GREEN MANURE CROPS

Any plant material incorporated in the soil while green or soon after maturing for the purpose of improving the soil is a green manure. Crops grown for green manure are often grown for only part of a season, such as summer catch crops and winter cover crops. Green manure may also include crop material which is grown, dried, and later incorporated.

Green manuring is an ancient practice used to increase the productive capacity of soil. Records show that green crops, primarily legumes, were plowed under or composted at least 3,000 years ago in China (Allison 1973). In America, legumes were used almost exclusively along with limited use of cereals and grasses. With increasing availability of nitrogen fertilizers, nonlegumes such as rye, wheat, oats, sorghum, Sudangrass, and recently sorghum-Sudan hybrids have been used more. Green manuring is used in forest nurseries in conjunction with crop rotation.

LEGUMES

Legumes fix nitrogen from the air as they grow, thus they can provide nitrogen to the soil when used as a green manure. Legumes should be inoculated with the appropriate strain of nitrogen-fixing bacteria (*Rhizobium* spp.) when they are sown to ensure efficient fixation. The total plant nitrogen that is fixed is much less for plants growing in soils with abundant nitrogen than in soils poor in nitrogen. Before legumes fix nitrogen from the air, they will use nearly all available nitrogen in the soil. The maximum amount of nitrogen uptake occurs in the first 50-75 percent of the legume's growing period (Allison 1973). The nitrogen content increases steadily during growth of the legume until the plants reach seed production, then it levels off. The range of values of nitrogen fixed varies widely but is estimated to be: alfalfa 50-350, clovers 50-200, peas 30-140, and pastures with legumes 10-550 pounds per acre per year (Allison 1973). Comparative values from different species of legumes are given in Table 25.

Table 25 - Nitrogen content of tops and roots of legumes, and the amount of nitrogen fixed

Legume	Dry weight		Amount of nitrogen		Total N in tops plus roots	Amount of nitrogen fixed[1]
	Tops	Roots	Tops	Roots		
	Pounds		*Percent*		*Pounds*	
Alfalfa	2,000	1008.4	2.56	2.03	71.67	47.78
Red clover	2,000	1006.6	2.70	2.34	77.55	51.70
Sweet clover	2,000	721.0	2.41	2.04	62.90	41.93
Crimson clover	2,000	644.8	2.85	2.29	71.77	47.85
Vetch	2,000	418.4	3.34	2.16	75.84	50.56
Cowpeas	2,000	337.8	2.70	1.45	58.90	39.27
Velvet bean	2,000	304.2	2.34	1.27	50.66	33.77
Soybeans	2,000	277.4	2.58	1.91	56.90	37.93
Blue lupines	2,000	342.0	2.60	1.40	56.79	37.86
Yellow lupines	2,000	255.0	2.57	2.17	56.93	37.95
Field peas	2,000	90.0	2.80	2.52	58.27	38.85

[1]Two-thirds of the total is assumed to be fixed from air.
Source: Allison (1973).

Soil physical properties are improved by the effects of green manure on root systems. Deep-rooted legumes, such as alfalfa (Figure 8), sweet clover, lupines, and kudzu, can penetrate two feet or more. This penetration is below the root zone of most other crops in the rotation (Allison 1973). Other crops such as red clover, soy beans, cowpeas, and small grains also root deeply. Legumes are usually more effective than nonlegumes on dense soil and in penetrating a layer of hardpan or near-hardpan. By remaining in the soil, these roots supply nutrients to future crops. Also, subsequent crop roots often grow down old channels and take advantage of increased available water as a result (Allison 1973). Thus, the use of legumes may be important in managing nursery soil with hardpans.

Figure 8. Alfalfa is commonly used as a green manure crop if more than one growing season is allowed.

BENEFITS AND HARMFUL EFFECTS OF GREEN MANURES

Green manure is usually beneficial to soil that is well managed. Benefits attributed to green manuring include addition of nitrogen (when using legumes), addition of organic matter, increase in the conservation and availability of nutrients, improved physical condition of the soil, erosion control, and weed and disease control. The root systems of green manure crops also have a big effect in aggregation of the finer-textured soils, as discussed above. The most effective root systems for this purpose are those with finely divided and extensive, but not necessarily deep roots. Small-grain crops best meet this requirement.

