OKLAHOMA

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 32--March, 1898.

PRACTICAL CHEMISTRY OF SOILS AND CROPS.

A STUDY OF THE CASTOR OIL PLANT.

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STILLWATER, OKLAHOMA.

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Practical Chemistry of Soils and Crops.

SUMMARY.

1. The fertility of every soil has a limit. Each crop grown removes a portion of the elements of fertility and leaves the soil poorer.

2. The staple crops of Oklahoma—wheat, oats, corn, kafir, cotton, and castor beans—if properly managed will not quickly exhaust the soil.

3. The portion of these crops that is sold, when intelligently handled, removes less plant-food than does that portion which is frequently wasted and which should be returned to the soil.

4. General farming, the growing of a moderate acreage of each of many crops, is to be preferred to the growing of but one or two crops year after year.

5. Stock-raising and feeding should be engaged in by every farmer who can possibly arrange to do so. Aside from the increased price thus secured for crops, this system of farming tends to keep the plant-food on the farm.

6. Stable manure is a valuable agent for the improvement of our soils, and should in all cases be well cared for and spread on the fields, and not be regarded as a nuisance to be disposed of in the easiest possible manner.

7. Castor bean pods contain a large amount of fertilizing constituents, are of fully as much manurial value as average wood ashes, and should be regarded as an important feature of the castor bean crop.

INTRODUCTION.

It should be the earnest endeavor of each owner of a farm to keep the original stock of fertility of the soil unimpaired, and, if possible, to so manage that an increase over previous yields will be secured rather than a continually diminishing return for the labor expended. That this may be accomplished, it is essential that the simpler facts of the chemistry of soils and crops be familiar to every one engaged farming. The following pages have been prepared for the purpose of acquainting the farmers of Oklahoma with what is known along this line, and of clearly setting forth the relation of our principal staple crops to the soil's fertility. The experience of the eastern part of the United States emphasizes the importance of this subject. The enormous sum paid annually for commercial fertilizers is, to a great extent, the penalty which must be paid for wasteful practices which were common when the "unbounded fertility" of the soil was never questioned.

PLANTS.

Every plant, from the vilest weed to the most valuable crop that grows, is made up of essentially the same elementary sustances. Part of these substances are taken from the air and part from the soil. At present, for sake of clearness, no further reference will be made to that portion obtained from the air. More than a dozen different elements contained in plants are derived from the soil. It is needless for our present purpose to complicate matters by giving a list of them. All of them are essential to the production of plants and all are found in almost every soil.

SOILS.

Practically, every soil contains all of these substances, with three exceptions, in sufficient amounts for the production of maximum crops if the other conditions, such as water supply and mechanical conditions, are right. This being the case, it is sufficient for our present purpose to consider only the exceptions.

The three substances frequently deficient in soils are nitrogen, potash, and phosphoric acid. These names have been assigned to certain substances that are present in and essential to the growth of all plants. If one is absent from a soil, the crop will not mature properly; if any one of them exists in a very limited quantity, continually decreasing crops will be the result. Nitrogen, potash, and phosphoric acid collectively are called plant-food, a term which carries its meaning with it.

This plant-food exists in several forms in the soil; some of it is soluble, and consequently called available, because it is in a form to be taken up by plants. Other portions are insoluble and not ready for use, hence termed unavailable. The amount of available plant-food in a soil is the factor which determines its ability to produce a crop and the number of crops which it will produce. The available plant-food is slowly replenished from the insoluble portion, but at the same time it is being diminished by crops and by the leaching of the soil by heavy rains. This supply of plant-food is the stored-up energy of the farm. Different crops remove these three materials in different amounts, but each crop leaves the soil with a portion of its stored-up energy expended.

SOIL ANALYSIS.

This being true, it would seem that a chemical analysis of a soil should tell exactly the amount of plant-food which it contained and afford a means of correctly estimating its crop-producing power. This, however, is not the case. The difficulty of securing representative samples, inability to determine the exact amount of available plant-food, and the impossibility of correctly forecasting the rate of change in availability of the plant-food, make a soil analysis of little direct, practical value to a farmer. Climatic conditions being favorable, the only true test of a soil's ability to produce a crop is a crop test.

