4. Green manuring and intensive fallowing

"...Nothing renders the ground more fruitful than sowing lupines and, before the pods are formed, turning these into the soil with a plow or two-pronged hoe or working bunches of cut lupines in at the roots of trees and grapevines...they make as good a fertilizer as manure."

(PLINIUS, 79 AD)[64]

4.1 Introduction

Green manuring has been used to enhance soil fertility since ancient times. The Greeks and Romans cultivated *Vicia faba*, *Phaseolus* spp. and *Lupinus* spp. The practice has for centuries played a major role in sustaining rice cultivation in China (KING 1911; FAO 1979a) where, then as now, legumes such as *Melilotus* spp., *Crotalaria* spp. and *Sesbania* spp. were the main species used.

Green manuring is also found in the indigenous land use systems of Africa even under intensive conditions. For example, LUDWIG (1967) describes how legumes (*Crotalaria striata, Tephrosia erecta*) and composites (*Erigeron bonariensis, Vernonia* spp.) are undersown in ripening millet fields. Tree leaves are also applied as green manure.

In India, manuring with green leaves (*Gliricidia sepium* etc) has traditionally been as widespread as the cultivation of green manure plants such as *Crotalaria juncea*, *Sesbania* spp., *Phaseolus* spp. and others which - formerly more than now - may also be used as food plants (ARAKERI et al. 1962).

[64] cited in KAHNT (1983)

In Europe during the last century, excellent results were achieved with legumes (*Lupinus* spp.) grown as green manure on light sandy soils (SCHULTZ-LUPITZ 1895). The spread of the practice even threatened to displace livestock production. However, it became evident that the results were not reproducible everywhere, but depended very much on location (HOWARD 1943). This was also found to be the case in the tropics (YOUNG 1976).

In deciding whether such techniques are suitable the natural site thus plays a vital role. Other conditions are also important, namely the labor resources of the farm, its technical capacity (hoe, oxen, sowing techniques) and the experience and interest of farmers. All these aspects must be taken into account, as well as land tenure factors and economic viability.

4.2 Some definitions

Green manuring in its narrowest sense involves the growing of plant material - usually legumes - for the express purpose of incorporating it into the soil (YOUNG 1976). KAHNT (1983) defined green manuring as the "working into the soil of fresh green, non-woody plants, rich in water, sugar, starches, protein and nitrogen". He adds that plant roots still alive at the time of plowing are killed off and incorporated at the same time.

This definition is valid for only some of the green manuring practices applied in the tropics. Green manuring is not always just a matter of producing green material to plow into the soil. In a number of cases, biomass is grown over longer periods of time, the plants develop a high proportion of woody material, and only some, if any of the biomass is incorporated into the soil. These approaches are also known as **intensive fallowing**, the purpose being to create more productive (short) fallows (KOTSCHI et al. 1982; EGGER 1983). The most important aspect of this practice is that land is taken out of production and allowed to regenerate. A third group of practices is known as **undersowing**. Here the biomass constitutes a live mulch that can be harvested, grazed or plowed under. Conceptually this overlaps with both green

manuring and intensive fallowing. The distinguishing feature of undersowing is that it is carried out concurrently with crop production itself, the green manure crop being sown into the food grain crop at varying intervals after the latter has emerged.

All these practices are subsumed in the literature under the term "green manuring". In the following sections, however, an attempt will be made to differentiate between them. In summary, the following practices can be distinguished:

* catch crop green manuring,
* seasonal green manuring (or intensive fallowing),
* undersowing (as green manure or intensive fallow),
* multi-seasonal intensive fallowing,
* green manuring with leaves,
* "green" manuring with roots and stubble,

These will be discussed in detail in Sections 4.4 to 4.10.

4.3 General principles

4.3.1 Selecting appropriate plants

The first step is to identify suitable green manure plants for the site. The most important considerations are the amount and distribution of rainfall (or the feasibility of irrigation), any special soil conditions (acidity, moisture regime, profile, texture, etc). The following characteristics[65] are important in green manure plants. They should:

a) quickly produce a large biomass,
b) provide rapid soil cover,
c) suppress the site's dominant weeds,

[65] It is usually easier to meet the various requirements by planting several species (mixed crop).

d) be able to develop a deep and/or extensive root system,
e) possess a strong capacity to assimilate nutrients,
f) have nitrogen-fixing properties (legumes),
g) be compatible with locally prevalent strains of mycorrhizae.

