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A TREATISE ON FLAX CULTURE.

☞ The Bulletins of this Station are mailed free to all residents of the State who make application for them.

NOTE. On the 5th day of last October our station office building was destroyed by fire. The laboratory, a large part of the library, and all Reports and Bulletins from 1 to 12 inclusive, were burned. It will be impossible to supply copies of Bulletins issued earlier than the present number.

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INTRODUCTION.

BY OTTO LUGGER.

The culture of flax in Minnesota has assumed large proportions, and the interest in it is still increasing, because the efforts of our farmers in this direction are frequently bringing them richer returns than the culture of any other plant. But, up to the present time, attention has only been given to the production of seed for its oil, and not to the production of fine fibre. Flax-culture and flax-industry promise a rich reward to those engaging in them, but it would be very unwise to expect too much in the immediate future. The determination to succeed is a wonderful factor to success, but such a determination must be in harmony with the existing natural conditions of our state. The old Latin proverb, "*Festina lente*" (Make haste slowly), is a very sensible one, and ought to be the motto for all new departures in agricultural pursuits. To make a success of something as yet almost untried in Minnesota, farmers ought to move slowly and carefully; they have first to study what methods are best, and must not expect that because our glorious agricultural state has a fine climate it must nesessarily be as suitable for flax as that of countries where the best sorts of fibre can be produced, and whose farmers have learned by experience—the only true teacher in matters of this kind—what to expect, and what to do under ever-varying conditions. Of course our farmers will learn this as well, but that requires time. The determination to succeed will help him vastly, but his store of knowledge must first be enriched by experience.

Having had but very limited practical experience in flax-culture in Minnesota,* I will simply state in the following pages what is being done in the famous flax-growing regions of Europe, or where flax is grown chiefly for its fibre. This experience will enable those interested in flax-culture to gain a clear insight of this culture in Europe, and may, perhaps, enable them to avoid falling into errors.

My thanks are due to Prof. H. Leslie Osborn, Ph. D., of the Hamline University, who has added a chapter on the histology of the plant, which shows why many operations are necessary to transform the straw of flax into useful fibre.

*My experience in flax culture was mostly gained in the flax-growing region of Westfalia.

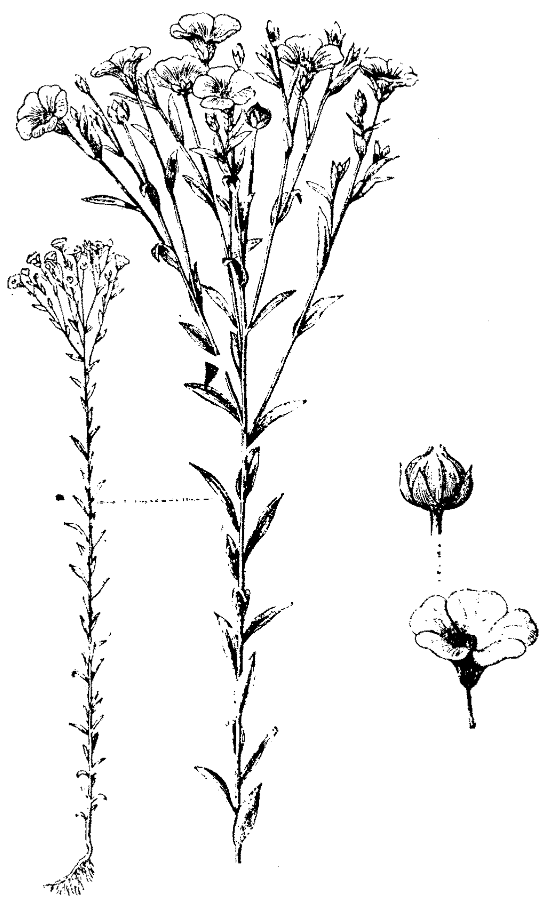

FIG. 6. Whole plant of *Linum usitatissimum*, very much reduced; parts of plant less reduced; flowers and seed-capsules natural size.

Flax has been cultivated from time immemorial for its textile fibre. It is frequently mentioned in the Bible, and the old Egyptians grew it upon a large scale. Even in Europe its culture must be very old, as undoubted proofs have been discovered that the builders of the lake dwellings in Switzerland knew and used it for various domestic purposes. Its original home is not known with certainty, yet it was probably very early introduced from the Orient. The genus of plants to which it belongs contains about eighty species, which grow wild in the warmer portions of the temperate zones. Although most farmers, at least those that came from the Eastern States and Europe, know the flax plant very well, there are many others in Minnesota that have never seen it, and for their benefit illustrations showing all the parts of the same have been added, with the necessary explanations (Fig. 6).

Flax is a very useful plant for many purposes. Its fibre and seed are, of course, the most important parts. The former is one of the most valuable fibres we possess, and is transformed into the most delicate and costly laces, and the most useful and durable articles of wear. Although the textile industry of flax received a very severe blow when cotton became the "sole king," it soon recovered its former position, and furnishes to-day in a number of large cities the principal work for the population. For instance, in Bielefeld, Westfalia, 50,000 spindles are in full operation, producing annually about 130,000 rolls of linen, each many yards in length. Yet the flax industry would never have regained its old position if factories had not been erected to perform the work formerly done by the farmers themselves, and produced, by means of improved machinery, an article which no human hand could make equally well. The old idea that linen produced by hand was stronger is gradually disappearing, as being entirely erroneous. The late war in this country, by causing high prices for cotton, had, in regard to flax-culture, one beneficial feature; it created again a demand for good fibre, and this demand has not ceased, but, on the contrary, is constantly increasing. Scientific flax-culture may be said to have been originated in Europe by a war in the United States, and it is about time that Americans should take part in the profits resulting from that industry.

