UNIVERSITY OF MINNESOTA

Agricultural Experiment Station

BULLETIN No. 47.

CHEMICAL DIVISION.

JULY, 1896.

FLAX.—THE DRAFT OF FLAX ON THE SOIL, AND THE COMPOSITION OF FLAX SOILS.
THE FEEDING VALUE OF FLAX PRODUCTS.

UNIVERSITY FARM, ST. ANTHONY PARK, RAMSEY COUNTY, MINNESOTA.

EAGLE PRINTING CO., PRINTERS, DELANO.

University of Minnesota.

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THE DRAFT OF FLAX ON THE SOIL.

HARRY SNYDER.

OUTLINE. During the last few years flax has become one of the leading crops of the state; in fact more flax is raised in Minnesota than in any other state. It is generally considered that flax removes a large amount of fertility from the soil and is hard upon the land on that account. Inasmuch as the growing of flax seems to be on the increase it was thought best to make investigations regarding the amount of fertility removed by this crop, and also to learn how this amount of fertility compares with that removed in other crops.

The draft of tne flax crop upon the soil was determined at three places: At the Experiment Station, St. Anthony Park; at the Cotean farm, Lyon County; and at the farm of Mr. Currie, at Euclid, Polk County. Plants were also analyzed at different stages of growth to determine the approximate time in the plant's development when each element was taken from the soil. Different types of both Minnesota and imported seeds were analyzed as well as samples of the straw and flax when cut and cured as hay. The amount of oil yielded by different samples of seeds was also determined. The composition, digestibility and food value of the linseed meal, and the loss of fertility in oil making, as well as a study of the soils best suited to flax culture, are topics which have received attention in the work reported in this bulletin.

Previous Flax Investigations at the Station.—In December, 1890, Dr. Lugger published a bulletin on flax culture, the supply of which is now exhausted. In this bulletin many of the peculiarities of the crop are discussed. At the time this bulletin was published there were a number of difficulties being experienced with the flax crop; attempts were made to raise flax too frequently upon the same land. The cause of the failure of the flax crop was found to be due to the old flax straw left in the soil from previous flax crops. Experiments plainly showed that the one or two preceding flax crops had not exhausted the fertility of the soil, because when the elements which had been removed in the crops were returned to the soil, the flax still refused to respond. The trouble, as previously stated, was found to be due entirely to the old flax straw. To avoid this difficulty Dr. Lugger recommended systems of rotations in which no two flax crops should follow each other on the same land for intervals of at least five, and preferably seven, years, so as to allow sufficient time for the old flax straw and crop residues to completely decompose.

The amount of Fertility Removed in the Flax Crop.—The amount of fertility removed by a flax crop from an acre of land was found to be small. Many of the grain crops remove more fertility than an average flax crop. An acre of flax producing fifteen bushels of seeds and 1,800 pounds of straw, will remove about eighty-seven pounds of mineral matter and fifty-four pounds of nitrogen from the soil. The mineral matter and nitrogen are distributed in the grain and straw in about the following amounts:

TABLE I.—Pounds of Plant Food Removed by an Acre of Flax.

	In 900 lbs. Flax Seed	In 1800 lbs. Flax Straw	TOTAL.
Potash (K_2O)	8.5	18.7	27.2
Soda (Na_2O)	.4	2.4	2.8
Lime (CaO)	3.2	13.5	16.7
Magnesia (MgO)	5.3	6.4	11.7
Iron Oxid (Fe_2O_3)	.4	1.8	2.2
Phosphoric Anhydrid (P_2O_5)	14.6	3.4	18.0
Sulphuric Anhydrid (SO_3)	.8	1.9	2.7
Silica ($Si O_2$)	.3	3.3	3.6
Undetermined	.1	2.2	2.3
Total	33.6	53.6	87.2
Total Nitrogen	39.	15.	54.

TABLE II.—Approximate Amounts of Nitrogen and Some of the Ash Elements Removed in Farm Crops from the Soil. Expressed in Pounds per Acre.

Crops	Gross Weight Lbs. per Acre	Nitrogen	Phosphoric Acid	Potash	Lime	Silica	Total Ash
Wheat, 20 bu....	1200	25.	12.5	7.	1.	1.	25.
Straw, ...	2000	10.	7.5	28.	7.	115.	185.
Total...............	....	35.	20.0	35.	8.	116.	210.
Barley, 40 bu....	1920	28.	15.	8.	1.	12.	40.
Straw....	3000	12.	5.	30.	8.	60.	176.
Total.....	....	40.	20.	38.	9.	72.	216.
Oats, 50 bu......	1600	35.	12.	10.	1.5	15.	55.
Straw....	3000	15.	6.	35.	9.5	60.	150.
Total.....	....	50.	18.	45.	11.0	75.	205.
Corn, 65 bu......	2200	40.	18.	15.	1.	1.	40.
Stalks	3000	35.	2.	45.	11.	89.	160.
Total..............	....	75.	20.	60.	12.	90.	200.
Peas, 30 bu......	1800	....	18.	22.	4.	1.	64.
Straw...............	3500	....	7.	38.	71.	9.	176.
Total...............	....	....	25.	60.	75.	10.	240.
Mangels, 10 tons	20000	75.	35.	150.	30.	10.	350.
Meadow Hay, 1 ton	2000	30.	20.	45.	12.	50.	175
Red Clover Hay 2 tons	4000	....	28.	66.	75.	15.	250.
Potatoes, 150 bu.	9000	40.	20.	75.	25.	4.	125.
Flax, 15 bu......	900	39.	15.	19.	3.	5.	34.
Straw...............	1800	15.	3.	8.	13.	3.	53.
Total.	....	54.	18.	27.	16.	3.5	87.

Fertility Removed in Flax Crop Compared with other Crops.—Table II. has been prepared so as to compare the fertility removed by a flax crop with the amounts of the principal elements removed in other farm crops. All of the figures in this table have been calculated from analyses of Minnesota products made in our chemical laboratory.