On the other hand, a study of the amount of plant-food removed by different crops, and of the most profitable way of converting those crops into money and still retaining their elements of fertility on the farm, is the true way for a farmer to conserve his capital. Leading toward this end, Oklahoma's staple crops have been studied and general plans of the way of disposing of them so as to reduce the loss of plant-food, by their sale, to a minimum are given in the following pages.

WHEAT.

One thousand pounds of winter wheat contain 24 lbs. nitrogen, 6 lbs. potash and 9 lbs. phosphoric acid.*

The straw harvested with this amount of grain will weigh approximately two thousand pounds, which contain 12 lbs. nitrogen, 10 lbs. potash and 3 lbs. phosphoric acid.

The grower of wheat has no option but to sell the grain.

*The commercial value of the elements of plant-food in farm crops is at present assumed to be the following per lb.: nitrogen, 12 cts.; potash, 5 cts.; phosphoric acid, 4 cts. These figures represent what these materials would cost if purchased in the form of fertilizers to be applied to the soil.

Present methods of disposing of the straw could be greatly improved. The straw is valuable not only on account of the plant-food which it contains but also on account of the large amount of organic matter. Many of our soils are hard and compact and would be greatly improved by plowing the wheat straw under, thus bettering their mechanical condition by making them take up water more readily and part with it by evaporation more reluctantly. The straw, instead of being burned or allowed to decay in one huge pile, should be hauled or dragged over the field, scattered about and plowed under. It is true that decomposition of straw takes place but slowly in this climate, but the little extra trouble in plowing will be repaid by the improvement of the soil which will result. Where headers are used, much of the straw is left in the fields, but that which is removed should nevertheless be returned to the soil.

The preceding remarks apply to farms almost exclusively devoted to raising wheat, and on which little stock is kept. On farms where a variety of crops is grown, the manure produced by bedding the stock in stables, as well as that which accumulates when cattle winter about the straw pile, should be hauled onto the fields and plowed under when the soil is being prepared for a subsequent crop.

OATS.

One thousand pounds of oats contain 20 lbs. nitrogen, 12 lbs. potash and 16 lbs. phosphoric acid.

The straw harvested with this amount of grain will weigh approximately two thousand pounds, which contain 12 lbs. nitrogen, 25 lbs. potash and 4 lbs. phosphoric acid.

The grain may be either sold or fed on the farm. At prices which usually prevail, it pays better to pursue the former course and feed corn or kafir.

The remarks made concerning the disposal of wheat straw apply with equal force in regard to oat straw, with the exception that the latter contains a larger amount of plant-food and its return to the soil is even more important.

CORN.

One thousand pounds of corn in the ear contain 14 lbs. nitrogen, 5 lbs. potash and 6 lbs. phosphoric acid.

Approximately six hundred pounds of corn stover will be produced along with this amount of corn. This weight of stover contains 6 lbs. nitrogen, 8 lbs. potash and 2 lbs. phosphoric acid.

By far the largest amount of corn grown in the Territory is husked from the standing stalks, which are left in the field and serve as winter pasture for cattle. It is, however, customary to drag off the stalks in the spring and burn them. This practice has its commendable features, as it is very difficult to get the soil in good condition when it is littered with corn stalks. Notwithstanding this, the practice is a wasteful one and should be resorted to as seldom as possible. All of the nitrogen is lost when anything is burned, as well as the organic matter in which many of our soils are deficient.

The disposal of the corn is accomplished in two principal ways, either by selling the crop direct, or by feeding it to cattle or hogs and selling them. From the standpoint of maintenance of fertility, the former method is undesirable. Better returns in money are usually secured and less depletion of the soil's resources takes place when the corn is fed to stock and the manure returned to the soil. When any crop is fed to stock, less than 25 per cent. of the manurial value of the feed is carried off by the animals when they are sold. This being the case, farms where a sufficient number of animals is fed to consume the corn crop will, beyond question, be producing good crops of corn long after the farms from which the crop is sold every year have been abandoned.

KAFIR.

One thousand pounds of mature kafir fodder (whole plant) contain 8 lbs. nitrogen, 22 lbs. potash and 9 lbs. phosphoric acid.*

For sake of comparison, one thousand pounds of corn fodder contain 12 lbs. nitrogen, 9 lbs. potash and 6 lbs. phosphoric acid.

Under present conditions, the bulk of kafir grown is fed on the farm. This, as with corn, is the most desirable method of disposing of the crop.

