guano as a fertilizer of the first order for tobacco cultivation, and as light and sandy soils possess in themselves the substances most suitable for the development of the tobacco plant, on such soils guano acts as a stimulant to the plant.

"Before using Peruvian guano, it should be sifted; all the stones and lumps remaining should be broken up, and again sifted, so that nothing may be lost. After this, three or four times its weight of dry sandy soil should be thoroughly mixed with it, and it should remain thus 6–8 days before being used. This preparation should be made under cover, to avoid the possibility of rain falling on the mixture, and the heap should be covered with the empty guano bags, or anything else, to prevent the evaporation of the volatile alkali which it contains.

"It is better to prepare this mixture in detail, each heap containing one bag of guano, whose weight is 150–160 lb., so as to facilitate the calculation of the quantity that should be applied, and prevent mistakes. We will start, therefore, on this calculation.

"On lands of good quality, but which, nevertheless, require manure, from having been overworked, one pound of guano should be applied to each 15–20 superficial yards, or, say one heap of compost for each 2500–3000 yards, or, otherwise said, one heap of manure will suffice for a surface that contains 5000–6000 plants.

"In sandy unproductive soil, and on sterile savannah lands, 1 lb. of guano to 9–12 yards; or a heap of compost guano to 1500–2000 yards; or one heap for 3000–4000 plants.

"These are the proportions to be used for the first year;

for the second, and forward, two-thirds of that employed the first year will be sufficient.

"When crops of tobacco and corn are grown on the same lands, half the guano should be applied to the corn and the other half to the tobacco; but then a somewhat larger quantity will be required. The manure should be applied shortly before transplanting, and after the ground has been well cross-ploughed and prepared, and the ground should be plotted out into squares or beds of 50 yards square. The manure should then be spread and ploughed in, and the land should at once be furrowed and planted.

"Under this system of applying Peruvian guano as manure for tobacco the best results have been obtained, and, of all the various trials made, this is the most simple and the easiest to execute."

The remarks of the last-quoted essayist are good so long as guano is to be had. But there is a limit to the supply, and in many places it would be unprocurable.

The necessity for more definite knowledge concerning the actual wants of the tobacco plant in the matter of food, led to an investigation of the subject some years ago by Prof. S. W. Johnson on behalf of the Connecticut State Board of Agriculture, and more recently by Schiffmayer for the Agricultural Department of the Madras Presidency.

Prof. Johnson aptly observes it to be "a well-established fact that plants may receive from the soil and retain a larger portion of ash-ingredients than is needful for nutrition. This is especially marked in case of the lime, potash, and soda salts. The excess of these sub-

stances thus taken up may either be deposited in the solid state in the cells of the plant, or may remain dissolved in the juices. In tobacco, a part of the nitrogen usually exists as a nitrate, in combination with potash. That is to say, portions of the nitrogenous food of the plant—the nitrates of the soil—are not completely worked over into albuminoids, and into nicotine, the nitrogenous constituents of tobacco, but accumulate and remain in considerable quantity in the sap. When a dry tobacco-leaf is set on fire, it often burns like 'touch paper' (paper soaked in a solution of saltpetre and dried) with bright sparkles of fire, indicating the points where the nitre has gathered in minute crystals as the juice of the leaf evaporated. The quantity of superfluous salts in the plant depends upon its succulence, and upon the supply of them in the soil. Doubtless certain definite amounts of potash, lime, magnesia, iron, sulphuric acid and phosphoric acid are absolutely necessary to produce a given weight of tobacco. In case several or all these substances are superabundant in the soil, the plant has no power to exclude any unnecessary surplus of one or all of them from its interior altogether, although there are good reasons known to prevent their entrance beyond a certain limit. In one soil potash may be relatively most abundant, and may for that reason be found in the crop in greater quantity than was necessary for the growth of that crop. In another soil lime may be in surplus, and there the crop may have the minimum of potash, and a considerable excess of lime.