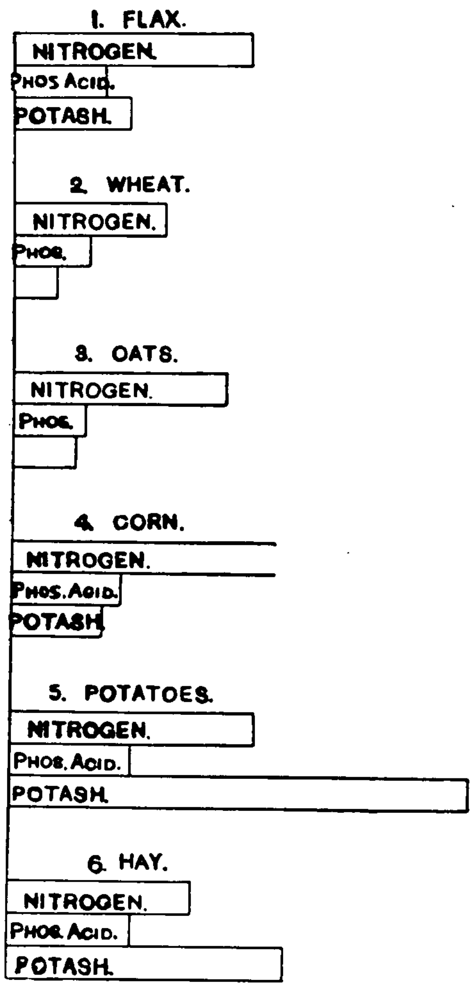

Figure No. 1.—Showing the relative amount of the three principal elements of Fertility removed by an average acre of Flax and of other Crops.

In comparing the amount of fertility removed in the flax crop with that removed in other farm crops as given in table II., it should be remembered that the figures given represent the total amounts of the several elements removed, and that they do not express the *ease* or *difficulty* with which the separate crops are capable of getting their food elements from the soil. The different farm crops have different feeding capacities the same as have the different kinds of farm animals. Flax belongs to the dainty or weak feeding crops. It does not take a great deal of fertility from the soil, but the small amount which it does take must be in the very best and most available forms. Mangels on the other hand belong to the gross feeding farm crops; mangels, and in fact nearly all farm crops, are capable of taking their food in cruder forms and with far less difficulty than is flax. A heavy crop of mangels will remove five times more potash, twice as much phosphoric acid and nearly one and a half times more nitrogen than a crop of flax.

A corn crop removes a-half more nitrogen, twice as much potash, and about the same amount of phosphoric acid, while a good oat crop removes practically the same amount of nitrogen and phosphoric acid and about three-quarters more potash than a flax crop. Compared with wheat, flax removes less phosphoric acid and potash per acre, and about a half more nitrogen. Potatoes remove about the same amount of phosphoric acid, about one third less nitrogen, and nearly three times more potash per acre than an average flax crop.

In flax growing the heaviest draft falls upon the nitrogen, but when clover is grown this loss of nitrogen is not a serious matter, because one fair crop of clover will more than return all of the nitrogen removed in two crops of flax. (Minn. Bul. 34, The Chemical Development and Value of Red Clover.)

From some of our analyses of weeds, it appears that in many cases there is more actual fertility lost in the weeds along with the flax than in the flax itself. The great difficulty with the flax crop is due more to getting the soil out of condition than to the removal of fertility. It is safe to say that with the proper rotation of crops there is no great danger of soil exhaustion from flax raising.

Composition of Flax Seed.—Flax seed contains from twenty-five to forty per cent of fat or oil. There is on an average about thirty-five per cent of oil present. The average per cent of total nitrogenous matter (crude protein) is about 27.00. The seeds contain about seven per cent of crude fibre (woody material.) The amount of ash is small, amounting in all to about 3.75 per cent of the total weight of the seed. When ripe the flax seed contains a small amount of water, the average being about seven per cent. The remaining twenty per cent is composed of non-nitrogenous constituents, flax seed mucilage being one of the compounds. This material produces the mucilagenous properties when either the seeds or the oil meal product are soaked in water.

Composition of Flax Seed Ash.—The ash of the flax seed is composed largely of phosphoric acid, potash, lime, and magnesia. A little over a quarter of the ash is potash, less than a tenth is lime, nearly a sixth is magnesia, while the phosphoric acid amounts to forty-three per cent of the total ash. The amount of the soda, iron, sulphuric acid, and silica, as in all seeds, is small. As a general rule the better grades of seeds contain the larger amounts of phosphoric acid. In table III. the composition of the ash of flax seeds from Minnesota and from imported varieties, is given. The imported seeds were furnished by Dr. Lugger. Sample 2215 was pale yellow in color, the seeds were more elongated and not so plump as ordinary flax seeds. Sample 2216 is Winter flax. (These seeds are sown in the fall, like winter wheat.) Note the high per cent of lime in the Winter flax. These seeds were dark brown in color and of good quality. There is one peculiar feature about the ash in the flax seed; the seed contains a larger per cent of ash than the straw. Usually the seeds of agricultural plants contain less, and not more, ash than the straw. In corn, wheat, oats, rye and all grains the per cent of ash is usually two to four times more in the straw and stalks than it is in the seeds. While flax seed contains on the average about 3.75 per cent ash, the straw contains about 3 per cent or less of ash.

Composition of Home Grown and Imported Seeds.—There is not a great deal of difference in the composition of the ash of imported and home grown samples. The imported seeds are no richer in their stored-up food for the young plants than are our own seeds; if anything the Minnesota seeds are a little richer in phosphoric acid while the imported seeds are richer in potash. The difference between the imported and the home grown seeds, if indeed there is any difference whatever, is more a physiological difference, such as the vitality of the germ, etc., rather than a difference in the chemical compositon of the seeds. The home-grown seeds were richer in both oil and total nitrogen—particularly so in total nitrogen. The total nitrogenous matter in the foreign seeds amounted to 23.12 per cent, while in the home-grown seeds the amount was 27.08 per cent. Instead of the extensive importation of foreign-grown seeds, an exchange and improvement of our home-grown seeds should first be tried.

Difficulties in the Analysis of Flax Straw and Seeds.—The chemical analysis of the flax straw as well as analysis of the seeds was more troublesome than is usually the case with farm products. On account of the peculiar nature of the flax straw, the grinding of the samples was impossible. The straw, instead of grinding, would roll up into a rope-like mass. For the ash analysis a large quantity was reduced to crude ash, the crude ash was then mixed and the analysis completed in the usual way. The nitrogen was determined by treating a large quantity of the material with sulphuric acid, and then completing the determination with a fractional portion of the solution. It is believed that in this way greater accuracy was secured.

