

QUEENSLAND

BUREAU OF SUGAR EXPERIMENT STATIONS

Division of Soils and Agriculture

FARM BULLETIN No. 10

GREEN MANURING AND SOIL
ORGANIC MATTER

By

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FOREWORD.

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Prior to the commencement of publication of the Cane Growers' Quarterly Bulletin in July, 1938, the Bureau published periodic Farm Bulletins dealing with many aspects of cultivation, sugar-cane diseases, pests, &c.

During the past fifteen years much of the advisory and extension work of the Bureau was achieved per medium of the Quarterly Bulletin, but the constant demand for detailed information on specific subjects indicates that the Farm Bulletin series is an essential component of our agricultural publications.

It is intended therefor that this Farm Bulletin No. 10 shall be the forerunner of a series of similar pamphlets dealing with subjects of interest to the canegrowers of the State.

NORMAN J. KING,

DIRECTOR.

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Green Manuring and Soil Organic Matter.

BY NORMAN J. KING.

THE following statement appears in "Soil Conditions and Plant Growth," by E. J. Russell.

"The effect of wild vegetation, sown grasses and clovers in increasing the organic matter and nitrogen content of the soil, has long been known to soil cultivators. The old method of replenishing soil fertility was to alternate the periods of arable cultivation with a year's 'rest' when the land was left to cover itself with wild or self sown plants which were then ploughed under; this so-called fallow was prescribed one year in seven in the Mosaic law and one year in three in mediaeval England."

The Effect of Green Manures in Increasing Soil Organic Matter.

It is a fact accepted by all agricultural authorities that the productivity of virgin soil is due in part to its excellent crumb structure or physical condition and to the amount of organic matter in the form of humus which it contains. As a result of continued cultivation over a period of years during which time plant residues are not returned to the soil and green manure crops are not grown and ploughed in, the action of the sun's heat results in the oxidation of the soil organic matter and its loss to the atmosphere as carbon dioxide. Concurrent with this loss of organic matter occurs a deterioration in physical texture of the soil, good tilth is more difficult to attain, and the moisture holding capacity of the soil is reduced. Row crop cultivation is particularly harmful to the soil from this point of view, more especially in hot climates. Crop growth conditions which allow constant stirring of the surface soil during summer months when high temperatures speed up oxidation processes are very conducive to loss of organic matter. The effect of cultivation is equivalent to stirring the ashes of a smoldering fire; combustion is accelerated in both cases.

Green manures—in particular the summer growing types—assist materially in two ways. Firstly, they have the mechanical effect of shading the ground during the summer heat. In this way they keep down soil temperatures and this is important because oxidation of organic matter proceeds much more quickly as the temperature of the soil rises. In the absence of a green manure crop during the summer fallow period the bare fields occasionally cultivated to control weed and grass growth, would be subjected to the full force of the sun's heat and would be rapidly depleted of their organic matter content. Secondly, a green manure crop consists mainly of seventy per cent. moisture and thirty per cent. organic matter, (the content of mineral ingredients being very small). A twenty-five ton crop of green material (and this would be a very heavy crop) therefore adds to the soil seven and a-half tons per acre of organic matter. This is not a great deal when one considers that a six inch depth of soil over an acre contains 750 tons of soil—it is just one per cent. of

the weight of the soil. But if this seven and a-half tons of organic matter were all transformed into humus the moisture holding capacity of the soil would be raised from a figure of 30 per cent. to one of 35 per cent. (It will, however, be shown below that all this organic matter is not converted into humus.) Even a small proportion of humus material in the soil makes a great difference to its physical conditions and its fertility. It is the humus which has the greatest influence on the crumb structure of soils—that structure which is broken down by constant cultivation and cropping, and it is also humus which plays such a large and important part in making possible the more effective use of fertilisers. The dual role of green manure crops, in relation to soil humus, is therefore to reduce losses of organic matter during the growth of the crop by shading and cooling the soil, and to add organic matter to the soil after turning in.

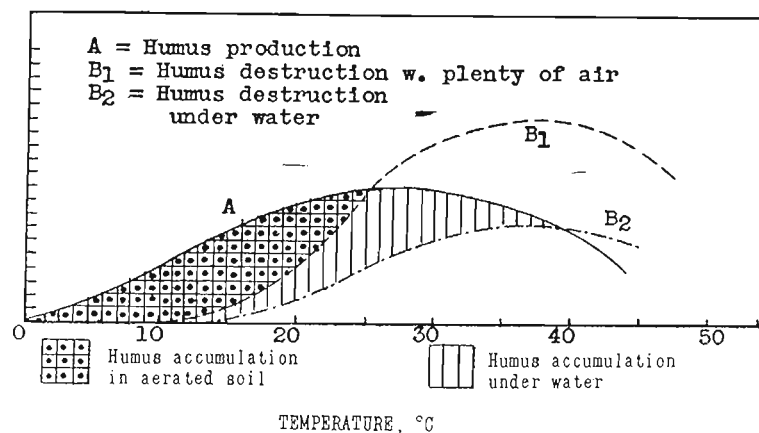


FIG. 1.—A graphical illustration of the conditions under which humus will accumulate in the soil, or will be destroyed at a faster rate than it is accumulated.

