TO MAINTAIN maximum amounts of organic matter in cultivated soils, the following principles should be followed:

Keep some crop growing on the land whenever circumstances permit. Meadow crops are most effective in maintaining organic matter. Intertilled crops are the least effective.

Use frequent short stands of meadow because they make the best use of the time the land is in meadow. The first year the land is in meadow is the most effective in the maintenance of soil organic matter as well as the fixation of nitrogen if the meadow crop is leguminous. Lesser contributions of organic matter and nitrogen result in subsequent years of meadow.

Follow good soil-management practices to produce high yields of crops. High yields permit the return of large amounts of crop residues and manures.

Return all residues to the soil. Mature residues and animal manures are most effective.

Cultivate no more than necessary, because tillage tends to hasten the biological decomposition process.

Control losses by wind and water erosion, which carries away the lighter organic materials from soil.

Green Manure and Cover Crops

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A green manure crop is grown and plowed under for the purpose of improving the soil. A cover crop is grown primarily to prevent or reduce erosion.

Both types of crops often are used for the same purpose, as well as for temporary grazing or for forage or grain.

In this discussion of the effects these crops have on the soil and on the following crop, we use the term "green manure crop" to include cover crops.

Green manure crops are usually annuals, either legumes or grasses.

Some advantages generally attributed to them: They add nitrogen to the soil for use by the following crop. They increase the general level of fertility by mobilizing minerals and building up the organic matter and the nitrogen content. They reduce losses from erosion. They improve the physical condition of the soil and permit a more efficient use of plant nutrients. They conserve nutrients by cutting down the losses from leaching.

Some disadvantages: A risk is involved in obtaining a satisfactory stand and growth of the crops. The cost of growing them may be more than the cost of commercial nitrogen. An increase of diseases, insects, and nematodes is possible. They may exhaust the supply of moisture. They may adversely affect the stand of the next crop.

Green manuring has been practiced a long time as a way to supplement animal manures. The efficiency of the practice depends on the soil, climate, and the crop.

It is often said that green manuring is not effective in regions with an annual rainfall of less than 20 inches.

In an experiment near Fargo, N. Dak., from 1929 to 1954, sweetclover, plowed early, did not result in an increase of flax as compared to straight fallow. When sweetclover was allowed to stay on the land during a large part of the fallow season, the yield of flax was less than when no sweetclover was used. Moisture was probably the limiting factor.

Green manure crops are grown most extensively in the Southeastern States. Usually they are planted in the fall and turned the following spring before the summer or cash crop is sown. About 13 million acres of green manure crops were grown in the Southeast in 1940. The acreage has since declined.

The rate of decay of the organic residues is determined by conditions for

microbial growth. Warmth, proper aeration, and ample moisture increase microbial growth. The decomposition releases carbon dioxide and weak acids, which act on insoluble soil minerals and may release nutrients for plant growth.

The decomposing crop residues also release inorganic plant nutrients in addition to nutrients from insoluble minerals. The chemical composition of the crops affects their value for green manuring.

An increase in potato yields in Maine following green manures was attributed to the nutrients added in the organic materials. Vetch used as a cover crop in North Carolina increased the available nitrogen, potassium, calcium, and magnesium of soil in both cotton-peanut and cotton-corn rotations. The cover crop did not increase the exchange capacity of the soil—the ability of the soil to hold or exchange plant nutrient elements. Alfalfa used as a green manure crop in Ohio increased the availability of residual soil phosphorus.

Some green manure crops with the approximate nitrogen percentages on a dry basis:

Crop	*Percentage of N*
Alfalfa	3.0–4.0
Austrian winter peas	3.0–3.8
Clover, Red	2.8–3.2
Clover, Crimson	3.0–3.3
Cowpeas	2.5–3.0
Lespedeza, Common	2.2–2.5
Lespedeza, Sericea	2.1–2.4
Lupine, Blue	2.0–2.5
Vetch, Hairy	3.0–4.0
Oats	1.3–1.4
Rye	1.2–1.3
Ryegrass	1.2–1.3

An experiment in progress at Athens, Ga., for 8 years showed no increase in corn yields or in soil organic matter from green manure crops—vetch, Austrian winter peas, and crimson clover—if adequate amounts of nitrogen, phosphorus, and potassium were added.

Experiments in all parts of the country have indicated that if soil nitrogen is deficient, leguminous green manure crops supply the needed nitrogen; the amount of nitrogen they fix depends on the crop and amount of growth.

Green manure crops have little influence on soil organic matter if cultivation is continuous. In cooler sections, green manure increases organic matter and nitrogen somewhat. Such crops in warmer areas have a temporary effect, with little or no overall increase in soil organic matter because only a relatively small amount of plant material actually is grown and returned to the soil by most cover crops and because cultivation speeds up the rate of decomposition. Even soils in forests lose their supply of organic matter rapidly when they are first cultivated.