Composition of the Flax Straw Ash.—The straw is more variable in composition than the seeds. A high content of potash, lime, and magnesia is characteristic of all of the samples of flax straw. Thus far in the work on the analysis of flax straw, the strongest and best quality of fibers has contained the largest per cent of lime. There is but little difierence in the composition of coarse and fine straw from the same source, there being a greater difference between flax samples grown in different localities and on different kinds of soil. No attempts were made to determine the special commercial qualities of the different samples of fiber, as this work was planned more to study flax as a farm crop.

Samples 2222, 2226 and 2227 were furnished by the Minnesota Flax Co., of Northfield, Minn. Samples 2223, 2230, and 2231, were obtained from Dr. A. W. Thornton, of West Ferndale, Wash., special flax agent of the U. S. Dept. of Agriculture. Sample 2229 was made up from five smaller samples grown on different plots at the University Farm. This sample is a fair average of the straw where the flax is grown more particularly for the seed.

The analysis of the retted flax straw, number 2231, shows that the retting process has resulted in washing out over two-thirds of the ash of the straw. The potash, soda, and phosphoric acid have been removed by the retting to a greater extent than have the lime and silica.

In order to produce good seed for seed purposes Dr. Lugger recommends in Bulletin No. 13, this station, that the best quality of seed that can be obtained should be seeded on good rich soil free from weed seed. Thin seeding, 20 quarts per acre, is recommended so as to allow the plants perfect freedom to branch, and produce complete capsules and seeds. The seeds must ripen well after cutting, the flax must be well dried in the air so as to prevent injury from moisture. The thrashing for seed should be done at a time when the air is dry. "A good seed should be moderately thick, short, and equal, should have a glossy yellowish-brown or greenish-yellow color, should be smooth and soft to the touch, and should taste sweetish." There is no reason why every farmer should not raise his own flax seed, rather than depend entirely upon imported seeds.

TABLE III.—Composition of the Ash of Flax Seed.

	Weight in grams per 100 seeds.	Percent of pure ash.	In one hundred parts of the pure ash. Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron F_2O_3	Phos. acid P_2O_5	Sulphuric SO_3	Silica SiO_2	Laboratory number
Imported Flax Seeds—											
Konig's	.3973	3.85	30.72	1.22	7.40	17.82	.49	38.70	2.40	.51	2212
Weissblickender	.5048	3.07	28.90	1.34	9.91	15.85	.95	40.11	2.00	1.61	2213
Riga	.4259	3.51	28.32	1.12	9.84	18.17	.30	40.59	1.70	.51	2214
Gelbsamiger	.4401	3.61	28.31	.82	10.30	17.3	1.26	39.70	2.15	.53	2215
Winter Flax	.5417	3.39	22.40	1.68	15.82	17.21	.91		2.13	.96	2216
Usital	.3882	3.42	28.21	1.30	9.49	15.84	1.62	41.38	1.79	.77	2217
Average	.4497	3.47	27.81	1.25	10.45	17.09	.92	40.09	2.03	.81	
Minnesota and Other Seeds—											
Minnesota Experiment Station Flax	.4023	3.54	21.13	2.12	10.35	15.51	1.21	46.21	2.21	1.10	2218
Minnesota Experiment Station Flax	.3719	3.92	26.22	.50	10.39	16.09	.87	40.46	2.16	1.42	2219
Minnesota Experiment Station Flax	.3400	3.98	26.05	1.38	9.45	15.87	.75	42.95	2.33	.83	2220
Minnesota Experiment Station Flax	.3286	3.88	25.22	.50	8.78	15.90	1.12	44.46	2.48	.77	2221
Minnesota Flax Company	.4212	3.83	25.35	2.01	9.90	15.95	1.02	43.07	2.05	.47	2222
Puget Sound Flax	.4269	3.25	27.66	.83	8.18	15.87	1.70	41.72	2.15	.68	2223
Average	.3818	3.73	25.27	1.22	9.15	15.86	1.11	43.14	2.23	.88	

TABLE IV.—Composition of the Ash of Flax Straw, and the Entire Plant.

	Weight in grams per 100 straws.	Percent of pure ash.	In one hundred parts of the pure ash.								Laboratory number
			Potash K_2O	Soda Na_2O	Lime CaO	Magnesia MgO	Iron Fe_2O_3	Phos. acid P_2O_5	Sulphuric SO_3	Silica SiO_2	
Flax Straw—											
Minnesota Flax Co., coarse	.56	2.86	32.49	5.10	26.66	13.01	3.65	4.75	4.59	8.03	2227
Minnesota Flax Co., fine	.28	2.85	31.80	5.55	26.33	12.98	3.67	4.80	3.12	7.31	2226
Minnesota Experiment Station, medium	....	2.88	37.93	2.46	21.45	13.12	3.68	9.19	4.63	5.77	2228
Minnesota Experiment Station, compound	.44	3.40	37.22	4.55	23.40	12.34	2.85	6.60	3.42	4.66	2229
Puget Sound, fine, not retted	.30	3.02	....	....	20.60	7.80	3.02	5.43	1.93	4.47	2230
Puget Sound, fine, retted	.20	.98	8.14	....	32.75	....	2.06	2.76	1.89	27.85	2231
Average (2231 omitted)	....	2.98	34.86	4.41	23.69	11.85	3.37	6.15	3.54	6.05	....
Flax, Entire Plant—											
Before bloom, Experiment Station	....	6.87	37.14	5.52	20.39	10.38	2.98	9.56	4.01	7.21	2224
Before bloom, Lyon County	....	7.07	32.57	....	20.21	10.06	3.38	10.66	....	5.50	2135
Before bloom, Polk County	....	5.34	35.10	4.80	22.46	15.23	2.00	8.93	4.80	4.45	2225
Seeds well formed, Lyon County	....	4.89	33.32	....	21.55	13.06	....	19.38	5.32	....	2136
When ripe, Experiment Station	....	3.20	32.01	....	20.85	12.55	....	20.10	3.25	....	2133
When ripe, Lyon County	....	3.43	31.15	....	22.05	....	....	19.92	....	....	2137
When ripe, Polk County	....	3.35	33.24	....	19.87	....	....	20.12	....	....	2138

Rate of Absorption of the Food Elements by Flax.—At different times during the growth of the crop a definite area of flax was cut and the plants counted, weighed, dried and submitted to chemical analysis. From the weight, and composition of the samples were determined the amounts of the principal plant food elements present at the different stages of growth.