With regard to phytosanitary requirements, green manure plants should:

h) be hardy,
i) be highly resistant to diseases and pests,
j) not be a good host to agents of diseases or pests that endanger other crops (ideally, they should be hostile to these, as for example lucerne and composites are to nematodes).

From a crop husbandry point of view, it is recommended that:

k) cultivation require as little labor and special know-how as possible,
l) the seed be inexpensive and simple to produce, locally if possible,
m) the green manure plant be easily controllable and unlikely to spread and get out of hand,
n) it should have an additional use, for example as livestock fodder, firewood, etc.

Special features are required of plants used for undersowing. The most important is compatibility with the main crop, for which they should be an "ideal" partner in terms of water consumption, habit and growth rhythm. Their growing period should fit well into the rotation pattern. Considerable advantage may be had from planting self-seeding plants under permanent crops.

4.3.2 Plant density

The optimal plant density varies according to how the green manure will be used. If firewood is an important by-product, then plants must not be sown too densely. If, on the other hand, a rapid production of biomass is desired, then denser sowing is

preferable, because a higher yield per area can be achieved through the greater population pressure on available growth resources (WILLEY and OSIRU 1972; BEETS 1982).

When sowing other crops, care must be taken to ensure that enough water is available for the development of the grain or other reproductive part. This consideration is of far less importance when sowing green manure. Here the chief aim is simply to produce a large amount of plant material. The seeding rate can thus be much higher than for a grain or fruit crop.

According to GRAHAM (1981), high plant densities in legume crops are also advantageous because of increased nitrogen fixation. He found that nitrogen fixation with *Phaseolus* legumes was greater with higher plant density. However, when insufficient water supply causes the green manure crop to suffer premature or permanent water stress, lower productivity leads to lower nitrogen fixation. In such cases it is better to plant a different green manure - a drought-resistant variety or species - than to sow sparser stands, as green manure plants should be chosen with a view to achieving complete ground cover as soon as possible.

Dense seeding is necessary to keep sprouting weeds in check, especially those regarded as most destructive (usually perennial species). Limited infestation by less harmful weeds is tolerable and is in any case virtually unavoidable. Such weeds promote biomass turnover and fulfill important ecological functions. For example, the weed *Tagetes minuta,* found in Rwanda, is hostile to nematodes (EGGER 1983). Weeds also contribute to rapid ground coverage and thus to the prevention of erosion.

Because of their wild nature, many green manure plants tend towards early woodiness. This is especially true of perennials[66] and of bushes and shrubs such as *Tephrosia vogelii, Cajanus cajan, Sesbania sesban,* etc. Dense planting helps minimize lignification and thick stems, promoting a taller plant that will give more shade. Thin, herbaceous stems decay in the soil better (NEUMANN, personal communication).

[66] According to WALTER (1964), perennials are the best plants for producing a high biomass in the first year.

4.3.3 Sowing, inoculation, and tending

Sowing. The cultivation of an intensive fallow should demand no special treatment and should be as simple and unproblematic as possible, to meet with farmers´ acceptance. Nevertheless, care should be taken to produce dense and even stands. If this is not achieved, the possible adverse effects of intensive fallowing can easily become dominant (erosion, loss rather than increase of nutrients, no stimulation of soil life, weediness, etc). Some tillage shortly before sowing - even if only shallow - is usually advisable or even imperative. Mulching is useful on soil prone to erosion or waterlogging. It protects the soil and encourages seed germination (see Chapter 5).

In legumes, the hard outer covering of the seed often causes uneven or poor germination. In such cases seed treatment with hot water or diluted sulfuric acid is recommended, though the use of sulfuric acid is not practicable on small-scale farms.

