THE PENNSYLVANIA STATE COLLEGE

Mineral Industries Experiment Station

Circular 5

BITUMINOUS COAL

NEITHER PLANT FOOD NOR FERTILIZER

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Mining literature occasionally makes reference to the use of coal as a fertilizer or aid in the growing of crops; one of the latest is a consular report from Germany: "Successful utilization of treated coal as a fertilizer is reported by the German Coal Research Institute of Mülheim, according to Trade Commissioner William T. Daugherty, Berlin. Experiments conducted by the institute are said to have shown the effectiveness of ground coal and lignite in plant life. The report also states that successful plant fertilization has accomplished by using mixtures of coal with soluble nitrogenous or potassium salts. It is believed, the report states, that such fertilizers may soon appear on the German market at a price range of about 25 to 30 marks per metric ton."

Earlier articles* attracted the attention of the Pittsburgh Coal Co., which, in consequence, made experiments on a plot of ground near Pittsburgh.

By using washery sludge, most of which would pass a 48-mesh screen, as a mulch or covering on top of the soil, the crop production on plots so treated was from 58 to 120 per cent greater than on adjoining plots not treated, the crops being wheat, oats and corn. A second year's experiment showed corresponding results with oats and corn, no experiments with wheat being made during that year. It was noted in these tests that the sludge, when plowed under or into the ground, did little or no good. The company then asked the Pennsylvania State College to interpret and continue these experiments. The department of agronomy of the Pennsylvania State College ran a carefully controlled experiment, under direct supervision of Prof. A. G. Merkle. The coal sludge received from the Pittsburgh Coal Co., was first subjected to a chemical analysis to determine its suitability for agricultural purposes, the results of which appear in Table I.

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* Coal Age, Vol. 30, pp. 288-289; Coal Age, Vol.30, p.308; and International Conference on Bituminous Coal, Transactions, 1926, pp.592-594. An article on the experiments followed, Coal Age, September, 1929, pp. 531-533.

The notation of the department on the analysis was that it "shows no appreciable quantity of nutrient elements; in fact, a good surface soil may contain more." Its effect on certain biological processes, particularly nitrification, and its influence on soil acidity were then determined. These tests not only showed that the coal sludge had no value for these purposes but indicated that its influence was slightly detrimental.

Table I--Chemical Analysis of Sludge From Pittsburgh Coal Co.

Combustible matter	78.4 per cent
Ash	21.6 per cent
Total nitrogen	0.024 per cent
NH_3 nitrogen	none
NO_3 nitrogen	none
P_2O_5 soluble in 0.05 normal H_2SO_4	0.0225 per cent
P_2O_5 water-soluble	none
P_2O_5 in ash	0.0234 per cent
SO_4	present
Calcium, water-soluble	0.026 per cent

Next, experiments were made with soils and plants in pots under controlled temperature and moisture conditions; corn, tomatoes and beans being used. In this group of experiments, coal sludge sometimes was mixed with the soil in varying quantities and in other cases was placed loosely on the top of the soil to act as a mulch. Under all the temperature and moisture conditions tried, the plants showed slower and less exuberant growth when the sludge was mixed with the soil than in the controlling experiments where the soil was used without such admixture.

Where 3/8 in. of coal sludge was used on top of the soil, the only effects apparent were a conservation of the moisture in the soil beneath the sludge and a very slight increase in temperature, resulting probably from the blackness of the coal sludge, which made the soil absorb more heat than it would have done if the surface had been of lighter color. The conclusions of the department from this series of experiments were that:

"A layer of sludge 3/8 in. deep decreases the evaporation of moisture. From every other viewpoint, it does more harm than good. However, even if it were used on the surface as a moisture conserver it would be of value for only one year, as it would be necessary to plow it under in the following season, with resultant injury to the soil, as the tests have proved."

