INTENSIVE METHODS AND SYSTEMATIC ROTATION OF CROPS IN TOBACCO CULTURE.

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WASTEFULNESS OF EARLY METHODS.

In the tier of States just south of Mason and Dixon's line and the Ohio River and stretching from the Atlantic Ocean to the Mississippi River, particularly including Virginia, Maryland, Kentucky, and areas adjacent to Kentucky in bordering States, the cultivation and exportation of tobacco was the foundation of the agricultural and commercial activities of the early settlers and pioneers. These men found a soil of excellent natural strength and fertility and a country which was generally heavily timbered. Through all the colonial period and even down to the present time it was, to a considerable extent, true that there was a large available supply of cheap and unimproved land. Until quite recently there was also an abundant supply of very cheap labor. With such conditions it was natural that agricultural methods should be extravagant and wasteful of both land and labor.

The method generally followed was to clear fresh or virgin land and crop in tobacco for two or three successive years until the fertility of the soil began to diminish. More fresh land would then be cleared for tobacco and the old land cropped in wheat and corn for a few more years until further depleted, when it would be abandoned as an old field.

Live-stock husbandry, except in a very limited way, was very generally neglected, and, where practiced, the stock was not handled in a way to save much barnyard manure for maintaining the fertility of the fields, while it is only during comparatively recent years that commercial fertilizers have been available to any extent. The loss of actual plant food due to cropping was not, however, the most harmful factor in this system of soil exploitation. Owing to the lack of live stock, soil-binding grasses and humus-yielding crops were but little grown. Stripped of their timber covering, and planted again and again in clean-cultivated crops, like tobacco and corn, the originally fertile fields were rapidly depleted of their life-giving store of humus. Much of the country is more or less broken and rolling,

and after the humus was gone the bare fields were washed, gullied, and broken in a way to cause incalculable and almost irretrievable loss and injury.

Since the settlement of the tobacco-growing area under consideration, much of the cultivable land has been through this round of clearing, depletion, and abandonment one or more times.

PRESENT CONDITIONS.

The section under consideration is the original tobacco-producing district of this country, and, taken together with the contiguous area of North Carolina and South Carolina, continues to-day to produce about five-sixths of the tobacco grown in the United States and practically all of the tobacco known as the export and manufacturing types. That is, the group of States south of Mason and Dixon's line grouped about Virginia, North Carolina, and Kentucky as centers and extending from the Atlantic Ocean to the Mississippi River continues to produce practically all the tobacco grown in this country except the seed-leaf or cigar types.

The tobacco growers of the present generation have as their heritage the fields once fertile but now impoverished by the unconsciously wasteful methods of their ancestors. This method of exploiting the superfluity of fertile land in a new country has generally prevailed in other sections, but its evil effects have been more aggravated here because of the essentially one-crop system of farming and the absence of a live-stock husbandry.

Conditions now, however, are radically changing economically. Both land and timber are rapidly increasing in value, and in place of a plethora of cheap labor farm helpers are now becoming extremely scarce and obtainable only at a greatly advanced wage. This combination of new conditions renders the system of clearing and subsequently abandoning land comparatively unprofitable. Agricultural methods are now in process of adaptation to a new set of economic conditions. In the future a large proportion of the tobacco produced must be grown not upon fresh land but upon old land, and the fundamental present-day problem of the grower is how profitably to restore the depleted fertility of the old fields. The time consumed in cultivating an acre of infertile land is nearly as great as that required for an acre of highly productive land, and it will not pay to employ high-priced labor on soils of low productivity. In restoring the crop-producing power of these soils, undoubtedly the most important step is to increase the humus supply. The diversification of crops, a greatly improved rotation system, an effective live-stock husbandry, and the general introduction of much more intensive methods will constitute the better and more profitable methods of the future.

TOBACCO ADAPTED TO INTENSIVE METHODS.

Compared with the grasses, grains, and most other general farm crops, tobacco may be classed as one of relatively high commercial value. As each unit of increase in production in a high-value crop is worth more, expenditures to increase production will be found relatively more profitable. This may be illustrated as follows:

Suppose that under certain conditions corn without fertilizer yields 25 bushels per acre. Even if intelligently expended, under most conditions it would probably take $25 worth of fertilizer to increase this yield to 50 bushels per acre. With corn at 50 cents per bushel, the fertilizer would cost more than the corn is worth. The higher money-value crop of tobacco, however, shows different results. Take a case in which tobacco without fertilizer would produce 600 pounds per acre. Intelligently expended, an application of fertilizer costing $25 an acre would usually increase the yield to upward of 1,200 pounds to the acre. At 8 cents a pound this 600 pounds increase in production would amply justify the expenditure for fertilizer.

Considering the matter in another light, it is apparent that an increase in the commercial value of any product will warrant an additional expenditure to obtain each increased unit of production. At 6 cents a pound for tobacco, 400 pounds increase in yield will just pay for the use of $24 worth of fertilizer; at 8 cents a pound, it will take but 300 pounds increase to pay the fertilizer bill; at 10 cents, 240 pounds. This illustration, however, is not to be taken as an argument for the use of $25 worth of fertilizer on tobacco or against the use of it on corn.