The seed of flax, of which fig. 7 shows all the details, is also a very important article; from it is made linseed-oil, a fat and drying oil, which is used for many technical purposes. By cold pressing about 20 per cent. of the seed is obtained as oil, by warm pressing about 28 per cent. The former oil is almost colorless, and the detached particles of plants in it soon settle; the latter is yellowish. Clear oil, obtained by cold pressing, is used as a substitute for butter in some regions, but has an unpleasant flavor. Most of the linseed-oil is manufactured into varnishes of various kinds. One of the most important by-products in the manufacture of linseed-oil is oil-cake, the remains of the expressed seeds. It is a pity that this valuable material is exported to such a large extent, chiefly to England, where it is used with

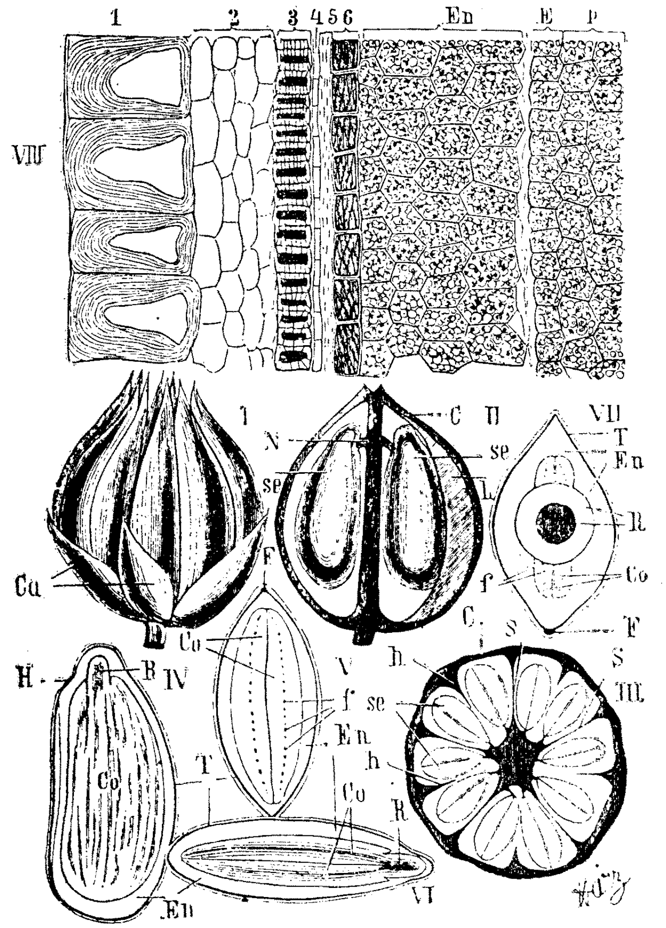

Fig. 7. Parts of capsule and seed. I., whole capsule opened; II., longitudinal section; III., cross-section; IV.–VII., longitudinal cross-sections through seeds; VIII., the different parts of skin of seed (after Harz).

great benefit for feeding sheep and other farm animals. It should be utilized for similar purposes at home; by sending it away we give color to the claim that flax-culture robs the soil, and that nothing is returned to it.

The flax plant was formerly used to some extent in medicine, and is, as *Placenta lini*, still utilized as a poultice. A liniment made of equal parts of the oil and lime-water is frequently used against burns, and a good balsam (*Oleum lini sulfuratum*) is made by heating six parts of oil with one part of flower of sulphur. Internally the oil is given to surround injurious chemical substances.

The straw is also used for various purposes. During the winter cattle like to eat it, and a large amount is thus utilized. If ground fine it forms an excellent material for manufacturing paper utensils and for various other purposes.

KINDS OF FLAX.

Several kinds of flax, which may be considered simply as varieties of the same species of plant, are grown for the sake of their fibre and seed.

1. PERENNIAL FLAX (*Linum perenne*), a plant with rather large blue flowers, is grown in some regions of Southern Europe. At one time great expectations were entertained in regard to it, but flax-growers have now very generally reached the conclusion that it is really of very little economic value.

2. WINTER FLAX is also grown to some extent in Southern Europe, but chiefly in the vicinity of Krain. Careful experiments made by a number of societies interested in flax-culture demonstrated that this kind is by no means superior to summer flax, as the yield of fibre in it is less certain, and not larger. Moreover, the plants branch much more, and in regions in which the month of August, the proper time for seeding this variety, is dry, success is always uncertain. In regions with a moist autumn, and with clean and light soils well protected during winter with a heavy coat of snow, its culture may prove very successful.

3. SUMMER FLAX seems to be the only variety of real value. Two kinds can be distinguished, *Linum crepitans* and *Linum usitatissimum*.

(*a*.) *Linum crepitans* (or humile). This kind received the name *crepitans* from the fact that its seed capsules explode with a peculiar crepitating or crackling noise if exposed to the sun during dry weather, thus scattering the seed. The plants do not grow as tall as the other kind of summer flax, their stems are thicker, stronger, more branched, and bear more and larger blue flowers, and consequently produce more seed capsules and seed. But as the capsules open so readily when ripe, a large amount of seed is lost if the plants are not harvested in time. The amount of fibre is also much smaller.