The first sample was taken just before the flax had produced any flowers. The second set of samples was taken in full bloom. When the seeds were well formed samples were taken again, the last samples being taken when the flax was fully ripe. Duplicate samples were taken at each of the three places previously mentioned. The results are all reduced to a uniform basis of 350 plants per square yard. It is believed that in this way greater accuracy is secured, because the results are then based upon a definite number of plants from a known area.

The analyses and weighings have all been reduced to a unit area. The largest amount of potash, by weight, present during growth is taken as 100. This amount was found to be at the time the seeds were well formed. At the time of full bloom 90 per cent of the potash was found to be present in the plant, hence the amount of potash present at the time of bloom is entered as 90 in Table V.

TABLE V.—Rate of Absorption of the Food Elements from the Soil by Flax and the Formation of Organic Matter.

	Total mineral matter	Total potash	Total phosphoric acid	Total lime	Total nitrogen	Total organic matter
Before bloom	60	55	35	32	55	40
In full bloom	88	90	70	64	80	75
Seeds well formed	100	100	98	98	100	95
Ripe	98	95	100	100	98	100

Before the time of flowering, the flax plant has devoted its energies to the absorption of mineral matter and nitrogen from the soil, rather than to the formation of vegetable (organic) matter. At the time forty per cent of the vegetable matter is formed, sixty per cent of the total mineral matter and fifty-five per cent of the nitrogen required by the mature plants have been taken from the soil. At the period of full bloom eighty-eight per cent of the mineral matter and eighty per cent of the nitrogen have been taken up by the crop. The period of ripening is mainly a period of rearranging the plant food elements already assimilated, rather than the addition of new materials. In the last period a slight decline of potash is noticeable, this is undoubtedly due to the retrograde movement of the potash, at maturity, from the plant to the soil, such as was noticed in the growth of wheat, and clover, in former reports from this station.

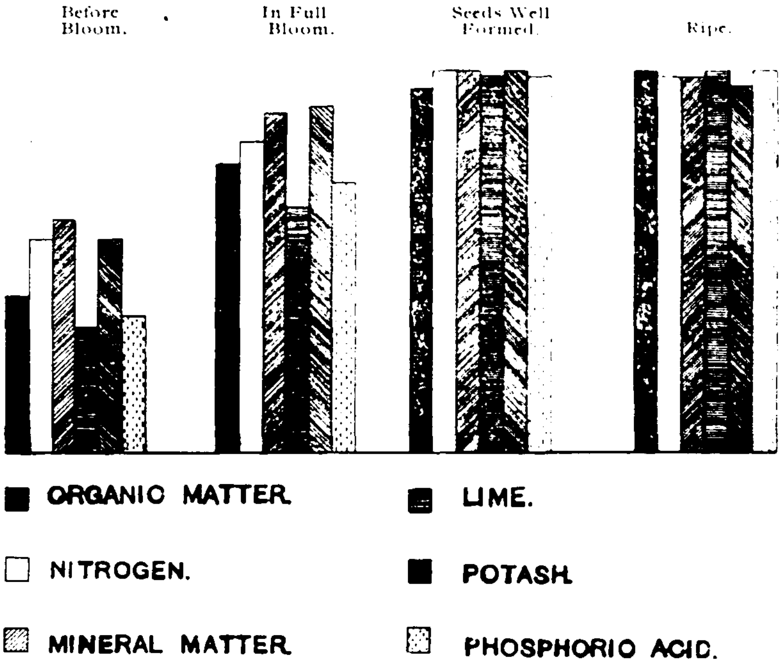

Figure 2, illustrating the formation of vegetable matter and the rate of the assimilation of the principal food elements from the soil.

These figures are particularly important inasmuch as they show the comparatively short period which the flax plant has at its disposal for obtaining food from the soil. Ordinarily the crop matures from 65 to 70 days after seeding.

From seventy to ninety per cent of the principal elements of plant food are taken from the soil during the first forty-five or fifty days. In order to furnish this plant food in so short a time the soil must be in the very best condition as to fertility. The flax crop is placed at a disadvantage in obtaining its food. As previously stated, it is not a strong feeding crop to begin with, and then all of the food which it does require must be supplied in a very short time. Other crops, as corn and small grains which have a longer growing period, are capable of thriving and producing good yields where a flax crop often fails, because the corn and grain have a a greater power of obtaining food from the soil, and they also have a longer time to obtain it. Applications of raw bulky stable manure are not suitable for flax, because the flax plant can not take its food in such crude forms. In order to get the best results, the manure must be applied to the preceding crop, particularly a corn crop. It takes nearly a year for raw manure to get thoroughly rotted and mixed with the soil before it is in condition suitable for food for the flax crop.

Following a light sod crop, or on new breaking, if the sod is not too heavy, the flax crop is placed in a position to obtain a liberal supply of plant food. When the sod is heavy, particularly on a clay soil, the vegetable matter does not become sufficiently decomposed the first year so as to liberate the plant food which it contains. In such a case the flax does not thrive as well the first year but will do better the next year and following a corn crop.

Flax Roots.—The roots of the flax crop have a tendency to extend perpendicularly into the soil, rather than to extend laterally and to cover the surface of the ground. The soil, after a flax crop has been removed, is very mellow. Farmers frequently speak of flax as having rotted the soil. This is because the soil has been only partially covered by the flax roots and the roots extending perpendicularly, which has favored the pulverizing and decomposition of the soil. The flax plant has not a very extended root system. The roots are smooth and quite free from root hair. This is undoubtedly one reason why the flax plant has greater difficulty in obtaining its food.

Composition of Flax Soils.—Flax thrives best in a soil that contains from 15 to 20 per cent of available water. In order to carry this amount of water the soil should have at least 12 per cent of fine clay. Any soil that produces a good corn crop is capable of fulfilling the requirements of a flax crop, because a good corn soil has the same mechanical structure as a good flax soil. But this soil must be in a higher state of fertility for the flax crop than for the corn crop.

The best flax soils are those that contain about 25 per cent of medium sand (Fig. III. *A*), 20 to 25 per cent of fine and very fine sand (*B*), 35 to 40 per cent of silt (*C*), and about 12 per cent of clay. A soil of this kind, known as a loam soil, is put together in such a way so as not to offer too great a resistance to the development of the flax roots, and at the same time the soil is capable of holding and supplying the proper amount of water for the growing crop.