A further group of experiments was made in which corn, oats and tomatoes were planted on adjacent alternating areas of land treated with ¼ in. sludge as a top mulch, with 1/8 in. sludge as top mulch, with sludge mixed with the soil, and with the soil entirely without coal treatment. The various treatments made no perceptible difference in the crop obtained, but the investigators expressed the opinion that if it had been an unusually dry season superior crops might have been expected on the sludge-covered soil, because the sludge would have conserved the moisture, as was demonstrated in the experiment already quoted.

The final conclusions of the department are stated as follows:

"1. The coal dust obtained from the Pittsburgh Coal Co. contained no appreciable quantity of any important plant nutrient.

"2. It tended to increase soil acidity slightly and to decrease nitrification.

"3. Used as a surface dressing or mixed into the soil, it tended to lower the temperature of the soil and delay germination.

"4. When used as a surface covering 1/8 to 3/8 in. deep, it decreased evaporation materially, hence in dry years it might increase the yield materially, while in moist years it might have no effect.

"5. After it has been used as a surface dressing, plowing and planting operations inevitably will incorporate it in the soil. As it has been shown that the product decreases nitrification and increases acidity, cumulative effect of its use year after year might be expected to be injurious.

"6. It does not inhibit weed growth; therefore it would not be feasible for use on any cultivated crop, because cultivation would mix it with the soil and nullify any possible mulching tendencies.

"7. Its use in plant production appears undesirable".

In a recent experiment conducted by the Tennessee Experiment Station, and reported in the annual report of that institution for 1931, p. 55, coal dust was applied in different experiments at the rate of 2 to 10 tons per acre on crops of corn, soy beans and millet. In any of the quantities used, it failed to increase the yields of any of the crops except millet, and that difference was within the limit of error. The average yields were as in Table II.

Table II---Crop Where Coal Was Used and Not Used

Crop	With Coal 5 plots	No Coal 3 plots
Millet hay	0.92 ton	0.83 ton
Soy beans	1.70 tons	1.68 tons
Corn stover	0.78 ton	0.79 ton
Corn grain	23.0 bushels	25.2 bushels

All these differences are within the limit of error. The coal dust was mixed with the soil to a depth of about 3 in.

The accuracy of the foregoing tests and experiments cannot be questioned, so only the following remote possibilities remain: First, that, in its action toward plants, the sludge tested is not representative of all parts of the coal seam; second, that coals from different seams may have a different action on plants; third, that freshly mined underground coal may act differently from coal which has been exposed to the weather for some time; and fourth, that the coal may affect cultivated plants differently from native or wild plants.

True, ammonium sulphate, a byproduct in the coking of coal, is used as a fertilizer, but that derivative does not occur as such in coal. The ammonia is produced in the byproduct coke oven by a rearrangement of elements in the coal at a high temperature. Some may say that, as wood ashes contain potash, a desirable plant food, this same potash should still be available in coal, as coal has been formed from wood. This apparently is not so, as the small quantity of potash present in coal is for most part so chemically combined as to be of no use as a plant food. The larger part of the potassium and calcium present in the original plant tissue was dissolved and carried away when the muck, which later became coal, lay under water.

Though it is difficult to see how there is any plant food in coal, some people still persist in their belief that coal may be of some value in agriculture, basing their conclusions not only on the German experiments quoted at the beginning of this article but also on the statement by Dr. Franz Fischer, at the International Conference on Bituminous Coal, reported in Transactions 1931, Vol. 2, page 809. He declared that: "In some few cited cases, coal when used in small quantities had a directly stimulating effect upon the growth of plants; larger quantities seemed to poison the soil."

Many undoubtedly recall seeing printed statements to this effect and possibly some have noted that vegetation, particularly sagebrush in the Rocky Mountain region, grows much more heavily on and below the outcrop of coal beds wherever the coal does not outcrop on cliffs too steep for vegetation. I have noted this phenomenon several times, particularly in northwestern Colorado and also in northern New Mexico.