(*b*.) *Linum usitatissimum* is so named because it is the most useful kind. The seed capsules of it do not open so readily by themselves, but have to be forcibly opened by various means to separate the seeds from the chaff. It is the best kind of flax as demonstrated by very numerous comparative experiments in the flax-growing centers of Europe and in this country. A similar and unanimous opinion was recently expressed in a resolution at the congress of the International Flax-growing Association in

Vienna. "As learned from numerous experiments we recommend the culture of the blue-flowering flax (*Linum usitatissimum vulgare*) as the best."

This kind of flax succeeds best in the baltic provinces of Russia, in Belgium, Holland, Tyrol, parts of Germany and Ireland. The seeds grown in Russia are sold in the markets as Riga, Courland, Pernau, Lithuania, etc., seed, but these names do not express different kinds, but simply tell us in what regions the parent plant was grown, and that seeds received from there may reasonably assure the buyers that he may expect good crops by using them. Other names, such as Crown-flax, Rose-flax, Tun-flax, Early flax, Late flax and others, neither refer to peculiar varities, but to brands prepared for the market.

Another variety of flax is the White-flowering American Flax. (*Linum americanum album.*) This plant grows very tall, has a white flower, is easily retted, produces a large crop of good fibre, but deteriorates so very rapidly that the seed has to be renewed at least every second year.

The Royal Flax (*Linum royal*) is claimed to grow even taller and to produce very fine and strong fibre. But it does not ret as well as the common flax, and experiments have clearly shown that the claims are exagerated, and that this variety is not nearly as good as the American variety.

THE CLIMATE.

The product of every cultivated plant is more or less dependent upon the climate, and this is the case to a very high degree with flax. This plant thrives best in regions with a moist, moderately warm climate, free of late frosts in spring, with numerous rains during the growing period, and where long, continued rainy spells do not alternate with long, continued dryness. Such conditions usually prevail along the coasts, in the bottom land along large rivers, near large lakes, and in the valleys of mountainous regions. Ireland, England, Belgium, Holland, the Baltic provinces of Russia and some regions in northern and central Germany are favored by nature for extensive flax culture.

The amount of rain per year should not be less than 26 inches, of which 8 to 9 inches should fall in the form of very many showers during the months of April to August. In regions with a dry climate flax is an unsafe crop as far as the amount of fibre is concerned, which is usually small and of poor quality. Late frosts are in so far injurious as the time of seeding has to be postponed until late in spring.

The amount of heat required by flax during its period of growth, which lasts from four to four and a half months, is about 1060° F. In a warm and drier season the plants remain short, but the seeds are more numerous, and vice versa.

Fields with a level soil sloping to the west are best for the culture of flax; those sloping to the east dry too rapidly in the morning, and those sloping to the south dry too thoroughly. Steep slopes are not suitable because the soil is generally of very unequal quality, causing a corresponding unequal stand of the plants.

As a general rule we may say that most of the level soils located in low land are suitable for flax, if the climate is also suitable. Unsuited are sloping hillsides and deep valleys, both of which are frequently injured by late frosts.

One of the reasons that Belgium produces the best flax for fibre is found in the fact that in that country the seeds can be planted very early in spring, as late frosts are almost unknown. Moreover, the continuous moist winters of Belgium insure the proper conditions of the fields for flax, and as the soil is made quite porous by very careful cultivation, excessive moisture is not to be dreaded. Spring commences there in March, and the land for flax can be prepared quite early. The best flax-growing regions of Belgium are also distinguished by a larger amount of atmospheric moisture, and by a moderate warm temperature of summer.

Fields protected by forests or even by hedges produce more and better fibre, and it is a well known fact in flax-growing regions that a narrow strip of flax located between fields of grains is very apt to produce the longest fibre.

THE SOIL.

The flax plant prefers a mild, soft soil, light and not too heavy, and free of weeds. A mild loamy soil with a deep layer of humus and a subsoil not too dry is best adapted for the requirements of this plant. A stiff soil composed of clay, or a dry and sandy one, is unsuitable. A very sandy soil is only good for flax culture if sufficiently moist. It is a rather remarkable fact that the very best fibre is grown in a part of eastern Flanders, in the so-called Waesland, upon a real sandy soil. In fact at one time that whole region was a dry and open waste. But by long, continued and very careful cultures this land was gradually reclaimed and provided with a deep layer of most excellent soil. It is true that this sandy region could be made so profitable for flax culture by being moist.

The most important quality of the soil for the successful culture of flax is great depth, and the careful removal of all standing water or ground water, such as is commonly disposed of by tile-draining, as the roots of this plant penetrate very deep. If such conditions can not be had or can not be made no one can expect to produce fine fibre. Under-draining is consequently of vital importance, as the plants can not thrive if the roots strike the ground water. But there is another important reason for under-draining. Since the roots penetrate to a great depth the food is taken from that depth, and the soil is there soon exhausted of soluble food for the plant. This is claimed by some to be the chief reason why flax can not be grown successfully upon the same soil for a number of seasons. Is the soil reached by the roots freed from water, the atmospheric gases will have no trouble to penetrate, and owing to their presence new soluble food for the plants can be and is produced.

In Belgium, Rhenish Prussia and Westfalia three classes of soil adapted to flax are recognized:

First Class—Light clayey soil, of blackish or gray color.

