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FLAX AND FLAX SEED SELECTION.

By H. L. BOLLEY.

Any farmer, teacher or student in the State may have this Bulletin mailed to his address, free of charge, upon application

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FLAX AND FLAXSEED SELECTION.

BY H. L. BOLLEY.†

If one wishes to succeed in flax culture, he must look well to the quality of the seed which he places in the soil.

Flax is not more exacting in its demands upon soil fertility than other farm crops, but is attacked by a number of destructive fungus diseases, which may persist in the soil when once implanted there. This is the explanation of the occurrence of flax-sick soil.

Though North Dakota now annually produces flaxseed in quantity equal to or exceeding the total yield of all other states, our farmers are not particularly happy over the result. As indicated in our Bulletin No. 50*, the crop has everywhere had its drawbacks, and there are troubles brewing for it here. The farmers are rapidly learning that, under present methods of extensive cropping the good fortune of such abundant yields must be looked upon as but temporary, the result of virgin soil. It is the experience of all, that only a few crops can be taken from the same land before it ceases to give the expected bounteous harvest.

The desirability of keeping this important crop as a permanent element of the agriculture of our state and nation can hardly be questioned by anyone interested in the development of permanent industries. An independent country should produce its food and clothing. To do this it ought to use its most available resources. We produce much cotton and a large supply of wool. We could,

*Flax Wilt and Flax-sick Soil, December, 1901.

†In all the laboratory work preparatory to the construction of this bulletin, Mr. Thomas Manns has, as Fellowship Assistant, rendered much aid.

it seems, produce an immence amount of flax fiber, at least ought to do so. Would there be any use for it? If our general import list of raw materials means anything the answer is evident. For the year 1901, the United States imported* animal fibers to a value of $42,581,246, miscellaneous vegetable fibers to a value of $29,720,-334. Of these vegetable fibers, $22,932,506 worth consisted of flax, hemp, jute, sisal, and other coarse fibers. From this last amount, $1,880,717 is the sum paid for flax fiber, of which but 6,878 tons were brought in, showing an approximate average value of $275 per ton. It would seem that these figures ought to appeal to the American farmer, who can now call to his aid the most improved types of farm machinery which the agricultural world has ever known. However, though flax fiber has many advantages of quality over its competitors for the market, and linen goods of all types are always in demand, as a nation, we still buy foreign linens in quantity; and practically all raw materials for the manufacture of thread, rope, twine, cordage, bagging and coarse warped stuffs are a matter of import.

In consideration of these conditions, it may be well to look for the reasons, especially as, during the past 35 years, the flax fiber production of the states has fallen off so as to amount to almost nothing.

Flax Culture in the United States: The original settlers of America were not strangers to the methods of flax growing or of producing home prepared fiber and homespun linen goods. They did as the Russians do today. They produced fiber for their own clothing and had enough to sell. As early as the thirties of the last century, the production of flax fiber had reached the 1,000,000 pound mark, and, in the year 1869, over 13,000 tons of the fiber were produced, chiefly by the states east of the Mississippi. Since that date, there has been a constant decline in fiber production and an increase in the production of flaxseed. The following table* is an interesting showing in regard to this point:

*See Yearbook of the Department of Agriculture, 1901, page 795.

*See Dodge, Report No. 9, U. S. Department of Agriculture, in "A Descriptive Catalogue of the Useful Fiber Plants of the World."

FLAX PRODUCTIONS IN THE UNITED STATES.

Year.	Bushels of Seed.	Pounds of Fiber.
1849	562,312	7,709,676
1859	566,867	4,720,146
1869	1,730,444	27,133,034
1879	7,170,951	1,565,546
1889	10,250,410	241,389

The product of fiber in 1889 was, excepting a small amount produced in the state of Virginia and Kentucky, merely coarse tow. The increased seed production is also seen to be but a natural consequence of the "flaxing out" of the virgin prairies of the western and northwestern states. Thus, while the yield of flaxseed in North Dakota, South Dakota, and Minnesota, in 1899, was 16,114,617 bu., or 12,249,742 bu. more than all states in the union besides, and the totals for these three states are yet on the increase, this fact is to be accounted for by the great increase in the acreage of new prairie lands placed under flax cropping, and not to any improved methods of farming. Some new and better methods must soon be found, and a change of purpose in the growing of the crop occur, or the flax industry of the country, it would seem is surely doomed. Flax as a first crop from new soil is now at its last stand. The travel of the crop from east to west has been so rapid in its change of location that no permanent fiber manufactory could possibly develop. Even the machinery of tow mills has been worn out by constant carting across country to keep up with this nomad crop. As now cultivated, it continually demands new soil areas. Thus the crop has finally come to North Dakota, not as a permanent one, unless a change is made at once in the methods of farming it.

THE CROP IN OTHER COUNTRIES: The native country of flax was probably south-central or western Asia. There are numerous native or wild species of rather world-wide distribution. An examination of the specimens stored in the national herbarium at Washington showed over seventy distinct species, each having a wide range of distribution. Of these, twenty-two were American and the others were of Asiatic, African, and European origin. Sufficient study was given to this collection to assure me that a study of the wild flax plants of the world in garden culture might yield scientific facts of much practical worth. The cultivated form of the plant, *Linum usitatissimum*, is grown throughout the world in temperate regions; and allows a wide range as to

soil and climatic variation. When this species came under domestication, is unknown. The time certainly antedates all forms

CUT 2.

Photograph showing the effects of the wilt disease upon flax plants of various ages.

of historical record. It is certain that the linen industry of Egypt flourished some thousands of years before the Christian era. At the present time, the principal fiber countries are Russia, Austria,

Italy, Belgium and Ireland, while the chief seed producers are Russia, United States, British India, Argentina, S. A., and Austria-Hungary, named in order of importance in production. Russia produces much more fiber than all the other countries combined, but in seed production is closely followed by the United States, and by British India. The following table* showing the yield of fiber and seed in 1900 is of interest in this connection:

SUMMARY OF FLAX PRODUCTION, SEED AND FIBER, IN 1900.

