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USE OF LIGNITE IN THE IMPROVEMENT OF PLANT FEEDING CONDITIONS

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Chemicalization of agriculture is a potent method for increasing agricultural productivity. In addition to organic and mineral fertilizers, many new chemical means must be widely applied to agriculture.

Not infrequently, the use of mineral fertilizers leads to increased concentration of salts around the seeds. The electrolytic property of most mineral fertilizers may perceptibly retard plant growth (especially during the early period of growth) with a consequently detrimental effect on the harvest. Methods which will mitigate sharp and sometimes even toxic effect of mineral fertilizers must be found. One such method is the joint use of organic and mineral fertilizers.

When organic fertilizers are used in combination, they absorb the nutrients from mineral fertilizers and the result is a decided improvement in the physiological feeding regimen of plants. However, in practice, it is not always possible to use organic fertilizers in combination with mineral fertilizers, and a mixture of the two is usually applied as a basic fertilizer. In addition to the basic fertilizer, mineral fertilizers are applied at the All-Union Scientific Research Institute for Sugar Beets, first to the sugar beet rows, then again to the growing crop during the growing period.

In many regions, ordinary mineral fertilizers often have too sharp an effect on the sugar beet seed because of a deficiency of soluble carbohydrates for combining with the ammonium nitrogen

of the fertilizers. To increase the effectiveness of mineral fertilizers applied to the rows of beets, application in granular form as well as application of sorbents to control the effect on the seed are indicated. At this institute, lignite and lignite tailings are being used as sorbents. ~~Such~~ a change of this nature in the plant feeding regimen, being in conformity with the biological requirements of the plants, increases both the size of the harvest and the quality of agricultural products.

This method of mitigating the sharp effect of ordinary fertilizers on sugar beets is of great interest.

Very often, upon application of ordinary ammonium sulfate and ammonium nitrate fertilizers, germination of sugar beets was retarded 1 1/2 - 2 weeks. With drying out of the upper layer of soil during that time, the young plants took root less securely in the moister layers of soil, the sprouts were less hardy, and the harvest was smaller.

Application of small quantities (20-30 kilograms per hectare) of high ash content lignite together with mineral fertilizers promoted better utilization of the nutrients contained in the fertilizers. The retardation of growth was eliminated, the effectiveness of ordinary fertilizers was increased, and as a result the sugar beet harvest and sugar content of the beets was greater.

The sorbents assisted the biological selection capacity of the young plants, eliminated mechanical manifestations of physical nutrient osmosis from fertilizers and soil, and thereby improved the physiological feeding regimen of the plants.

This institute carried out experiments with sugar beets and other crops jointly with workers of the Physiology of Plant Feeding Laboratory in the Institute of Plant Physiology and Agrochemistry of the Academy of Sciences USSR, from 1946 through 1948. During this time, while searching

for a method of reducing nitrogen losses, scientists developed the method of composting lignite and lignite tailings with manure. With aerobic storage of manure, nitrogen losses were as high as 50 percent with ammonium nitrogen disappearing completely. But it was found that when sorbents were composted with manure, losses of nitrogen as well as of other nutrients were reduced and the physiological effect of manure on plant feeding was improved.

Laboratory and field experiments were conducted with lignites from the Yurkovka (Zvenigorodskiy Rayon, Kiev Oblast) and Aleksandriya (Kirovograd Oblast) deposits. Lignites from the Yurkovka deposit contain 0.53 percent nitrogen, 0.39 percent phosphoric acid, and 0.63 percent potassium oxide. Those from the Aleksandriya deposit contain 1.15 percent nitrogen and 0.67 percent potassium; no phosphoric acid has been detected in them. According to data of A. D. Khomenko, one gram of lignite adsorbs on its surface 30 milligrams of a 100-cubic-centimeter one-percent solution of ammonium sulfate, 18.6 milligrams of a 0.1 percent solution, and 1.51 milligrams of a 0.01 percent solution. In the ashes of the lignites, traces of magnesium, sodium, and several trace elements were detected in addition to nitrogen, phosphorus, and potassium. Laboratory experiments showed that 100 grams of lignite absorb 2.5 grams of methylene blue. This absorptive capacity testifies to the unusual qualities of lignites as sorbents.