Second Class—Heavier clayey soil, mixed with gray or yellow sand.

Third Class—Heavy clay, mixed with much sand, so that the soil is not tough.

Unsuitable for flax is pure sand or tough clay, and also all soils containing much iron, since that substance prevents good bleaching of the fibre. Burned land and well-drained ponds produce good crops.

PREPARATION OF THE SOIL.

The best rule to follow in preparing the soil is to make it clean, deep and fine. All weeds existing in the soil have to be removed, and their seeds must be brought to the surface, where the young germinating plants can later be destroyed. As weeds are the greatest enemies for flax, if good and uniform fibre is the desired crop, it is always best to select land free of them; for instance land upon which corn, potatoes, turnips, or any other well-cultivated crops have been grown during the previous season, or freshly burned clover fields, are suitable for flax, as being comparatively free of weeds. Experience has shown that in the same ratio in which weeds are exterminated the expense of weeding, etc., decreases. It is frequentlv advisable to plow to a depth of 12 inches in fall, so as to bring soil free of weeds to the surface. Deep plowing has another advantage, as it enables the plant to penetrate very deep with its tap-root, a very important item, since the length of the stem increases in about the same ratio as the length of the root. In a field with a good subsoil the plow should go as deep as 18 inches; in this case it is best to have one plow follow the other, the second plow to either simply stir up the deeper layers of soil, or to throw them bodily over the ridge made by the first plow. If, however, the subsoil is less suitable for flax, or of an inferior quality, great caution is necessary. In such a case it is best to plow deep during the second previous fall, and to improve the soil by means of a well-manured hoed crop. Deep plowing in fall is always very important for flax, because by doing so the soil is enabled to store much more moisture than would otherwise be the case. By leaving the field very rough or in ridges during winter the soil is greatly benefitted, because thus more surface is exposed to the decomposing actions of the atmosphere. In most cases it is not necessary to plow again in spring, but very liberal use should be made of pulverizer, harrow and roller. If the fall plowing was not sufficient, one or even two plowings in spring are advisable, and are almost always necessary in colder regions. The flax plant loves a soil which has thoroughly well settled, another reason to plow during fall. It is also a good plan to make the surface of the fields quite flat, or to divide it in broad flat plats, since by this means we can produce plants of equal length, as plants growing in the furrows or near them are usually very unequal in length.

CROP SUCCESSION.

It is always necessary to recollect two things: That the soil must be rich in food for flax, and that this plant can not successfully resist weeds. Fields which during the previous season have been hoed by hand or cultivated are therefore considered best for the purpose of the flax-grower, as they are also fairly free from weeds. It is peculiar, however, that flax will not succeed very well after turnips or beets. As a general rule, flax will succeed well after any crop which had been well manured, and also after clover. Oats, sown in a broken clover field, is followed with excellent results by flax; the same may be stated of wheat in a heavy soil. Potatoes grown in broken meadows or low clover-fields usually assure a good crop of flax, if succeeded by that plant.

We find that if flax is harvested before its seeds are ripe that the soil is less exhausted than would otherwise be the case, and that other varieties of crops can follow without first manuring the soil.

It is claimed, sometimes, that flax could be grown successfully in the same season after an early crop of cereals had been harvested. Experiments have demonstrated, however, that such a method is not a profitable one, as flax thus grown produces but very poor fibre. Experience has also shown that flax will not succeed after flax, and that we have to wait from 7 to 12 years before another crop upon the same field can be reasonably expected. The causes for this peculiarity are not clearly understood (see report to the Governor).

MANURING.

Flax plants are greedy feeders and absorb a large amount of food-salts from the soil. I quote from a number of experiments made to investigate this matter.

A crop of *flax* composed of 8,800 ℔ of air-dried stems and of 2,200 ℔ of seeds and chaff absorbed 124.52 ℔ potash and 81.4 ℔ phosphoric acid.

A crop of *wheat* composed of 4,400 ℔ of grains and of 8,800 ℔ of straw absorbed 83.6 ℔ potash and 77 ℔ phosphoric acid.

A crop of *rye* composed of 3,960 ℔ of grains and of 8,800 ℔ of straw absorbed 96.8 ℔ potash and 66 ℔ phosphoric acid.

Another experiment gave the following result: A crop of 1,320 ℔ seeds, 9,900 ℔ stems and 1,100 ℔ chaff absorbed from the soil 125.18 ℔ potash, 29.36 ℔ soda, 89.03 ℔ lime, 29.96 ℔ magnesia, 63.09 ℔ phosphoric acid, 25.27 ℔ sulphuric acid, and a large amount of nitrogen. This shows very plainly that flax grown for fibre is more exhausting to the soil than wheat; it also shows that flax can only be grown successfully in a soil rich in food-salts, and if these are lacking the soil must be manured to make up for any deficiency. Only in cases where the previous crop had been very well manured it is not so necessary to add fertilizers.

Stable manure should not be used, at least not when fresh. It contains too many seeds of weeds, produces a poor fibre, and has other disadvantages. But if we have to use it we must apply it to the deeply-plowed field in the fall, so that all the soluble substances will be extracted in good time. The remaining insoluble parts can be worked in the soil with the spring manipulations. In some parts of Belgium farmers imbed stable manure to a great depth and thus try to escape its injurious effects. Yet no matter how stable manure is applied the result is always a more or less uneven stand of the plants. If the farmer cannot buy artificial fertilizers for his flax he should substitute a liquid form of the stable manure, to which may be added with good results the dung of fowls. An application in this form can be made just before sowing the flax. Or, what would be as well, if not better, farmers should transform the stable manure into compost. In doing so the seeds of nearly all weeds will be destroyed, the compost will mix more uniformly with the soil, and thus produce a very uniform stand of the plants.