Generally speaking, then, tobacco, being a high-value crop, justifies a greater expenditure for fertilizer and greater care in soil preparation, cultivation, and handling than do other general farm crops of lower commercial value. It is also true that as tobacco increases or decreases in price so does the profit resulting from fertilization increase or decrease; that is, tobacco at 10 cents a pound is more likely to pay for increased expenditures in production than tobacco at a lower price, and the percentage of profit for the increase in expense is higher at 10 cents than it is at a lower price.

It is also true that tobacco is peculiarly subject to variations in price, owing to differences in quality resulting from the methods employed; and it frequently, in fact usually, happens that better fertilizing, preparation of the soil, cultivation, and handling not only increase the yield, but result in a materially better average price for the crop, conditions of soil, climate, etc., remaining the same. This point is well illustrated by the results obtained in the series of fertilizer experiments with dark tobacco conducted on a variety of soils in the vicinity of Appomattox, in the heart of the dark-tobacco belt of Virginia, and now covering a period of five years. The experiments

were conducted jointly by the Department of Agriculture and the Virginia Agricultural Experiment Station. The results of these experiments showed not only a great increase in yield from the use of increased quantities of properly balanced fertilizers, but showed at the same time that the quality of the tobacco was improved and an increase of 1 to 2 cents per pound was generally secured. Thus there was a gain in both quantity and quality. The soils used for these experiments varied considerably in fertility, but were naturally good tobacco soils, possessing fairly good depth and friability, but in a comparatively low state of fertility, being about on a par with most of the land used for tobacco in the neighborhood.

FERTILIZERS FOR TOBACCO.

The fertilizer experiments show that a soil which will yield, say, 900 pounds of tobacco to the acre from the use of the customary application of 400 pounds of 3–8–3 fertilizer (3 per cent of ammonia, 8 per cent of phosphoric acid, and 3 per cent of potash) costing $5, will generally yield as much as 1,400 pounds by using a much heavier application of a properly balanced fertilizer costing $30 per acre under the same conditions of cultivation, handling, etc. The price obtained for the lower yield was about 7½ cents per pound and that obtained for the larger yield about 9 cents, the 900-pound yield selling for $60 and the 1,400-pound for $126. The difference in cost of fertilizer was $25, and in the case of the larger yield the extra cost of handling, marketing, etc., was about $10 an acre. Deducting this increased expenditure ($35) from the gross proceeds leaves $91 for the highly fertilized acre, a gain in net profit of $31 over that obtained from the poorly fertilized acre, or a gain equal to 90 per cent of the cost of securing the increased profit. The formula for the fertilizer used has been modified slightly each year, that used in 1908 being shown in Plate XXXIV, figure 1. Compared with fertilizers generally used, this contains a very high percentage of ammonia, the analysis showing 7 per cent of ammonia, 8¼ per cent of phosphoric acid, and 3 per cent of actual potash. This furnishes per acre of soil 119 pounds of ammonia (equivalent to 98 pounds of nitrogen), 140 pounds of phosphoric acid, and 50 pounds of actual potash, as against 12 pounds of ammonia, 32 pounds of phosphoric acid, and 12 pounds of actual potash furnished in the 400 pounds of 3–8–3 fertilizer. The best fertilizer furnishes to the soil ammonia equal to the quantity removed from the soil in producing the roots, stalks, and leaves of a 1,500-pound crop, very much more phosphoric acid than is actually removed in such a crop, and about half the potash that a 1,500-pound crop uses.

The extensive series of plat experiments with fertilizer in different sections of the Virginia tobacco-producing area indicate the

general need of liberal applications of phosphoric acid—amounts, in fact, greatly in excess of the quantity actually assimilated by the crop. Experiments conducted by the Kentucky Agricultural Experiment Station in the western or dark-tobacco section of Kentucky show a similar ready response to the application of phosphoric acid. In the experiments conducted on the worn tobacco soils of Virginia there has also been a ready response to liberal applications of ammonia in easily available forms, either organic or inorganic. This, of course, was to be expected, because a run-down soil is usually one depleted of its vegetable matter, or humus, and the humus of the soil is practically the only source of the soil's ammonia supply. On soils in which the humus supply has been well maintained by good handling, especially by the turning under of clover or other leguminous plant growth, the returns from such large applications of ammonia would in all probability have been much less striking. Plate XXXIII and Plate XXXIV, figure 1, show the difference in yield of tobacco from the use of different kinds and amounts of fertilizer. The fertilizer plat experiments in different sections of Virginia varied considerably in the relative returns from phosphates or ammonia when applied separately, sometimes the ammonia and sometimes the phosphoric acid giving relatively better returns; but in every case, with the class of soils experimented on, the results were very materially improved by using both liberally in combination.

Although the tobacco plant's requirements for potash are greater than for either ammonia or phosphates, the experiments on the tobacco soils of Virginia have not shown as good results from the use of potash, indicating that those soils generally are relatively better supplied with available potash. When used alone, potash has not as a rule brought any striking gains over no fertilizer; but when added to a fertilizer already well supplied with phosphates and ammonia it has given profitable results for moderate applications. The experiments also show the relative need for potash to be somewhat greater on the lighter soils. Potash has given favorable results in the experiments with bright yellow tobacco in the light-colored soils of Pittsylvania County, near Chatham, Va., not only in increasing the yield somewhat, but in materially brightening the color of the leaf produced. Phosphoric acid also brightens the color, and it was observed that considerable quantities of ammonia could be used even on bright tobacco, thereby materially increasing the yield, without injuring the color seriously if counterbalanced by correspondingly increased quantities of phosphates and potash.