It is, of course, well known that the organic matter or humus content of the soil is intimately related to the moisture holding capacity of the land. When virgin soil is brought into cultivation there is a marked and rapid decrease in the organic matter content of the soil and this decrease goes hand in hand with loss of moisture holding capacity. In the Woongarra scrub area of Bundaberg a small acreage of the original scrub still exists and tests on soil from this virgin area and from the adjacent farmed soil reveal the following figures:—

		Virgin Soil.	Adjacent Soil Cultivated 22 Years.
		Per cent.	Per cent.
Moisture equivalent	38	30
Organic matter	7.8	3.6
Nitrogen	0.48	0.22

This soil contains a high proportion of so-called "hygroscopic" moisture which is not available to the plant—approximating to 20 per cent. If the above figures are corrected therefore to show the percentage of available moisture we find that there is 18 per cent. available moisture in the virgin soil compared with 10 per cent. in the cultivated soil which means that the soil now has a capacity to supply water to the plant which is only slightly more than half its original figure. Soil fertility as measured in terms of phosphoric acid and potash is of little value if the soil loses its capacity to retain moisture after rain and it is this property which is conferred upon the soil by organic matter.

Unfortunately, all of the organic matter turned into the soil is not converted into humus. The amount retained by the soil varies with the temperature and certain other factors, but it may be broadly accepted that in cool climates more of the organic matter is retained than in tropical zones. Under hot conditions it has been proved that the loss of organic matter during decay may be so excessive that no permanent addition to the soil organic matter is made even by turning under a heavy green manure crop. However, the aim should be to maintain rather than to increase the quantity of organic matter in the soil. The roots and stubble of sugar cane are no doubt an excellent source of organic matter, and do much to assist in maintaining soil fertility and texture. At the most a cane grower can grow only one green manure crop each three or four years when the land is being fallowed, and this one opportunity should not be lost to turn in the maximum body of green material possible. Organic matter is a very complex mixture of compounds, but is mainly composed of carbon, hydrogen and oxygen. Under the influence of soil organisms the carbon is converted to carbon dioxide gas, and the speed of this conversion is markedly affected by temperatures. Fig. 1 shows how the rate of decomposition of humus matter is influenced by temperature, and indicates also that, under certain tropical conditions, the rate of decomposition may be greater than the rate of formation. Such a set of conditions would mean that only a short term benefit would be achieved from the turning in of a green crop, and that no permanent humus gain would result.

Green Manuring in the Sugar Cane Rotation.

The value of green manure crops as regenerators of land is not sufficiently appreciated in the sugar industry, or for that matter, in any agricultural industry in this State. Cane-growers, as indicated above, depend on the one short green manure crop every four years or so, and a goodly proportion of them do not go even this far to assist in the practice of good husbandry. It is appreciated that in the more closely settled areas the fact that the gross assigned area is almost equal to the total farm acreage debars the grower from practising long fallows and crop rotation but there is a large number of cane farmers who are not in this category. In parts of the central and southern districts the relation between assigned areas and farm peaks would allow of considerable crop rotation, particularly long fallowing under legumes. There is little doubt also that considerably more green fallowing could be practised in the Burdekin delta than is being done at present, nor can it be gainsaid that such a procedure would do much to solve the ratooning problem in that area. During the past couple of years

evidence has been forthcoming of the remarkable improvement in water absorption by the soil following two Poona pea crops in an eight months fallow period.

Where it is possible to keep a block of land out of cane for two years there is no doubt that tremendous benefits would accrue to the soil if kept under green manure crops for this period. It is not necessary to keep planting and ploughing in such short periods crops as cowpeas; under average rainfall conditions velvet beans can cover the land for nine or ten months of the year and the matured seed can, with one cultivation, be covered and utilised to reseed the land.

Perennial legumes are also obtainable to keep the land covered for long periods. The Bureau of Tropical Agriculture at South Johnstone has proved the value of certain perennial types under high rainfall conditions and these provide a dense ground cover as well as supplying



FIG. 2.—A fair crop of Giant cowpea growing at Bundaberg. A few rows of maize were planted through the legume.

a continuous heavy leaf fall and a protection against erosion. A block of this old cane land which had been growing a perennial legume for three years was last year ploughed up again and planted with Badila cane. The remarkable growth of the cane crop after the three year spell under green manure is sufficient evidence of the regeneration of the soil. It is a long time since such Badila has been grown on this class of land.

There is a growing weight of opinion that decomposition of plant residues on the surface of the soil is more effective in improving physical condition of soils than the ploughing in of the same plant residues. It is claimed that a different type of decomposition takes place on the

surface and that the products of decomposition, as they move down through the surface soil, bring about a considerable improvement in soil structure. Under natural conditions of forest or grass growth plant remains are never turned under the soil; they decompose on the surface and the products of decomposition are washed downwards by rain. It is in this way that virgin soils develop their excellent physical characteristics. There is much room for experiment in this phase of green manure work. Land could be properly prepared before sowing a green manure and then when the crop was mature it could be cut up with disc harrows, left on the surface, and the cane planter run through it. Such a method, or some modification of it, is well worth a trial.