Green manure crops also shade and cool the soil. By providing a dense vegetative cover, the damage to soil aggregation produced by raindrop splash is eliminated (Allison 1973). This reduces the tendency toward crust formation, a serious problem in many nurseries.

Green manuring is often used in rotation in agriculture for disease control. But the common pathogens of tree seedlings, such as *Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp., have a wide host range and their incidence does not appear greatly affected by crop rotation (Aldhous 1972). The one exception found in the literature is with western redcedar seedlings. In England (Aldnous 1972), these seedlings can be infected by the fungus disease *Didymascella (Kethia) thujina*, causing severe losses. Aggravation of losses occurs from cross-infection of first year seedbeds from older stock. Crop rotation is an effective control because it ensures that cedar is not grown in seedbeds for more than one year.

There is some disagreement about whether green manure actually provides an increase in the organic content of the soil. It appears that green manures may have a negligible effect on total levels of soil organic matter under systems of continuous cultivation (Allison 1973). They do add active, rapidly decomposing organic material. The actual percent organic matter in soils may be determined primarily by climate. Higher levels may be obtained by replacing crops with sod or periodic additions of organic material such as animal manure. Green manuring involves soil disturbance, and accelerated oxidation would counteract some of the possible increases that could be expected. Beneficial effects of green manuring are generally evident from other characteristics associated with addition of organic material.

The effect of green manure on humus is subtle. Slight increases, which may appear "negligible" to some, may be significant. Experiments in crop rotation have resulted in increased humus content of the soil by 0.12 percent over 12 years when compared to a single crop grown continuously. This is equivalent to an annual gain of 165 pounds of humus per acre. The gain from rotation under irrigation is equivalent to 227 pounds per acre (Stephenson 1941). Humus renewal is more effective under irrigated rotation than under dry-farm operations. The above values reflect considerable addition of humus associated with very slight increase in total humus content.

The excess fertilizer and other available soil nutrients may be leached in periods when ground is barren. As much as 25-30 pounds per acre of nitrate nitrogen, 10-20 pounds of potash, and 175-350 pounds of lime can be lost annually by leaching on bare soils (Stephenson 1941). The quantities of added fertilizers are sometimes in excess of the amount taken up by plants during the growing season. The green manure crop grown as a cover or catch crop is able to utilize excess fertilizer and minimize loss by leaching. Such benefits are realized by having an actively growing winter cover crop or by allowing a crop to be winter killed and remain undisturbed until time for spring plowing. This practice also gives good soil protection during winter rains. Physical benefits from root growth and improvement of tilth are also provided (Allison 1973).

Most of the harmful effects related to green manure occur only when the crop that follows is grown too soon after plant material is incorporated. Seedlings grown too soon after turning under a green manure crop are sometimes injured by damping-off fingi (Allison 1973). A green manure crop can deplete soil moisture temporarily while it decomposes. This problem is more critical with dry-land farming in areas of low rainfall. With irrigation, it is not a serious concern. Incorporation of non-legumes with high carbon-to-nitrogen ratios may deplete soil nitrogen during decomposition and depress uptake by succeeding crops. To avoid this, supplemental nitrogen fertilizer can be added at the time the nonlegume is incorporated. For a short period after such material is incorporated, there can also be an inhibiting and toxic effect on seedlings from high concentrations of nitrites and non-ionized ammonia (Allison 1973). After a few days, this does not appear to be a problem.

Toxic organic substances may be formed by some plants grown as a green manure crop. Phytotoxic substances are formed by some higher plants and micro-organisms associated in their decomposition. Antibiotics produced by soil organisms can also be toxic to some plants. Harmful products derived from green manures are usually destroyed within 2 to 3 weeks. Antibiotics are generally adsorbed by soil colloids (Allison 1973). Some plants known to have produced growth inhibitors are listed in Table 26. Unfortunately, little information is available regarding inhibition of tree seedling growth by other plants, but some indications of allelopathic plants important to forestry are provided in Table 27.