The necessity for applying fertilizing materials in properly balanced proportions, particularly as they may affect the color and quality, is strikingly brought out in the 1908 Chatham (Va.) fertilizer-plot experiments with the bright flue-cured tobacco. With

this type color and fineness are important considerations. The soil used was very uniform and as with most bright-tobacco soils was very poor in vegetable matter, being even below the average, perhaps, in this regard. The yield on all the plots was probably somewhat below normal, because of the protracted dry weather during the growing season. The yield on the check plots receiving no fertilizer was 300 pounds of tobacco per acre, valued at $21.30. As was to be expected on such a soil, there was a very striking increase in yield where ammonia was applied. Cotton-seed meal analyzing 7½ per cent ammonia, 2 per cent phosphoric acid, and 1 per cent potash was used alone on one plot at the rate of 800 pounds per acre. The small quantities of phosphoric acid and potash contained in the meal had some effect in increasing the yield secured, but the principal effect was undoubtedly due to the large amount of ammonia which it carried. The yield on this plot was 740 pounds per acre, valued at $59.08, approximately 8 cents a pound. The tobacco had good body and oil, but was rather coarse and decidedly dark in color. This would appear to be against the use of cotton-seed meal in this quantity for bright tobacco, but on another plot where this same quantity of meal was used to which was added 600 pounds of 16 per cent acid phosphate, not only was the yield increased to 920 pounds per acre, but the color was materially brightened and the value was $79.06, or about 8.6 cents per pound. On still another plot, where 200 pounds of sulphate of potash (50 per cent potash) was added to these two materials, making a complete fertilizer, the yield was again increased to 1,180 pounds per acre; the color and quality generally was still further improved, and the value went up to $135.41, or approximately 11.5 cents per pound. Thus it appears that the tobacco on the plot receiving only cotton-seed meal was of inferior quality, not because it received too much ammonia absolutely, but rather because it received too much ammonia in proportion to the phosphoric acid and potash used with it.

How far this principle may be carried in offsetting the darkening effects of increased applications of ammonia by increasing sufficiently the quantity of phosphoric acid and potash yet remains to be determined, but in any case it opens up an important field for investigations, especially in connection with the growing of soil-improving crops, as cowpeas and crimson clover, in rotation with bright tobacco. Bright-tobacco growers have not generally considered this good practice, because of its bad effect, if persisted in, on color and quality, but it may be found that this tendency can be offset by decreasing or withholding altogether the ammonia in the fertilizer and increasing the application of phosphoric acid and potash—one or both.

It should of course be noted that an increased expenditure for any item, as, for example, greater cost of fertilizers, increases the chance

FIG. 1.—PLOT OF TOBACCO WHICH RECEIVED NO FERTILIZER.

[Yield, 820 pounds per acre; value, $56.85 per acre.]

FIG. 2.—PLOT OF TOBACCO WHICH RECEIVED THE CUSTOMARY APPLICATION OF 400 POUNDS OF 3-8-3 FERTILIZER TO THE ACRE.

[Yield, 900 pounds per acre; value, $63.11 per acre.]

FIG. 1.—FIELD OF TOBACCO FERTILIZED WITH A MIXTURE PROPOSED BY THE DEPARTMENT OF AGRICULTURE.

[Yield, 1,880 pounds per acre; value, $157.63 per acre.]

FIG. 2.—A MARYLAND TOBACCO FIELD IN WHICH THE CHANCES FOR A PROFITABLE CROP ARE GREATLY REDUCED BY AN UNEVEN STAND OF PLANTS.

[Repeated resettings were made necessary by the attacks of the stalkworm or wireworm.]

of loss in case of failure due to neglect or unfavorable conditions. In the writer's experience, weather conditions are the most negligible factors of probable adverse conditions. Poor crops are much more frequent from any one of several causes than from bad weather. It is an exceptional year when a well-fertilized, seasonably planted, and well-cared-for crop will not come through in good shape in the end; and it is on the infertile, poorly cultivated soils that the bad effects of unfavorable weather conditions are most serious.

Intensive farming presupposes that all the coordinating factors incident to the production of a paying crop shall receive their proper share of attention. In order that deep plowing, thorough preparation, and careful cultivation may pay, the field must be made fertile, a good stand must be secured, and the crop must be planted at the most favorable season; conversely, in order that liberal fertilizing may pay, the field must be so prepared and cultivated that the growing crop can best utilize large amounts of available plant food; and, above all, strenuous efforts should be made to secure a good and uniform stand. The crop should also be planted as close as it can be without injuring its quality. Such experimental data as are available indicate that the yield of tobacco is increased by closer planting up to a certain point, and that the texture of the leaves is finer. Closer planting may thus be taken advantage of to prevent the individual leaves from becoming over-large and coarse, while increasing the total yield per acre at the same time. Higher topping to a certain extent may also be practiced to accomplish the same purpose, although the higher the plant is topped the less uniformity will there be in the leaves from different portions of the plant.