Yet compost alone is barely sufficient, and we ought to add to it wood ashes or potash, and bone meal. Common salt as well as potassium chloride improves the fibre. A fertilizer composed of phosphate alone, or of lime, produces short and coarse fibres. The best and most practical fertilizer, that is, a fertilizer which will produce both large and good crops of fibre, is yet to be discovered, but a compositlon of nitrogen, potash and phosphoric acid in a soluble form and in the right proportions, ought to work well if applied in sufficient quantity. A fertilizer composed of 130 to 260 ℔ Chili salpeter, 175 to 260 ℔ superphosphate (of a strength of 20 per cent) and 350 to 530 ℔ kainite per acre has been proposed by Wagner, who says that a fertilizer composed of too much phosphoric acid and little nitrogen is not advisable, as its use had the tendency to mature the stems of flax too rapidly.

An experiment made at Hohenheim, Germany, gave the following result: A fertilizer composed of 114 ℔ Chili salpeter and 343 ℔ potash salt (triple concentration) gave per acre 1,408 ℔ seeds and 9,383 ℔ dry stems over three feet long. It must be added that the previous crop upon this trial field had been fertilized with phosphates.

In general it may be stated that it is best to apply and plow under during the fall potash salts, rich in chlorides and the phosphate, and add at seeding time Chili salpeter. It would perhaps be still better to apply one-half of the nitrogen in the form of Chili salpeter, and the other half as ammonium sulphate so that the plants have sufficient nitrogen throughout their whole period of growth, and not alone at the beginning of it. A very uniform application is very important to produce an equal stand of the plants. Chili salpeter acts very rapidly and is consequently of great value early in the season, so as to make strong plants. Peru guano must be plowed under during the fall to obtain telling benefits.

After a very thorough discussion the Association of Flax-growers at the Congress in Vienna adopted the resolution: That stable manure should only be applied to the previous crop, and that artificial fertilizers, such as ashes, compost, phosphates and Chili salpeter were of great value. To fertilize with lime was considered not advisable as its application made a rough fibre.

PROPER SELECTION OF SEED.

Nothing is more important in flax-culture than to use only the very best seed, an essential too often neglected. There is at present no more doubt that the selection of good seed is very important for every cultivated plant, and that it is all-important in the case of flax. The greatest attention to the proper selection of seed is the first step to successful flax-culture. Over a century ago Justus Maeser in his "Phantasies" said: To improve the linen industry we must select good seed.

Good seeds should possess the following external characters: They should be of an uniform elongated shape; the odor should be fresh, not stale or mouldy; if thrown upon a glowing coal or upon a hot stove they should explode with a crackling noise; thrown into water they should *all* gradually sink, as only the heavier ones are fit for seeding purposes. 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. In some regions seed is preferred the point of which possesses a small bent hook.

It is customary in many localities to roast the seed before sowing, and a number of experiments *have indicated that the plants resulting from this method are stronger. A temperature from 112–122° F. is necessary for this purpose. The explanations of this phenomenon are various, but I think roasting simply destroys the germs of the weaker seeds, and thus only healthy and strong ones will germinate and produce plants. Simply a case of the survival of the fittest! According to Rufin the seeds, piled up from 3 to 4 inches high, are exposed to a temperature of 122° F., after removal from the heat are stirred until cool. During this operation the seeds lose in color and brightness, and the outer skin indicates numerous little cracks. When planted moisture is more readily absorbed, and the young plants, though a little later than usual, appear more uniformly. Of course to make up for the death of the germs in the weaker seeds, a greater quantity must be used for sowing.

Opinions differ greatly as to the value of old seed in comparison to young or fresh seed. Numerous experiments have shown that a long rest of the seed (2 to 5 years) resulted in large crops of fine fibre. Yet, on the other side, only the freshest seeds are used in Russia and Belgium, and the crops are excellent, providing the seeds were of the very best quality. At all events every farmer who intends to grow flax should make certain that the seed to be used is of the best to be had, and to test the matter he should always make a trial before seeding time. A handful of seeds laid between two moistened pieces of woolen goods, and left in a warm place, will soon show how many of the seeds have germinated. If he requires still more positive assurance that the young plants are strong enough to absorb food from the soil, let him put a number of seeds in a flower-pot filled with sawdust. By putting this in a warm place, and keeping the sawdust moist with tepid water, he will, in the course of four to six days, observe the young plants. If one-third of the seeds do not produce healthy and strong plants he must discard the seed as too poor for his purpose.

Soaking the seeds in water and exposing them afterwards to freezing seems to be of benefit, but more and careful experiments are required to settle this question.

Many seeds of flax are adulterated, both accidentally and purposely. It is true flax seed is very difficult to clean thoroughly, and honest dealers claim that even with the greatest pains taken, about two per cent. of it may be composed of the seeds of weeds. Still, with the improved machinery, there should be no excuse to sell unclean seeds. Farmers should insist

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*The results of careful experiments recently made by Wollny are also here given: The seeds were roasted for 25 days at a temperature of 110° F. 1,550 grains of seed produced 4,495 grains of seed and 24,722.5 grains of raw flax; 1,240 grains of seed produced 4,386.5 grains of seed and 14,802.5 grains of raw flax, and 3,689 grains of chaff.