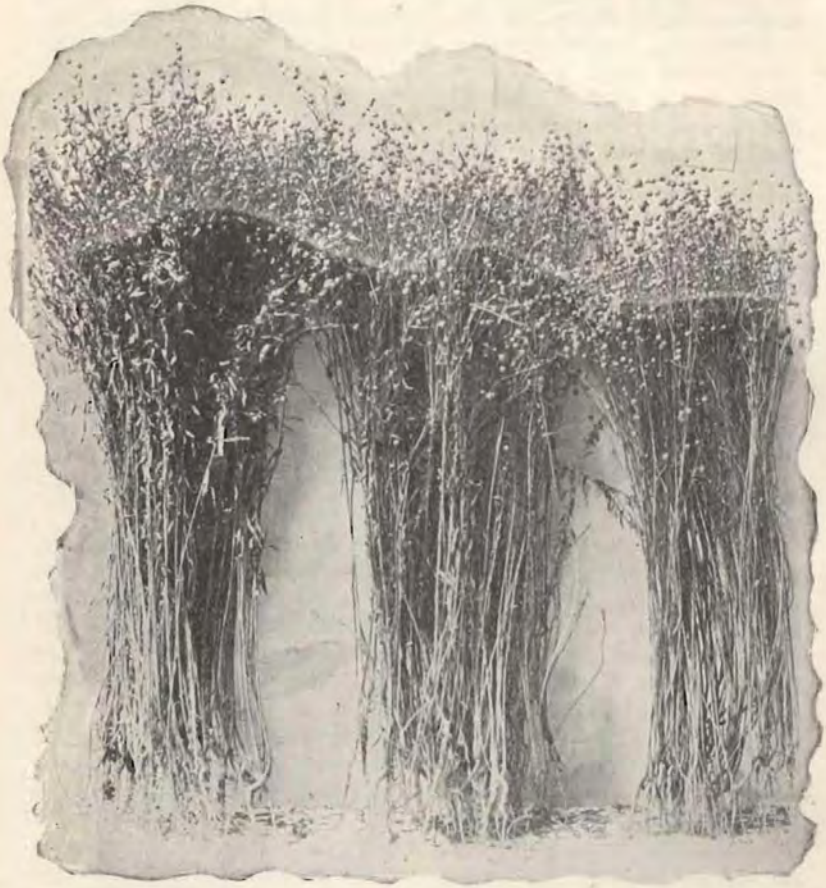
America	29,184,000 bu.
Europe	23,272,500 bu.
British India	12,000,000 bu.
Algeria	10,000 bu.

Of the 29,184,000 bushels produced in America, fully 13,000,000 bushels grew in the state of North Dakota, and the crop for the season of 1902 was easily 16,000,000 bushels. The position which our state holds in seed production is thus seen to excel that of any equal area in the world.

Through the investigation of the literature of flax culture, and by an extensive correspondence with flax experts, I learn that flax culture has always been characterized by the same failings and difficulties. The two great difficulties relate, first to the cost of labor demanded to save the crop properly, especially for fiber production, and second to the more serious fact that the crop has always been found to unfit the soil on which it is grown for future growths of flax in any thing like close succession. This latter condition has tended to prevent the crop from becoming a permanent one, except in certain districts. Its lack of permanence in a given farming region, of course militates against the establishment of permanent manufacturing industries. However, the crop is an old one in many Russian provinces, in northern France,, Belgium, Holland and in Ireland, and forms an important element in the agriculture and manufacturies of these peoples. From Dr. Franz Schindler,** I learn that the flax fiber industry of Russia was an important one as early as the 15th and 16th centuries. As early as the year 1790, the exportation of fiber had reached 1,115,000 Pud, (4,027,380 lbs.). In 1840, the export of flax products from that country took first place in value, representing

*See Yearbook of the Department of Agriculture, 1901, page 761.

**Die Flachsbau und Flachshandels-Verhaltnisse in Russland, p. 1.



CUT 3.

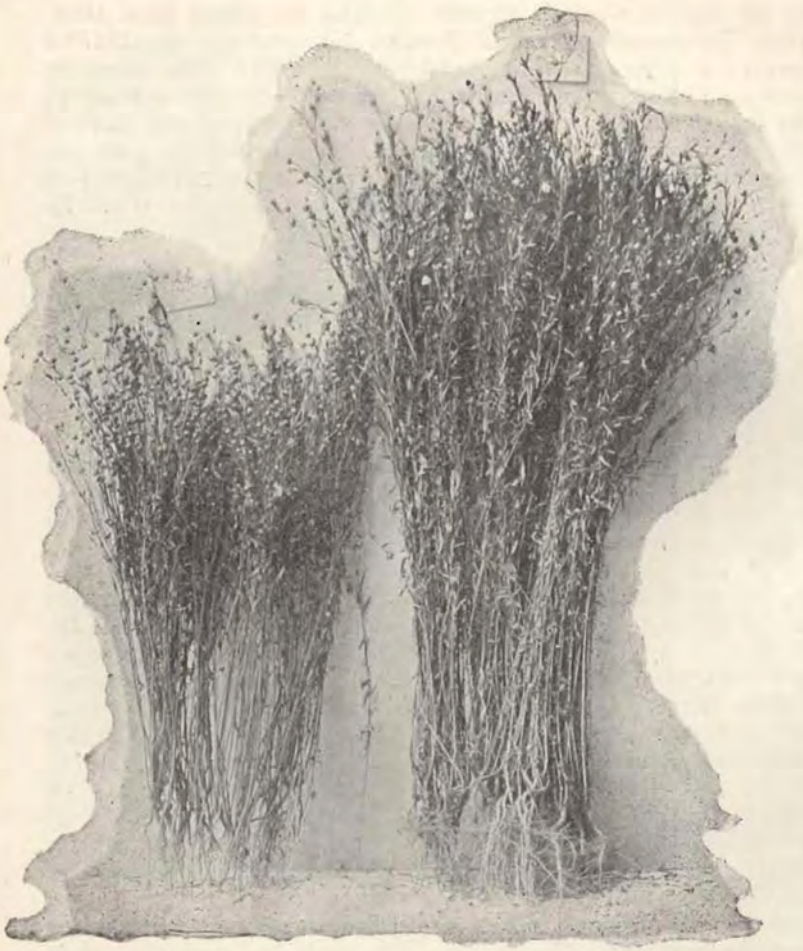
A photograph illustrating the effectiveness of a proper treatment of flax seed for the prevention of flax wilt. Bundle No. 1 shows the growth from a formaldehyde treatment; bundle No. 2. from untreated seed; bundle No. 3, from untreated seed planted with an extra infection of the spores of the flax wilt fungus. Each bundle represents the entire crop from an equal area of ground.