EFFECTS OF CROP ROTATION.

SUPPLY OF HUMUS.

Agriculture is unquestionably greatly aided by commercial fertilizers, and with a high money-value crop like tobacco they can be used in liberal quantities in most cases with very profitable results. Commercial fertilizers, however, are lacking in at least one all-important quality for the permanent upbuilding of the soil. A soil can not remain permanently fertile without maintaining an adequate humus supply. Fertilizers, to have their best effect, must be applied to a mellow loamy soil, rich in decaying organic matter and with good moisture-holding capacity.

The most available, economical, and satisfactory way of building up or maintaining the all-important humus content of the soil is found in the systematic rotation of crops. The rotation should include crops whose cultivation leaves a large residue of roots and stubble. If necessary to maintain the supply of humus a green crop should be turned under occasionally.

WORK OF SOIL BACTERIA.

A fertile soil teems with countless millions of various kinds of micro-organisms constantly active in breaking down and nitrifying organic matter; and, in the chemical recombinations which their activity causes, they have the additional effect of liberating or placing in available form much mineral plant food. Under favorable conditions millions of these organisms are also active in extracting from the air and fixing within the growing plants or soil large quantities of that essential and, when purchased, most costly plant-food element, nitrogen. The numbers and beneficial activities of these organisms are markedly dependent upon the physical condition of the soil. Warmth, moisture, air, and the presence of large quantities of decaying vegetable matter are essential soil conditions for the best activities of these helpful microscopic creatures. The growing of crops in rotation, including, of course, those which increase the soil's humus supply, together with good cultivation, can do more to bring about the most favorable conditions for the beneficial activities of these organisms than any other practical means.

Barnyard manure is, of course, a very desirable and effective means of increasing the fertility, friability, and bacterial efficiency of the soil, but in the tobacco sections under consideration it is not available in sufficient quantities for general use. Indeed, the size of the manure pile depends upon the crop rotation. It is noteworthy that the same crops that furnish a large residue of roots and stubble for building up the soil—the grasses and legumes—also yield in the harvested portion a large quantity of material generally used, and which should be used, on the farm for feeding stock, thus increasing the supply of manure available.

TOXINS IN THE SOIL.

Crops in their growth, it is now believed, have an important toxic reaction upon the soil in which they grow—that is, they give off from their roots during growth matter of a toxic or poisonous nature. Aeration, oxidation, and the chemical recombinations incident to the decay of organic matter are important aids in breaking up and removing these poisonous excretory compounds. Different classes of crops excrete somewhat different kinds of toxic matter. The crops in the rotation should therefore be so arranged as to prevent the toxic effects due to the continuous growing of the same crop.

PLANT DISEASES AND INSECT ENEMIES.

The danger from outbreaks of plant diseases, particularly those which are spread by infection through the soil, is greatly minimized by not growing the same crop or those crops subject to the same dis-

eases too frequently on the same soil. After the soil is once infected with a plant disease from the growing of any crop too persistently, the disease may frequently be completely eradicated by a change to an altogether different kind of crop for one or more years.

Crop rotation can also be made to serve a most useful purpose in many cases by preventing or minimizing the danger from insect enemies,[a] especially those which spend a portion of their life cycle in the soil. Take, for example, the two greatest pests of newly set tobacco, and of many other crops for that matter—cutworms and the so-called "wireworm," or "stalkworm." Their presence depends almost entirely upon the character of the vegetation growing upon the land during the previous season; that is, whether it was attractive or not to the adult forms of these insects during the period when they deposited their eggs. To apply this principle, it is necessary to see that the soil is not occupied at the egg-laying season by vegetation which is attractive to the adult insect or, better still, to see that it is occupied by a form which is altogether repulsive. It is generally known by tobacco growers in many sections that after heavy growths of weeds, particularly the ironweed or stickweed, the soil is very likely to be seriously infested with the dreaded "wireworm;" indeed, it is frequently infested to such an extent as to render it almost impossible to secure a stand of tobacco until the pests leave or pupate, when it is too late to secure anything like a normal crop. A field intended for tobacco, or corn, or any other crop which these pests attack should not be allowed to grow up in ironweed during the previous year. It is the writer's observation, moreover, that a field which has grown cowpeas the previous season, provided they have been kept clean of weeds, will be free from both cutworms and the "wireworm." This fact, if taken advantage of, is of inestimable value to tobacco growers, because the presence of "wireworms" or cutworms in the soil is a most serious drawback to any effort toward the increased use of fertilizers and the adoption of more intensive methods. It is a happy circumstance also for all dark types of tobacco—and these are types grown on soils most likely to be troubled with these pests—that the repellent crop is so desirable and valuable otherwise.

The feeding value of cowpea hay is very great, and the stubble adds much to the fertility of the soil. Increased quantities of ammonia tend to darken tobacco, and in cases where brightness is an important consideration, as in the bright-tobacco belt of southern Virginia, North Carolina, and South Carolina, the cultivation of cowpeas preparatory to tobacco might be objectionable.