As a rule, **fertilizing** fallows cannot be considered, given the social and economic circumstances of smallholders in the tropics, where fertilizers are usually in short supply. Indeed, few farmers would be willing to use their valuable fertilizer on a fallow, which does not feed the farm family. Nevertheless, just a light application of stable manure can achieve excellent results, as was demonstrated by HOWARD (1943) in India. Applications of fertilizers (phosphorus, manure, compost) are particularly warranted when very degraded, poor soils are to be rendered arable again and a closed stand cannot be achieved without their use.

Whether inoculating leguminous seed is advisable depends on many factors and on their combined effects (see Chapter 8). The question is usually somewhat academic, since in practice there is usually a chronic shortage of both seed and its specific, locally effective rhizobia. An inoculation process suitable for smallholders was, however, developed in China (FAO 1979b):

* The plants are pulled out carefully when they show maximum rhizobia activity (around flowering time). They are then dried in a shady, airy place and the small nodules on the legume roots are removed for the preparation of the inoculum.

* The nodules are ground up and mixed with sterilized, cold water, and 1% sugar, 1% starch (yeast) and di-potassium hydrogen phosphate (K_2HPO_3) are added (this last can be substituted by superphosphate neutralized to pH 7).
* Seeds to be inoculated are exposed to the sun for 3 to 4 hours and then soaked for 20 hours. After that they are mixed with the inoculum. Because the partially germinating, inoculated seeds tend to form clumps, they are mixed with rice husks or similar materials (e.g. peat, sawdust) to make sowing easier.
* If the seed is not to be used immediately after inoculation, then the soaking step is omitted and the seed is simply mixed with the inoculum.

In Rwanda an even simpler procedure was used (RAQUET, personal communication): the seed was mixed with soil containing nodules.

Even when the most appropriate plant species are selected and the sowing time is right, **weeding operations** cannot always be avoided. Legumes, in particular, often develop much more slowly in the first few weeks than do weeds. This is even the case in locations with high rainfall, such as in Rwanda or Cameroon. Under some circumstances, selective hand weeding may suffice. However, many of the more aggressive weeds propagate vegetatively, i.e. underground. These really need to be dug right out, but often this cannot be done without damaging the young crop. The only means of controlling such weeds is to block their light, and in the meantime they have to be tolerated. Though legumes such as *Crotalaria, Cajanus cajan* and *Tephrosia vogelii* do not develop well at first, they succeed in the end.

4.3.4 Incorporation

Conventional wisdom recommends incorporating the green plant material at full vegetative development so as to achieve maximum effect. This is at flowering[67] in legumes and somewhat earlier for grasses. At this time the plants are rich in sugars,

[67] In the case of *Crotalaria juncea*, about 8 weeks after sowing, and for *Phaseolus aureus*, about 4-5 weeks.

energy and easily soluble N compounds, and poor in lignins and cellulose. Thus favorable conditions exist for rapid decomposition and mineralization, and the release of nutrients.

Today this recommendation is disputed, especially under tropical conditions. The effect of incorporating all above-ground green biomass is not necessarily greater than that gained from incorporating stubble and root biomass. Plowing under large masses of plant matter is very labor-intensive and there may be more profitable ways of using the plant growth (fodder, firewood, mulch for other fields).

The time of incorporation should not be too close to the planting of the next crop, which may be damaged by the inhibitors and toxins released during decomposition. For example, aromatic acids can increase the permeability of the root cells, rendering them more susceptible to soil-borne diseases (*Fusarium*, etc)(LINDERMANN 1970)

Generally, 3 to 6 weeks are sufficient to ensure adequate decomposition in the tropics (ARAKERI et al. 1962). A somewhat shorter interval is necessary for light, sandy soils, while loamy-clayey soils require longer (KLAPP 1967). Too early incorporation can result in the loss of mineralized nutrients through leaching. In experiments conducted by AGBOOLA (1975) in the humid tropics, *Phaseolus aureus* (mung beans) supplied nitrogen for the accompanying food crop within 1.5 to 2 weeks of incorporation. In rice cultures, the waiting time after leguminous green manuring is usually only a few days.

Decomposition greatly depends on when green manure is incorporated and on the soil conditions. Young plants decay quickly, while older plants containing lignin and cellulose take longer. Good decomposition can be expected when the soil is well aerated, sufficiently moist, and already fairly fertile. The soil temperature should also be relatively high - a condition that can be relied on in the tropics.