"The crop is a result of the working together of a number of causes or conditions; these are the heat and

light of the sun, carbonic acid and oxygen of the atmosphere, water, nitrates and ammonia, and the ash-elements enumerated in our table of analyses. The crop is limited in quantity by that condition of growth, which is presented to it most sparingly. The richest and best prepared soil without solar warmth, or without due supplies of rain, cannot give a crop, and if weather be most favourable, then in one field it may be too little potash, in another too little phosphoric acid, in another too little nitrogen, which lowers the yield, or reduces the quality of the product.

"It is usual in tobacco culture to manure very heavily, and in many cases it is probable that all the various forms of plant food are present in available abundance. But soils differ in the nature of the supplies which they are able to yield to crops, and fertilizers even, when the same in name, may be very unlike in fact. The chief reliance of the tobacco farmer is stable manure. This, however, is by no means uniform in origin, appearance, evident quality, or chemical composition. The manure from bullocks, wintered on hay and roots, is very different from that of horses maintained chiefly on oats or corn. The yard manure that contains much strawy litter or much wasted hay, differs again from that of the city stables, from which the straw is carefully raked out to be used over and over again for bedding. The farm-made manure is likely to be much richer in potash and lime, and the city manure is richer in phosphates and nitrogen. Yet in the reports of the farmer, these two essentially different fertilizers are designated as stable manure simply.

"Every one understands that a fertilizer acts upon the plant to supply it with food, and to favour its growth; everybody is also convinced that some fertilizers act upon the soil, improving its texture and composition and increasing its fertility. It is an equally well ascertained fact that the soil acts upon fertilizers to modify their effect. A very wet or very dry soil is known to nullify the benefit which might be expected of a fertilizer in a simply moist soil; but more than this, more than by the accident of external circumstances, it is a fact that each kind of soil has a special action of its own on fertilizers, so that if it were asserted of two soils, which, unmanured, were of equal fertility, that a given fertilizer applied to both, greatly improved the crop on one, and had little effect on the other, such a statement might not only be accepted as a fact, but an explanation might be given in general terms for such a fact.

"Now experiments have shown that different soils when mixed with like quantities of various fertilizing elements and then treated with water, in imitation of rain, manifest very different behaviour toward the admixed substances. One soil will lay hold of the potash in a fertilizer, and fix it in a kind of chemical combination so firmly that water can dissolve it but with extreme slowness; another soil puts its grasp on the lime of a fertilizer, and at the same time allows potash which belongs to itself to be dissolved out freely. There is, in fact, always a complicated series of changes set in operation whenever any fertilizer is incorporated with the soil, be it animal, vegetable, or mineral; be it alkali, acid, or saline; be it made on the farm or imported from abroad; be it natural

or artificial. The fertilizer acts on the soil, and the soil reacts on the fertilizer; but the point we wish to make prominent is this, that different soils are differently affected by one and the same application, or in other words, a given manure fertilizes a given crop unequally in degree, and unlike in kind, on different soils, by virtue of the different assimilating or fixing power, which the soil exerts upon its ingredients.

"We know of the existence of these peculiarities of soils, and something of their causes and of the laws by which they act; but the real necessities of the tobacco crop, or of any other crop, as respects soil-ingredients, cannot be arrived at by chemical analysis of a single sample, nor of a dozen samples." Thus analyses of a dozen New England tobaccos showed the following highest and lowest percentages of each ash-ingredient, and of nitrogen:—

Silica	0·05 to 0·30	Magnesia ..	0·94 to 2·21
Chlorine ..	0·08 „ 2·55	Potash	3·90 „ 7·45
Sulphuric acid	0·52 „ 1·69	Soda	0·08 „ 1·81
Phosphoric acid	0·47 „ 0·80	Nitrogen ..	3·20 „ 5·11
Lime	3·17 „ 8·22		

"It appears that the percentages of nitrogen, phosphoric acid and potash are nearly twice as great in some samples as in others; that the proportions of magnesia and lime are about 2½ times greater in some samples than in others, and that sulphuric acid is 3 times more in one case than in another. The variation of silica is still greater, and the disparity rises to its extreme in case of soda and chlorine, whose maxima are respectively 20 and 30 times greater than their minima."