*Calculated from but one analysis, sample No. 576: moisture, 7.53 per ct.; nitrogen, 0.76 per ct.; potash, 2.22 per ct.; phos. acid, 0.91 per ct. No analyses of kafir grain for fertilizer constituents are available.

COTTON.

There is no other crop that will, if improperly managed, more certainly diminish the fertility of the soil. The impoverished soils of the old cotton-growing states are a more convincing argument in support of this proposition than any arrangement of the results of chemical analyses could possibly be. Yet it may serve a useful purpose for us to examine the composition of the cotton plant, that we may understand clearly why it is so exhausting to the soil and how to avoid this exhaustion.

One thousand pounds of ginned cotton contain 3½ lbs. nitrogen, 4½ lbs. potash and 1 lb. phosphoric acid.

With this amount of lint will be produced two thousand pounds of cottonseed, which contain 63 lbs. nitrogen, 23 lbs. potash and 25 lbs. phosphoric acid.

If nothing but the lint is sold, and the seed is in some way returned to the soil, but very little diminution of the soil's fertility will result, the lint containing but an insignificant amount of plant-food.

The seed, on the contrary, is a concentrated substance which contains a large amount of materials whose removal impoverishes the soil. Cottonseed may be disposed of in a variety of ways, chief among them being (a) selling for an absurdly low price to gins, where it is sometimes used for fuel, thus entailing an enormous waste of nitrogenous matter; (b) selling to oil mills, where the oil is extracted and the cottonseed meal shipped to northern markets, carrying with it the fertility of our soils; (c) feeding the seed to cattle, or exchanging it for cottonseed meal at the oil mill and feeding the meal.

Without losing sight of the fact that it is not always possible to do the best thing from an economic standpoint, it does seem that the lesson of the old states should not be lost on this new country. At times it may be necessary to sell the seed for what it will bring and use the proceeds for pressing necessities. This should, however, be the exception and not the customary method. The cotton-grower is very apt to become a "one-crop" man, and, if he does, the chances are that he will leave neither money nor a good farm to his children.

The general results of feeding experiments with cottonseed are that it may be fed with profit to steers in connection with our common forage plants, such as corn or kafir stover. It is not considered safe to feed it to hogs, but bad results are not always experienced when hogs are allowed to run after steers that have been fed cottonseed. The building of oil mills should be encouraged and, when they are established, an exchange of cottonseed for cottonseed meal, which is the better feed, should be made instead of selling the seed. The meal is left after the extraction of most of the oil, and is an excellent feeding stuff in addition to its containing nearly all of the plant-food which was in the hulled seed. The feeding of cottonseed and its products to cattle by cotton-growers is the proper method of keeping up the fertility of our cotton-fields. Had this plan been followed by cotton-growers in the old South, they would not now be under the pressing burden of an enormous annual expenditure for commercial fertilizers.

CASTOR BEANS.

An extended study of the castor oil plant has been made. Details not of direct, practical interest are given at the close of this bulletin.

Since the leaves and stalks of this plant remain in the field, the plant-food which they contain returns in a great measure to the soil and need not enter into this discussion.

The portion which is gathered when the crop is harvested consists of the pods containing the beans, together with the stems of the spikes. This is later divided into two portions, which we have designated respectively as beans, the part which is sold, and pods, which remain on the farm. One hundred pounds of the dry, gathered spikes yield, as the average of our determinations, 55 lbs. of cleaned beans and 45 lbs. of pods. The features of this crop which deserve study are (a) the amount of plant-food sold with the beans and (b) the amount of plant-food contained in the pods and whether or not they are worth looking after.

One thousand pounds of castor beans contain 35 lbs. nitrogen, 4 lbs. potash and 14 lbs. phosphoric acid.

The pods gathered with this amount of beans weigh approximately eight hundred pounds and contain 13 lbs. nitrogen, 46 lbs. potash and 1½ lbs. phosphoric acid.

The beans themselves are not exceptionally "hard" on the soil, and a comparison of the money value of castor beans with that of an equal weight of other crops leads to the conclusion that it is desirable to grow them in preference to crops that require a large amount of expensive machinery to handle.