The flax crop is injured by either a deficient or an excessive amount of water in the soil. When flax is grown on soils that are not well drained the young plants will turn yellow, make a sickly growth and die. Extremely sandy or heavy clay soils are unsuited to flax. In sandy soils there is not a sufficient amount of water, and frequently not enough plant food present. In the heavy clay soils the flax roots can not readily penetrate to their usual depth for development. The silt particles in the flax soil, being between the sand and clay in size and character, impart permeability to the soil without the too open character of a sandy soil or the close texture of a heavy clay.

In figure, No. 3, the relative proportional amounts of sand, silt, and clay are given for a good flax soil. It represents the soil particles magnified 325 times. These small particles of the soil exhibit all of the forms and peculiarities of the larger particles from which they have been formed. They are irregular, and not spherical, like shot or peas, as they are frequently represented.

Figure 3. A good flax soil magnified 325 times. *A*. Medium sand. *B*. Fine sand. *C*. Silt. The clay is the uncolored space between the particles.

Flax soils should be well supplied with humus (decayed animal and vegetable matter.) The best flax soils which have been analyzed show usually .2 of a per cent or more of nitrogen. This nitrogen must be in the most available forms, otherwise the flax crop will be unable to obtain its necessary supply. Fall plowing rather than late spring plowing is better for flax because the nitrogen is brought under better condition for crop use. Late spring plowing brings the raw nitrogen to the surface and buries the available nitrogen, which is disastrous to the germinating and starting of the flax crop in the spring.

The management of soils for flax so as to prevent the spread of weeds, and to determine the best position of flax in a rotation, the amount of seed to use, as well as flax machinery, etc., are all points which are being studied by Professor Hays, of the Agricultural Division, and will be presented in future bulletins from the Station.

Flax Hay and Flax Straw.—The flax crop is valuable not only as an oil and fiber crop but it is also valuable as a fodder crop. Flax hay is made by cutting and curing as hay the flax when it is in early bloom before the oil develops and the fiber becomes tough and woody. When cut at just the right stage it makes an excellent fodder. A sample of flax hay furnished by Mr. Currie, who has had good results from the feeding of flax hay, showed the following composition:

TABLE VI.—Composition of Flax Hay and Straw Compared with Other Crops.

	Water	Ash	Fat	Crude Protein	Crude Fiber	Nitrogen free extract
Flax hay	14.30	5.50	3.1	15.00	32.00	30.10
Clover hay	12 25	6.78	2.97	12.67	24.05	41.08
Timothy hay	12.32	5.11	2.38	6.07	30.62	43.50
Flax straw	4.86	3.18	.89	5.02	48.00	38.05
Wheat straw	7.41	9.22	.96	3.25	40.89	38.27
Oat straw	8.36	9.00	1.40	4.06	38.07	41.11

[NOTE.—The crude protein is the muscle forming and muscle replenishing nutrient while the fat, fiber, and nitrogen free extract are the heat producers.]

For the purposes of comparison, the composition of clover hay, timothy hay, and of wheat straw and oat straw are also given. The flax hay contains 15 per cent of protein which is more than in clover hay and 32 per cent of fiber. Having been cut before the oil formation the flax hay contains but little fat. This is an advantage because it makes the flax hay more concentrated in protein which is the most expensive nutrient in foods. The flax hay is a very promising fodder, and wherever clover is grown with difficulty flax hay should be given a trial by all who are interested in adding another very valuable fodder to the list of our feeding stuffs. The flax straw compares very favorably in composition with the wheat and oat straws; it is richer in protein than either wheat or oat straws. As ordinarily used flax straw contains a small proportion of seeds which have not been removed in thrashing; this adds to the feeding value of the straw. Flax straw also contains a larger per cent of fiber, which decreases its value as a fodder. The peculiarities of the flax straw require that it shall be fed with caution. The fiber absorbs water and then expands. When taken into the digestive tract the fiber may expand and occupy nearly twice the space of the original straw. The flax straw should be fed in small amounts, and animals should not be allowed to eat too much of it at one time.

The amount of *chemical* fiber given in the table is not to be confused with the *commercial* fiber. Dr. Thornton informs me that as a general rule 10 pounds of flax straw will produce about one pound of finished flax fiber of the best grades. In this work our equipment was not sufficiently extensive to allow of the investigation of the flax as a fiber crop.

Yield of Oil per acre of Flax.—A yield of fifteen bushels of flax will produce 315 pounds of oil—not all of this oil, as will be noted later, is removed in oil making by pressure or what is known as the old process. A yield of ten bushels of flax produces 210 lbs. of oil. In a bushel of well cleaned flax seed there is on the average about 21 pounds of oil. There may be as high as twenty-four lbs. or as low as seventeen pounds of oil. There are no direct statistics giving the amount of oil obtained from a bushel of flax by the pressure or by the chemical processes. Chemical analysis shows the flax seed to contain 35 per cent of oil. The ground flax seed cake, after the oil has been pressed out, contains from 7 to 8.50 per cent of oil. From these two facts we should expect to obtain from eighteen to nineteen pounds of crude oil from a bushel of flax, and about 40 pounds of oil meal allowing a pound for shrinkage, due to moisture and mechanical losses. At this rate the acre of flax yielding fifteen bushels would produce 270 pounds of crude oil and over 600 lbs. of oil meal. During the past year the oil meal has been selling for about $15 per ton, making the oil meal worth $4.50 per acre. Flax seed oil has a specific gravity of .935 at 60 Fr. which makes the yield of fifteen bushels of flax seed equivalent to nearly 35 gals. of crude oil. The oil yields, as well as the flax seed cake yields for 12, 10 or 8 bushels per acre can readily be calculated from the figures given.

The flax crop should be paid for on the basis of the fat present in the seed the same as milk is paid for at the creamery on the basis of the fat present in the milk, because there is proportionally as great a variation in the oil content of flax seeds as in the fat content of different milks.