Dryness or waterlogging hinder decomposition. The latter creates oxygen-poor (reductive) zones in the soil and encourages the formation of growth-inhibiting substances. Burying the green manure too deep also causes reductive effects, slows decomposition and causes harmful by-products to form. Denitrification is promoted

under anaerobic conditions. According to ALLISON (1973) this can occur in only a few minutes if waterlogging coincides with the optimal nutrient supply for denitrifying bacteria. For this reason, the Wakara on the island of Ukara in Lake Victoria never incorporate green manure into the soil immediately before the rainy season. At this time they use already rotted, strawy (*Crotalaria*) residues and manure compost instead (LUDWIG 1967). Mixing the green manure evenly into loose, moist soil near the surface is the best way to ensure a good effect.

To incorporate green manure, the plants are lopped close to the ground and worked into the soil, usually by hand hoe. Care should be taken to spread the plants and incorporate them into the furrows evenly. Thick "mattresses" of material decompose slowly and may considerably obstruct the spread of roots by the next crop.

In India it is common practice to use a draft animal to drag a plank sideways across the standing green manure, which is thus flattened before being plowed under in the same direction. "Dragging" is best done in the mornings, when plants are in a turgid state. A somewhat more labor-intensive method is to lop plant material by hand and lay it in the plowed furrow. Incorporating the green manure with a disc harrow is also recommended (ARAKERI et al. 1962).

4.4 Green manure as a catch crop

Planting green manure as a catch crop or intercrop is appropriate when a dry season falls between two cropping periods (i.e. rainfall is bimodal). A ground cover of legumes protects the soil during the dry season and adds to the supply of nitrogen when plowed under. The amount of additional labor involved is small as the fields must be plowed towards the end of the dry season anyway. In northwest Cameroon, for example, *Mucuna utilis* is sown into the standing crop towards the end of the first rainy season, shortly before harvest. By the beginning of the second rainy season 4-5 months later, the plants have long since withered and are easily incorporated. The result is a higher yield for the following food crop (RAQUET, personal communication). This approach of using the period between two cropping cycles is also successful in rice cultivation (see below).

Catch crop green manuring should not be practised in such a way as to necessitate more soil tillage than is required for seasonal rotation. Tillage hastens the breakdown of carbon and of humus in the soil (KAHNT 1983). This has been observed under summer conditions in Central Europe (KÖHNLEIN 1964). It is assumed that the effect in the tropics would be even more pronounced. Experiments by BUANEC and JAKOB (1981) tend to confirm this assumption, as do studies in Ibadan, Nigeria (AGBOOLA 1975; OFORI 1980).

4.5 Seasonal green manuring or intensive fallowing

In seasonal green manuring, a growing period is used to grow biomass to regenerate the soil. Whether this is actually green manuring or intensive fallowing depends on whether incorporation is carried out at all and, if it is, on whether the biomass that is turned under is still green or not. In most cases we are dealing with intensive fallowing. The period involved, which usually includes a single rainy season and the subsequent dry season, is generally long enough to accommodate more species than in catch cropping (see above).

Seasonal green manures or intensive fallows should be managed so as to produce a good fertilizing effect (friable humus) on the following crop, while at the same time contributing to the basic humic content of the soil (stable humus). For the smallholder, who usually plans for the short term and who must sacrifice a food crop through this practice, the fertilizing effect on the subsequent crop is all-important. Of course, no food crop is sacrificed if the alternative to green manuring or intensive fallowing is a weed fallow.

In some locations it may be possible to improve the fallow by sowing green manure plants into the spontaneously germinating weed stand. Because it requires little work and does not take up land that might otherwise be used for crops, this practice is more

readily accepted by farmers. Nevertheless, thorough preparation of the seedbed is necessary where weed infestation is heavy. The ability to compete with weeds and develop rapidly varies strongly with species (BOUHARMONT 1979).

Numerous authors point out that the fertilizing effect is strongest when the plants are worked into the soil while still green and before seed maturity. Studies by RATTRAY (1956, cited in WEBSTER and WILSON 1980) showed that yields from the subsequent maize crop were 15-30% higher when the green manure crop was incorporated before seed maturity (see Table 4.1).