Perennial sod or cover crops increase soil organic matter and nitrogen.

Four years of cropping to kudzu in Mississippi brought an increase of 43 percent in nitrogen and 85 percent in carbon over the nitrogen and carbon present when corn was grown all the time. A long-term rotation, including alfalfa, in Ohio gave increased yields, but the top yield levels were reached quickly. In a 5-year rotation of corn, oats, alfalfa, alfalfa, alfalfa, no sustained benefit accrued once the first round of the rotation was completed.

Green, easily decomposable organic materials added to soils may speed up decomposition of the soil organic matter already present. F. E. Broadbent and A. G. Norman, at Iowa State College, found by using isotopic carbon and nitrogen that adding young Sudangrass increased the rate of loss of native carbon in soil.

Green manure crops can be expected to have more effect on soil organic matter when the soil clays are the montmorillonitic type (expanding clay with high exchange capacity) than when they are of the kaolinitic (nonswelling with low exchange) type. Proteinaceous organic materials have been shown to react with clays, especially montmorillonitic clays.

F. E. Allison and others at Beltsville, Md., found that more carbon was retained after adding soybean plants and corn stover to sand-bentonite clay mix-

tures than in sand-kaolin mixtures or in pure sand. Perhaps one reason that soil organic matter is low in the Southeast is that the soil clays are largely kaolinitic.

COVER CROPS prevent leaching of nitrogen and potassium and possibly other elements from soils. Studies throughout the United States have shown that losses from leaching are reduced greatly by soil cover—a matter of great importance when soils are light and sandy.

The time of turning green manure crops under is important from this standpoint. Fall-turned crops may lose most of their nitrogen by leaching before the following crop can utilize it. Soybeans turned into a sandy soil in Alabama in the fall lost 70 percent of the added nitrogen by leaching, but the loss was 38 percent when soybeans were turned in the spring.

Cover crops improve the soil physical properties of aggregation, porosity, bulk density, and permeability. The effects are more pronounced on fine-textured soils than on coarse ones.

Any material that supplies a readily available source of food for soil microorganisms will cause an increase in soil aggregation. Rapidly decomposing organic residues are more beneficial than slowly decaying materials.

G. M. Browning and F. M. Milam in West Virginia showed that cane sugar was more effective in producing aggregation of a Gilpin silty clay loam than alfalfa, rye, and vetch, or wheat straw. Aggregation no doubt is associated with the gums, slimes, and other products of soil micro-organisms, which tend to cement soil particles together. The benefits of decomposing cover crops generally are of rather short duration, because the rapidly decaying materials remain briefly in the soil.

Good ground cover reduces soil erosion. The crops slow down the beating action of rain on soil particles and so lower the runoff and erosion.

Many fall-planted green manure crops, however, make too little growth to check erosion before winter rains set in. Residues from the preceding summer crop and from weed growth might do a better job of preventing soil loss by runoff than plowing and planting a new crop.

Data from the Georgia Coastal Plain Experiment Station indicate that soil loss is greater on land that has an annual winter cover crop than on land on which corn stubble is left on the ground. Seeding without disturbing the surface residues may be the answer.

Because most of the soil loss from cultivated fields by water occurs in June, July, and August, summer crops would be best for controlling erosion. When corn followed a winter cover of rye and vetch in South Carolina, the soil loss was less than when no cover crop was used.

Cover crops can help control wind erosion, but often the crops are not on the land during periods of high winds.

Cover crops increase the rate at which water filters into soils. Leaves and stems catch the rain, and the roots open channels for the water. Improved aggregation, which usually follows green manuring, also allows better penetration. The improved permeability of soils to water does not mean, however, that more nutrients would leach away. The growing crop would absorb a large part of the nutrients.

Deep-rooted crops, such as some of the legumes, help open up soils with restricted subsoils. Crops grown for a short time usually have little effect on heavy subsoils.

Bulk density of soils is lowered and porosity is enhanced in turn by the use of green manure crops. The improved aggregation allows more space between soil particles and therefore less weight of soil per unit volume.

There is little experimental evidence that green manure or cover crops boost the water-holding ability of soils except while growing on the land. Ryegrass, vetch, crimson clover, and Austrian winter peas did not improve the water-holding ability of Onslow fine sandy loam in Virginia. The amount

of water held by a soil is increased, however, if the soil organic matter is increased appreciably by a cover crop, such as a perennial grass or legume.

The effect of green manure crops on the yield of corn varies with the crop, the soil, climate, and other factors.

F. S. Arant, of Auburn, Ala., found less damage to corn from the Southern corn rootworm when corn planting was delayed 3 to 4 weeks after the green manure crop was turned.