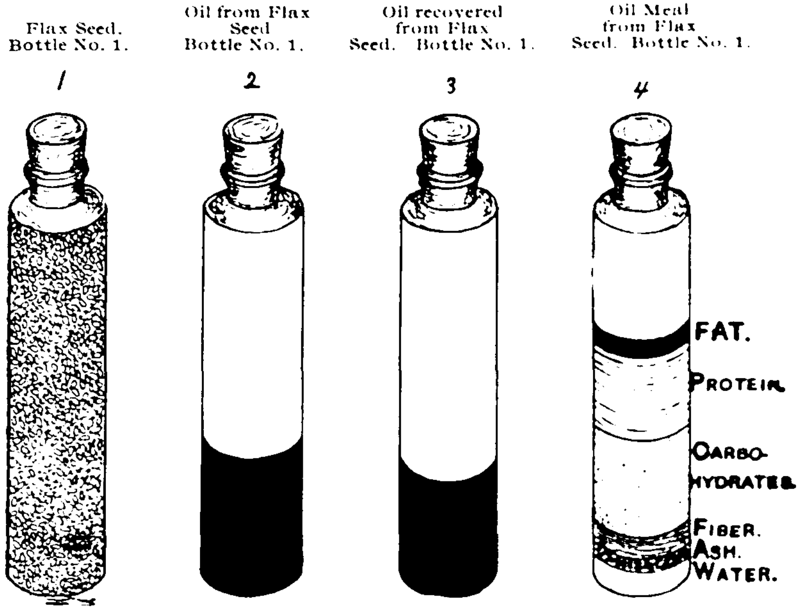

Figure 4. The oil and the oil meal obtained from a bottle of flax seed

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COMPOSITION AND DIGESTIBILITY OF LINSEED MEAL.

The flax seed is valuable not only for its oil, but the product known as oil meal which is left after the oil has been removed is very valuable for feeding animals. Inasmuch as the value of any food depends upon the three factors: composition, digestibility, and palatability it will be necessary to consider these three points in regard to the linseed meal.

The composition of the linseed meal varies according to the thoroughness with which the oil has been removed from the seeds. When the oil is extracted with chemicals, as carbon bisulphide or naptha, the new-process oil meal is produced in which there is only a very little fat left. When the fat is extracted with pressure, the oil meal, known as the old-process oil meal, contains from 7 to 8 per cent or so of fat. Inasmuch as most of the oil meal that is fed in this state is old-process oil meal, this kind was made use of in the digestion experiments.

The average composition of twelve samples of oil meal used in various feeding experiments at the station showed that about seven per cent of fat or oil was the usual amount present. In some cases the fat left in the meal was as high as nine per cent, and in one case it was as low as five per cent. With the hot extraction, pressure process, the amount of fat left in the oil meal is quite uniform. When cold pressure is used, then the fat left in the product is variable.

The average amount of protein in the oil meal is 32.50 per cent. It is this constituent or nutrient which gives the high value to the oil meal. The oil meal is a very concentrated protein food. It is valuable because it furnishes such a large amount of material for replenishing the waste tissues of the body, the construction of muscles, and the stimulation of milk production. Nearly a third of the weight of the oil meal is this vital nutrient known as protein. In the making of oil practically all of the protein of the flax seed is recovered in the oil meal. In fact the oil meal is richer in protein than the original oil seeds, because the forty pounds of oil meal contains all of the protein in the original sixty pounds or bushel of flax seed.

The amount of fiber in linseed meal ranges from 7.20 to 9.7 per cent, 8.5 per cent being about the average, which is larger than the fiber in wheat bran, but is not quite as large as the amount in shorts. As a rule there is less than ten per cent of water in linseed meal. The amount of ash is about 5.25 per cent, while the amount of carbohydrate compounds ranges from 40 to 45 per cent.

In order to determine the digestibility of the oil meal two pigs weighing about 170 pounds each were fed a pound and a half of oil meal and nine pounds of raw potatoes a day. The digestibility of the same potatoes had previously been determined in earlier experiments. The oil meal was mixed with a little water, and then the sliced potatoes were mixed with the moistened oil meal. When fed dry in such large quantities the pigs refused to eat the oil meal. In order to induce the pigs to eat a full ration it was found necessary to add four ounces of shorts per day to the ration.

Two separate tests of the digestibility of the ration were made with each pig. The food consumed was weighed and analyzed. The manure was also carefully collected, weighed and analyzed. The amount of the separate food constituents or nutrients present in the manure was subtracted from the corresponding amount of nutrients present in the food consumed. The difference between the food nutrients consumed and the indigestible food nutrients of the manure gives the digestible nutrients. This amount is expressed in percentage of the total food nutrients consumed, as protein 86 per cent digestible, meaning that 86 per cent of the total protein in the linseed meal was digested and made use of by the pigs, while 14 was given off as indigestible products in the manure.

The digestibility of the several nutrients of linseed meal for each trial, as well as the general average, will be found in table VII.

TABLE VII.—Digestibility of Linseed Meal.

	First Trial		Second Trial		Average four Trials
	Prince	Duke	Prince	Duke	
Total dry meal	77.	79.	76.	78.	77.5
Ash	10.	10.	12.	8.	10.
Crude protein	83.	90.	84.	88.	86.
Ether extract (Fat)	80.	80.	78.	82.	80.
Crude fiber	12.	10.	14.	12.	12.
Nitrogen free extract	82.	85.	86.	87.	85.

These results show the linseed meal to be a highly digestible food. Compared with corn meal it is found to be slightly less digestible. Compared with wheat, barley, shorts or bran, the oil meal is found to be equally as digestible.

When the oil meal was fed to sheep, the Massachusetts station found that an average of 89 per cent of both fat and protein were digested, as well as 78 per cent of the nitrogen free extract and 57 per cent of the fiber. As would naturally be expected the pigs have digested less fiber and less fat. In many of our digestion experiments we have found that pigs have a poorer capacity for fiber and fat digestion than ruminants, while the power for protein digestion is nearly the same. The decrease of fiber and fat digestive power in many cases seems to be compensated for by an increased capacity for carbohydrate digestion.

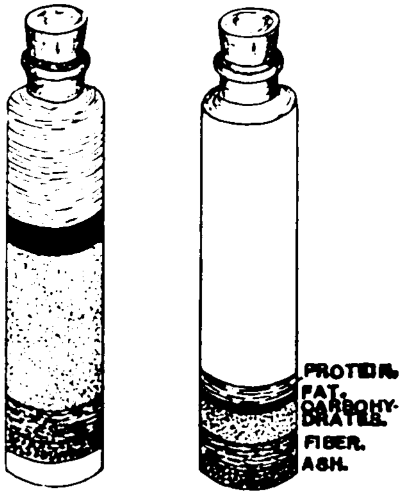

Figure 5. Showing digestibility of linseed meal. Bottle No. 1 is filled with linseed meal. Bottle No. 2 shows the relative amounts of indigestible nutrients.