During the past twenty years a very large number of leguminous crops has been tested on the three Sugar Experiment Stations of the State in an endeavour to locate types more suitable to the wide range of conditions of the sugar belt. (A list of these will be found at the



FIG. 3.—Illustrating the growth of *Dolichos biflorus* with sorghum nurse crop on Bundaberg Experiment Station.

end of this pamphlet.) But during that period of time the only varieties grown widely by canegrowers were Poona pea, Giant cowpea, Mauritius bean, Gambia pea (*Crotalaria gowensis*), New Zealand blue lupin and the field pea. The two latter are winter cover crops.

The Declining Productive Capacity of Sugar Growing Soils.

There is a growing feeling within the sugar industry that the scientific achievements of the past fifty years are not reflected in a production increase commensurate with the improvements made. Since 1898 fertilizing has advanced from an agricultural curiosity to a standard farm practice, a gradual improvement in varieties has taken place, diseases and pests have been controlled, and irrigation has become an

important source of increased production in some areas. In that period the average yields of sugar cane in tons per acre in Queensland have been as follows:—

1898-1907	1908-1917	1918-1927	1928-1937	1938-1947
15.08	17.42	16.49	18.46	18.81

It is seen that despite these advances made in all agricultural phases of the industry the yield has done little more than hold its own and one is prompted to ask the reason why. The fifty-year period has witnessed the extension of cane growing onto much new land and perhaps this supplies some of the answer since much of the expansion was on marginal lands of poorer quality. Perhaps also we should not expect too much increase in acreage production from fertilizers but rather look upon these soil amendments as the means of maintaining production at virgin land levels rather than increasing them. However,



FIG. 4.—Inoculated (left) and non-inoculated (right) plants of New Zealand Blue Lupin.

the plant food supply in the soil, which is frequently but erroneously used as the sole criterion of productive capacity, is not the only factor to be considered. More important, because of the greater difficulty in correcting it, is a deterioration in physical condition and there is ample evidence on certain soil types that such deterioration has taken place. Certain of our cane-producing lands which had a state of good tilth when first brought into cultivation became progressively intractable with row-crop cultivation, and this was probably associated to a considerable extent with the loss of organic matter under the influence of a tropical climate. To recover the good tilth will be a difficult and lengthy process. There is no simple solution of the problem; the loss of humus from the soil is at least an important part of the cause and the recovery

of that lost material cannot be achieved under the present farming system. Longer fallows and an alteration of the general mode of land usage are probably desirable. So important is this aspect of our productive capacity that it may eventually necessitate a review of existing assignment legislation.

A quotation from "Fifty Years of Field Experiments at the Woburn Experimental Station," by Russell and Voelcker, is of particular significance when read in conjunction with the above comments. It reads: "The most probable cause of the deterioration seems to be the exhaustion of some soil constituent necessary for full plant growth under field conditions. If humus is the effective substance . . . the soil productiveness rises and falls with the percentage of humus present."

The Value of Legumes for Green Manuring.

Literature, ancient and modern, bristles with the experiences of practical farmers that legumes*, under appropriate conditions, render the soil more productive. In ancient Rome the farmers understood that crops following beans, peas and vetches were usually better than those following wheat or barley. The reason for this was not known, nor was it until the latter quarter of the nineteenth century that an explanation was forthcoming as to the peculiar powers which the leguminous plants possessed. It has been proved beyond doubt that plants of the legume family have the property of collecting nitrogen from the atmosphere when in association with a certain type of bacteria which live on the roots of the legumes.

The value of this property cannot be overestimated. Above every acre of land the atmosphere contains about half a ton of carbon and 25,000 tons of nitrogen. Although the plants growing on that acre never lack carbon, they frequently starve in the midst of this vast surplus of nitrogen. All plants are able to obtain their carbon requirements from the atmosphere in the form of carbon dioxide gas, but relatively few can extract their ration of nitrogen from this abundant source. What is the essential difference between the plants concerned? The credit for solving this mystery is due to Hellriegel and Wilfarth who, in 1888, demonstrated that leguminous plants would grow quite normally in soils which lacked nitrogen provided these soils contained a certain type of bacteria. It was found that the legumes always had nodules or tubercles on the roots and that these nodules contained large numbers of the bacteria. These bacteria collect nitrogen from the air which is present in the soil and hand on the nitrogen for the plants' requirements. In return the plant supplies carbohydrates to the bacteria—an excellent example of symbiosis.

Any grower who has examined the root system of a green manure plant is familiar with the wart-like protuberances which are formed on the roots. As the root hairs of the plants push out into the soil some come into contact with the nitrogen-fixing bacteria present in the soil. The bacteria, by some means, dissolve the cell wall and enter the root hair. Once inside the bacteria multiply rapidly and the irritation produced causes enlargement of that part of the plant and formation of a nodule at this point. Conditions favouring the development of nodules are (1) good soil aeration, (2) optimum soil moisture conditions, (3) normal supplies of other plant nutrients such as potash and phosphates, and (4) a favourable soil reaction.

* Legume is a popular name applied to members of the family Leguminosae. It includes many kinds of plants.

It is stressed that this ability to utilise atmospheric nitrogen belongs only to the leguminous plants and not to sugar cane, cereals and a host of other plants. Annually, the sugar industry requires 30,000 tons of sulphate of ammonia to supply nitrogen to the crop. If sugar cane had the property of utilising atmospheric nitrogen, the industry would be saved the formidable annual expenditure of nearly £600,000.