The three ingredients chlorine, silica, and soda cannot be considered in the light of essentials to tobacco culture; but the other substances are absolutely indispensable to plant growth, and the absence of any one of these would render a soil incapable of sustaining agricultural vegetation of any kind. "The variation in the percentage of these ingredients depends somewhat upon the fact that the leaves of different crops are unequally developed, and therefore their nutritive needs are unlike; but it is, no doubt, chiefly connected with the fact that the plant takes up from a highly fertilized soil more of each or every element than is essential for growth. The nearly certain conclusion is that every one of the crops analysed contains more of some elements than belongs to its nutrition. It is quite certain that the average of the analyses of the New England tobaccos is fully up to the mark as regards the necessities of the crop. It is, indeed, not improbable that the lowest percentages of each ingredient are quantities sufficient for a perfect crop. Still, it is not proved that lime may not partially take the place of potash, or the reverse. The probability of such a substitution is great upon the face of most of the analyses. As a rule, those which show most potash show least lime and *vice versâ*; but in one sample both ingredients are considerably below the average. The practical issue of these considerations is to give great probability to the view that the tobacco crop is fed unnecessarily (and wastefully?) high." (Prof. Johnson.)

Tobacco is usually characterized as a very exhausting crop. This is not true as regards the amount of nutriment taken from the soil, for in this respect tobacco is less

exacting than hay, potatoes, or rye. It demands chiefly potash and lime, with phosphoric acid and nitrogen. Prof. Johnson recommends for the manuring of one acre, besides ploughing in the stalks of the plants, 500 lb. rock guano or 800 lb. fish guano, 500 lb. kainit (potash salts), and 50 lb. quicklime. But surely it cannot be advisable to mix quicklime with an ammoniacal manure like guano; it seems to the writer that gypsum, or spent calcium oxide from gasworks, would be a far preferable medium for conveying lime to the soil.

As observed by Johnson, the "demand made on the soil or on fertilizers by the tobacco crop, is for certain reasons greater than that made by other crops which receive more of nearly every kind of plant food. Hay is more exhausting than tobacco as measured by total export from the soil, but grass grows the whole year throughout, save when the ground is frozen or covered with snow, or for more than 8 months. The period of active growth which is required to mature a hay crop, begins indeed in April, and is finished by July, a period of 3 months, but during the year previous, for at least 5 months, in case of the first crop, the grass plants have been getting a hold upon the soil, filling it with their roots, and storing up food in their root-stocks or bulbs, for the more rapid aftergrowth. Tobacco on the other hand cannot be set out in the field before about the 10th of June, and should be in the shed in about 3 months. Its growth then must be a very rapid one, and the supplies of food in the soil must be very abundant so that the quick-extending roots may be met at every point with their necessary pabulum. A crop of 1260 lb. dry leaves requires about 1100 lb. of dry stalks

to support the leaves, making a total of 2360 lb. of dry vegetable matter. As new hay contains not less than one-sixth of moisture, we increase the above dry weight of the tobacco crop by one-sixth, to make a fair comparison, and obtain as the yield of an average tobacco field 2750 lb. of air-dry vegetable matter, or more than $1\frac{1}{3}$ tons. The matter stands then thus: An acre of first-rate grass land yields as the result of 8 months' growth, $2\frac{3}{4}$ tons of crop, while the tobacco land must yield $1\frac{1}{3}$ tons in 3 months.

"If the above data are correct, the *average* rate of growth of tobacco is greater than that of a corresponding hay crop, in the ratio of 9 : 7. The real disparity is, however, much greater. The principal growth of tobacco is accomplished in the hottest summer weather, and in a period of some 40–50 days. Very heavy manurings are therefore essential to provide for its nourishment, and the more so because the best tobacco lands are light in texture, and may suffer great loss by drainage, evaporation, and decomposition."

From these premises, Prof. Johnson advances to the question of what should or should not be presented to the plant in the form of manure. He commences with a caution that, in general, growers must "avoid employing fertilizers which contain salt or other chlorine compound in raising wrapping or smoking tobacco. It is evident, also, that there is no occasion to use any fertilizer for the special object of supplying phosphoric acid, since the heaviest export of this substance does not exceed 10 lb. per acre, annually. It may be well to mention here that phosphates which may be put upon a tobacco field, in

guano, &c., cannot suffer waste by washing out, and will come to use when grain or grass shall follow in the rotation."