21 per cent of all their exports. During the period from 1889-1898, the annual export* of Russian flax products was 721,000 tons at a value of, approximately, $50,000,000. This, however, does not well show the value of this crop to the Russian peasantry; for they, in large part, produce their own clothing and there is besides a large home consumption of the different flax products. The crop has also been a permanent one in parts of Austria, in northern France, and in the Netherlands; and these countries yet gain a large revenue from its production.

European and American Flax Growing Conditions Contrasted. A study of the general distribution of the crop shows that it is able to withstand a wide range of climate and soil variation. It is grown successfully, either for fiber or seed, from Algeria on the south to Archangel on the north. The best grades of flax for fiber are produced in regions of fertile soil and in districts of even, moist, rather low temperature, such as is found in the Low Countries, and the Baltic provinces of Russia; while the great seed producing areas have drier, less fertile soils and drier, more rigorous climatic features.

A study of the temperature and moisture records shows that there is as wide a range of variation in the different Russian flax producing provinces as that found upon our Northwest plains. Indeed, there are many similarities of conditions. Thus the Russian flax areas all lie well within the mean temperature lines which enclose Manitoba, North Dakota, Minnesota, Iowa, Wisconsin, and parts of Michigan. For example, the same lines of temperature *(isotherms)* July 60° and January 0° pass through Archangel, Viatka and Winnipeg; and the great flax producing areas of each country lie just south of this line.. Again, the isotherms of July 80° passes through Pierre, S. D., Dubuque, Iowa, and slightly south of Odessa. A consideration of the moisture conditions of the areas included does not show an unfavorable comparison; and the soils of North Dakota are without doubt sufficiently strong and of a proper type. The Russians raise heavy seed crops upon their dry, windy plains and make a marked success of producing both fiber and seed in the central provinces, under soil and climatic conditions which resemble quite closely those of the Red River Valley. Two features of the Russian culture, however, are very apparent, (1) More attention is given to the variety and quality

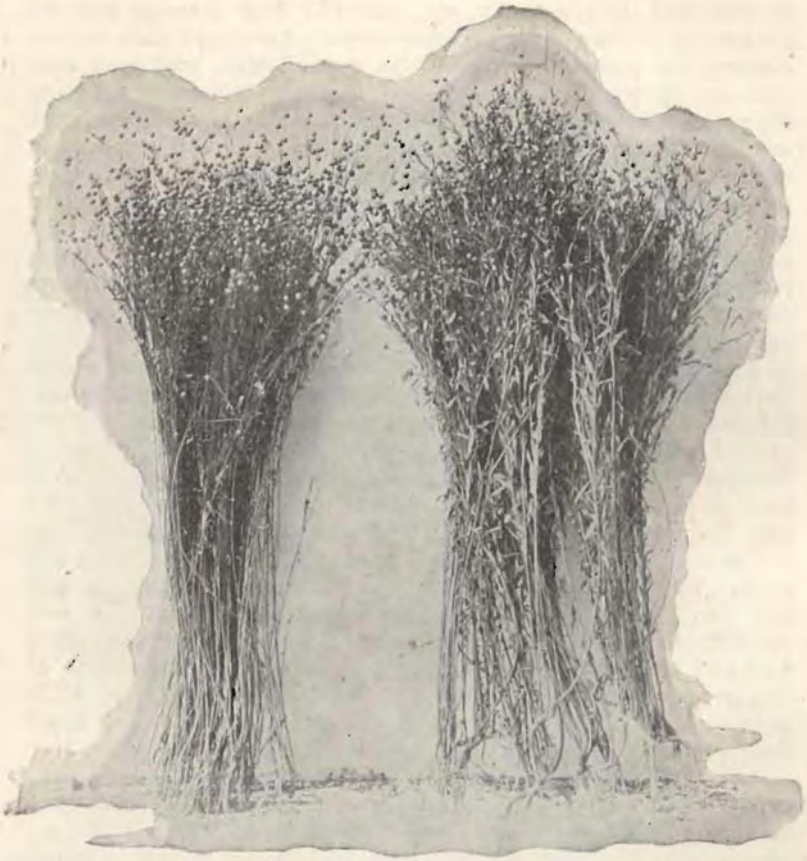
*Catalogue des Collections du Department de L'Agriculture a L'Exposition Universelle de Paris en 1900, p. 50, by Prince V. Massalski, chief of the Department of Agriculture, St. Petersburg.



CUT 4.

Photograph of *short* and *long* seed flax. Each bundle was grown from the seed of one plant which was selected from a field of seed flax in the summer of 1899. They grew side by side and were planted and cared for alike. NOTE: It may be said that this flax and that shown in each of Cuts 5, 6, and 7 was grown during the very dry season of 1900, and that, in part, accounts for the short straw. However, by sample in Cut 6 it is seen that we even then grew straw 36 inches long.

of seed used, crop rotation, etc., and (2) Flax farming and the production of fiber are much more closely associated than in this country, the peasants there, each in a small way, producing both seed and fiber. It seems apparent that the difficulties affecting the success of the crop and industry in this country are, in general, not those arising from poor soil and climatic conditions, but are rather to be referred to methods practiced in the culture and in the handling of the crop, which American machinery and intelligent labor ought readily to overcome. Most of the trouble due to improper methods of culture will disappear when our farmers recognize the importance of growing their own flax seed from pure strains or varieties, and when they have in view a definite purpose with regard to the quality of seed and type of straw to be grown. A very great gain will also be made when our people have reached such a study of the fiber side of the question that this most valuable part of the crop may be saved. Because of the cost of labor, we cannot hope to compete with the hand labor of European peasants. To succeed in this fiber production we shall have to develop types of farm machinery which may not only take the place of hand labor but excel it in quality. A machine for pulling flax seems possible of construction and would do much toward building up our growing fiber industry. The rational flax crop for North Dakota is one grown both for fiber and for seed production; but to succeed, the farmers will have to select their seed and keep it pure when once it is obtained. The growth of the present fiber and tow industry, if properly fostered, ought to grow naturally into a permanent fiber industry, in which much finer grades of fiber may be produced. It cannot, however, last, in any particular community, unless the farmers can keep up the supply of straw. If it is to improve, the quality of straw produced by the farmer must be improved. This can only be accomplished by a rigid determination to improve present methods of cropping, especially the principles of growing, selecting, curing and saving flax for seed.