J. L. Stephens, Tifton, Ga., conducted extensive tests with winter legumes in the Coastal Plain of Georgia. He reported that winter legumes do not furnish an adequate amount of nitrogen for maximum yield of corn and recommended the addition of commercial nitrogen when corn follows a winter legume. The residual effect of hairy vetch and monantha vetch was greater than that of Austrian winter peas.

S. S. Obenshain, Blacksburg, Va., and P. T. Gish, Shenandoah Valley, Va., tested a number of green manure crops in Virginia. Vetch in 8 years gave a greater increase in the yield of corn than any other crop tested. Crimson clover produced the next highest increase. Rye and buckwheat produced less than did the crop without green manure.

Martin Nelson, Fayetteville, Ark., found that the removal of the tops of green manure crops had an appreciable effect on the yield of corn at the Arkansas Cotton Experiment Station. When the tops of burclover were removed, the increase in the yield of corn was less than half of what it was when the entire plant was turned. Of the various crops tested, burclover gave the highest increase in the yield of corn. Crimson clover was second. Oats had no significant effect.

Austrian peas and vetch were compared in a 2-year cotton-corn rotation at Rocky Mount, N. C. Corn following Austrian peas produced 57 bushels an acre. The addition of 80 pounds of nitrogen lifted the yield of corn to 84 bushels. The addition of another 80 pounds of nitrogen had no significant effect. Austrian peas were found to be less valuable for corn production than 80 pounds of commercial nitrogen. Addition of 80 or 160 pounds of nitrogen to corn following vetch did not increase the yield of corn during the 5 years the experiment was continued.

Another experiment conducted for 8 years in North Carolina on Marlboro very fine, sandy loam compared vetch with no cover when no nitrogen and low and high rates of nitrogen were added. The low rate of nitrogen was 60 pounds an acre the first 2 years, 90 pounds the following 2 years, and 110 pounds the last 4 years. The high rate was double the low rate. In the 8 years, the average yield of corn with low nitrogen and no cover was the same as the corn that had vetch and no nitrogen. Vetch and low nitrogen produced 92.9 bushels an acre, or 17.3 bushels more than vetch without nitrogen. High nitrogen and no vetch produced 89.1 bushels an acre.

On the basis of these and other experiments, we can summarize the effect of green manure crops on the yield of corn thus: Of the various green manure crops tested, legumes are superior to nonlegumes. Winter legumes are superior to summer legumes. Hairy vetch is the most dependable green manure crop. The removal of the top growth of green manure crops usually results in a reduction in yields below that obtained when the whole plant is turned. A good growth of a winter legume turned 3 to 4 weeks before planting corn will produce as much corn as 50 to 100 pounds of commercial nitrogen.

Experiments in the hilly section of Mississippi indicate that the value of a winter legume to the following crop of cotton depends largely on the natural fertility of the soil. Winter legumes increased cotton yields about the same as 24 pounds of commercial nitrogen, even when the legume turned under added up to 75 pounds of nitrogen.

In a 14-year comparison of different winter green manure crops preceding cotton on Delta soil at Stoneville,

Miss., hairy vetch was superior to the other crops tested. Hairy vetch turned as a green manure crop produced slightly more than 300 pounds of seed cotton than 30 pounds of nitrogen from commercial fertilizer.

California burclover produced almost as much as hairy vetch. Rye produced less than 60 percent as much.

At two places in Arkansas, cotton responded to 20 pounds of commercial nitrogen after winter legumes were turned. There was no response to 40 or 60 pounds of commercial nitrogen when cotton followed a winter legume.

In another 10-year experiment in Arkansas, the effects of removing and turning the green manure crop were compared. The yield of cotton when hairy vetch was removed was 72 percent as much as when it was turned.

In one of three 6-year studies in Alabama, hairy vetch was superior to no green manure plus 36 pounds of nitrogen—apparently a reflection of the total amount of green material turned. In the other experiments, the residual effect of vetch preceding corn in a cotton-corn rotation was equivalent to 213 pounds of seed cotton.

Annual winter legumes turned as green manure increased cotton yields over the no-cover treatment plus 30 pounds of nitrogen during a 17-year test in Georgia. When no nitrogen was applied, rye produced 313 pounds less seed cotton than Austrian peas.

Several winter annuals were tested as green manure crops on Olivier silt loam in Louisiana. Certain of the legumes were as effective as 36 pounds of nitrogen in the production of cotton. Oats produced approximately half as much cotton as 36 pounds of nitrogen.

Research at the Northeast Louisiana Experiment Station showed that the use of winter legumes as green manure crops increased the yield of cotton from 1 bale to 1.5 bales an acre and maintained the high yield over a period of 23 years. After turning under good growths of winter legumes for 3 years in succession, the beneficial effect extended to the following second and third cotton crop. The application of 30 pounds of nitrogen an acre at the time the green manure crop was turned was profitable.