But the fact that legumes, or green manure crops as we popularly term them, collect nitrogen from the air and thus add it to the soil when the plants die and decompose, does save the farmer some of his expenditure. When a green manure crop is grown and ploughed in the added nitrogen is sufficient to supply the nitrogen requirements of the plant cane crop and no sulphate of ammonia is necessary. Figures are available to show the amount of nitrogen in legumes and some of these are given below.

TABLE I.

Laboratory Number.	Variety.	Crop, Tons per acre.	Nitrogen, lb. per acre.	Equivalent to sulphate of ammonia lb. per acre.
577	Cowpea	9.3	72	351
578	Poona pea	9.8	102	498
613	Mauritius bean	7.0	110	537
806	Canavalia ensiformis	16.8	274	1,337
A1922	New Zealand Blue Lupin	20.6	96.9	473
A2003	Crotalaria goreensis	23.2	207	1,010
A2004	Crotalaria goreensis	24.58	267	1,303

The various types of green manure crops do not vary greatly in nitrogen content with the exception of New Zealand Blue Lupin which is usually lower than the others. Variations in nitrogen content exist from crop to crop but from a large number of analyses the following average figures have been obtained.

TABLE II.

Variety.	Nitrogen per cent dry material.
Poona pea	2.79
Black Cow pea	2.48
Giant Cow pea	2.81
Brazilian lucerne	2.38
Gambila pea	2.08
Mauritius bean	2.63
Sword bean	2.95
New Zealand Blue Lupin	1.50

Contrary to popular belief, the nitrogen is not concentrated in the roots of the plants where the nodules are located. In fact the leaves and stems contain a higher percentage of nitrogen than do the roots as indicated by the average analysis of eight Poona pea crops; these analyses show 2.93 per cent. nitrogen in the above ground portion as compared with 2.25 per cent. in the roots and nodules.

Although the nitrogen from the air is collected by the bacteria which inhabit the nodules, the nitrogenous compounds formed there are taken up by the plant and transferred to all portions of the plant, including the leaves, stems and seed pods.

The Presence of Nodule-forming Bacteria in the Soil.

Many generations before the explanation of legume association with nitrogen fixing bacteria was known farmers had encountered the problem of being unable to grow lucerne and other green manure crops on new

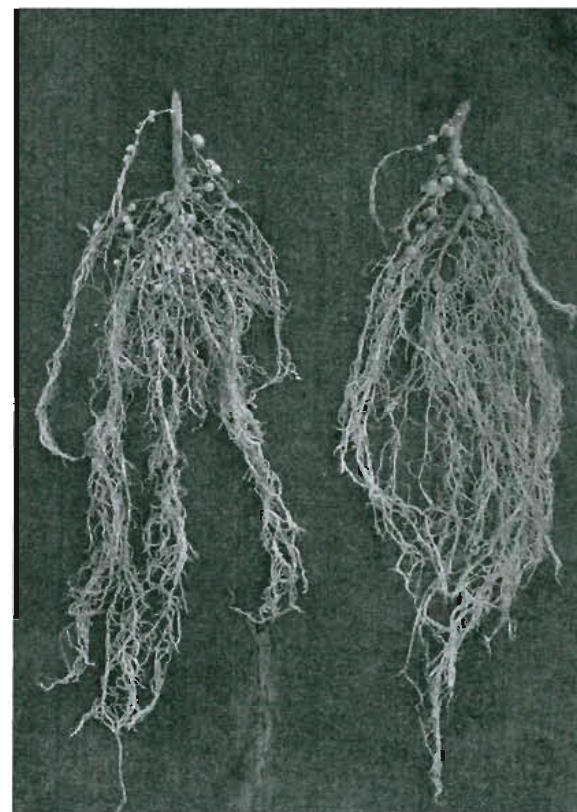


FIG. 3.—Roots of soybean plants showing nodules produced by nitrogen fixing bacteria.

land. Sowings of seed would produce crops, but these, after a short period, would exhaust the natural nitrogen supplies in the soil and then become unthrifty and die out. This experience applied more especially to perennial crops like lucerne, but as time went on the farmers discovered that if the new fields were given a light dressing of soil from a successful lucerne block the trouble was overcome. Although quite a mystery at that time the explanation in the light of

later knowledge was obvious. With the soil from the old field came a supply of the bacteria which were essential to establish the association of plant and nitrogen fixing organisms.

In modern times the necessary bacteria are obtained and applied much less laboriously than by top dressing with soil from successful fields. Bacteria from the nodules are propagated in culture media in the laboratory and this culture is used to inoculate the seed which is to be sown. Inoculation is simple; it merely consists of wetting the seed with a water suspension of the culture and then planting without undue delay. But one precaution must be taken; any culture of nitrogen fixing bacteria will not do. The correct bacteria to use varies with the type of legume being planted. Agricultural scientists have found that legumes can be divided into seven groups and that the plants within each group can be inoculated with the same culture, but that different groups require different cultures.



FIG. 6.—A good Poona pea crop at Bundaberg.