CUT 5.

Example of first year's selection for comparison of *earliness* and *lateness*. The selections were made from the same field as in case of the seed for the growth shown in Cut 4. There was two weeks difference in the date of maturing the seed in these two selections.

A Statement of the Troubles Connected with the Growth of Flax in America: The difficulties affecting the growth of the flax industry with us may be summarized about as follows: (1) The cost of labor and the absence of machinery to properly make use of the straw for the development of the fiber side of the industry results in a great loss to the farmer and all others concerned.

(2) Carelessness as to the quality and variety of seed used for sowing results in poor crops, poor quality, and diseased soil.

(3) Lack of knowledge as to methods of culture often results in much loss in crop value, if not also in injury to the soil.

(4) Diseases which attack the crops and a lack of knowledge of their effects result in poor crops and final sterility of the soil for flax.

In this bulletin I propose to consider only points 2, 3, and 4, and hope to point out methods of procedure which will lead to profitable results.

Dakota Conditions of Flax Cropping: First let us consider the methods of growing the crop in this state.

North Dakota is now a greater producer of flax seed than any other equal area. In 1902, it is conservatively estimated that the yield of matured flax was between 13,000,000 and 16,000,000 of bushels. Fully one-third of the area under crop was subjected to autumn frosts. It is estimated that had the state escaped this one early frost the yield of seed would have approximated 25,000,000 of bushels. It is also a well known fact that the general average yield per acre for the state was also much reduced, because of weak types of seed in the spring, deep planting and poor drainage, etc. There were other large areas on which the crop was almost or even a total loss because of the occurrence of the wilt disease (*flax-sick soil*). We have by experiments and observations learned that such soils are not really exhausted for flax and have reasons to believe that proper types of seed would overcome the troubles and allay or remove all prejudice against flax as a crop. (See our bulletin No. 50 and other published records to show that the trouble is not soil exhaustion.)

The great yield in the state is, as elsewhere stated, due to the vast areas of new lands which are now being placed under flax cropping. Unfortunately this cannot last under the present regime of carelessness and wholesale seeding. The older flax areas, especially in Minnesota and the Red River Valley region of North Dakota, are rapidly losing their capabilities for producing a paying crop. Cropping under the present methods and with the present

types of seed, western prairie soils lose their capabilities to produce a crop in from one to four or five years, whether the seed is sown in ordinary rotation with wheat crops or in close succession, flax after flax. Our proofs are such as to convince us that the entire reason for this condition is to be found in the poor, diseased types of flax seed which is generally used.

In order that any farm crop may be grown successfully, and be developed in its qualities by the farmers of a particular region, there should be one or more standard varieties or strains of such seed in general use. These types of seed should be sufficiently well marked in character that the ordinary farmer may easily recognize them. (As witness, Haynes' Blue Stem Wheat, White Russian oat, Minnesota King corn, Early Ohio potato, etc.). No such recognized strains of seed flax exist in the entire flax growing area of the United States. It is all mixed in type, and, for such reason the crop suffers its greatest drawbacks, among which may be mentioned uneven ripening, frosting, both spring and autumn, and diseases of various types, including that particular type of disease which is the direct cause of flax-sick soil. The farmer cannot hope to mature an even, perfect quality of seed from a mixed lot of varieties and strains. By the use of such seed, the way is open for a perpetuation of all of the troubles to which the crop is heir.

Such pure varieties of seed flax cannot be obtained or purchased upon the open market. All such market seed is subject to mixing at the central shipping points, as for example Buenos Ayres, Riga, Reval, Rotterdam and Minneapolis. Thus, for example, the noted "Riga" flax does not indicate a variety or strain, but simply that the sample so marked is from the export town of Riga, Russia, where the flax from many Russian provinces and districts is placed upon the general export market. Speaking upon this point, Professor Franz Schindler* says: "In the seed sorting at Riga, unfortunately, insufficient care is taken with reference to the origin especially, seed from the different provinces are often mixed with one another." From Professor Jaczewski of the Botanical Institute in St. Petersburg, I learn that nearly one hundred varieties of flax are recognized in Russia.

They Use Mixed Seed and of Poor Quality: As our first samples of seed came from Russian ports and as farmers have never made any definite effort to breed or save pure varieties, it is easy to surmise that the entire crop of seed in this state is a mixed lot. This proves to be the case upon close examination.

*Flachsbau-und Flachshandels-Verhaltnisse in Russland, p. 46.

CUT 6.

Photograph showing the possibility of improving our strains of *fiber* flax by selection. The parent plants for these two bundles were selected from the same field of fiber flax, and were planted and cared for alike during the season of 1900.

Many farmers are trying to raise an even maturing crop from a mixture of varieties and strains. Even fiber varieties are present in almost all of our Dakota samples of "common seed." If all our different varieties and strains of wheat were dumped together

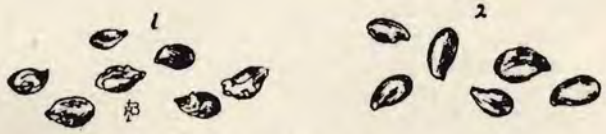
CUT 7.

The bundles of flax shown in this cut were all grown from the same sample of seed flax which was hand picked to an evenness of quality. The seed for each was sowed upon the same even bed of soil, on the same day, but at different DEPTHS. The crop was grown during the dry season of 1900, and illustrates well the evil effects both of deep planting and of planting on an irregular seed bed which might allow the seeds to be buried at different depths. All were pulled on the same date. The flax shown in the large, mature bundle grew from seed which was planted ¾ in. deep. The bundles in the series grew from plantings at depths varying from 4 inches on the right to only ½ inch on the left.

into the elevators of this country, and the farmers used seed from such a mixture, every one knows, at once, what would be the result upon the general crop. It is apparent that there would

be uneven ripening of the crop with all its attendant evils. This is just the case with the present flax crop of the country. Very few farmers take the trouble to grade the seed to an even standard of quality and size before seeding as they do in the case of wheat and other grains. Indeed, if I may judge from the samples sent to the station for examination, many believe that any dark-colored shriveled stuff will do for seed, if only it is but strong enough to sprout. This is a great error and not only results in poor, uneven crops but is rapidly ruining the soils of the state for flax growing; for most such dark-colored, shriveled, scaly seeds bear the germs which cause flax-sick soil.