Seeds not roasted: 1,550 grains of seed produced 3,445.6 grains of seed and 18,724 grains of raw flax; 1,240 grains of seed produced 5,285.5 grains of seed and 12,896 grains of raw flax, and 3,658 grains of chaff.

on buying nothing but perfectly pure seeds, even if they cost twice as much, as weeds of all sorts are so readily introduced, and so very difficult to eradicate if they once obtain a foothold.

CHANGING OR RENEWAL OF SEED.

The necessity of frequently changing the seed is still an open question as far as flax is concerned, and many facts might be adduced which are in its favor, whilst others are not.

The production of good seed depends even more upon the quality of the soil than the production of fine fibre, and, consequently, not every farmer can grow good seed. To produce it the soil should contain, in soluble form, sufficient amounts of salts, but chiefly of potash. The best regions for excellent seed are the clayey soils of the Baltic Provinces of Russia, the Dutch low-lands recovered from the ocean, and the valleys in the Tyrolese mountains, where the soil is composed of finely ground stones (granite and gneiss) brought down by glaciers. Fertilizing with the proper materials to add all lacking substances to the soil can not produce such an even composition of it as has been made by nature. Consequently, and until we can by proper fertilization produce equal results, we must largely depend for good seed upon such favored regions. But if we do not possess soil fit for the successful growth of flax, the importation of the very best seed will be of very little avail; even in favored regions it is not always easy to obtain the best seed. In flax-growing centers the production of fine fibre pays much better than that of the seed, and not much more seed is grown than is absolutely necessary for home consumption. We must recollect that good seed in a plant can only be produced at the expense of the quality of its fibre. In Holland flax-growers select for the purpose of growing seed and fibre at the same time such fields that have a peculiarly rich soil. They sow 2 bushels of seed per acre and pull the flax at a time when, in the majority of plants, the capsules are so far advanced that a cross-cut through them shows an uniform surface. The seeds are kept in the capsules until ready to be threshed, when the seeds are cleaned and carefully sorted. Yet, notwithstanding all such precautions, it is even necessary in Holland to change the seed from time to time.

It is thus plainly seen that the success of flax-culture for fine fibre does not alone depend upon good farming, upon good soil, but also very much upon good seed. Practical flax-growers have learned this fact long ago, and in consequence of this the seeds obtained in the Baltic provinces of Russia, from Riga, Pernau, Windau, Pskow, in the Dutch and Zealand regions, and in the province of Prussia in Germany, have acquired such great fame. Experiments with these seeds have clearly demonstrated that larger crops are the results of their use, but that owing to a less favorable soil in the regions where such experiments were made, a few years suffice to degenerate the seed. To show the importance of good seed it may be mentioned that farmers in Holland buy Russian seed, grow two crops with it, and sell their third crop of seed as "Zealand Flax Seed" for export.*

*Flax-seed from Riga contains more phosphoric acid than any other flax-seed. The ashes contain 40 per cent. of phosphoric acid, those of the first generation of

A periodical exchange of seed is also carried out in Russia between farm and farm, or, village and village. A series of very interesting experiments made for a number of years in Ravenberg clearly proved that for that region at least it was absolutely necessary to import northern grown seed. In Belgium, where besides fibre a large amount of seed is grown, it is usual to use for seeding purposes one-third Riga seed and two-thirds of the best home-grown kind.

This degeneration of the seed is most rapid in regions where the conditions are unfavorable for flax, or in other words, in regions with a dry climate and soil, and where the time for sowing is late.

As a rather general rule we may say that seed imported from a colder region with poorer soil will produce the best crops if used farther south upon a richer soil.

It is frequently stated that the reason for the superiority of Russian flax seed was owing to the fact that it was grown in poorer soil, in a more rigid atmosphere, but in a very favorable climate. This is only partly true, as the methods of farming and caring for the seed have also a beneficial influence. To produce good seed the Russian farmer uses a small amount of seed upon a strong and well-manured soil, and he does not allow the capsules to ripen fully. When ready for the harvest the capsules are cut off in such a manner as to retain short stems which are tied together in a spiral around some pole, or upon a wheel, and they are thus allowed to ripen in a dry place. The capsules being well separated can not heat, sweat and turn dark. This method is considered of vital importance to produce good seed. When the capsules are dry they are carried into a moderately heated room until they are perfectly dry, when the seeds are removed by thrashing. Many other methods are in vogue, all having the same object in view, i. e., to dry the capsules separately before removal of the seed.

To recapitulate: To obtain good seed the plants must be grown upon a strong or well-manured soil, little seed should be used so that the stems can grow thick and carry complete capsules; the seeds must ripen well; the cut stems with the capsules should be dried in the opén air to prevent heating, and thrashing should be done at a time when the air is dry. If the capsules cannot be dried artificially threshing ought to be carried out as soon as possible, as even apparently dry capsules, if piled together, contain sufficient moisture to cause injury.

From what has been said it does not seem to be a very simple matter to obtain good seed. And this is only too true! Only responsible wholesale dealers in flax seed are able, if they pay the very necessary attention to it, to obtain real good imported seed. And such seed must be imported as soon as the crop has been harvested, otherwise the best quality is no longer obtainable. In flax-growing districts the formation of societies to import seed directly or through a responsible seed house having a branch house in Russia, would be a step in the right direction.