When land was first cleared for sugar-cane growing in Queensland it is probable that much of the soil did not contain the specific organism which would fix atmospheric nitrogen for the particular green manure crops being grown. No doubt certain groups of bacteria existed in certain of the soils since native legumes such as acacias, rattlepod, and others had been growing on them for generations, but experience in recent years has indicated that the correct bacterial strains for certain of our popular green manure crops were not present. The Bureau operates a service to all canegrowers requiring cultures for any leguminous crops and this ensures that the correct bacterial strain is present in the soil for nitrogen fixation. When applying for cultures

farmers should state the type of legume, amount to be planted, and approximate date of planting. If possible, a fortnight's notice should be given to allow preparation of the culture.

Table I. indicates the amount of nitrogen, expressed as lb. of sulphate of ammonia, turned into the soil in different green manure crops. The amount of nitrogen in a legume when ploughed in represents the nitrogen it has taken from both the soil and the air, but the amount it has taken from the air is all that is really added to the soil. The relative amounts derived from each of these sources are difficult to determine, and it can only be stated that as a broad average about two-thirds of the nitrogen in a legume is believed to have been taken from the air and one-third from the soil.



FIG. 7.—A shoulder high crop of Poona pea at Edge Hill, Cairns.

Apart from the peculiar property possessed by legumes of associating with nodule bacteria to fix atmospheric nitrogen they feed in the same way as any other plants. The roots take up soluble plant nutrients in the normal way, including available nitrogen in the form of nitrate. It is probable that in soils where nitrate supply is ample for the growth of the crop less atmospheric nitrogen would be fixed than in soils with a low nitrate status.

Varieties of Green Manure Crops Suitable for the Sugar Belt.

The sugar-producing belt extends over 1,000 miles of coast line from south of Brisbane to Mossman, with a rainfall range of from 40 to 180 inches per year. It is natural to expect, therefore, that no variety of legume would be eminently suitable for all conditions, although during the past fifteen years one variety, Poona pea, has been the popular choice in nearly all districts. However, several types are grown to a considerable extent and a short description of each is given below—

Cowpeas.

Poona pea belongs to the cow pea family and possesses several favourable attributes which have made it a valuable green manure crop in the sugar-cane rotation. It is a good and rapid germinator and in its early stages has an erect habit. Later it develops vigorous runners which rapidly cover the ground and form a heavy mat of foliage, amounting under good conditions to approximately 15 tons per acre of green matter. The variety has a growth period of about three months after which it normally, but not always, flowers and seeds profusely. As a crop it is cheap to sow, since a good cover can be obtained with 15 to 20 lb. of seed per acre broadcast: it produces a good early ground cover and shades out weeds and grasses; it is easy to plough in with standard farm implements and it decomposes rapidly in the soil unless conditions are very dry. It is essentially a hot weather crop. In South Queensland Poona pea will germinate freely in August if soil moisture is available but growth will not take place until about October, when summer temperatures are beginning. This variety possesses three distinct disadvantages from the canegrower's point of view. It is not particularly drought resistant and this is a major drawback in parts of the sugar belt, as legume crops are usually planted in late spring or early summer when dry spells are frequent: secondly, the variety is somewhat susceptible to bean fly attack in late plantings, and thirdly it is very susceptible to "wilt," which has of late years become a major source of loss in wet soils in the northern and central districts.

Consequently, a good deal of attention has been given to the search for suitable types to replace Poona pea. Within the past few years a considerable number of cowpea varieties, bred by the plant breeder of the Agricultural Branch, have been tested for resistance to both bean-fly and "wilt" and the variety Reeves' Selection Q.1582 has been found to have satisfactory resistance as well as possessing all the good characteristics of Poona pea plus a longer growth period. At present seed stocks of this variety are being built up in seed-producing areas, and it is hoped to have large quantities available commercially within two years.

Also during the past few years another cowpea type has attained some popularity in the north. It is known as Cristando pea or Ingham pea and would appear to be a selection made in the Ingham area from a cowpea crop. Both types were described by Humphry in the *Cane-growers Quarterly Bulletin* of April, 1948.

Giant Cowpea is a variety which lost a great deal of its popularity with the advent of Poona pea. Its name is derived from the large-sized clay-coloured seed, which necessitates the sowing of up to three times

the amount which is normally used for Poona pea. The crop is vigorous and is characterised by its running habit and rather coarse vines. Parts of North Queensland as well as the Childers district in the south continue to grow this type as a green manure crop and there is a steady demand for seed. The growth period is intermediate between that of Poona pea and the velvet beans. Giant Cowpea is susceptible to "wilt" in wet situations and is adversely affected by bean fly, particularly in late plantings.

Velvet Beans.

Mauritius bean.—This is one of the velvet bean family and was, up to twenty years ago, a favourite green manure crop in the sugar districts. It is a summer-growing crop, and is characterised by exceptional vigour and high yielding capacity. It is a large-seeded plant, the seeds being



FIG. 8.—Velvet beans and volunteer cane stools at Mackay Sugar Experiment Station. Such crops have particular value on this physically poor soil type.

produced in tough pods covered with velvety hairs, and is generally planted in rows to reduce seed costs and to allow of a cultivation to destroy weeds before the vines cover the ground. Mauritius bean has several excellent characteristics: it is remarkably drought resistant, and this is doubtless the result of an intensive and deep rooting system; it has a long growth period—at least six months before maturing seed; it is resistant to bean fly attack and it produces a heavy mulch of dead leaves on the soil surface which are decomposing while the top is still in growth. Among its disadvantages are irregular germination. A percentage of seed lies in the soil until the next year and then germinates in the growing cane crop, causing obstacles to cultivation and harvesting. The principal reasons for its loss of

popularity, however, were (1) difficulty in ploughing in the heavy viny crop and (2) reputed poor early cover. The former objection could not obtain today, when modern tractor ploughs aided by pre-treatment with tandem discs would deal easily with the crop. The second objection is to a large extent overcome by newer velvet bean varieties, which are described below.