Poor Methods of Culture: Poor methods of culture with regard to preparation and care of the soil and seeding are responsible for much loss in crop value and serve, in part, to perpetuate the poor qualities of seed in use by the farmers. In this con-



CUT 8.

Sketches showing: 1, scaly flaxseed, and 2, smooth, plump flax-seed. Farmers should screen out all scaly, immature seeds. They harbor the spores of flax wilt.

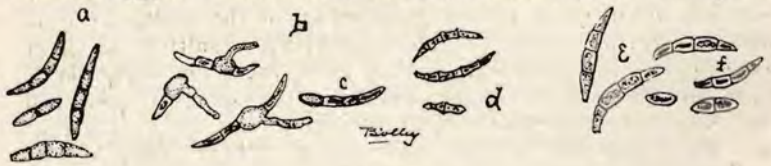
nection, we may name: (1) late seeding which allows the crop to be frosted before mature; (2) sowing upon a rough, uneven seed bed, resulting in uneven germination of the seeds, hence an uneven maturing crop; (3) deep planting, resulting in great weakening of the aftergrowth from all seeds, and many young plants either die before reaching the surface, or are so much weakened that they are often green when the rest of the crop should be cut. It is impossible to save such a crop without either loss by shelling or loss in grade by the presence of immature, soft seeds.

Lack of Proper Crop Rotation: The worst evils arise largely because of the persistent disregard of the most elementary principles of crop rotation. Men who know that no soil can continue to produce the same crop of plants in close succession, losing their head in hope of temporary riches, persist in sowing flax year after year upon the same land. The result is flax-sick soil, and it comes the sooner because they pay but little atten-

tion whether sound or imperfect, scaly, diseased seed is used. Real estate companies and speculators rejoice in this wholesale method of destroying the soils of the state, while they wait a year or so for a rise in the price of the new lands which they hold. The lands thus cropped are not only filled with disease due to the poor seed used, but become sources of soil infection for entire neighborhoods. Flax should not be seeded upon the same land more often than five or six years; for if by chance a few points of soil infection occur, the sick areas enlarge from year to year by feeding upon the constantly increasing masses of flax rubbish in the ground. Every farmer in the state knows a neighbor or so who is thus careless about the quality of seed used. Would it not be a matter of policy and self preservation to try to educate such men to do differently.

Diseases of Flax and Flax-sick Soil: Since Bulletin No. 50 on Flax Wilt and Flax-sick Soil was written, December, 1901, we have learned many new points with regard to the general trouble. The chief of which is that besides the regular fungus, (*Fusarium lini*), which was demonstrated to be the cause of the characteristic wilt disease, there are other species of fungi which may kill young flax plants and persist in the soil so as to take part in the production of the conditions of the soil which make it sterile for the growth of flax.

Detection of the Presence of the Disease Producing Fungi in the Seed and Soil: As the fungi which occasion this sterility of soil are microscopic in size and form, it is of the greatest importance to be able to detect their presence in the soil or in seed grain. Considerable effort has been made to accomplish



CUT 9.

Figure showing: *a*, Normal untreated spores of *Fusarium lini*; *b* and *c*, the same after a weak treatment with formaldehyde—some cells are yet able to germinate; *d*, spores which were killed by formaldehyde; *e* and *f* show the effects of different strengths of corrosive sublimate solution. Highly magnified.

this result. It has been found that by means of the ordinary physician's centrifuge, one can readily detect the spores in the

seed. A large number of seed samples from all parts of the state, and from several counties in Minnesota, have been examined. It is found that the disease is very generally distributed, fully eighty per cent of the number of samples examined were heavily infected. This teaches that farmers ought not to rely upon unknown flax for seed purposes. One ought to grow his own seed. See Bulletin No. 50 upon this point. The spores of the wilt organism have also been detected in flax seed from the following foreign countries: Argentine Republic, Japan, Austria, Holland, Russia and Belgium.

In conducting this work, we have also found that there is a second species of Fusarium of much larger form than the species *lini*, which possesses the same flax destroying ability. There is also a species of *Colletotrichium*, which is very destructive to young flax plants; and a species of the Genus *Alternaria* is very destructive to young plants in damp soil. It is also probably the direct cause of a peculiar boll stem disease which kills the young bolls or the fine branches to which the bolls are attached just when the seeds should be forming, giving the appearance of ripening prematurely. During the season of 1902 this last disease very greatly reduced the crop in almost all parts of the state. By methods of soil analysis it has been found that all of these different fungi live in the flax-sick soil from year to year. The study of their natures, characteristics and life habits in the soil, in manures, etc., forms a very important present line of investigation.

The Wilt Disease Proper: The following are some of the chief points concerning the wilt disease:

1. There is a diseased condition of flax soils which has long been known to farmers in flax producing regions as flax-sick soil.
2. If flax is sowed rather continuously for a number of years upon the same soil, this disease tends to thoroughly infect the soil so that flax growing becomes no longer profitable.
3. The disease may be spread by way of the seed flax.
4. The plants attacked die at all ages as if for want of water; hence I have called the trouble the flax wilt disease.
5. The direct cause is a minute fungus parasite which grows on the inside of the flax plant, starting either from the seed, or by attacking the roots of older plants, if the soil has previously been infested.
6. There are many ways in which the infection might reach new fields, but the chief one is by way of the seed.
7. The spores of the parasite get into the seed flax at thresh-

ing time, rattling off from the sides of the flax straws which have been attacked by the parasite.

8. When such infected flax seed is sown, the spores of the fungus germinate and at once attack the young plants. Those attacked early die at once and there may be no stand even from good seed if the spores of the parasite are abundant. When once in the ground the fungus spreads rapidly, attacking new plants throughout the season. It can live from year to year upon the humus of the soil, hence the soil is ruined for flax.