GREEN MANURE CROPS TO USE

Selecting a Crop. Ideally, a green manure crop should be easily established and grow rapidly. There are a variety of legumes and nonlegumes that produce abundant growth in a short time. Choice of the crop should include consideration of the purpose for green manuring and climatic factors. A list of commonly used green manures is given in Table 28.

Nurseries in Oregon and Washington frequently use oats, rye, Austrian peas, Sudangrass, crimson clover, and lupines. Residues of sorghum-Sudangrass have suppressed growth of seedlings in nursery soils

Table 26 — Plants reported to produce differential growth inhibitors of known and unknown composition

Source plant	Chemical constitution	Plants inhibited	Parts of plant Inhibited	Plants resistant	Remarks
Tonka bean, sweet clover	Coumarin	Carrot, onion, lilly, alfalfa	Roots	Cress, cabbage	
Spreading pasque—flower. buttercup	Protoanemonin	Cress, corn			
Angelica glabra	Byakangelicin	Tomato			
Thamnosma montana	Byakangelicin, isopimpinellin, $C_{16}H_{15}O_5(OCH_3)$ with isobergaptene nucleus	Tomato			
Guayuie	Transcinnamic acid	Guayule, pea		Tomato	Homologous
Encelia farinosa	3—acetyl-6 methoxy—benzaldehyde	Tomato, pepper, corn		Barley, oats, sunflower	Inhibitor in leaves
Mountain ash berry, wheat middlings, orange rind	Parasorbic acid	Onion, tomato	Roots		
Vanilla bean	Vanillin	Wheat seedlings	Roots		
Bergenia crassifolia	Arbutin	Wheat seedlings			Inhibitor in leaves
Pyrus communis, oats	Scopoletin	Oats			Homologous
Not listed	Umbelliterone	Red kidney bean, cucumber seedlings	Roots	Peas, corn, wheat	
Clover	Unknown	Kentucky bluegrass		Bromegrass	
Kentucky bluegrass	Unknown	Canada bluegrass	Foliage and roots		
Domestic ryegrass	Unknown	Kentucky bluegrass, Chewing's fescue			
Redtop	Unknown	Timothy,	Foliage and roots		
		Kentucky bluegrass,	Foliage		
		Chewing's fescue			
Bromegrass	Unknown	Bromegrass seedlings			Homologous
Mesquite	Unknown	Tomato			
Greasewood	Unknown	Tomato			
Viguiera reticulata	Unknown	Tomato			
Creosote bush	Unknown	Tomato			
Encelia frutescens	Unknown	Tomato			

Table 26 — continued

Source plant	Chemicai constitution	Plants inhibited	Parts of plant Inhibited	Plants resistant	Remarks
White Bur-sage	Unknown	Tomato			
Wormwood	Unknown	Sage, groundsel		*Datura, Stellaria*	Inhibitor in leaves may be absinthin
Peach	Unknown	Peach			Homologous
Sorghum	Unknown	Other grasses			
Black walnut	Unknown	Broomsedge, poverty grass, blackberry, dock, common cinquefoil, red pine, white pine, apple, potatoes, alfalfa, tomatoes, hydrangea, lilac, chrysanthemum, asparagus	Leaves	Timothy, black raspberty, red-top, fleabane, ferns, asters, goldenrods, mints, violets, wild grape, clovers, Virginia creeper, thistle, ironweed, tall oat grass, meadow fescue, nimble-will, velvet grass, purple top, poison ivy, corn, oats, wheat, rye, buckwheat, peach, plum, pear	
Sunflower	Unknown	Sunflower			Homologous in spring
Rye	Unknown	Grapes			
Antennaria fallax	Unknown	*Antennaria fallax*			Homologous
Aster macrophyllus	Unknown	*Aster macrophyllus*			Homologous
Erigeron pulchellus	Unknown	*Erigeron pulchellus*			Homologous
Horse thistle	Unknown	Oats			
Euphorbia	Unknown	Flax			
Butternut	Unknown	Shrubby cinquefoil			
Tridax procumbens	Unknown	Other weeds			
Zacate	Unknown	Rice			
Black locust	Unknown	White pine. barley			
White ash	Unknown	White pine			