[a] A special investigation of the tobacco insects throughout the export-tobacco region is being conducted by the Bureau of Entomology.

Plate XXXIV, figure 2, shows an uneven stand in a Maryland tobacco field due to the attacks of "wireworms." The field was reset several times. With such a stand the prospects for a profitable crop are very poor under any system of culture.

THE EFFECT ON THE SOIL OF CROPS AVAILABLE FOR ROTATION.

The selection of standard crops generally regarded as adapted for cultivation on most tobacco farms in the export and manufacturing districts under consideration may be divided into four main classes: (1) The inter-cultivated crops, corn and tobacco; (2) the small grains, particularly wheat and oats; (3) the grasses, such as redtop and timothy; and (4) the legumes, including the clovers, vetches, and cowpeas.

In producing the inter-cultivated crops—corn and tobacco—the soil should be deeply broken and thoroughly aerated and pulverized. This is highly desirable, but, by hastening nitrification, oxidation, and decay, it serves also to use up the humus supply more rapidly. In the cultivation of the small grains, like wheat and oats, the soil is not so thoroughly and deeply broken and aerated. These crops are not so hard on the humus supply as tobacco and corn, but they are exhaustive rather than recuperative in their effect. The true grasses are similar to the small grains in that their cultivation is not attended with deep breaking and aerating of the soil and their entire plant-food requirements are extracted from the soil itself. There is this marked difference, however, in their effect upon the fertility of the soil: They occupy the soil continuously for two or more years, have a dense root system, and form a good sod, which, when turned under, adds materially to the soil's supply of humus, and during the period of their occupancy they hold the soil against washing and leaching. For these reasons they are to be classed as distinctively soil improvers.

The perennial clovers, such as red, sapling, and alsike clover, in certain respects might best be classed with the true grasses, but they have the additional advantage of being leguminous plants and are able to supply their requirements for ammonia from the air through the aid of the colonies of bacteria living symbiotically in the nodules which they form upon the roots. Their deep taproots also have a valuable effect not produced by the grasses in opening up and aerating the subsoil and in bringing up from the subsoil and utilizing plant-food material not accessible to many other classes of plants. The perennial clovers are often grown with the grasses, and when so grown the combination probably has few superiors in building up the fertility of the soil. The annual legumes, such as cowpeas, crimson

clover, and vetch, also fix atmospheric nitrogen through the aid of bacteria on their roots, and the long taproots have a favorable action similar to the perennial clovers. Some of the annual legumes, like crimson clover and vetch, also occupy the soil only during the cooler months of the year, when they do not interfere with the growing of a regular summer crop. Cowpeas are especially valuable because they will produce a fair crop on a much poorer soil than will some of the other legumes and are a much surer catch under various conditions.

It is noteworthy that the growing of any crop of these four classes reacts upon the soil in a different way from any of the others, and each, except possibly the small grains, serves some particularly desirable purpose in soil improvement not so fully accomplished by any one of the others. It is desirable, therefore, that these different crops be grown in systematic rotation, so that the improving effects of each class may be regularly received and the ill effects of the exhaustive crops be systematically neutralized.

As previously stated, the principal crops grown in the early days were tobacco, corn, and wheat, all exhaustive rather than recuperative crops, and but little attention was given to the grasses and legumes. These early methods finally crystallized under ante-bellum conditions into custom, and it is only in very recent years that attention has been seriously directed to the systematic cultivation of the grasses and legumes in rotation with corn, tobacco, and wheat. It has, indeed, been the custom of many of the best tobacco growers to sow clover seed in their wheat in the spring, and on freshly cleared land a fair stand and growth often resulted. In the larger part of the old tobacco-growing area, however, none of the grasses, clovers, or other leguminous crops have been grown to a sufficient extent or with sufficient success to anywhere near offset the cumulative exhaustive effects of repeated cropping with tobacco, wheat, corn, and oats. The methods employed were so ineffective and the soil was so completely impoverished under the system employed that when attempts were made to grow grasses and clovers the results were generally anything but encouraging. But the case is far from hopeless. Experiments conducted by the writer during the past few years in different sections of the tobacco-producing area, notably in the dark-tobacco district of Virginia, indicate plainly that, with proper adaptation of methods, the soil-improving legumes and grasses can be grown in rotation with tobacco and wheat with most surprising success, and may become such important sources of income, aside from their soil-improving value, as to render the farmer less dependent upon tobacco as the cash crop of the farm.

In placing the cultivation of the soil-improving grasses and clovers upon a successful basis at once the tobacco grower is greatly aided

by the fact that his rotation includes a crop of such high commercial value as tobacco. There are but few general farm crops that will give profitable returns for applications of such large quantities of commercial fertilizers as will tobacco, and the after effects from this heavy fertilization are materially effective in insuring and increasing the success of the wheat, grass, and other crops succeeding the tobacco.