9. All other farm crops do well upon the flax-sick soil. It has not lost fertility for flax, as is proved by experiments which destroy the spores without injuring the soil.* If soil is once infected, these last facts teach that the farmer should have recourse to the growth of other crops than flax until the land is again free of the disease. This is exactly what has always been done in Russia and other noted flax countries, though, heretofore, it was never known why this rotation was so necessary to flax.

10. The fungus belongs to a genus of plants which botanists have called Fusarium. As this is a new species, I have called it Fusarium lini.**

11. Much of the soil of this state has not yet been infected, but practically all samples of seed flax yet examined show the presence of the Fusarium spores. It is probable that no sample of flax seed is entirely free from infection by this particular fungus parasite. Our latest studies show that one or more other species of this same genus are also active.

12. One of the worst features of the wilt disease is that some plants which are attacked late in the year are able to partly mature seed. Many of such seeds are found to be internally diseased; that is, the parasite has grown from the mother plant up into the embryo within the seed coats. Such seeds cannot be treated so as to prevent soil infection without killing the seeds. Each internally infected seed invariably produced a wilted plant some time during the growing season, and each wilted plant starts a new area of soil infection. We have worked with samples of seed flax which contained as high as 25 to 30 per cent of such internally attacked seeds. If a sample of flax has been properly ripened and saved dry, one can usually recognize internally diseased seeds. They are often imperfectly developed, may have a dark colored point, or may have a spot or area of improper color

*See Bulletin No. 50. North Dakota Experiment Station, page 35, Experiment No. 1.

**Same citation, page 38.

showing through the transparent seed coat. In samples of seed from a diseased crop, there will always be found many light weight, dark colored seeds. Often the seed coats are scaly or scurfy because attacked before properly matured. The seed coats of such seeds are usually thoroughly infested with one or more types of disease producing fungi, including the wilt fungus.

13. The resting spores of the wilt producing fungus are developed in the pith or other open tissues of the stem of the flax plant. This kind of spore is very resistant, and being protected by the tissues of the stem is safe from injury in the ordinary methods of seed treatment. Bits of diseased stem, even in treated samples, start points of soil infection. Bits of chaff or the hulls of the flax bolls may do the same thing. (See Bul. 50, p. 37.)

14. Barnyard manure in which disease bearing flax straw or waste has been thrown is probably one of the worst sources of soil infection. We have proved by experiments and by numerous observations that one application of such infected manures may ruin the soil for the growth of flax.

15. The growth of weeds in a flax crop is very favorable to the rapid increase of the disease from year to year. Flax bundles which contain a lot of rough green weeds cannot properly dry out; and we have found that the fungi which produces flax sick soil multiply profusely in such damp straw and even invade the seed coats of mature, though damp seeds. Seed flax which came from even a slightly diseased crop, if stored damp, is found to be very destructive to soil for the same reason.

16. These soil infecting fungi have been found to be cosmopolitan with the growth of flax.

17. We have not been able to associate *Asterocystis radicis,* Wild.* with the production of flax sick soil in the field. This organism is a common, widely distributed one but seems to be harmless under our conditions.

18. Common rust of flax (*Melampsora lini*) causes an early browning or maturing which is often mistaken for wilt, but may be recognized by the yellow or orange spots upon the green leaves and by black spots upon the older parts of nearly mature stems. Rust seems to do but slight injury to a crop which is grown for seed purposes.

19. Besides the resting spores which are on the inside of the flax straws, numerous crescent shaped spores (see cut 9) are found on the outside of the stems. It is these spores which become abundantly dusted over all of the seed at threshing time.

*Marchal, Recherches Biologiques sur une Chytridinee Parasite du Lin in Bulletin de L'Agriculture, Tome XVI, p. 574, Brussels, 1900.

20. Proper seed treatment insures the killing of all wilt producing spores which are present on the outside of the seeds, or may be intermixed as dust particles.*

THE REMEDY IS PURE, CLEAN, MATURE SEED: It is evident from a consideration of the conditions cited under points 12, 13 and 15 that proper seed selection, seed cleaning, curing and grading are first essentials to the prevention of flax sick soils. Proper selection demands that one should raise his own seed, and that he should save the best possible cleanest, undiseased, weed-free part of the field to thresh for this purpose. Proper curing demands that the seed must be harvested when mature and when dry, threshed when dry, and that it must be kept dry. Proper cleaning insures the removal of dust, dirt, straw, chaff and light weight, imperfect seeds, all of which trash may contain the wilt producing spores. Proper grading leaves only large, plump seeds. If the color of these is seen to be bright, one can rest assured that after using the formaldehyde treatment, there will be a clean, healthy stand of flax when it is sown upon clean undiseased soil. No sample of flax seed should be trusted without treatment. We have been unable to find one which is entirely free from the wilt fungus. Proper seed treatment greatly improves the first growth from the seed. Our experiments teach that a stronger growth occurs from properly treated seed throughout the season.

SEED SELECTION: This is the line of work from which I have much hope both from efforts to be continued at the Experiment Station and from the work of the farmers themselves.

Against the common belief that there are but one or two varieties of flax, my experiments, correspondence and samples of seed on hand, teach that there are several of very definite character. The general flax seed products commonly spoken of as "common fiber flax" and " common seed flax," by our tests, appear to be only general mixtures of strains and perhaps varieties. We have proved that in these mixtures there are early ripening types, frost resisting types, fiber strains, seed types, and finally wilt resisting types. As to the matter of resistance to frost or to wilt, the tests tend to show that it is probable that some samples of common flax are more or less resistant in character, acording to the purity of the sample.

*For many other general notes and observations upon the characteristics of the disease; and for a description of our experiments with different substances for seed disinfection, methods of disinfecting by vapor, etc. consult the Annual Report of the North Dakota Experiment Station for 1902.

This all teaches that there is hope of obtaining flax seed of the type desired, as has been done in the case of other farm crops, and that it is not illusionary to hope to find strains which will produce fine qualities of seed and also strains which will produce fine qualities of fiber under our soil and climatic conditions. One would hardly select the climatic and soil conditions of Dakota for the production of typical fiber flax, yet our experiments at Fargo, and those of Prof. Hays at St. Anthony show that very fine fiber plants can be grown in these climates, to a length and

CUT 10.