He observes of gypsum (lime sulphate) that it is "a valuable application to tobacco, not because it is very largely taken up by the crop, for the greatest export of sulphuric acid, viz. 20 lb. per acre, is restored by 50 lb. of plaster, and the greatest export of lime, 120 lb., is made good by 400 lb. of the sulphate, but because lime sulphate dissolves in 400 times its weight of water, and may rapidly wash out of the porous tobacco lands, and especially because the solution of lime sulphate in the soil is a very effective agent in rendering soluble and accessible to crops the potash and magnesia, which too often exist in close-locked combinations. The average annual rainfall (snow included) in our latitudes, is no less than 10,000,000 lb. per acre. This enormous quantity of water would be enough to dissolve and wash out of the soil 25,000 lb. of gypsum per acre if it had time to saturate itself, and then flowed off. In fact, but a small proportion of the rainfall runs through and out of the soil, not more than 10 to 20 per cent., according to its porosity and situation; but it is plain that there is nothing to hinder the waste of a hundred pounds or more of gypsum per acre yearly, since all investigations go to show that the soil has no retaining power for lime sulphate as it has for potash and for phosphoric acid. In Nessler's experiments, gypsum had an excellent effect on the burning quality of the tobacco raised under its application, an effect attributable, he believes, to the fact that this fertilizer often liberates potash in the soil, as Liebig and Deherain have demon-

strated, and is therefore equivalent to an application of potash, provided the latter actually exists in the soil.

"Potash is exported in the tobacco crop to the amount of 70–80 lb. per acre yearly, and is required for the stalks to the extent of some 50 lb., making a total of 120–130 lb. As already intimated, potash does not commonly waste from the soil by washing. It is seldom found in appreciable quantity in well or drain water, and most soils absorb it and fix it so firmly that water can remove it but very slowly. It does, however, appear in the drain water from very heavily dunged fields, though in small proportion. Stable or yard manure on the average contains one-half per cent. of potash, or 10 lb. per ton. Twelve or thirteen tons of stable manure would therefore contain the potash needful to produce a crop. The dressing of 20 tons of 10 cords of stable manure, per acre, which is often employed on tobacco, is doubtless enough to fully supply the crop, and the application of additional potash is apparently quite unnecessary. The employment of potash salts upon tobacco lands would therefore seem to be uncalled for unless the amount of stable manure is greatly diminished, or its quality is very inferior. In case potash salts are to be applied, the best form to make use of is potash sulphate, of which 250 lb. contains 135 of potash. Next to this is probably potash carbonate, i. e. the ordinary potash of commerce, which contains some 70 per cent. of potash; 200 lb. of this would be sufficient for an acre. To apply it I would suggest breaking it up into small pieces and soaking it in two or three times its weight of water until the lumps crush easily, and mixing these with so much ground gypsum as will make a mass dry enough to handle.

"Kainit, which contains some 15 to 20 per cent. of potash, but also 10 per cent. or more of chlorine, is not so good for leaf tobacco, and least of all to be recommended is potassium chloride (muriate of potash) which is nearly half chlorine.

"Magnesia is an element which is abundantly provided for in stable manure, every ton of which, according to analyses on record, contains some 3 lb. of this substance.

"Lime is supplied in relative abundance in stable manure, the average ton of which contains some 15 lb. We have seen that 600 lb. of gypsum contain as much lime as the average tobacco crop: guano, dry fish, and superphosphate, each contains some 5–10 per cent. of lime. There is, furthermore, little likelihood that any soil intended for tobacco would not of itself contain enough lime to support the crop. Lime in the caustic state has, however, a value independent of its direct nutritive power, which is well worth the attention of the tobacco raiser. Of this I shall write briefly in a subsequent paragraph.

"Nitrogen in absolutely dry New England tobacco leaf ranges from 3·2 to 5·1 per cent., or 4·24 as the average. This is a larger proportion than exists in any of our ordinary field crops, except the seeds of legumes. The grain of wheat and red clover hay contain when dry scarcely 2½ per cent., and they exceed all other usually raised vegetable products, except the leguminous seeds. The pea and bean contain, when dry, 4·5 to 4·7 per cent. of nitrogen. The acreage export of nitrogen is nevertheless not large according to the data of our tables. It should be remembered, however, that the average is

derived from 5 samples only. . . . There are reasons to suppose that this result is too low. Furthermore it is not improbable that tobacco loses nitrogen during the curing process."