Table 26 — continued

Source plant	Chemical constitution	Plants inhibited	Parts of plant Inhibited	Plants resistant	Remarks
Oats, alfalfa, avocado. barley, cocklebur. Sudan grass	Unknown	Tomato crown gall			
Evergreen creosote bush	Unknown	Evergreen creosote seedlings			Homologous

Source: Allison (1973).

Table 27 — Some allelopathic plants important in forestry, chemicals they produce and plants they affect

Allelopathic species	Class of chemical produced	Example of species affected
Trees:		
Sugar maple	Phenolics	Yellow birch
Hackberry	Coumarins	Herbs, grasses
Eucalyptus	Phenolics, terpenes	Shrubs, herbs, grasses
Walnut	Quinone (juglone)	Trees, shrubs, herbs
Juniper	Phenolics	Grasses
Sycamore	Courmarins	Herbs, grasses
Black cherry	Cyanogenic glycosides	Red maple
Oaks	Courmarins, other phenolics	Herbs, grasses
Sassafras	Terpenoids	Elm, maple
Shrubs:		
Laurel	Phenolics	Black spruce
Manzanita	Courmarins, other phenolics	Herbs, grasses
Bearberry	Phenolics	Pine, spruce
Sumac	Phenolics, terpenoids	Douglas—fir
Rhododendron	Phenolics	Douglas—fir
Elderberry	Phenolics	Douglas—fir
Other:		
Aster	Phenolics, terpenoids	Sugar maple, black cherry
Goldenrod	Phenolics, terpenoids	Sugar maple, black cherry
New York fern	Phenolics	Black cherry
Bracken fern	Phenolics	Douglas—fir
Fescue	Phenolics	Sweetgum
Short husk grass	Phenolics	Black cherry
Clubmoss	Phenolics	Black cherry
Reindeer lichen	Phenolics	Jack pine, white spruce

Source: Fisher (1980).

Table 28 — Commonly used green manure crops and the adaptability to difference climates

Legumes		Nonlegumes	
Adaptable in warm regions	Adaptable to wide range of climates	Adaptable to wide range of climates	
Crimson clover	Alfalfa[1]	Rye	Sudan grass
Bur clover	Red clover	Oats	Mustard
Lespedeza	Sweet clover	Millet	Rape
Vetch	Soybean	Ryegrass	Weeds
Austrian winter pea	Canadian field pea		
	Cowpea		

[1] More than one growing season is needed to fix appreciable amounts of nitrogen.

Source: Brady (1974, p. 549).

of Wisconsin (Iyer 1979). Green manuring with a sorghum-Sudangrass hybrid (Hyden grass) resulted in about 50-percent mortality of pine seedlings. The 10-week-old seedlings that survived were smaller and had much smaller root systems devoid of mycorrhizal short roots. Soil toxicity was still evident after a detoxification period of 4 winter months (Iyer 1979). Southern nurseries have used sorghum-Sudangrass without phytotoxic effects. Warmer soils (and perhaps better aeration) probably account for this apparent discrepancy. Production of phytotoxins enhanced in cold, wet soils more than in warm, well-aerated soils (Toussoun 1969).

Barley has produced phytotoxic compounds under certain conditions (Toussoun 1969 and Linderman 1970). Use of barley as green manure, like sorghum Sudangrass, may be no problem in the South. Growing buckwheat in colder, wetter soils of the North could be monitored for possible phytotoxic effect.

Increase in *Fusarium* root rot in areas where buckwheat had grown as a cover crop was observed in the Saratoga Nursery in New York. When the cover crop was changed to another species, there seemed to be no problem.