Table 4.1. Maize yields (bags/acre) as affected by degree of maturity of preceding green manure

Preceding crop	Incorporated green	Incorporated after the seed harvest
Crotalaria	24.5	19.4
Mucuna utilis	24.3	15.8
Glycine max	22.2	18.2
Helianthus annuus	18.0	12.0

Source: RATTRAY (1956) cited in WEBSTER and WILSON (1980)

There are, however, also examples to the contrary, and the recommendation to incorporate the biomass before the seed harvest is now disputed. In addition, there may be other good reasons for waiting for the seed to mature: the farmer may wish to market seed or to use it him- or herself.

At locations in Rwanda, a herbaceous, seasonal green manure was only effective on relatively fertile soils and when a whole growing period was available. On poor sites, only multi-seasonal intensive fallows could be established. The yield of *Mucuna utilis* amounted to 3-8 t of fresh matter/ha (NEUMANN and PIETROVICZ 1983).

WEBSTER and WILSON (1980), reporting on over 30 years of trials at Ibadan, Nigeria (with rainfall of 1250 mm/yr and two growing seasons), found that rotating green manure and maize maintained yields of the latter.[68] Maize yields without green manure declined rapidly. The trials were carried out on relatively fertile, freshly cleared land.

In similar experiments in Zimbabwe, excellent results were achieved with *M. utilis* and *C. juncea* (see Table 4.2). Over the 22 years in which green manuring was carried out regularly, only 14 maize harvests were obtained. Nevertheless, the total maize yield was still higher than under continuous maize cropping. Averaged over the years, maize yields under rotation were more than twice as high. As Table 4.3 shows, the yields from successive maize crops fell rapidly. Clearly the yield capacity of the soil is maintained with green manuring, whereas continuous maize cropping leads to a swift decline in soil fertility and decreasing yields.

Table 4.2. Maize yields under continuous maize cultivation and under rotation with green manure (1928 to 1950)

System	Number of maize harvests	Total maize yields (bags/acre)	Annual average (bags/acre)
Continuous maize	22	132.2	6.0
Maize rotated with green manure	14	186.9	13.5

Site: 1650 m a.s.l.; rainfall 750 mm/yr (monomodal)

Source: RATTRAY and ELLIS, cited in WEBSTER and WILSON (1980)

[68] Research in Europe also shows that green manure sustains the yield capacity of the soil only when green manuring is carried out at frequent intervals (GLIEMEROTH 1958).

Table 4.3. Mean maize yields (%)* in different crop rotation systems compared with alternating green manure (GM) and maize (=100%)

Succession of maize crops following green manure crops	1	2	3	4
A. GM and maize alternately	100			
B. GM followed by 2 x maize	93.5	52.9		
C. GM followed by 3 x maize	95.6	53.5	48.2	
D. GM followed by 4 x maize	87.1	51.5	41.2	36.4

* Averaged over 6 years

Source: RATTRAY and ELLIS (1953), cit. in WEBSTER and WILSON (1980)

Similarly striking results were reported by RODRIGUEZ (1972) in Colombia (Table 4.4). During 9 years of trials in which *Dolichos lablab* was rotated with maize, yields of the latter were 100% higher than those under continuous maize cropping, and 60% higher than those obtained using a weed fallow. Planted in the main growing season of the next year, the crop following green manuring more than compensates for the maize yield that might otherwise have been gained from the preceding rainy season, which is shorter and less reliable.

In Ibadan, trials on the rotation of maize with *Calopogonium, Phaseolus* and *Vigna* were not as successful. Over 2 years the increase in maize yields averaged only about 25%, which was not enough to compensate for the sacrifice of a crop. Here undersowing produced better results than a seasonal intensive fallow (AGBOOLA and FAYEMI 1972a).