The advantages of artificial manuring have been made manifest in all branches of agriculture, and there is no doubt that the nitrogenous qualities of farmyard dung may be replaced by soda nitrate, ammonia sulphate, &c., only it must be remembered that these have not nearly the lasting effect of dung, the latter liberating its ammonia but slowly. Indeed "when a soil has been heavily dunged for a term of years, it accumulates a large quantity of nitrogen, which is comparatively inert and therefore nearly useless to crops. Quicklime assists to convert this nitrogen into the active forms of ammonia or nitrates," hence Prof. Johnson's suggestion that an "application of lime may sometimes be advantageously substituted for one of stable manure. In fact, it is not improbable that moderate doses of lime might be turned under with stable manure or green crops, with the effect of exalting the action of these fertilizers, and obtaining from them a larger return of nitrogenous plant food. Lime, however, gives effect to the nitrogen of the soil by causing the destruction of the organic matters—*humus*—in which this nitrogen lies in an inactive state. These organic matters have themselves a value independent of their nitrogen, which must be taken account of, and therefore the use of lime must be undertaken cautiously, and with an intelligent comprehension of the various effects which it may produce."

Rotation.—A proper rotation of crops is particularly

advantageous for the cultivation of tobacco, since it requires a great amount of readily accessible inorganic matter in the soil, especially potash and lime. Although the importance of cultivating tobacco in rotation is admitted, there may be circumstances that justify the growth of this crop consecutively for several years in the same field. In America, tobacco is grown successively for several years on new land, where the elements of plant food exist in such abundance that the crop may be thus cultivated without for a time showing any notable decrease in yield; it is even said that the outturn of the second year is heavier than that of the first. In Hungary and Holland, the best tobacco is grown for many years in succession on the same land. There the plan is adopted partly out of necessity and partly for convenience. The small landholder is often obliged to grow tobacco on the same field, because he has only one properly fitted for it; for convenience, he grows it every year on the same place near his homestead, to allow of the closest attention to the crop, but he manures heavily. Nessler, in Carlsruhe, cultivated tobacco during six consecutive years in the same field, without noticing any perceptible decrease in yield or quality. To admit of such a system, the soil must either be very rich in the essential elements, or be heavily manured, as is the practice in Holland. It is generally assumed that, when tobacco is grown on the same field in succession, the leaves do not become so large after the first year, but grow thicker and more gummy, and contain less water.

From the foregoing, it would appear that, although tobacco may be grown successfully on the same land

uninterruptedly under special circumstances, the cultivator will find it advantageous to adopt some plan of rotation. Cereals and pulses are very well adapted for this purpose, the reason being that tobacco removes but little phosphoric acid from the soil, and thus leaves it rich in the element most necessary for the growth of cereals. It has also been found that hemp thrives particularly well after tobacco.

Judson Popenoe suggests that there "should be a good coat of clover to plough under; if the ground is naturally rich, this alone will make a good crop, but hog and stable manure, well rotted, is what the tobacco, as well as any other crop, delights in, and the more manure the better the tobacco. The plan that I am now experimenting on is, as soon as I cut my tobacco in the fall I give the ground a good harrowing, and then drill in wheat; the ground being well cultivated all the fall, is clear of weeds and mellow and needs no ploughing. In the spring I sow clover, after the wheat is off; I keep the stock off until about September, to give the clover a chance to harden and spread. I then let the stock eat as low as they want to, which drives the clover to root, and causes the crown to spread; I do not suffer stock to run on the clover during winter or spring; about the last of May or first of June I plough the clover under, which is now in blossom, and so I alternately keep two fields in tobacco and wheat, at the same time feeding the ground a crop of clover every two years; in this way I expect my land to increase in fertility all the time. The clover turned under makes food for the cut-worms, and they trouble the tobacco-plants but little."

Selection of Sort.—The cultivator must carefully com-