It is not practicable to attempt to lay out a rotation scheme adaptable to all tobacco sections, nor to all tobacco farms within a given section. The soil and climatic conditions of each section will necessitate modifications of any scheme that might be suggested, and the peculiarities of each farm, as well as the individuality of the farmer, will prove additional modifying factors. The important point, however, is that each farmer should study out for himself the best possible rotation for his own farm. So far as possible this rotation should include in systematic sequence all of the standard crops produced; and, under average conditions, the farmer will make a mistake if he does not include in that rotation enough of the soil-improving grass and leguminous crops to furnish a liberal supply of feed for live stock, so as to increase the available supply of barnyard manure and also by the stubble help to maintain the physical condition and bacterial activity of the soil at the maximum state of efficiency. Leguminous crops should be grown also with sufficient regularity to restore so far as possible the nitrogen removed by the nonleguminous crops.

Corn is a gross feeder and under the inadequate system usually followed it has not been considered advisable by farmers to grow corn in the same rotation with tobacco, because it so exhausts the soil as to materially injure the all-important tobacco crop. The result is that, except where there are lowlands or river lands unsuited to tobacco, the corn crop has been relegated generally to the poorer parts of the farm, which are thus made still poorer by continuous corn cropping; or, what is little better, corn is made to alternate with occasional resting years, when the land is given over to weeds and bushes. The result, of course, is a very poor yield of corn. However, with an adequate rotation system, including soil-improving crops, especially the legumes, it would be much better to include the corn in the general rotation unless there is sufficient river land unsuited for tobacco culture to grow all the corn necessary. By placing the corn crop in the general rotation on the better land of the farm the yield secured will necessarily be greatly improved; and, with the introduction of an intensive rotation system, together with a much heavier use of fertilizers on the tobacco, it may be found beneficial even to the tobacco by reducing excessive organic fertility, which would tend to make the tobacco coarse.

In any scheme of rotation proposed for a tobacco farm, the tobacco will probably be regarded as the important money crop of the rotation, and as such may be considered as standing at the head of the proposed rotation.

In connection with the experiment work which the writer has been conducting in Virginia, he has proposed and initiated in an experimental and demonstrative way a rotation scheme, fundamental in its nature, which will bring out the important factors in planning a cropping system in which tobacco is the important crop. The rotation proposed is adapted more particularly to the dark-tobacco district of Virginia, and for other sections it will need modification to make it suitable for the type of tobacco grown and the different soil and climatic conditions.

SUGGESTIONS FOR A ROTATION.

THE TOBACCO CROP.

Heading the rotation as the important money crop stands the tobacco. It should be fertilized very liberally with all the properly balanced fertilizer that the crop will pay a profit on. The results in Virginia go to show that from $20 to $30 worth of such fertilizer per acre can be used to advantage. In the experimental work in Virginia it has been found desirable to set the tobacco somewhat closer than is the custom in order to keep the leaf from becoming overgrown and coarse. The usual distance has been about 3 feet apart in rows that are 3½ feet apart, making about 4,200 plants to the acre. With heavier fertilization it has been found best to set the plants 2½ feet apart in the rows instead of 3 feet, the distance between the rows remaining the same, thus increasing the number of plants to the acre to approximately 5,200. The system of cultivation has also been slightly modified in some respects. The cultivation should be approximately level, except on fields likely to suffer from excess of moisture or standing water, which can be hilled or bedded to advantage in "laying by." Level cultivation is cheapest and best conserves the soil moisture under ordinary conditions.

Cultivation should begin as soon as the plants show signs of growth. The first time over, the double-shovel plow fitted with narrow teeth run three times in a row has been found useful to thoroughly break out the middles after the trampling to which they had been subjected during the setting and resetting. Subsequent cultivations, however, were very shallow and frequent, using a five-tooth cultivator with an 18-inch sweep attachment. This is an extremely effective instrument and leaves the soil fine and mellow on top. The 18-inch blade cuts off all weeds, leaves them on the surface, at each cultivation rolls the soil slightly toward the row, which prevents

water from standing immediately around the plants, and covers and kills small grass and weeds. The cultivation with this implement after the tobacco is well started should be repeated every week or ten days according to conditions until the tobacco is topped and too large to work without breaking the leaves.

Very strenuous efforts have been made in the case of all the experimental crops to plant early rather than late in order to insure a good cure, as it is often very difficult to properly cure late-harvested crops in the cool dry weather likely to be encountered. The damage from the hornworm is also considerably less in early tobacco, the yield is usually larger, and the leaf is more elastic and finer in quality. The only drawback to early planting is the danger of damage from cutworms and "wireworms," which makes an uneven and broken stand. It is essential, therefore, to so arrange the rotation that the crop preceding the tobacco will be unattractive to the adults of these species. As already stated, cowpeas grown free from weeds have been found most satisfactory and valuable for this purpose.

THE WHEAT CROP.

The crop following the tobacco in most sections is wheat. This seems most practicable and desirable and is regarded with favor. In preparing land for wheat, it is the general custom in most parts of Virginia to throw out the tobacco stubble with a 2-horse turning plow. A better way, it is believed, and one that has been followed most successfully in the writer's experimental and demonstration work, is to harrow the field over several times with a disk harrow until it is thoroughly pulverized to a depth of 2 or 3 inches without throwing out the stubble with a plow at all. A better and more uniform surface preparation with a firm subsoil such as is best for wheat seeding is secured by this method. If the tobacco has been heavily fertilized it is not probable that it will pay to use any fertilizer on the wheat. It is important, however, to sow the wheat neither too late nor too early. Experiments by the Virginia Agricultural Experiment Station covering a period of four years go to show that the yield is materially affected by sowing too early or too late. From October 1 to 10 is the best season in most sections of that State.