A special experiment was set up to clarify the sorptive qualities of lignites and the mode of plant feeding: one gram of lignite was added to a 450-cubic-centimeter nutrient mixture and young sugar beet plants planted in it. For comparison, other sugar beet plants were planted in a similar nutrient mixture but without lignite added.

The change in concentration brought about through sorption of nutrients by the lignite prior to planting of beet plants and through controlled reactions during 30 days of their growth demonstrated that lignite can serve as an important means of controlling mineral feeding of sugar beets.

At the beginning of the experiment, the nutrient mixtures contained 2.49 molecular equivalents of ammonia and 2.03 molecular equivalents of phosphoric acid; 48 hours after one gram of lignite had been added to one mixture, its ammonia content had declined to 0.13 molecular equivalents as compared with 2.49 molecular equivalents in the control mixture, while phosphoric acid content had declined to 0.98 molecular equivalents in the mixture with sorbent as compared with 1.98 molecular equivalents in the mixture without the sorbent. After the sugar beet plants had grown in the mixtures for 30 days, nutrients remaining in the mixture without lignite were considerably less than in the mixture with lignite. This fact indicates that a positive effect is obtained by using lignite as a sorbent.

It is significant that ammonia content in the mixture without the sorbent declined by 0.35 molecular equivalents while in the mixture with the sorbent it even increased by 0.40 molecular equivalents during the given growing period. This difference is explained by the exchange reactions taking place between the nutrient-saturated particles of lignite and the root excretions of the plants. Thus, the sorbent qualities of lignite manifest themselves during the earliest part of the growing period.

After the conclusion of this experiment, a series of experiments was conducted with different agricultural plants. In 1946, laboratory experiments were conducted with winter rye, corn, and

barley; in 1947, with beans and oats. Results of the 1946 experiments are given in Table 1.

Table 1 - Effect of Lignite in Improving Plant Feeding

Experiment Variants	Winter Rye			Corn			Barley	
	Number of Sprouts	Height of Plants (cm)	Weight of Dry Mass (g)	Height of Plants (cm)	Weight of Above-Ground Mass (g)	Weight of Roots (g)	Weight of Above-Ground Mass (g)	Weight of Roots (g)
Nutrient mixture with ammonium sulfate	7.5	14.0	11.79	15.1	109.6	112.5	39.5	21.0
Same, with lignite added	15.6	17.55	16.60	18.2	121.1	62.9	24.0	24.0

The table shows that plant growth increased except in the case of barley. The number of winter rye sprouts doubled upon addition of the sorbent; average plant height was greater; and dry mass weights increased considerably. The same increases were noted for corn, except that root weight was decreased almost halved. ~~two times.~~

As shown in Table 2, the results of the 1947 experiments were similar.

Table 2 - Effect of Sorbent on Plant Growth

Experiment Variants	Beans					Oats		
	Number of Sprouts	Height of Plants (cm)	Weight of Green Mass (g)	Catalase (cu cm $0.1N$ $KMnO_4$ on 1 g)	Peroxidase (cu cm $0.1N$ $KMnO_4$ on 1 g)	Number of Plants	Weight of Plants (g)	Length of Roots (cm)
Control	15.7	18.7	125.72	3.0	47.9	135	30.9	14.8
Lignite, 1 g	19.3	21.3	130.92	2.43	57.3	142	33.0	6.8
Lignite, 5 g	15.8	26.6	140.2	1.80	58.7	154	23.0	17.4

Germination of beans was better with the smaller addition of the sorbent, that of oats with the larger dose. Bean plant height, on the other hand, as well as total weight of bean plants and

peroxidase action, were greater with the larger dose. But with the increase of peroxidase action, catalase action declined.

The 1948 experiments conducted with corn gave still more definite results, as shown in Table 3.