The pods contain an amount of plant-food of more value than that present in an equal weight of average wood ashes. The value of ashes as a fertilizer is well known and utilized by careful farmers. The pods of castor beans are fully as valuable and should be taken care of and returned to the soil. Their value as a manure, based upon what the plant-food in them would cost if purchased in the form of fertilizers, is over ten dollars per ton. This figure represents the extent to which the stored-up capital of the farm is drawn upon and wasted when this portion of the crop is not returned to the soil The plant-food in the hulls is slowly available and their effect would be lasting. From their composition, they are well suited for the manuring of fruit trees and similar valuable crops. The pods cannot be sold for money, but they are a feature of this crop second only in importance to the beans, and should be put to good use and not be wasted.

ALFALFA AND COW-PEAS.

The preceding comprise the principal crops that are grown for market. In this connection, the class of plants to which alfalfa and cow-peas belong should be mentioned. These two are the most promising leguminous plants for forage in this climate. They differ from the crops previously mentioned in that they possess the power of securing from the air a portion of the nitrogen which their growth requires. Thus, when grown and fed on the farm, they increase rather than diminish the stock of fertility in the soil. When cow-peas are plowed under, not only is the mechanical condition of the soil improved, but there is an increase in the store of plant-food available for subsequent crops. The same is true of alfalfa, whether it is pastured or cut for hay and fed on the farm, the manure being returned to the soil.

A Study of the Castor Oil Plant.

1897.

This study consists of a determination of the amounts of nitrogen, potash and phosphoric acid removed from the soil by (a) the entire crop, (b) the stalks and roots, (c) the leaves, (d) the beans and (e) the pods.

Seed of the common variety from two sources, one Oklahoma and the other Kansas grown, and of an ornamental variety, were planted May 4. During the next two weeks there was a rainfall of approximately ten inches, which hindered germination and, to some extent, prevented the plants from getting a good start. After the plants were a few inches high,

Table 1.

VARIETY AND PLANT No.	Total Weights	Stalks and Roots	Leaves	Beans	Pods	Beans and Pods
No. 1—A	2095	1052	396	324	323	647
B	2255	1127	498	363	267	630
C	1692	840	431	224	197	421
D	1382	615	220	318	229	547
E	2025	1055	433	312	225	537
Total	9449	4689	1978	1541	1241	2782
Average	1890	938	396	308	248	556
No. 2—A	2513	1332	531	337	313	650
B	1370	600	330	245	195	440
C	2160	1168	330	361	301	662
D	1077	470	227	208	172	380
E	1599	786	305	286	222	508
Total	8719	4356	1723	1437	1203	2640
Average	1744	871	345	287	241	528
No. 3—A	1845	1026	294	305	220	525
B	1121	658	178	160	115	285
C	1794	946	318	302	228	530
D	2511	1389	346	458	318	776
Total	7271	4019	1136	1225	891	2116
Average	1818	1005	284	306	223	529

all except five of each variety were removed. The plants were numbered as follows:

No. 1—A, B, C, D & E. Common variety, Oklahoma grown.
No. 2—A, B, C, D & E. Common variety, Kansas grown.
No. 3—A, B, C, D & E. Large ornamental variety.

The dead leaves and ripe pods were removed daily and kept in separate sacks for each plant. The plants, having been killed by frost, were removed from the soil November 8. Plant No. 3E produced no beans, and was discarded.

Table 1 gives the weights of each plant and of each part at the time when the samples were taken for analysis. All weights are stated in grams.

Samples of the stalks and roots, the leaves, the beans and the pods were taken for each sort grown, and water, nitrogen, potash and phosphoric acid determined in each. The results of these determinations appear in Table 2.

Table 2.

VARIETY No. AND PART	LBS IN 100 LBS. AS SAMPLED.			
	Water	Nitrogen	Potash	Phosphor. Acid
No. 1—Stalks and roots	69.89	0.24	0 34	0.06
Leaves	39.52	1.66	1.29	0.23
Beans	4.84	3.51	0.41	1.38
Pods	7.14	1.84	5.76	0.20
No. 2—Stalks and roots	68.99	0.27	0.45	0.05
Leaves	32.62	1.61	1.49	0.22
Beans	4.66	3.39	0.54	1.38
Pods	10.72	1.42	5.74	0.15
No. 3—Stalks and roots	72.24	0.31	0.32	0.05
Leaves	26.77	1.71	1.18	0.22
Beans	5.03	3.58	0.54	1.48
Pods	8.72	2.82	6.54	0.37

Table 3.