THE VALUE OF MANURE FROM ANIMALS FED ON OIL MEAL.

Oil meal produces a small quantity of very concentrated manure. The oil meal and potatoes, when fed in the digestion experiments at the rate of $1\frac{1}{4}$ pounds oil meal and nine pounds potatoes per day produced two pounds of manure. The two pounds of manure contained about a pound and a half of water and half a pound of dry matter. The six pounds of urine and 2 pounds of manure produced per day by the pig weighing 175 lbs. contained .09 pounds of nitrogen while the food contained .10 of a pound of nitrogen. Hence the dung and the urine contained 90 per cent of the total nitrogen of the food consumed. With the proper amount of care the larger portion of this nitrogen may be returned to the land; but if the liquid manure is lost and only the solids are saved, then about one-sixth of the total nitrogen is returned to the soil, because three-quarters of the total nitrogen is in the urine, only a small amount of the nitrogen being retained in the body. Inasmuch as pig manure is usually allowed to ferment and leach before it is drawn to the fields it is safe to calculate that about one-tenth of the original nitrogen of the food is returned to the soil while 80 to 90 per cent is lost in the urine and through leaching and fermentation. These figures are not only true for the manure from oil meal but they are in general true for other products like bran and shorts.

These results from the manure of oil meal-fed animals suggest that flax raising, like wheat raising, instead of exhausting the soil of its fertility, may be made a means of keeping up the fertility of the soil by using as feed for the stock six hundred pounds of oil meal for every fifteen bushels of flax seed sold from the farm. The six hundred pounds of oil meal will contain practically all of the fertility in the fifteen bushels of flax seed sold. When flax is raised and oil meal is fed to the stock, then only oil is sold from the farm. The oil contains only a trace of the fertility of the soil. The three elements of which oil is composed—carbon, hydrogen and oxygen—are obtained from water and the carbon dioxide of the air.

The loss of fertility from the state through the wholesale exporting of oil meal is in the aggregate very large. Before the present year there was practically no oil meal fed in this state; all of the oil meal was shipped East and South and in many cases even to foreign countries. The oil meal should be fed at home, and this fertility, as well as the fertility in bran and shorts, retained in the state. Oil meal is sometimes applied as a fertilizer directly to the soil; it is better, however, to first obtain its feeding value.

COMPARATIVE FEEDING VALUE OF OIL MEAL.

When the oil meal is fed with bran, shorts, wheat screenings, or even ground corn and oats, better returns are obtained than if simply one food was fed alone. An example will illustrate this point. A dollar expended in oil meal at $14.00 per ton will purchase thirty-nine pounds of digestible protein, ten pounds of digestible fat and forty-eight pounds of digestible carbohydrates. When the dollar is expended for twenty-five cents worth of oil meal, fifty cents worth of shorts and twenty-five cents worth of wheat screenings, then a smaller amount of protein is secured—thirty-five pounds; but the dollar also procures over one hundred and twenty-five pounds more of digestible starch and sugar compounds, which makes the dollar's worth of mixed feed more valuable and better balanced than the dollar's worth of oil meal alone.

In order to compare the food value of oil meal at fourteen, fifteen and sixteen dollars per ton with the food value of other grains and milled products, table VIII. has been prepared, which gives the number of pounds of the separate nutrients and heat units in a dollar's worth of material when the prices are as stated in the table.

In purchasing fodders the preference should first be given to the protein. When there is but a slight difference in the amount of digestible protein in two foods, then purchase the one containing the larger number of heat units. By referring to the table the reader can compare one food with another. In some cases a dollar's worth of mixed feed will procure more nutrients or a better balanced feed than if just one of the foods were purchased. When the prices are different from those given in the table, the amount of each nutrient procured for a dollar can be calculated by proportion.

Incidentally the table shows the comparative feeding value of other grains and products. Oats at 12 cents per bushel will furnish practically the same amount of protein as corn at 20 cents per bushel, but the dollars worth of corn contains over fifty pounds more of carbohydrate compounds than the dollars worth of 12 cent oats. When the corn is twenty-five cents per bushel, the oats at 12 cents are the cheaper and better balanced food. The oil meal at 14 dollars per ton supplies more protein for one dollar than any of the other foods given except bran at $6 per ton. The dollars worth of oil meal however supplies a smaller number of heat units than many of the other foods, particularly shorts, corn, or wheat screenings, etc. Hence a mixture of the two classes of foods supplies the largest proportional amounts of both protein and heat units.

When barley is 35 cents per bushel, and shorts six dollars and oil meal $14 per ton it will pay to sell the barley and purchase shorts and oil meal, because a dollars worth of barley at 35 cents per bushel supplies only 12½ pounds of protein and 184,000 heat units while the dollar's worth of oil meal or shorts will supply respectively 39.4 and 33.3 pounds of protein as well as 206,000 and 440,000 heat units. Not only will the oil meal and shorts supply a larger amount of nutrients but they will also produce a more valuable manure. The increased value of the food and manure will more than repay the time and labor spent in exchanging the barley for the shorts and oil meal.

Wheat at fifty cents per bushel is also a more expensive food than oil meal at sixteen dollars per ton. Potatoes at ten cents per bushel will supply more starch than oil meal at any of the prices given. But the oil meal furnishes over three times more protein than the potatoes. The dollar's worth of potatoes and oil meal, fifty cents worth of each, will supply more heat units and protein than a dollar's worth of barley, or a dollar's worth of oats at eighteen cents per bushel, or a dollar's worth of wheat at 50 cents per bushel.

In the table, the protein for the potatoes is a little higher than the actual amounts of true protein found by analysis, but is no larger than the amounts obtained when the potatoes are judiciously combined with other foods. The reader is referred to bulletin 42 of this station for the feeding value of potatoes.

The feeding value of flax seed, before removing the oil, has not been considered because it is too expensive to feed and is not as valuable as the meal. The meal contains less fat and more vital protein. If the flax seed were fed in large quantities, the oil would probably result in causing diarrhœa or other digestion disorders.

Effects of Oil Meal upon the Quality of Butter, Etc.—In a dairy ration the oil meal is valuable not only on account of the protein which it contains, but it is frequently valuable for improving the quality of the butter product. Many of our fodders, particularly the over ripe and coarse ones, have a tendency to produce over hard butters. Oil meal, when fed in liberal quantities, has a tendency to produce a softer butter. In the winter, when coarse fodders are used, a little oil meal in the ration will aid in the production of a softer butter and one of better quality.