Table 4.4. The influence of nitrogen, weed fallow and crop rotation on maize yields (t/ha) in Colombia (1956 to 1964)*

Nitrogen (kg/ha)	Continuous maize crop	Maize/weed fallow	Maize/ Soybean	Maize/ Dolichos
Long rainy season				
0	2.95	3.69	3.28	5.91
40	4.52	4.68	4.73	6.20
80	5.52	5.66	5.38	6.23
Short rainy season				
0	2.06	----	2.96	4.86
40	2.91	----	3.51	4.85
80	3.51	----	4.45	4.84

* Averaged over 9 years

Source: RODRIGUEZ (1972)

NEME (1955), cited in SCHAAFHAUSEN (1963), found that *Dolichos lablab* produced excellent results when undersown in maize. Sown at the same time as the maize (seeding rate 10-20% of the maize seed), *Dolichos* was able to establish well from the fifth month onwards. Incorporated before seed maturity, it increased the yield of the following maize crop to 4150 kg/ha, compared with 2400 kg/ha without green manuring. As *Dolichos* is a valuable livestock fodder, an additional benefit is gained by grazing livestock on the fields once the maize has been harvested. The different effects of soybean and *Dolichos* (in Table 4.4) suggest that experimenting with different plants can be extremely rewarding. Success often depends on whether the grower manages to find suitably adapted plants. Finally, a note of caution must be sounded: follow-up crops other than maize are likely to produce completely different results. In other words, the best combination of green manure/intensive fallow and follow-up crop must be found through trial and error.

4.6 Undersowing as green manure or intensive fallow

Compared with catch crop and seasonal green manuring, undersowing in the form of synchronous green manuring or intensive fallowing usually has a still more favorable effect on the carbon and nitrogen status of a site. The soil is undisturbed for longer, more shade is provided, and more nitrogen fixed. Undersowing is carried out either at the same time as or before the cover crop is sown. In Ibadan, Nigeria, prior undersowing with *Desmodium trifolium* permitted a mixture of maize and *Vigna sinensis* to be sown with no damage to the green manure plants (WIJEWARDENE 1976, cited in OKIGBO 1977).

Green manure plants are often sown into the cover crop at the time of the first or second weeding, thus giving the cover crop a head start. Here soil moisture conditions, the ability of the green manure crop to compete and the challenge by weeds play an important role. If the main crop has a plentiful supply of water at the time of sowing and during early growth, it is a good idea to sow short-cycle green manure plants at the same time. These help to cover the soil early. They also protect against the loss of nutrients by assimilating soluble nitrogen which they can later return to the main or a subsequent crop.

In Nigeria, AGBOOLA and FAYEMI (1972b) carried out trials on leguminous crops undersown in maize. The legumes (*Vigna unguiculata, Phaseolus aureus* and *Calopogonium mucunoides*) were sown at a spacing of 30 x 30 cm concurrently with the maize, sown at 30 x 90 cm in March. As Table 4.5 shows, undersowing did not lead to a decline in yield. *Phaseolus aureus*, which is short-lived, reaching maximum N fixation after only 7 weeks, supplied the maize with nitrogen during the first growing period, so that the yield from this treatment without N fertilizer was equal to the yield obtained without undersowing but with 45 or 90 kg N/ha. In most cases, however, a decrease in yield can be expected when the green manure crop is sown at the same time as the main food crop, and where this practice has not been tried and proven, it is advisable to delay planting the green manure until the first weeding.

Table 4.5. Influence of undersown legumes on maize yields (kg/ha) during the first growing period in humid western Nigeria

Mineral fertilizer (kg/ha)	No legumes	*Vigna unguiculata*	*Phaseolus aureus*	*Calopogonium mucunoides*
-	1790 c*	1850 bc	3080 a	1850 bc
45	3080 a	2750 ab	3070 a	3050 a
90	3420 a	2750 ab	2750 ab	3070 a
135	2580 b	2920 ab	1960 bc	2920 ab

* Values with the same letters do not differ significantly (p = 0.05)

Source: AGBOOLA and FAYEMI (1972b)

Thus, in the experiments by AGBOOLA and FAYEMI, it was only during the second growing period (August planting) that the other legumes (*Vigna* and *Calopogonium*) produced a significant increase in the yield of the maize crop, which did not receive fertilizer and was this time planted without undersowing (Table 4.6). All yields following previous undersowing were higher than the maize-maize control. *Phaseolus aureus* manifests little further effect, having spent itself during the first growing period. Of all the legumes, *Calopogonium* produced the largest amount of fresh matter and had the greatest impact on the yield of the second maize crop.