Studies in North Carolina disclosed that a good crop of Austrian peas or vetch produced as much cotton as 80 pounds of commercial nitrogen. No significant increase in the yield of cotton was obtained from 120 pounds of nitrogen as compared to 80 pounds or when 20 or 40 pounds of nitrogen was added to cotton following Austrian peas or vetch.

Workers at the Pee Dee Experiment Station in South Carolina reported that in 3 years out of 5 difficulty is experienced in obtaining and maintaining the stands of cotton following green manure crops, particularly when weather conditions are adverse.

Results of experiments studying the effect of green manure crops on the yield of cotton may be summarized thus: The beneficial effect of green manure crops is related to the nitrogen supplied by the crop. This tends to eliminate nonlegumes as green manure crops. Annual winter legumes have been found equal to 80 pounds of commercial nitrogen in producing cotton. It often is necessary to delay the turning of a winter legume in order to obtain sufficient growth. This may result in planting cotton too late for maximum production.

Research workers in States in which peanuts are grown commercially usually recommend that green manure crops follow the peanut crop. The Alabama Station compared peanuts in a 2-year and a 3-year rotation for 10 years at two places. The yield of peanuts in the rotation cotton-peanuts was 1,349 pounds an acre. When the rotation was cotton-winter legumes-peanuts, the yield of peanuts was increased 130 pounds. In a 3-year rotation—cotton-winter legumes-peanuts-winter legumes-corn—the yield of peanuts was 134 pounds more than the 2-year rotation without legumes.

Several winter annuals were tested in a cotton-peanut rotation at Rocky

Mount, N. C. Average yields for a 6-year period indicated crimson clover, vetch, ryegrass (plus 18 pounds of nitrogen), and Austrian peas, in that order, were effective in increasing the yield of peanuts. In 2 years out of the 6 years, none of the green manure crops produced a significant increase over the crop without green manure.

The Georgia Coastal Plain Experiment Station has recommended the use of green manure crops in peanut rotations. It is suggested, however, that the green manure crop precede corn, cotton, or some other crop that can use large amounts of nitrogen more effectively than peanuts can.

The evaluation of green manure crops in the production of peanuts can be summed up in this way: The peanut, a legume, can obtain part or all of the needed nitrogen from the atmosphere when it is properly inoculated. Large amounts of nitrogen may be detrimental to peanuts. In order for fruits to be formed, the peanut peg must penetrate the surface of the soil. Measurements made after green manure crops are turned indicate that they made the soil less compact and more easily penetrable. The use of green manure crops preceding peanuts may result in increased damage from diseases, insects, and nematodes.

In considering the influence of green manure crops on tobacco, one must take into account the effect on yield and quality. A 7-year experiment in Maryland showed that the highest yield and the best quality tobacco was produced when tobacco was grown following ragweed turned in the spring. The lowest yield and quality was produced when tobacco followed lambsquarter. Lespedeza produced a fairly satisfactory yield, but it was of low quality.

An experiment in North Carolina compared the effect of vetch, crimson clover, fallow, cowpeas, soybeans, and lespedeza on flue-cured tobacco. Vetch and crimson clover resulted in lower quality and acre value. There were no striking differences in the other.

These and some other experiments are summarized thus: Flue-cured tobacco should not be grown immediately following a leguminous crop. The amount and availability of nitrogen is too difficult to control. Some weeds appear to exert a favorable influence on the yield and quality of tobacco. Others exert an unfavorable influence. Management of the green manure crop will affect its influence on tobacco. Rye turned late may tie up nitrogen during the early part of the tobacco season and release it late in the season, causing an inferior quality of tobacco. Certain green manure crops may result in an increased damage to tobacco from diseases and pests. Crotalaria and velvet beans appear most effective of the legumes tested in reducing damage by nematodes.

GREEN MANURE CROPS often are used in vegetable rotations. The effects of various organic matter additions on yield of potatoes in a 2-year rotation were studied for 16 years in Maine. Green manure increased the yield of potatoes an average of 53 bushels an acre. When the green manure crop was removed, the yield of potatoes was reduced 38 bushels, as compared to turning the crop.

Another experiment in Maine showed that legumes increased the yield of potatoes considerably more than nonlegumes. Eighty pounds of commercial nitrogen was applied in both of these experiments.

L. M. Ware and W. A. Johnson, of Auburn, Ala., studied the value of vetch with and without commercial nitrogen. During a 6-year period, they obtained only 3 bushels of snap beans an acre when no nitrogen was used. Snap beans following vetch produced 161 bushels. When 60 pounds of nitrogen was applied, the yield was 144 bushels. Similar results were obtained with lima beans and eggplant. They reported that the average value of the organic treatment on all vegetables studied was 135 dollars an acre above the cost of the practice.

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