Table 3 - Effect of Lignite on Corn Growth

Experiment Variants	Two Months after Germination				At Harvest Time			
	Height of Plants (cm)	Length of Roots (cm)	Weight of 100 Plants (g)	Chlorophyll (%)	Weight in Grams			
					Green Mass	Roots	Stalk	Grain
Control	45	13.6	640	0.89	310	45	265	26.3
Lignite	48	15.0	725	1.11	350	52	298	34.1
Manure	59	16.6	953	1.18	793	132	661	256.0
Manure and lignite	74	17.3	1,230	1.40	880	150	730	341.0

The given data testifies that the addition of lignite sharply improved the physiological properties of the feeding regimen in all cases. As a result, the height and weight of the plants as well as the harvest of grain increased greatly. The amount of chlorophyll in the leaves likewise increased, a fact which confirms the favorable effect of sorbents on the feeding regimen and synthesis processes in plants. These properties of lignite were verified also with respect to other plants, as shown in Table 4.

Table 4 - Effect of Lignite on Pea and Millet Growth

Experiment Variants	Peas				Millet			
	Height of Plants (cm)	Weight of 100 Plants (g)	Weight of 100 Pods		Number of Plants	Weight of Plants (g)	Number of Panicles	Weight of Panicles (g)
			g	%				
Control	46	360	18.6	100	19	36	3	20.0
Lignite	62	420	25.6	137	23	65	13	24.7
Manure	95	573	142.0	763	39	235	27	89.4
Manure and Lignite	99	758	158.0	849.4	52	327	32	103.8

As is seen, the weight and height of plants as well as weight of

fruit in pods and panicles became considerably greater under the influence of lignite. After laboratory experiments had been completed, field experiments were carried out. ~~Doverkina~~ a graduate student, A. D. Khomenko, conducted the experiments on the experimental area of the Institute of Plant Physiology and Agrochemistry and on a number of kolkhozes in Kiev Oblast. In 1947, experiments were conducted with sugar beets on 200-square-meter plots of freshly fertilized land on the kolkhoz imeni Stalin. Results of these experiments are shown in Table 5.

Table 5 - Effect on the Harvest and Sugar Content of Sugar Beets of Adding Varying Doses of Lignite to Mineral Fertilizers Applied to the Rows (Centners per Hectare)

Experiment Variants on Land Fertilized with N_{15}, P_{20}, K_{15} (kg/h)	Beet Harvest (c/h)	Increase (c/h)	Increase due to Sorbent (c/h)	Sugar Content (%)	Amount of Sugar (c/h)	Increase in Sugar (c/h)
Control	150.0	-	-	17.5	26.3	-
NPK	160.5	10.5	-	18.2	29.2	2.9
NPK and 10 kg/h lignite	181.0	31.0	20.5	18.4	33.3	7.0
NPK and 20 kg/h "	191.0	41.0	30.5	18.5	35.3	9.0
NPK and 30 kg/h "	185.0	35.0	24.5	18.6	34.4	8.1
NPK and 50 kg/h "	183.0	33.0	22.5	18.6	34.0	7.7

These data show that in all cases the addition of lignite contributed to a larger beet harvest and greater sugar content in the beets, although the addition of 20-30 kilograms per hectare produced the best effect.

Average results of experiments conducted by Khomenko in 1947 and 1948 on sandy loam soils at Goloseyevo near Kiev are shown in Table 6.

Table 6 - Effect on the Harvest and Sugar Content of Sugar Beets of Adding Lignite to Mineral Fertilizers Applied to the Rows (Centners per Hectare)

