuring system for tea plantation has been established. Tea growers are now quite familiar with the effectiveness of lupine in green manuring for tea plantation. It is estimated that a total of 5,718 hectares of lupine has been planted in 1953-54. Members of this Division are of the opinion that this project should be terminated after completion of a 5-year extension program. However, through the course of four years of extension, some difficulties have been encountered in this project and remain to be solved. Firstly, in the first year planting, lupine growth is always poor due to lack of inoculation. Secondly, climatical fluctuation has effect on lupine growth. In some years, too dry weather in the seeding time and too much rain in the flowering stage cause poor growth and poor harvest of the crop. Thirdly, in some localities lupine growth is very poor due to deficiency of phosphorus in the laterite soils. This has been found by the Pingchen Tea Experiment Station, but is not yet known to farmers.

After inspection of the extension work and reviewing the present status of this project, members of this Division recommend that the following activities be taken up in the continuation of this project for 1954.

1. Continuation of lupine seed extension

Since this is the last year of extension of lupine seeds, principles for the distribution of seeds for this year should be laid down as follows:

a. The total extension acreage for lupine seeds should be reduced

to 1,000 hectares instead of 2,000 hectares in the past years.

b. The distribution of seeds should be concentrated in those areas where the growth and harvest conditions of lupine were quite promising but the total extension acreages were still limited. It will not be extended in those areas where lupine growth was very good and the density of lupine plantation was already considerable.

c. Extension work should be stopped in those areas where lupine growth was very poor. Instead, the demonstration field for lupine plantation as set-up during last year should be continued in order to study the causes of failure in the past. Calcium superphosphate at a rate of 200 kg. per hectare should be given free of charge to the demonstration farmers so that they would recognize the effect of the fertilizer to lupine growth.

d. In consultation with PDAF, the seed distribution is tentatively listed below:

Hsien and township	Acreage of lupine to be extended in 1954 (ha.)	Amount of lupine seeds required (kg.)
Taipei, Hsintien	80	2,000
Taipei, Sanchia	70	1,750
Taoyuan, Chungli	57	1,425
Taoyuan, Pingchen	35	875
Taoyuan, Yangmei	76	1,900
Taoyuan, Peiteh	28	700
Hsinchu, Hsinpu	100	2,500
Hsinchu, Omei	36	900
Hsinchu, Hukow	30	750
Miaoli, Toufen	80	2,000
Miaoli, Sanwan	150	3,750
Miaoli, Tou-oo	138	3,450
Nantou, Minchien	20	500
Seeds for demonstration field	100	2,500
Total:	1,000	25,000

Note: The seeding rate per hectare is 25 kg.

2. Study of Rhizobium Lupinus in tea soils

In view of the poor growth of lupine in the first year due to lack of inoculation, the presence of causative organism of the nodule on the root and the isolation of a good strain of the organism—Rhizobium Lupinus are the important problems which should be further studied. After taking fiield inspection, Miss Wu Wei-ming, a micro-biologist in the Provincial Taichung Agricultural College, had now submitted a plan for this study as follows:

a. Determination of soil fertility:

Lupine growth may not be limited by nitrogen fixers but by the soil's lack of fertility. So a determination of soil fertility should be necessary as a preliminary step. Of the factors that influence soil fertility, the following are the important ones:

i. pH
ii. Organic matter
iii. Potash and phosphoric acid
iv. Calcium and magnesium
v. Compare the chemical composition of those plants with or without nodule and their effect on nodule formation

b. Isolation and cultivation of Rhizobia Lupinus from nodules:

Different strains of this organism may be parasitic in different localities of the same host. The nitrogen fixation power is also quite different. So the organism must be isolated from each locality of the lupine area.

i. Isolate nodule bacteria from large firm nodules on young plants, notice its characteristics, size, color and ease of colony development on the different culture medium.
ii. Inoculate several representative colonies onto the medium to make pure cultures.
iii. Make smears with the same colonies, using the various staining methods to differentiate the morphology, size and reaction of them.
iv. Identification and physiological test of good strains.

c. Test for nodule formation with the selected Rhizobia:

Sterilize the seeds, plant them in semi-liquid yeast water mannitol agar, sand culture with special nutrient solution under a sterilized greenhouse, and determine the nitrogen fixing power.

d. Test for optimum age of Rhizobium to infect the host plant and test the advantages and disadvantages of various methods to be employed in producing cultures on commercial scales for the farmers. Prepare a directive for the farmers on how to use the culture in inoculating the seeds.

Photos Showing the Growth of Green Manure Crops in Feld

Soybean as a green manure crop for rice at Ilan

Lupine planted between the tea rows for green manuring

Mucuna as a green manure crop for pineapple before planting of pineapple seedlings.

Tephrosia as a green manure crop planted in the pineapple field

Mucuna planted in the banana field as green manure as well as cover crop