VARIETY No., AND PART	GRAMS IN AV'AGE OF 5 PLANTS		
	Nitrogen	Potash	Phosphor. Acid
No. 1—Stalks and roots	2.25	3.19	0.54
No 2—Stalks and roots	2.36	3.92	0.44
No. 1—Leaves	6.57	5.11	0.91
No. 2—Leaves	5.55	5.14	0.76
No. 1—Beans	10.81	1.26	4.25
No. 2—Beans	9.73	1.55	3.96
No. 1—Pods	4.56	14.28	0.50
No. 2—Pods	3.42	13.83	0.36

From these results have been calculated the following tables showing the weight in grams of plant-food removed by each part. For sake of comparison, the weights for the two sorts of the common variety are given in Table 3. Averages are shown in Table 4, as well as the total amount removed by one plant weighing 1817 grams, the average weight of one plant of the common variety.

Table 4.

PART.—AVERAGE OF Nos. 1 AND 2.	GRAMS IN ONE PLANT		
	Nitrogen	Potash	Phosphor. Acid
Stalks and roots	2 30	3.55	0.49
Leaves	6.06	5.12	0 84
Beans	10.27	2.40	4.10
Pods	3.99	14.06	0.43
Entire plant	22.62	25.13	5.86

From these data the following percentage composition has been calculated for the common variety:

Table 5.

MATERIAL	IN 100 PARTS FRESH SUBSTANCE		
	Nitrogen	Potash	Phosphor. Acid
Stalks and roots	0.26	0.40	0.06
Leaves	1.64	1.39	0.23
Beans	3.45	0.48	1.38
Pods	1.63	5.75	0.18
Entire plant	1.24	1.38	0.32

In a similar manner the following tables have been calculated from the data relating to the ornamental variety, the average weight of one plant being 1817 grams:

Table 6.

PART.—No. 3	GRAMS IN ONE PLANT		
	Nitrogen	Potash	Phosphor. Acid
Stalks and roots	3.12	3.22	0.50
Leaves	4.86	3.35	0.62
Beans	10.95	1.65	4.53
Pods	6.29	14.58	0.83
Entire plant	25.22	22.80	6.48

From these data the following composition has been calculated for the ornamental variety:

Table 7.

MATERIAL	IN 100 PARTS FRESH SUBSTANCE		
	Nitrogen	Potash	Phosphor. Acid
Stalks and roots	0.31	0.32	0.05
Leaves	1.71	1.18	0.22
Beans	3.58	0.54	1.48
Pods	2.82	6.54	0.37
Entire plant	1.39	1.25	0.36

Of the common variety, 55 per cent. of the portion removed from the field, as the crop is gathered in practice, consisted of beans and 45 per cent. of pods.

Beans of each variety were carefully hulled and the per cent. of hulls and of beans determined with the following results:

No. 1—75.27 per cent. hulled beans; 24.73 per cent. hulls.

No. 2—74.75 per cent. hulled beans; 25.25 per cent. hulls.

No. 3—75.72 per cent. hulled beans; 24.28 per cent. hulls.

The most striking feature of these results, the high manurial value of the pods, has already been pointed out in this bulletin. Comparison with other analyses published in Bulletin 25 of this Station reveals the uniformity of the results now reported with previous work.

DETERMINATION OF OIL IN CASTOR BEANS.

The large amount of oil in castor beans makes it impossible to pulverize them before extraction. In making determinations of the total oil the following method proved satisfactory.

The beans were first hulled, using a knife, and the percentage of hulls determined. The hulled beans were then sliced with a sharp knife. Five grams were weighed into an extraction tube, dried to constant weight at 100° *C.*, weighed, and extracted for sixteen hours with anhydrous ether. The oil was determined by loss in weight of extraction tube. The extracted slices were emptied from the tube, pulverized in an agate mortar, returned to the same tube, dried to constant weight, and again extracted for sixteen hours. A third extraction for sixteen hours showed no further loss in weight.

The following table gives the weight of different extracts from five gram charges of the same sample of beans:

SAMPLE 721	First Extraction	Seco'd Extraction	Total Oil	Per Cent. Oil
Number 1	2.9504	0.0670	3.0174	60.35
Number 2	2.9526	0.0632	3.0158	60.32
Number 3	2.9701	0.0585	3.0286	60.57
Number 4	2.9542	0.0603	3 0145	60.29