Fig. 1. Fig. 2.

Fig. 1.—Sketch showing a clump of young flax plants which have wilted, due to early attacks of the wilt fungus from flax sick soil. Original.
Fig. 2.—Figures showing various grades of diseased growth from immature scaly flaxseed. All are more or less attacked by wilt fungus.

a fineness equal to the best plants produced in the regular fiber producing countries. In 1899 I selected some individual plants from a rather short appearing crop of fiber flax. From the seed which descended from one of these, the farm department grew plants varying in length from forty to fifty-seven inches. This work tends to show that the matter of obtaining fiber types and seed suited to our conditions is only one of breeding strains which are suited to such climatic and soil conditions. In general, our experiments tend to show that these select plants which we have worked with are not simply sports or accidents, but are rather to be looked upon as representatives of real strains or types which are mixed in the samples of "common" seed upon which we have worked. (See results upon early and late ripening, selections for length, strength, etc., as shown in the different photographs taken

from plants of the first year's growth from our individual selects, season of 1900.)

The details of the work upon the selections cannot be given in full here, but it may be said that the seeds of each pair of parent plants selected for comparison were hand planted, side by side, at an equal depth, under equal conditions, on the same date. The seed from a part of the best fiber plants was turned over to the farm department and the continued selections, during 1901, and 1902, show by the improved products that the flax plant is easily amenable to improvement, year by year, through methods of selection.

IMMUNITY EXPERIMENTS: Director L. Broekema of the Agricultural School of Holland has had flax sick soil under consideration in his own gardens for many years, extending back of 1893, when he reported upon the disease at some length.* He described the disease in all its various forms very accurately and made some very interesting observations upon the fact that certain plants in common seed varieties of sowing flax seemed to possess resistant capabilities with reference to this soil trouble which he characterizes as "Vlasbrand."

As a knowledge of Dr. Broekema's experiments did not come to us until December of 1901, our work of selection along this line had already been outlined and well started. In 1899 we selected from the field plants for earliness, lateness, strength of stem, length of stem, evenness of ripening, rust resistance, freedom from wilt appearance, shortness of stem, etc. Each of these individual plants was threshed separately and the seeds sowed in drills side by side on the same date and under the same conditions of planting. Such marked results were gained in these selections that we at once became aware not only of the fact that flax as a species or variety is exceedingly liable to variation, but gained definite information pointing to the conclusions that the progeny from different individuals show marked variation in ability to resist the attacks of the two diseases known respectively as rust and wilt. These diseases, however, are very different, and plants which seem more or less resistant to rust succumb to the wilt. In 1901 a piece of thoroughly flax sick soil was seeded to flax, using three different samples of seed. The results were discouraging. The young plants died off so thoroughly that, owing to lack of labor at the time, the beds were allowed to grow up to weeds, with the result that no seed was saved; but observations taught that this neglect was perhaps a costly error.

*See "Landbouwkundig Tijdschrift, 1893, Bl. 59 en 105."

In 1902, after sowing a mixed lot of flax seed, which we procured by sending for samples of seed to a great number of farmers in various parts of the northwest, upon a piece of flax-sick soil, we found that a small percentage of plants were resistant to the disease and were able to mature seed, some being slightly blighted by the disease, but many apparently living without the slightest injury. These plants were pulled and saved for a test upon this question of immunity. A part of the seeds from twenty of these plants have been given greenhouse culture in competition with eight samples of common seed flax selected from various portions of the states of Minnesota and North Dakota. These checks were selected because representing apparently variable samples; the seed from these was hand picked and of the best quality in each sample. These checks were either seeded in the same box with the select seeds or in similar boxes of flax-sick soil on the same day and received like treatment. All seeds were planted upon date of December 4th.

The following tables will give an idea of the conclusions which should be drawn from the work:

CUT 11.

Photo showing experiment with immune seed in flax-sick soil. The plants were about sixty days old from the seed. The plants in the right and left boxes grew from seeds of individual plants which grew the year before on sick soil, and were selected for test because they then showed powers of resistance to the wilt fungi. The plants in the middle box grew from a sample of "common seed" planted as a check for purposes of comparison. Most of the plants were dead of wilt at the date of photographing. See table p. 194.

RECORD OF IMMUNE SELECTS, COMPARED WITH GROWTHS FROM "COMMON SEED" SAMPLES.

Plant No.	No. of seeds used	Sound plants Dec. 15	Wilted plants Dec. 15	Sound plants Feb. 5	Plants dead Feb. 5
1.	50 plump	50	0	50	0
	25 poor	10	1	9	1
2.	25	17	1	12	6
3.	25	24	0	24	0
4.	20 large	19	0	19	0
	5 weak, dark	1	0	1	0
5.	20 normal	17	0	17	0
	5 dark	0	0	0	0
6.	10	9	1	8	2
7.	5 plump	5	0	5	0
	5 dark	2	0	2	0
8.	20	20	0	20	0
9.	10	10	0	10	0
With check 4.		15	3	1	14
10.	20 normal	20	0	15	5
	20 immature	13	0	13	0
11.	20 normal	19	0	17	2
	20 dark	20	0	18	2
12.	25	25	0	24	1
With check 6.		12	3	0	12
13.	20	20	0	19	1
14.	20 thin	20	4	12	8
15.	15	15	1	15	1
Check 8.	20 best	20	1	1	19
16.	20	16	0	13	3
17.	20	20	0	20	0
In same box with plant 14.					
18.	25	25	0	25	0
19.	20	17	0	17	0
Poor, thin seeds, the mother plant was not mature.					
20.	25	24	0	21	3
Check 1.	50	30	6	10	20
Check 2.	50	35	0	16	19
Check 3.	20 best	17	1	3	14
	5 dark	0	0	0	0
Check 5.	40 dark	33	2	6	27
Check 7.	60	44	3	10	34

By a consideration of the data given in the foregoing table, we find that the select seed gave a very much larger production of plants at germination time, that is, less plants died before getting through the earth, and that out of a total number of 468 plants which came up from the select seeds, only 35 died of all causes, previous to the date of Feb. 5th. These plants mostly died of wilt but came from seeds, the mother plants of which it is known were sufficiently diseased to give internally diseased seeds. Of these dead plants from the selects, 5 parent plants furnished 26 of the wilted seedlings.