During 1946 six new varieties of velvet beans were made available by the Director of Agriculture for trial work in sugar-growing areas. These were named Black Mauritius, White Mauritius (not to be confused with the previously grown Mauritius beans), Marbilee, Somerset, Jubilack, and Smith. Plantings at the Bundaberg Sugar Experiment Station demonstrated in no uncertain manner the drought-resisting properties of this type of green manure crop. At a period when Poona pea planted alongside on the same date died during a very dry two-

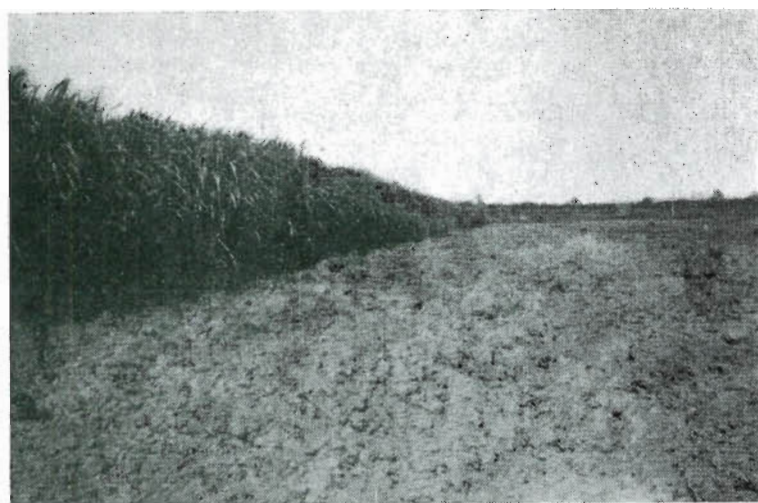


FIG. 9.—Just after ploughing in the velvet bean crop illustrated in Fig. 8. A single disc plough was used and there was no pretreatment with disc harrows.

months, the velvet beans continued to make good growth and covered over the 4-ft. interspaces left between the rows. As with the Mauritius bean described above, these varieties exhibited excellent vigour and developed a soil surface layer of dropped leaves beneath a heavy canopy of green material. The growth period was so long that the first check was caused by the early June frosts, which killed all leaves and growing points. Plantings were made in all major sugar areas in the subsequent year and harvesting data on trials are given in Table IV. In all cases, and under both good and harsh conditions, these legumes made excellent crops. Careful attention was paid to difficulties in ploughing in the mass of viny material, and in general it was found that the job was satisfactorily performed by a single disc plough unit either with or without pretreatment with disc harrows.

TABLE III.
RESULTS OF THE 1946-47 TRIAL AT BUNDABERG.

Variety.	Green material T.p.a.	Per cent N Dry material.	Lb. N per acre.	Equivalent to lb. ammonium sulphate per acre.
White Mauritius	11.7	2.96	252	1,229
Black Mauritius	14.9	3.00	300	1,463
Somerset	14.1	3.13	301	1,468
Marbilee	16.8	3.10	350	1,707

In this particular planting Smith and Jubilack gave poor germinations and the crops were not weighed and analysed. The results from certain further trials are shown in Table IV.

TABLE IV.
RESULTS OF THE 1947-48. TRIALS ON ALL STATIONS.

Variety.	Green material T.p.a.	Per cent N Dry material.	Lb. N per acre.	Equivalent to lb. ammonium sulphate per acre.
Bundaberg—				
White Mauritius	10.7	2.30	176	857
Black Mauritius	14.2	2.43	217	1,057
Somerset	13.9	2.28	225	1,100
Marbilee	15.4	1.89	176	861
Smith	11.7	2.17	151	733
Jubilack	15.1	2.65	246	1,198
Meringa—				
White Mauritius	4.6	2.37	43	212
Black Mauritius	13.4	2.30	118	577
Somerset	13.0	2.03	101	495
Marbilee	9.6	2.30	82	399
Jubilack	10.4	2.29	93	453
Mackay—				
White Mauritius	7.3
Black Mauritius	8.8	2.81	138	675
Somerset	8.4	2.36	117	570
Marbilee	10.4	2.97	146	712
Jubilack	9.6	2.89	126	616

Crotalarias.