Experiment Variants on Land Fertilized with N_{15}, P_{20}, K_{15} (kg/h)	Beet Harvest (c/h)	Increase (c/h)	Increase due to Sorbent (c/h)	Sugar Content (%)	Amount of Sugar (c/h)	Increase in Sugar (c/h)
			1947 Data			
Control	188.6	-	-	18.2	34.3	-
Lignite	190.0	1.4	1.4	19.0	36.1	1.8
NPK	214.7	26.1	-	19.0	40.8	6.5
NPK and lignite	256.9	68.3	42.2	19.2	49.3	15.0
2N and PK	227.3	38.7	-	18.8	42.7	8.4
2N and PK and lignite	258.5	69.9	31.2	19.2	49.6	15.3
			1948 Data			
Control	168.0	-	-	18.0	30.2	-
Lignite	166.9	-1.1	-1.1	18.2	30.4	0.2
NPK	196.2	28.2	-	18.0	35.3	5.1
NPK and lignite	224.1	56.1	27.9	18.4	41.2	11.0
2N and PK	193.9	25.9	-	17.8	34.5	4.3
2N and PK and lignite	237.8	69.8	43.9	18.4	43.8	13.6

It is seen from the table that the addition of lignite almost doubled the effectiveness of fertilizers applied to the rows, increasing the 1947 beet harvest 42 centners per hectare and the amount of sugar 9 centners per hectare. This increase was maintained ~~also~~ when the amount of nitrogen was doubled. In 1948, the addition of lignite raised the effectiveness of the fertilizer by increasing the beet harvest 27.9 centners per hectare and the amount of sugar 6 centners per hectare.

Data compiled by Khomenko shows that lignite sorbents, used together with mineral fertilizer and applied to sugar beet rows,

considerably changed the physiological plant feeding regimen. The assimilation surface per plant increased from 1,785 to 2,316 square centimeters upon application of mineral fertilizer to the rows and to 2,298 square centimeters when the amount of nitrogen was doubled. When the sorbent was added, the corresponding increase in the first case was from 1,785 to 2,365 and in the second case to 2,658 square centimeters (as of 19 June). The amount of chlorophyll likewise increased.

The change in physiological regimen resulting from the addition of lignite increased the beet harvest in all experiments carried out during the past two years both on the experimental area and on the kolkhozes. Results of the experiments are presented in Table 7.

Table 7 - Effect on the Harvest and Sugar Content of Sugar Beets of Adding Lignite to Mineral Fertilizers Applied to the Rows

Indexes	Soil Type	Control	Lignite Applied	NPK Applied	NPK and Lignite Applied
Kolkhoz imeni Stalin at Zvenigorodka, 1947					
Harvest, centners per hectare	Leached chernozem	150	147.5	160.5	185
Increase, c/h		-	-2.5	10.5	35
Sugar content, %		17.5	18.4	18.2	18.6
Amount of sugar, c/h		26.3	27.1	29.1	34.4
Increase in sugar, c/h		-	0.8	2.9	8.1
Scientific-Experimental Area, 1947					
Harvest, c/h	Slightly podsolic sandy loam	188.6	190	214.7	256.9
Increase, c/h		-	1.4	26.1	68.3
Sugar content, %		18.2	19.0	19.0	19.2
Amount of sugar, c/h		34.3	36.1	40.8	49.3
Increase in sugar, c/h		-	1,8	6.5	15.0

Indexes	Soil Type	Control	Lignite Applied	NPK Applied	NPK and Lignite Applied
		Same, 1948			
Harvest, c/h	Slightly podsolic sandy loam	168	166.9	196.2	224.1
Increase, c/h		-	-1.1	28.2	56.1
Sugar content, %		18.0	18.2	18.0	18.4
Amount of sugar, d/h		30.2	30.4	35.3	41.2
Increase in sugar, c/h		-	0.2	5.1	11.0
		Kolkhoz imeni Shevchenko at Gusakovo, Zvenigorodskiy Rayon, 1948 Squad Ya. M. Kryuchmk			
Harvest, c/h	Leached chernozem	154	160	197	224
Increase, c/h		-	6	43	70
Sugar content, %		15.6	15.8	17.4	18.2
Amount of sugar, c/h		24.0	25.3	34.3	40.8
Increase in sugar, c/h		-	1.3	10.3	16.8
		Same, Squad Ya. G. Yatsenko			
Harvest, c/h	Leached chernozem	174	174	190	205
Increase, c/h		-	-	16	31
Sugar content, %		15.4	15.6	18.8	19.8
Amount of sugar, c/h		26.8	27.1	35.7	40.6
Increase in sugar, c/h		-	0.3	8.9	13.8
		Kolkhoz imeni Voroshilov at Zvenigorodka, 1948 Squad N. M. Kul'bachenko			
Harvest, c/h	Slightly leached chernozem	96	94	120	143
Increase, c/h		-	-2	24	47