Table 4.6. Influence of unfertilized undersown legumes* on maize yields (kg/ha) during the second growing period in humid western Nigeria

--- Legume undersown in preceding maize crop ---			
None	*Vigna unguiculata*	*Phaseolus aureus*	*Calopogonium mucunoides*
1210	1970	1510	2120

* Incorporated as green manure: although the maize residues were incorporated with the green manure shortly before the second sowing, there was no decrease in yields on the site.

Source: AGBOOLA and FAYEMI (1972b)

Table 4.7. Effect of different maize cultivation techniques on grain yield (kg/ha), on a ferruginous soil at Ibadan, Nigeria, 1966-67

Crop season	Without legumes	*Vigna unguiculata*	*Calopogonium muconoides*	*Phaseolus aureus*
1st season 1966	2520 a*	2670 a	2690 a	2800 a
2nd season 1966	1190 b	1150 b	2000 a	1150 b
1st season 1967	1610 b	2390 a	2560 a	2550 a
2nd season 1967	710 b	1270 a	1270 a	1230 ab
Average	1510 b	1870 ab	2240 a	1930 ab

* Values with the same letter do not differ significantly (p = 0.05)

Source: AGBOOLA and FAYEMI (1972a)

Two years of cropping trials on a neighboring site with somewhat higher soil fertility produced further evidence in favor of undersowing with legumes (Table 4.7).

In these trials *Vigna* and *Phaseolus* had already matured by the time they were plowed under (i.e., strictly speaking they cannot be regarded as green manure), whereas *Calopogonium* was still growing. Over the four growing periods covered by the trials, *Phaseolus* yielded an average of 3300 kg/ha of beans. *Vigna* ripened in the first season, yielding 3800 and 3000 kg/ha.

This experiment corroborates the results of RATTRAY (1956; see Table 4.1), who found that the green manuring effect of grain legumes is diminished following harvesting, because the amount of energy and N-rich compounds stored in the mature legume seed is particularly high. However, it should be noted that, compared with the control, the green manuring effect improves with repetition.

Table 4.8 shows the results of experiments with undersown legumes at unfertilized sites in the highland tropics of Bolivia.

Undersowing with Russian vetch (*Vicia villosa*) proved especially beneficial. It had a positive effect on the maize yield, provided plentiful fodder[69] and gave good ground cover. The best sowing time was after weeding the maize, which was then 25 cm high. Further studies also showed the importance of choosing the right maize variety (Figure 4.1). *Aychasara* was the most suitable legume for use in rotations without undersowing, whereas *Choclero* clearly performed better when undersowing was practised.

[69]According to KAHNT (1983), proper treatment and spreading of stable manure ensures that 40% of the nitrogen harvested in the green manure for use as fodder is ultimately returned to the soil.

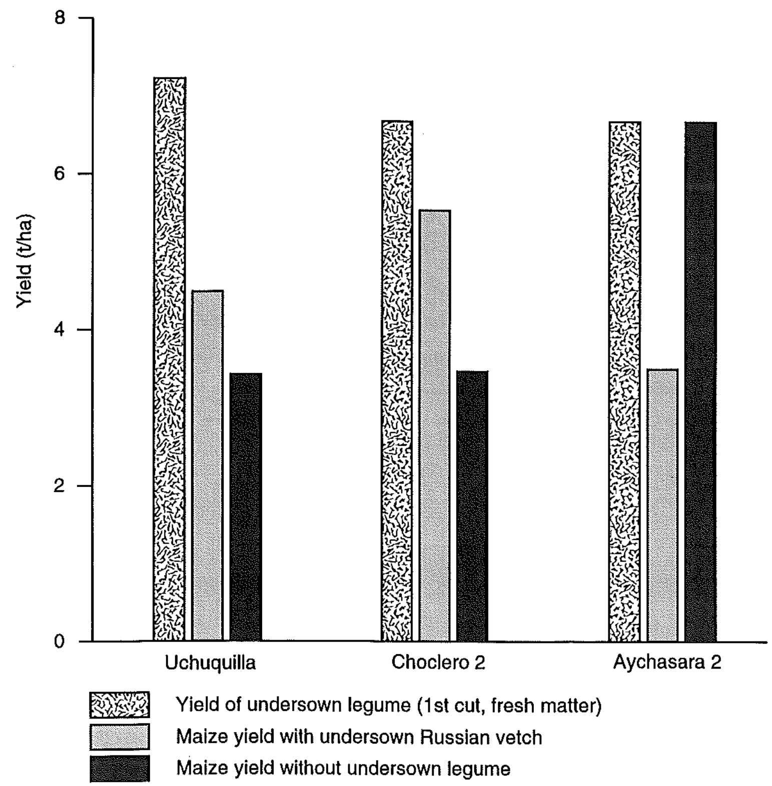
Table 4.8. Effect of 14 undersown legumes on maize yields, fodder yields and soil coverage in the highlands of Bolivia*, 1979/80