In experiments at Appomattox, in the Virginia dark-tobacco district, yields have been obtained of from 25 to 30 bushels of wheat per acre after tobacco with heavy fertilization, costing $32 an acre, and of from 12 to 15 bushels per acre on check plats where the tobacco was fertilized with 400 pounds of ordinary 3–8–3 fertilizer, costing $5. No fertilizer was applied directly to the wheat in either case. These yields illustrate in a most striking way the beneficial

FIG. 1.—FIELD OF WHEAT SUCCEEDING TOBACCO WHICH HAD RECEIVED 400 POUNDS OF FERTILIZER, AS SHOWN IN PLATE XXXIII, FIGURE 2.

[Yield, 12 bushels per acre.]

FIG. 2.—FIELD OF WHEAT SUCCEEDING TOBACCO WHICH HAD BEEN FERTILIZED WITH A MIXTURE, AS SHOWN IN PLATE XXXIV, FIGURE 1.

[Yield, 29 bushels per acre.]

FIG. 1.—FIELD OF GRASS SUCCEEDING WHEAT WHICH FOLLOWED TOBACCO.

[The tobacco had received a heavy application of fertilizer, as shown in Plate XXXIV, figure 1. Grass top-dressed in the spring with 300 pounds of nitrate of soda per acre. Yield, 5.06 tons of field-cured hay per acre.]

FIG. 2.—THE SAME FIELD OF GRASS SHOWN IN FIGURE 1, AFTER IT HAD BEEN CUT AND COCKED.

FIG. 1.—FIELD OF TIMOTHY AT BOWLING GREEN, VA.

[The grass at the right received no nitrate and was hardly worth cutting. That at the left was top-dressed with nitrate at the rate of 300 pounds to the acre, an excellent yield being the result.]

FIG. 2.—VIEW OF SOME OF THE CROP ROTATION PLOTS AT UPPER MARLBORO, MD.

[At the extreme left is land fitted for sowing grass. The cowpeas in the center will be plowed down in the fall and be succeeded by corn the next season. The corn, seen at the right, which has an excellent stand of crimson clover in it, will be succeeded by tobacco heavily fertilized.]

after-effects resulting from liberal applications of fertilizer on the tobacco, and should be regarded as an additional credit against the cost of the tobacco fertilizer. Plate XXXV, figures 1 and 2, strikingly illustrates the benefits to the succeeding wheat crop from the use of an increased quantity of fertilizer on tobacco.

THE HAY CROP.

Grass will most naturally follow the wheat in the rotation, and most encouraging results from the methods pursued have been secured in the Virginia experiments. The custom has been to sow grass, if at all, with the wheat in the autumn, and to sow clover, when that is used, on the wheat land early in the spring. This is a cheap method of seeding, but can not be relied upon to give satisfactory results. After the wheat is harvested, the long, hot summers give the young grass or clover plants a hard struggle for existence, and in any case the field is almost sure to become very weedy during the summer period. The stand of grass secured, furthermore, by this method is not likely to be thick enough to produce a heavy crop, and the hay is almost sure to be full of weeds and bushes. On very rich land, also, sowing the grass with the wheat is almost sure to injure the chances of securing a good wheat crop. On poor land the wheat is not much injured, because the grass makes so little start, but the chances for securing any grass worth cutting on such soil are meager.

To make the growing of grass in the section under consideration fully realize its possibilities, separate preparation of the land and separate sowing of the grass seed in the late summer or early fall, after the removal of the wheat crop, is by far the most promising method. As soon as possible after the cutting of the wheat, the stubble should be disk-harrowed and the surface put into a fine and mellow condition, preferably not to exceed 1 or 2 inches in depth. It should be occasionally reharrowed through the summer when the moisture content is right and then heavily seeded, preferably with mixed grasses, in the late summer—from the middle to the latter part of August. It is important to have only a very shallow surface preparation for sowing grass seed. What is needed is a fine mellow seed bed, with the firm undersoil so near the surface as to bring the moisture up far enough to sprout the seed and keep the young plantlets alive, even in the event of prolonged dry weather immediately after seeding. Unless the soil is known to be very fertile, enough fertilizer should be applied at seeding time to give the grass a good start for the winter. Preparing the seed bed for grass with a disk harrow is much more expensive than sowing the seed with grain, but the chances for a large crop of grass for at least two years are greatly increased thereby,

and, as shown by the Virginia experiments, the increase in the crop is much more than sufficient to pay for the increased cost of preparation. A thick, uniform stand over the entire field is imperative if big yields of grass are to be secured.

Our experiments have given the largest yields from a mixture of 12½ pounds of timothy, 7½ pounds of redtop, and 10 pounds of sapling clover to the acre. In the test of these one year, clover alone gave 2.81 tons, redtop and timothy 4 tons, and a mixture of all three 5.06 tons of field-cured hay per acre. If a good stand is secured it has been found to pay liberally to top-dress the grass very early in the spring, say the latter part of March, when the grass shows signs of starting to grow, with 200 to 300 pounds of nitrate of soda per acre. Top-dressing in this way has been found to increase the yield from 1 to 2 tons per acre. Plate XXXVII, figure 1, shows clearly what a great difference nitrate of soda frequently makes in the yield of grass.