In the case of the checks, out of a total of 222 seedlings which actually came up, 159 were dead of wilt before the date of Feb. 5. At this date, Feb. 12th, no further plants have died in the select experiments, while quite a large percentage of the plants from common seed were either dead or dying. March 31st, all check plants were dead except two plants in one box; while all immune plants remain strong and are in blossom.

It is an interesting fact that some of the samples of common seed, such as No. 8, one of the finest appearing samples of flax to be had, are apparently wholly unable to resist the flax-sick soil disease, while in the case of some other samples of seed the number of resistant plants remaining to date indicate a considerably larger percentage of resistant seeds in the original sample.

The conclusion to be drawn seems to be in line with that indicated by our other selection experiments, that common seed flax as found upon the market is made up of a mixture of various strains or possibly varieties, and that some of these strains or varieties exhibit a high grade of resistance to the wilt disease, or indeed any other disease which may be associated with flax-sick soil; and, further, that there is much reason for the hope that we may eventually escape the ravages of this soil trouble by the use of immune strains of seed.

What the Farmer Can Do: It is evident that this process of selection and breeding from individual plants or strains must be a slow one, and that the average farmer has no time for such effort. That is the duty which falls naturally to Experiment Stations and Seed Farms.*

There are, however, open to the farmer, the processes of general selection, seed cleaning, seed grading and seed disinfection. He can also proceed to follow a common sense process of crop rotation, which is sure to bring paying returns.

*I think I am safe in asserting that a properly conducted general seed-breeding farm located in the Red River Valley would pay the owner well, and would be a great benefit to the state.

That there is great enough variation in flax samples to allow any one to intelligently make a selection for farm use, I call attention to photograph of seeds shown below, also to the fol-

CUT 12.

This cut shows the *variation* in the size of flaxseeds. Five different samples are shown, all perfect seeds. Let no man tell you that flaxseed cannot be graded to size and weight. See also table.

lowing table which shows the possibility of grading seed flax in a fanning mill.

THE WEIGHT OF FLAX SEEDS.

Sample used	Weight of 10 smallest seeds	Weight of 10 largest seeds
Big Seeded Austrian	.0854 grains	.1270 grains
Yellow Seeded French	.0360 grains	.0480 grains
College Grown Common	.0265 grains	.0530 grains
Langdon Grown Common	.0385 grains	.0630 grains

*NOTE.—All seeds selected were mature and plump. It will thus be seen that aside from the improperly developed and scaly seeds which may be removed, there is plenty of room for the work of grading that may be done by a mill. From the table it is seen that the large seeds, for each sample, average almost or quite twice the weight of the small mature seeds. See also the results of the growth from such seeds contrasted in Cut 13.

RECOMMENDATIONS: (1) Use only plump, bright colored flax for seed.

(2) Treat all seed flax every year. The treatment was found by many farmers to be a great success in 1902.

(3) Before treating clean all seed thoroughly in a fanning mill until all bits of straw and chaff as well as light weight seeds have been removed, or blown out. The treatment recommended will not kill the fungus which is always to be found inside diseased straws and chaff, because it cannot penetrate to it. In a diseased crop, most of the light weight, dark colored and scaly seeds bear the fungus on the inside of the seed-coats. Such seeds must be removed, for the treatment cannot prevent these from infecting the soil.

TREATMENT: Use formaldehyde at the rate of one pound of the standard strength to forty gallons of water. Spread the seed upon a tight floor or upon a canvas and sprinkle or spray on a small amount of the liquid, (a fine spray thrown by a small force pump is best). Shovel, hoe or rake the grain over rapidly. Repeat the spraying, shoveling, hoeing or raking until the surfaces of all the seeds are evenly moist, not wet enough to mat or gum but thoroughly damp. (This can be done without matting, if well hoed or shoveled over). Leave the grain piled for several hours. The dry grains will absorb the excess of moisture without injury or matting, and the spores of the disease will be killed by the fumes. It takes about one-half gallon of water solution to properly wet one bushel of flax seed.

FURTHER PRECAUTIONS: After this care has been taken with the seed, I recommend these further precautions:

Sow all flax on a compact, even seed bed.

Sow flax seed as shallow as possible and yet have it well covered.

Sow smaller areas to flax, and never follow flax by flax until a number of years have intervened.

I recommend the following series of crops until we have learned reasons for a better one:

Flax.
Wheat, oats or barley.
Corn or other cultivated crop or fallow.
Wheat.
Grass.
Grass.
Pasture one or more years, then flax if desired.

Raise your own seed, thresh it in a clean machine from a patch

of mature, healthy flax. Keep it dry, for the fungus propagates on damp flax, grows inside the hulls and ruins such seed.

Finally, do not allow any flax straw or waste to get into the

Fig. 1.

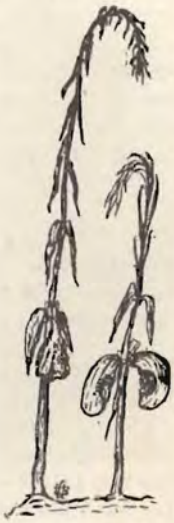


Fig. 2.

CUT 13.

Fig. 1 shows the advantage of removing all small flaxseed, even though sound. The two plants were thirty days old from sound seeds, but the seed from which the large plant grew was twice as heavy as that which produced the small plant. The figure is one-half size.

Fig. 2 shows two wilted plants from internally infected *scaly* seeds. The seed leaves were attacked before the period of germination. See the spots on the right hand plant.

manure. It will be impossible to feed flax straw and not have flax-sick land wherever such manure is applied.

I sincerely hope that the farmers of this state may quickly appreciate the serious nature of this soil disease and begin at once to take all necessary precautions to keep their farms free from the trouble.

HENRY L. BOLLEY,

North Dakota Agricultural College, March 31*st,* 1903.

Cut 14 shows the type of pump one should have to treat grain with by the spraying and shoveling method. The nozzle may be set to throw a spray of any degree of finenes.