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seeds grown elsewhere from Riga flax, 30 per cent., and those of the second generation only 15–20 per cent. Many flax-growers believe that this decrease in phosphoric acid is the cause for the rapid degeneration of Russian seed, if grown elsewhere.

AMOUNT OF SEED.

The flax plant does not tiller or stock out like wheat, and consequently we have to use more seed upon rich soil than upon that of a poorer quality. The amount of seed is also dependent upon the character of the crop desired, whether fibre or seed, upon the age and condition of the seed, time of year, etc.

1. If we intend to produce common fibre we need 48 quarts of good seed per acre. A close stand of the plants prevents to some extent the growth of weeds, shades the ground, prevents branching, and thus produces longer and finer fibre.

2. If we intend to produce very fine fibre by means of the practice called "Ländern," (see page 25) about 60 quarts should be used.

3. If a crop of fibre and seed is desired 32 quarts is sufficient, and if we intend to produce only seed 20 quarts is enough.

4. Above quantities of seed are intended for best flax soil; upon medium soil deduct one-sixth, and upon still poorer soil one-fourth.

5. Of Rnssian seed, if not injured during the transportation to this country, one-third less should be used as the seed is so much stronger.

6. Larger quantities of seeds sown early, or of weak seed, should be used than if sown later, or if the seed is stronger.

7. To produce a crop of seed flax seed of the previous season is preferable.

For the production of fine fibre more seed must be used, since by doing so the stems of the plants grow longer, have fewer leaves and less branches. For a crop of seed less flax seed is required, so as to give the plant ample room to produce a thick stem and many branches.

Von der Goltz advises the following quantities of seed: For fibre, 185 to 250 ℔ per acre; for seed, 115 to 170 ℔ per acre.

I find it very difficult to give the proper amount of seed necessary for the various purposes mentioned above, as both weight and size of flax-seed are such a variable quality.

1,000 seeds had a minimum weight of	56.42 grains
1,000 seeds had a maximum weight of	112.22 grains
1,000 seeds had a mean weight of	81.99 grains

The diameter of a seed varies from a minimum of 0.8 to 1.0 mm., to a maximum of 3.5 to 5.5 mm., giving a mean of 3.5 to 5.5 mm.

TIME OF SEEDING.

Sowing at the right time is very important in the case of flax for fibre. We know that success in flax-culture depends, to a high degree, upon soil and atmospheric conditions. The selection of suitable soil is in our power, not so the necessary favorable condition of the climate. To be successful every farmer must study all conditions and must ascertain for himself when the right time for sowing has arrived in his vicinity. No binding rules can be given, nor should they be followed in the case of flax, as every farmer must suit his actions to the ever-changing conditions.

Early sowing is adopted in Belgium, a late one in parts of Germany. Both methods are based upon the experience that flax needs considerable moisture to succeed well, and early sowing is best for the peculiar climate of Belgium, late sowing for that of Germany.

The good results of early sowing are due to the moisture left in the soil by the melting snows, the cooler temperature of early spring is beneficial to the plants and they produce a longer fibre. The fibre of early flax is tougher, more elastic and stronger than that produced by later plants. Another advantage is found in the fact that after an early crop—harvested in the early part of July—the water in rivers and lakes is quite warm, and particularly good for retting the plants. To insure to some extent against late frosts flax-seed may be sown at different times, so as to obtain a rich crop from at least part of the plants. Of course the expression "early sowing" means a different period in each locality, and what is considered early in one region may be called late in another one. Early sowing simply means that it is performed in a given locality at the earliest safe day, so that the plants reach a fair size before a continuous dry period commences. Early frosts are not so very injurious after all, because a healthy and strong plant possesses wonderful powers of resistance. A crop produced from late sowing has the great disadvantage that the farmer has to store his flax-straw at least one year before he can transform it into saleable fibre. Of course if factories are started to do this work for him, this view of the case loses in importance.

The Congress of Flax-growing Agriculturists in Vienna formulated their views in the resolution that early sowing was, as a general rule, the most satisfactory one. Sowing flax as a second crop in the same year was considered unadvisable, as the fibre thus produced was brittle.

SOWING.

The preparation of the soil for flax, and the labors to be performed, depend upon the character of the soil. As a rule we must prepare a fine, deep, not too loose or dried out bed of good soil. Upon a very loose soil the plant can not find the necessary moisture so important to it. Every good farmer no doubt knows how to exactly produce such a condition of the soil. It is, as a general rule, not necessary to plow again during spring, and a field requiring such a treatment is barely suitable to produce a fine quality of fibre. But repeated harrowing is very necessary. It is a common saying in Belgium that, "Whoever wants a good crop of flax must tire his harrow." The surface of the soil must be made very even and smooth, or the stems of the flax plants will grow unequal in length. In friable soil two harrowings at intervals just before sowing are sufficient, but in a freshly-broken field four are barely sufficient. It is all-important to retain as much moisture in the soil as possible, and to bring, at the same time, as many seeds of weeds to the surface as possible, so that the latter can germinate before sowing time; thorough harrowing is the best method for this purpose. The use of a pulverizer is best for sowing; it is to be followed with a harrow and a roller. In doing so we destroy nearly all weeds upon the surface, and as no fresh seeds are exposed the ground is made very smooth, even and free of weeds.