In a personal communication, Meritt Hutton, chief engineer, Colorado & Utah Coal Co., Mt. Harris, Colo., states: "I have frequently noticed that the growth of vegetation along outcrops is heavier than in other places, and I used this as one of my guides in the location of outcrops. This difference may be due in part to the presence of coal in the soil, although I believe it is due largely to the fact that practically all the coal seams in that section being underlaid with clay, which is quite impervious to moisture, the ground water frequently follows these coal strata to the outcrop.

"For this reason, I have usually found much moisture along the outcrop; so much, indeed, in places as to form springs and boggy places. In general, I have found that the outcrops occur along a bench or somewhat level place on the hillside, and that usually above the outcrop the slope of the hill is of more than average steepness."

In the same communication, he also states: "Though I am unable to support my opinion with any definite information, it is my belief that the presence of decomposed coal in the soil stimulates the growth of vegetation."

All gardeners have a high regard for the growing qualities of "nice black soil," which contains, of course, much carbonaceous material from vegetation that has fallen on it and in cases been plowed under. Recalling that coal is vegetation which has been carried a few steps farther in its decomposition, it does not, at first, seem impossible that coal might have an effect when mixed with soil similar to that of the carbonaceous matter in "nice black soil", despite the fact that on rock dumps, where sandstone, slate and clay are mixed with carbonaceous matter, seldom is any vegetation to be found. However, in that case its absence might be explained by the fact that there is not enough soil on the waste pile to permit of vegetation or that the coil is of a type unsuited to plant growth.

It must be remembered that the carbonaceous matter in the black soil does not in itself stimulate plant growth. The action of vegetation is to increase bacterial action by which the decay of certain parts of the plants and the release of certain mineral plant foods are effected. The black carbonaceous matter remaining is largely humus and lignin, which in themselves play little or no part in future growth. Perhaps it would be well to state that the humus in

normal soils forms a coating on the soil particles and granules and serves a physical rather than a chemical purpose. It is doubtful whether coal previously lignified and added as dust can fix itself on soil particles and bring about these physical effects.

Peat, the first stage in coal formation, does not seem to provide any plant stimulus, although no definite experimental results covering this are known. Certainly, vegetation is not heavier on peat deposits than on other rich soil. The use of peat and muck for soil amendment has generally given little or no promise, except when something is needed to increase the water-holding capacity of the soil and prevent excessive compacting, as on the putting greens of golf courses.

Brown coal, or lignite, the next stage in the formation of coals, contains a still larger percentage of lignin or non-active carbonaceous material, and with the development of this stage the bacterial action which accompanies the release of humus and aids in plant growth has been practically completed. It is with this type of coal apparently that most of the German experiments in the use of coal for fertilizer have been made. It is difficult to see how any treatment coal may be given will induce further bacterial action after this stage has been reached.

In bituminous coal such as we mainly use in the United States, coalification has proceeded still farther, and the possibility of any part of the vegetal matter remaining which will serve as a plant food or stimulant with or without treatment is still more remote.

Those nutrients which plants draw through their roots are received in true solution. These include nitrogen as nitrates or ammonia, potassium, calcium, magnesium, phosphates and sulphates. Nitrogen in the form of nitrate performs a certain function in the soil stimulating plant growth and entering into the plant itself; it is probably the most important elemental plant food in the soil. The rest of the plant food is carbohydrate made in the plant itself from carbon dioxide taken in from the air and converted under the action of light. Many experiments have shown that carbonaceous matter in the soil will not substitute for the carbon dioxide in the atmosphere.

In conclusion, I think it might be safely said that, while many feel that natural weathered coal in soil promotes plant growth, all carefully controlled experiments indicate that bituminous coal or coals of higher rank have little or no value when used in quantities sufficient to afford the coal producer an additional market, the only exception indicated being that afforded by Dr. Fischer's statement, already quoted, regarding its use in small quantities. There is a remote possibility that by treating it in some way it might be made useful in agriculture, but, judging from its chemical composition, this surmise would seem very doubtful.