Gambia pea.—This is the popular name given to the member of the rattlepod family known as *Crotalaria gorgensis*. This crop first became known in the early thirties and was selected from several green manure varieties growing on the Bundaberg Sugar Experiment Station because of its performance during the severe drought of 1932, when most other legumes died out completely. Like most others of the rattlepod family it is a small-seeded type and the seed is very hard. The seed hardness affects germination and it is found that soil moisture must be at a good level for a period of five or six days to ensure a good

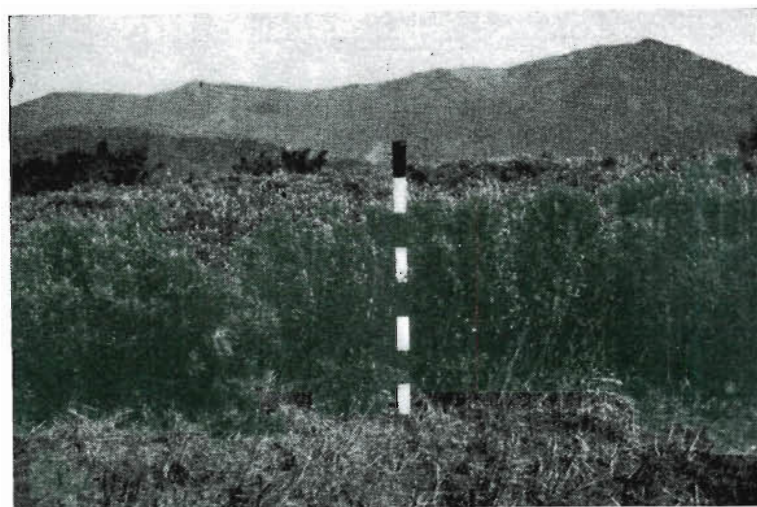


FIG 10.—Gambia pea (*Crotalaria goreensis*) growing at Meringa Sugar Experiment Station. This seven feet high crop was five months old when photographed.



FIG. 11.—Illustrating the ease of ploughing under a heavy crop of Gambia pea. This photograph was taken on a farm situated on Babinda granite soil.

stand; 10 lb. of seed per acre is more than ample to ensure a thick crop. In the early growth stages development is rather slow and, if planted in mid or late summer, weeds and grass are likely to cause some smothering. It is, therefore, advisable to plant in September or October to ensure that this early development period is complete before summer weeds make vigorous growth. The later growth is rapid and a good stand will choke out all weeds and grass. The crop has a long growth period, not flowering until May and it can, therefore, be grown to cover the land during the wet season without any fear of it seeding prior to ploughing in. The crop is erect and of a bushy habit. In thin plantings much branching develops, but in thick seedings single-stemmed plants predominate. Up to flowering time the plants are fairly succulent but if left to seed they become hard and woody. Ploughing in presents no



FIG. 12.—A twelve months old crop of *Crotalaria anagyroides* at Childers.

difficulty; the upright crop lies down as the tractor or drawbar passes over it and is easily and completely covered by the plough. Gambia pea has gone out of favour in recent years on account of longevity of the seed in the soil. Land once planted with this crop continues to produce plants every time the soil is turned over. The seed is remarkably hardy and will even survive steam sterilisation which kills all other seeds normally present in these soils.

Crotalaria usaramocensis (Cusara pea) is a giant rattlepod which was first grown on the Meringa Station in 1939. It is a native of east tropical Africa, and is an exceptionally vigorous type suitable for poor land conditions. It is similar to Gambia pea in many of its characteristics. The germination of seed is inclined to be erratic in spring, when it is unusual to receive rains which keep the soil moist for a week.

but summer plantings ensure a good germination and the production of satisfactory crops. Early growth is slow but somewhat better than Gambia pea, and early cover is also an improvement on the latter type. Summer plantings do not flower until June and it is found that growth continues for some months after flowering. As a long fallow crop and a soil improver, this type has much to commend it.

Winter Legumes.

There are two winter legumes which have been proved suitable for sub-tropical Queensland conditions, the field pea and the New Zealand Blue Lupin. The growing of winter crops is intimately tied up with the farm practices of the various cane districts, and it is usually only in the south that winter crops are sown. Where autumn planting of



FIG. 13.—Cusara pea (*Crotalaria usaramoensis*) on Meringa Station. An excellent long fallow crop for land rejuvenation.

cane is the rule there is, of course, no time to grow a winter legume, and the grower depends on a short fallow Poona pea crop. Where spring planting is to be carried out there is time, after destruction of the previous cane stubble, to grow a Poona pea crop and then to seed with lupins or field peas for a winter cover crop. If such a crop can be grown there is little doubt regarding the benefit of the increased amount of organic matter on the soil and the following cane crop, but there are two factors which detract somewhat from the value of the practice. Firstly, winter rain in the cane areas is most unreliable, so that there is no surety of a crop, and secondly the crop, if successful, is turned into the soil in early spring, when low temperatures retard decomposition, thus delaying cane planting. Further, the decomposition of a green crop tends to dry out the soil at a time when soil moisture is essential for cane planting. The practise of winter green manuring would have particular value in a long fallow scheme of soil regeneration, where a farmer planned to leave the land out of cane for two years or more. The above objection would not then apply. A long-range rotational trial on the Bundaberg Sugar Experiment Station includes an



FIG. 14.—An excellent New Zealand Blue Lupin crop at Bundaberg. Note the height relative to the standing horse. The stems are succulent and rot quickly.

eighteen-months' fallow under legumes, and in this scheme a Poona pea crop is followed by a winter lupin crop and then a further summer Poona pea crop. Field peas are quite popular in the Moreton alluvial areas where winter rains are fairly reliable and where time is allowed for the crop to decay before spring planting is done.

The Optimum Period for Ploughing in of Legumes.