These data attest to the great effectiveness of sorbents under production conditions. Recognizing this, the Council of Ministers USSR proposed to the Ministry of Agriculture that lignite be widely used on kolkhoz and sovkhoz fields in 1949. It is to be tried out on 8,500 hectares.

The question of using lignite in connection with manure storage

merits serious attention. The first experiments were carried out in 1946 under field and laboratory conditions by members of this institute in association with P. Z. Lasoval and I. M. Bernsteyn of the Institute of Plant Physiology and Agrochemistry of the Academy of Sciences USSR. Manure was composted with lignite from the Yurkovka deposit and placed in small trenches holding one kilogram for aerobic storage. Results of the experiment are shown in Table 8.

Table 8 - Composition of Manure Upon Composting with Lignite

Experiment Variants	Ammonium Nitrogen per Kg of Absolutely Dry Manure Matter (mg)			Total Amount of Nutrients in Dry Manure after 7 Months (%)		
	5/6	17/6	3/9	Nitrogen	Phosphorus	Potassium
Control	590	260	305	1.77	0.46	0.76
Lignite (40 g)	590	340	780	2.08	1.44	0.97

The table shows the extent of nutrient losses during storage of manure and, on the other hand, the retention of nutrients when manure is composted with lignite. Microbiological analysis established that the manure was enriched by microflora generally and, more specifically, by ammonifiers expediting decomposition of organic matter. The results of this experiment were substantiated by those (Table 9) conducted in 1947 on a larger scale with lignite from the Aleksandriya deposit.

Table 9 - Composition of Manure Upon Composting with Lignite

(in Percent of Absolutely Dry Matter)

Experiment Variants	7/4/47				23/6/47	7/12/47			
	Ammonium Nitrogen per Kg (mg)	Total Amount %			Ammonium Nitrogen per Kg (mg)	Ammonium Nitrogen per Kg (mg)	Total Amount %		
		N	P_2O_5	K_2O			N	P_2O_5	K_2O
Control	1,920	1,768	0.957	1.99	232.8	50.0	2.19	0.78	1.98
Lignite (5 g)	"	"	"	"	410.5	59.0	2.34	1.092	1.96
Lignite (10 g)	"	"	"	"	1,896.0	60.3	2.55	0.956	2.05
Lignite (20 gram)	"	"	"	"	1,952.0	66.0	2.63	1.10	-

The results of the experiments show that high ash content lignite, an inexpensive and readily procurable material, preserves manure during storage, promotes retention of escaping ammonia, and enriches manure by increasing the nutrients per unit of dry matter. The main difficulty connected with manure storage, especially by the aerobic method, is the great loss of the most valuable nitrogenous nutrients. The aerobic method of storage eliminates the need for excessive hauling of water, since water composes not more than 20-25 percent of the total mass of manure. With the anaerobic method, on the other hand, manure contains about 75 percent water on the average.

It is clear from the data given that lignite permits the preservation of all nutrients in manure as well as the enrichment of its composition, which are important factors in aerobic storage. Table 10 illustrates these factors.