Legume	Maize yield (t/ha)	Fodder yield 2nd cutting (t/ha)**	Ground cover (without weeds) (%)
Medicago lupulina	6.35	9.00	47
Medicago sativa	7.47	10.24	31
Lotus corniculatus	6.63	3.67	3
Trifolium pratense	6.49	10.40	40
Trifolium repens	5.74	7.23	37
Trifolium resupinatum	6.26	4.60	13
Trifolium alexandrinum	6.18	9.87	23
Trifolium subterraneum	7.10	4.03	24
Trifolium hybridum	7.12	5.10	4
Melilotus albus	7.72	5.97	46
Anthyllis vulneraria	7.03	5.63	3
Onobrychis viciolia	9.66	4.20	3
Vicia sativa	5.36	15.62***	23
Vicia villosa	8.70	20.43	61
Without legumes	5.67	2.00	42****
LSD (P=0.05)	2.90	3.60	19

* PAIRUMANI, 2620 m a.s.l.; ** Fresh matter; *** 1st cutting only; **** Weeds only

Source: SCHWEIZERISCHE STIFTUNG (1981)

Figure 4.1. Effect of undersowing with Russian vetch on the yield of three different maize varieties, 1979/80.



* Molino Blanco, Bolivia (2820 m a.s.l.)
** Yield of undersown legume (fresh matter)

Source: Adapted from SCHWEIZERISCHE STIFTUNG (1981)

At higher elevations, undersowing Russian vetch in barley proved successful. These results complement the research of DO VAN LONG (1978), who studied the competitive behavior of *V. villosa* and *Stellaria media* in oats. He too found almost no sign of competition, with both legumes producing substantial amounts of biomass.

Other methods of synchronously producing biomass to fertilize the soil are found in the rice cultivation systems of South China. There it is common to raise the flood-, acid- and alkaline-tolerant *Sesbania cannabina* in special, fertile nursery beds and to then transplant it into the established rice stands (FAO 1979b).

The ratio of nursery bed to rice field is about 1:50, and the seeding rate around 0.5-0.7 kg/100 m^2. After one month in the nursery bed the *Sesbania* plants reach some 15 cm in height. When they are 10-15 cm taller than the rice, they are planted out in the rice field (rows of 3 x 0.25-0.35 m). Once they are well established, the tops are lopped off so that they branch well and produce plenty of leaf material. The rice is harvested, after which the *Sesbania* continues to grow another 10-15 cm alone. Three days before the second rice crop is transplanted, the *Sesbania* is incorporated, providing 15-22 t/ha of fresh matter, a yield similar to that of a normal intensive fallow. The leaf matter yields some 80 kg/ha of nitrogen, of which about 40% can be utilized by the subsequent crop. This represents a considerable saving in mineral fertilizer. Despite a reduction in the amount of mineral N fertilizer applied (45 kg/ha instead of 75), yields of 5,000 kg/ha obtained in trials in China were 20 % higher than in the control without *Sesbania*.

This approach is suitable for locations where two rice crops per year are possible. The effect when other crops follow rice is yet to be investigated.

Starting the plants in a nursery bed has the advantage of reducing the risk of weed infestation (REHM and ESPIG 1976). Since the plants remain in the rice field for only one month (FAO 1979b), they offer little competition for the rice.

Alley cropping is, in principle, a similar procedure and may also be regarded as intensive fallowing. This approach is discussed in Chapter 3.