It has been generally recommended for a long time that the crop is at its best when the seed is in the dough stage. However, the time ploughing in is practised on cane farms is mostly governed by expediency rather than the correct stage of the crop. Wet season rains play a big part in limiting the cultivation periods and the advance of the planting



FIG. 15.—A seven foot crop of New Zealand Blue Lupin being ploughed in at Bundaberg.

Queensland conditions the nitrogen content of green manure crops does season also has an influence on the time when the plough is used. Under not vary greatly with age, and so long as the crop continues to grow the amount of nitrogen per acre keeps increasing. If farm routine allows it, therefore, it is advantageous to leave the crop as long as possible providing that mature seed does not form and result in volunteer germination when turned into the soil. With cowpeas, even this latter eventuality is not serious, as the young volunteer plants are so easily killed by cultivation implements. But with Gambia pea or velvet beans, volunteers in the cane crop can be objectionable. A question asked very frequently in regard to time of ploughing in a green manure crop is what loss, if any, results from allowing the crop to die and dry out before ploughing it in. Experimental work on this aspect of green manuring does not appear to have been done in Queensland but growers who, through force of circumstances, have sometimes allowed crops to die before ploughing in have reported good results.



FIG. 16.—A recumbent Field Pea crop. Length of plants can be judged by the figure in the photograph.

It is very probable that the results obtained would depend to a large extent on the soil conditions at the time. Turning a mass of very dry plant material into the soil means that a large quantity of soil moisture will be absorbed by the plant residues, and this results in drying out of the soil to the detriment of subsequent cane planting. There is also the point that dry plant material tends to keep the soil open, and causes air pockets which are also conducive to rapid drying out. If good soil moisture existed at the time of ploughing in and further rains fell, no harm would be done and decomposition would proceed normally. The drying of the crop before ploughing in does not result in any loss of plant food ingredients; only moisture is lost. There is a general tendency for nitrogen in the leaves to be absorbed into the stems before they fall off, but all the nitrogen is retained in some part of the plant and is, of course, available as plant food for the succeeding crop.

Sugar Cane Residues and other Green Manuring Crops.

In Queensland sugar-cane agriculture green manures are generally accepted as comprising the various bean and pea crops, which are normally grown on fallows. Strictly speaking, green manures may be considered as including all plant materials turned into the soil, where they decompose and enrich the soil in organic matter. Such crops as maize, oats, Sudan grass, &c., are frequently used for this purpose, and in the sugar belt a certain amount of prominence has been given to the use of cane trash and tops for this purpose.



FIG. 17.—Giru bean growing over a fence in the Giru area. This vigorous type has not been commercialised.

It has been pointed out previously that the proportion of trash and tops in a cane crop is quite high. Although it varies with the cane variety an average figure indicates that for every 56 tons of millable cane there is produced 44 tons of green leaf. There are considerable practical difficulties in the way of restoring all of this crop residue to the soil—principally the fact that nearly all cane crops are now burnt before harvesting, thus destroying all of the dead trash—but there is no good reason why the remaining tops should be raked up and burnt instead of being retained as a source of much needed organic matter. Cane tops and trash, by reason of their low nitrogen content, do not decompose readily in the soil, but, because of their slower rate of decomposition they do provide a longer, lasting supply of humus than is obtained from materials which decompose more quickly. The practise of trash conservation is one which should commend itself to all cane-growers who have reason to be perturbed regarding deterioration in soil structure and the attainment of good tilth.

LIST OF LEGUMES TESTED ON SUGAR EXPERIMENT STATIONS.

Cajanus indicus (Pigeon pea).
Calopogonium mucunoides (Calopo).
Canavalia ensiformis (Jack Bean).
Canavalia gladiata (Sword Bean).
Centrosema pubescens (Centro).
Crotalaria anagyroides.
Crotalaria governsis (Gambia pea).
Crotalaria intermedia.
Crotalaria juncea (Sunn hemp).
Crotalaria spectabilis.
Crotalaria usaramoensis (Cusara pea).
Dolichos biflorus (Madras bean).
Dolichos debilis.
Dolichos lab lab (Bonavist bean).
 Giru bean.
Glycine indica.
Glycine max (Soy bean).
Indigofera enneaphylla (Indigo).
Lathyrus tingitanus (Tangier pea).
Lespedeza striata (Japan clover).
Leucaena glauca (Mimosa).
Lupinus angustifolius (New Zealand Blue Lupin).
 Partridge pea.
Phaseolus aureus (Mung bean).
Phaseolus lathyroides.
Phaseolus lunatus (Sieva bean).
Phaseolus ricciardianus (Rice bean).
Phaseolus trinervis (Jerusalem pea).
Pisum sativum (Field peas).
Pueraria phaseoloides (Pacro).
Pueraria thunbergiana (Kudzu).
Sesbania sp.
 South African pea.
Stizolobium atterinum (Velvet bean).
Stizolobium derringtonum (Velvet bean).
Stizolobium pachylobium (Velvet bean).
Stylosanthes guianensis (Stylo).
Trifolium alexandrinum (Berseem).
Trigonella foenum-graecum (Fenugreek).
Vicia sativa (Vetch).
Vigna sesquipedalis.
Vigna unguiculata (Groit, Black, Victor, Giant, Poona cowpeas).