Table 10 - Composition of Manure, Composted with Lignite and Mineral Fertilizers (in Percent of Absolutely Dry Mass)

Experiment Variants	25/4/48				25/8/48			
	Ammonium Nitrogen	Total Amount N	P_2O_5	K_2O	Ammonium Nitrogen	N	P_2O_5	K_2O
Control	0.1904	1.825	0.871	1.693	0.1249	1.074	1.066	1.396
NPK	0.3516	2.488	1.606	2.186	0.2435	1.429	1.612	1.650
PK	0.1860	1.820	1.613	2.144	0.2316	1.389	1.610	1.473
NPK and lignite	0.3422	2.410	1.685	2.168	0.4292	1.780	1.637	1.528
PK and lignite	0.1830	1.847	1.567	2.220	0.2427	1.754	1.669	1.652
Lignite	0.2660	1.866	0.863	1.820	0.1935	1.120	1.134	1.566

As we see, composting of manure with lignite and mineral fertilizers considerably increases the physiological activity of manure as a fertilizer. In a series of experiments, the results of which were published in Agrobiologiya, No 6, 1948, a high level of effectiveness was established in timely composting of manure with mineral fertilizers.

This method, as contrasted to the customary method of using organic and mineral fertilizers jointly, increases the sugar beet harvest 25-30 centners per hectare and the amount of sugar obtained 7-11 centners per hectare.

Members of this institute together with P. Z. Lisoval carried out an experiment in composting manure with mineral fertilizers and lignite under production conditions. Layers of manure were interspersed with quantities of mineral fertilizers and lignite. Then, the manure was applied in sugar beet planting.

The harvest of beets on the control part of the field was 291 centners per hectare. Application of manure increased the harvest 102 centners per hectare, application of mineral fertilizer alone (at a rate of 45-60 kilograms per hectare) increased it 77.5 centners per hectare. Application of lignite by itself (10 centners, the same amount used for composting with manure) increased the harvest 43 centners per hectare, while application of composted lignite and manure increased it 121 centners per hectare. Application of manure together with mineral fertilizer without composting caused an increase of 147 centners per hectare in the harvest, while application of manure composted with mineral fertilizer produced an increase of 165 centners per hectare. Application of lignite composted with mineral fertilizer raised the harvest 185 centners per hectare, while application of lignite and mineral fertilizer without composting raised it only 169 centners per hectare.

It can be stated with complete confidence that the improved quality of the manure and its increased physiological effectiveness by virtue of microbiological processes, which take place most favorably when manure is composted with lignite and mineral fertilizer, are the main reasons for the sharply increased harvest.

On the basis of all that has been pointed out above, it is

possible to make the following summations:

1. The high sorptive qualities of lignite make it a useful agent for improving the physiological feeding regimen of agricultural plants.

2. The positive effect of lignite on the plant feeding process was established when sugar beet plants were grown in water containing uniform feeding mixtures with and without lignite sorbents for periods of 48 hours and 30 days.

3. Under the influence of sorbents, the biochemical and physiological sugar beet development processes (assimilation surface, chlorophyll accumulation, oxidation-reduction enzymatic activity, and respiration intensity) improved noticeably.

4. The sugar beet harvest increase upon application of mineral fertilizers in numerous experiments amounted to 16-43 centners per hectare, but upon application of the same fertilizers together with 30 kilograms of lignite per hectare it amounted to 31-70 centners per hectare. Beet sugar content increased an average of 0.2-1 percent under the influence of lignite.

5. The high ash content lignites of Yurkovka and Aleksandriya deposits are good sorbents, increasing the effectiveness not only of mineral fertilizers, but also of manure, and reducing or eliminating the retardation of plant growth during the early growing period resulting from the application of mineral fertilizers.

6. During aerobic storage of manure, lignite promoted its enrichment with nitrogen, phosphorus, and potassium and favored the growth of microflora and ammonifiers. The same action was observed when manure was composted with mineral fertilizers and sorbents.

The best compost was shown to be formed by a ratio of 10 centners of lignite to 20-30 tons of manure ~~to the~~ per hectare.

7. Joint application of lignite, manure, and mineral fertilizer in the form of compost increased the sugar beet harvest 26 centners per hectare and the amount of sugar 8-9 centners per hectare. A subsequent effect was an increase of the oats harvest by 3.2 centners per hectare.

8. Lignite is an inexpensive and highly effective means for composting manure and is recommended for wide application on kolkhozes and sovkhozes of the USSR.

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