From this system of preparing the land, seeding, and fertilizing following wheat, which in turn had succeeded heavily fertilized tobacco, a yield of first-class hay has been obtained under a considerable variety of soil and seasonal conditions. These results are extremely encouraging, insuring the rapid upbuilding of the soils on which the grass is grown and promising to the growers a source of income of such importance as to render the farmer relatively much less dependent upon tobacco for ready cash. The experiments thus far conducted indicate that grass grown in rotation, with the intensive methods employed, will stand for at least two years, giving practically as heavy a crop of first-class hay the second year as the first. The field in Appomattox which grew 5.06 tons of hay per acre the first year after seeding also produced 3.7 tons per acre the second year, but under seasonable conditions not quite so favorable as in the first year. Plate XXXVI, figures 1 and 2, shows views of this field before and after the cutting of the grass.

THE CORN CROP.

After the grass has stood for two years, having been pastured, perhaps, after the first cutting of the second season, it is recommended that it be plowed under during the fall or winter and followed by corn. On a two-year-old sod that has produced a heavy crop of grass each year an excellent crop of corn should be secured, probably exceeding 50 bushels per acre in most years if it has the benefit of good cultural methods and perhaps a small application of fertilizer.

LEGUMINOUS CROPS.

Taking advantage of every opportunity for working in a soil-improving crop, crimson clover should be sown in the corn at the last working. The chance of securing a good stand and a satisfactory growth during the fall and spring months should be exceedingly good on the fertile soil handled in rotation so intensively. This crimson clover might be harvested or turned under and the field prepared for tobacco, but the great drawback to this course on the stiffer soils is often found in the poor or too late preparation for the tobacco. A dry spell at the proper time for turning under the clover or stubble may cause serious delay or bad preparation or both. It will be much better to delay the tobacco another year and grow a crop of cowpeas after the crimson clover, thus securing the additional benefit to the tobacco from turning under the stubble of the leguminous crop and the invaluable freedom from cutworms and "wireworms" to the newly set tobacco, besides enough pea hay (excellent for cows) to more than pay for the cost of growing the crop. The pea stubble should be plowed under during the fall or winter in order to insure sufficiently early preparation of the soil to take advantage of the best seasonal conditions for the growing and curing of the tobacco.

CHANGES AND ADAPTATIONS.

The suggested rotation covers six years, includes the standard crops of the average tobacco farm, and arranges them in such sequence that the exhaustive crops are interspersed with the soil-improving crops. It can be easily modified in a variety of ways without changing its fundamental features. If it is desired to give wheat a larger place in the rotation it can be done by following the corn with wheat instead of crimson clover. The proportion of corn can be increased by following the crimson clover or the cowpeas with corn and again following the corn with cowpeas in preparation for the tobacco. Plate XXXVII, figure 2, gives a general view of some of the crop-rotation plats at Upper Marlboro, Md., where experiments are conducted cooperatively by the Bureau of Plant Industry and the Maryland Agricultural Experiment Station. The fallowed land on the left is fitted for grass seed. The cowpeas in the center will be followed by corn next year, and tobacco will follow the corn, seen at the right, which contains a good stand of crimson clover. This is such a light soil that satisfactory preparation for the tobacco crop is not likely to be delayed by hard, dry soil, as might be the case on stiffer soils.

SUMMARY OF FEATURES OF THE SUGGESTED ROTATION.

The rotation proposed gives three important sources of money return—the tobacco, the wheat, and the live-stock products from the feeding of the hay and other forage. In only two crops out of the six is any considerable quantity of plant food removed from the farm—the leaf tobacco and the grain of the wheat. Four of the crops out of the six produce stock food in large quantities—the corn, the two grass crops, and the cowpeas, while the straw of the wheat is also of material value for feeding purposes. Three of the six crops are distinctively soil-improving in their nature, replenishing the humus supply and the nitrogen content—the two grass crops, including clover, and the cowpeas.

From the feeding of so much forage a greatly increased supply of barnyard manure should result, sufficient, probably, to manure each field once during the full course of the rotation. It is suggested that this manure be used for top-dressing the second-year grass field during the winter and early spring. This would greatly increase the grass yield and take the place of the nitrate of soda on the second-year grass. When the second-year grass sod is turned under for corn, the manure will continue to have considerable effect in increasing the corn yield.

The tobacco is the only crop of the rotation to which it is proposed that any large quantity of fertilizer shall be applied. As previously suggested, as much fertilizer should be used on the tobacco as it will pay a profit on. The Virginia experiments indicate that on ordinarily good soils in their unimproved condition, from $20 to $30 worth of properly balanced fertilizers can be used to the acre with profit. When the rotation becomes well established, however, and the soil has been materially improved by the growing of the heavy grass and leguminous crops and the use of increased amounts of manure, it may be found that the quantity of fertilizer used on the tobacco can be materially decreased, particularly in respect to the proportion of ammonia which it carries.