It is not economical, neither is it advisable, to feed the oil meal in excessively large quantities. The oil meal should never constitute more than a quarter of the grain ration for dairy stock. The oil meal may be fed at the rate of four pounds or more per day; but it is advisable to feed about two pounds of it and then eight or ten pounds or so of some other grain or mixture, as shorts or bran, along with the oil meal. The price of oil meal is usually too high to admit of its extensive use in rations.

The oil meal is not only valuable for feeding to dairy stock but it is also valuable for feed to all kinds of stock, particularly beef cattle and sheep. When it is occasionally fed to horses, in small amounts, it will result in producing a healthy and glossy growth of hair. Its effects upon the quality of wool are equally noticeable. It is also a valuable food inasmuch as it favorably effects the process of digestion. At first it may take stock a little time to get accustomed to it, but in a short time it will be greatly relished and in the end prove to be a very valuable food.

TABLE VIII.—Giving the Number of Pounds of Digestible Nutrients and Heat Units that can be Obtained for One Dollar when Grains and Milled Products are at Different Prices.

		Digestible Pounds Of				
	Price	Dry Matter	Protein	Fat	Carbohydrates	Heat Units
Oil meal, per ton	$14.	102.	39.4	10.4	47.9	206416.
Oil meal, per ton	15.	95.	36.8	9.7	44.7	192634.
Oil meal, per ton	16.	89.	34.5	9.1	41.9	180611.
Wheat shorts, per ton	6.	223.	33.3	7.7	186.3	440673.
Wheat shorts, per ton	7.	191.	28.6	7.6	159.7	377952.
Wheat shorts, per ton	8.	168.	25.0	5.8	139.8	330728.
Wheat bran, per ton	6.	200.	41.7	12.0	140.3	389220.
Wheat bran, per ton	7.	171.	35.7	10.3	120.3	333574
Wheat bran, per ton	8.	150.	31.3	9.	105.3	291910.
Screenings, best, per ton	5.	295.	33.9	7.6	233.2	528953.
Screenings, best, per ton	6.	246.	28.3	6.3	194.3	440780.
Oats, per bushel	12 cts.	175.	24.5	10.4	136.0	342626.
Oats, per bushel	15 "	140.	19.6	8.3	108.8	274032.
Oats, per bushel	18 "	116.	16.4	6.9	90.7	226949.
Corn, per bushel	20 "	224.	25.8	8.7	191.8	440335.
Corn, per bushel	25 "	179.	20.6	6.9	153.4	352854.
Barley, per bushel	35 "	97.	12.5	2.5	80.9	184123.
Wheat, per bushel	50 "	88.	13.2	1.8	70.3	162952.
Wheat, per bushel	60 "	73.	11.0	1.5	58.6	135794.
Potatoes, per bushel	10 "	143.	12.6	....	118.8	244404.
Pototoes, per bushel	12 "	119.	10.5	....	99.0	203670.
Potatoes, per bushel	15 "	95.	8.4	....	79.2	162936.
25 cts. worth oil meal, 50 cts. worth screenings and 25 cts. worth shorts		229.	35.2	8.3	175.2	426226.
33⅓ cts. worth of oil meal, 33⅓ cts. corn meal, and 33⅓ cts. worth bran		175.3	35.6	10.4	126.	348323.
33⅓ cts. worth of oil meal, 33⅓ cts. worth potatoes, and 33⅓ cts. worth screenings		179.8	28.7	6.0	133.3	326591.
33⅓ cts. worth of oil meal, 33⅓ cts. worth oats, and 33⅓ cts. worth bran		158.7	35.2	10.9	108.	312685.

SUMMARY NOTES ON FLAX.

1. Flax does not remove an excessive amount of fertility from the soil. An average yield of fifteen bushels of flax per acre will remove less fertility from the soil than one hundred and fifty bushels of potatoes, forty-five bushels of corn or thirty bushels of wheat.

2. Flax is a weak feeding crop, possessing but little power of obtaining its food from the soil. It absorbs the larger portions of its nitrogen, phosphoric acid and potash during the first forty or fifty days of its growth. In order to supply the food in so short a time the soil must be in a high state of fertility. Raw stable manure, applied directly, is unsuited to flax because the plants are incapable of feeding upon such crude forms of food. In order to be beneficial the manure must be applied to the preceding crop, as corn, so as to become thoroughly rotted and mixed with the soil.

3. Home grown flax seeds were found to be equally as rich in stored up plant food as imported seeds. There was found to be only a slight difference in chemical composition between home grown and imported seeds.

4. The best flax soils of the state were found to be composed of sand, silt and clay in the following proportion: one-fourth medium sand, one-fourth fine and very free sand, one-third silt, usually spoken of as clay, and about one-eighth of the finest clay. Any soil capable of producing a good corn crop can be made to produce a good flax crop. Extremely sandy or heavy clay soils are both unsuited to flax.

5. When flax is cut on the green side, after bloom and before seed development, and cured as hay, it makes a valuable fodder, rich in protein, and containing about the same amount of fiber as timothy hay. Flax straw is richer in protein than either wheat, oat or barley straw.

6. A yield of fifteen bushels of flax will produce about

315 pounds of total oil, yielding from 270 to 280 pounds of crude linseed oil by the pressure process.

7. Linseed meal, the product obtained in making linseed oil, is a valuable food, rich in protein which was found to be easily and quite thoroughly digested. The manure from linseed meal fed pigs was found to be very concentrated and rich in nitrogen. If six hundred pounds of linseed meal were fed for every fifteen bushels of flax sold and a good rotation of crops followed, flax raising would then be a means of keeping up the fertility of the soil. When only the oil is sold there is but little fertility lost from the farm.

8. In the raising of flax, the fact that flax will not thrive on the same soil where it has been grown for at least five years previously should be kept in mind, because, as shown by Dr. Lugger, the flax straw and roots in their decomposition produce products which will destroy a following flax crop. When five or seven years intervene between two flax crops, then the old straw and crop residue is thoroughly decomposed and will not injure a new flax crop. For successful flax raising on soils worn by grain cropping, a liberal use must be made of farm yard manure so as to bring the land up to a high state of fertility. The manure should be applied to corn crops, and not direct to the flax, then a good yield of flax can be obtained and no injury to the soil will follow.