Rolling is a very important and necessary operation after continuous dry weather, and upon freshly broken ground. Sowing should be done at a time when there is no wind; cloudy weather, with indications of approaching rains, is a very suitable time for sowing. During a dry spell heavy dew has to assist us, and it is then best to sow towards evening and harrow the next morning. Sowing must be performed either by a very practiced hand, or still better, by a broad-cast machine. If finished we follow with a light harrow, and as a last operation with a roller. The seeds should not be imbeded deeper than 0.6 inch. In Ireland farmers harrow three times, twice in one direction and once diagonally. Great care is necessary so that the seed is distributed very uniformly. The use of a drill is not advisable for producing good fibre; for a crop of seed, however, it is excellent.

TREATMENT OF THE GROWING PLANTS.

Between the time of sowing and the pulling of the plants many operations may become necessary. Rolling, manuring, weeding, prevention of diseases, removal of noxious insects, and "Ländern" are the principal ones.

Rolling.—In warm and moist weather the seeds will germinate very rapidly, and after five or six days the young plants appear above ground. But frequently it requires eight days to two weeks. If beating rains should fall soon after sowing a very injurious hard surface may form upon the soil; this crust must be removed to assure an uniform stand of plants. The use of a light harrow or of a light roller composed of numerous independent narrow rings, is very profitable and should be employed; best very early in the morning, or as long as the soil is still damp.

Manuring.—If the atmospheric conditions are not suitable and the plants remain small and of unequal length, it is very advisable to add some fertilizers. They should be applied as soon as possible, and as long as the plants are still small. Well-sifted wood ashes are excellent for this purpose, and should be applied during a dry day without wind. If such an application is followed by rain a very rapid growth soon indicates its beneficial influence. Finely ground gypsum applied at a time when rain can reasonably be expected, and not in too large quantities, is also of great value. Lime, on the contrary, should not be used for this purpose. Peruvian guano applied to a wet field is also beneficial.

Weeding.—Thorough weeding is of the greatest importance to success. No matter how carefully we have been to select seed free of impurities, and how much time and attention had been given to the destruction of weeds in the fields, weeds of various kind will appear. Flax-growers in Europe are very much satisfied if only one weeding of the fields soon after the appearance of the young flax becomes necessary. Weeding is most usually performed when the plants of flax have reached a height of 7 or 8 inches. Most thorough and quickly performed weeding is absolutely necessary, as the flax grows very rapidly, and as a later weeding becomes both more laborious and injurious to the plants. We should in weeding work towards the wind so that the plants of flax will soon be able to reassume a perpendicular position. During a wet period no weeding should be performed; if very dry, persons engaged in the work should be careful to compress again the soil loosened by the pulling of the larger weeds, so that the roots of flax are not exposed to any drying influences. All weeds should be pulled and not broken, too frequently done with young and still tender plants. In Belgium children and women perform this work. They remove their shoes and replace them by thick socks if working in an upright position, or they fasten some heavy rags to their knees if working in a kneeling position, so as to injure the young flax as little as possible. If it becomes necessary to resort to a second operation of weeding this should be performed not later than ten to fourteen days after the first one.

Flax-growers in Scotland resort to a very peculiar method of getting rid of weeds by pasturing their sheep in fields sown with flax. The sheep do not eat the flax but the weeds. Of course this sort of weeding is by no means equal to that performed by manual labor, yet is better than no weeding at all. In France this Scotch method is also used to some extent; it is claimed there that the compressing of the soil by the feet of sheep acts beneficial, and that their droppings produce excellent crops. The number of sheep used for this purpose must not be too great; a few of them forced to make many trips in all directions over the field are preferable, and the young plants of flax do not sustain as much injury as if a larger flock had been used.

ENEMIES OF THE FLAX.

All weeds are very injurious to successful flax-culture. At present the worst enemies have not yet found their way to Minnesota, but with an increase of flax-culture there is but little doubt that the one or the other injurious plant may be introduced in time, and it behooves us to pay the greatest attention to prevent it as long as possible.

Among injurious plants we already possess the wild Mustard, the Pigeon grass and the wild Morning glory. All three are very difficult to eradicate when once thoroughly established. But Mustard and Morning glory would not find so easily a lodgment if only perfectly clean seed of flax had always been selected, or would be selected now. The common Morning glory is very bad as the tough, winding stems cannot be separated from the flax even after the most thorough retting. Pigeon grass is also exceedingly difficult to remove; it stands retting as well as the flax and the blades must be later removed singly by hand, by no means an easy operation. The worst enemy among plants is the common Dodder of Europe, a parasitie plant almost impossible to eradicate. At present it is not found in this State, but with the importation of unclean seed of flax it is almost certain to appear sooner or later. The size of the seed of this dangerous plant is about that of a large mustard seed, and is of a brown color.

Among insects some species of the omnivorous Cut-worms are said to be very injurious in Minnesota. Yet during my labors in the flax regions of Southwestern Minnesota I have never been able to detect any nor their work, which, of course, does not prove their absence in other parts of the State. Yet adjoining fields with wheat contained immense numbers of cut-worms; in fact cut-worms were everywhere excepting in fields of flax. The White grub is sometimes injurious, but not sufficiently so to cause alarm. A small Flea-beetle is very injurious in parts of Europe, but is not found in this country. At all events, as far as insects are concerned, flax in this country is at present remarkably free of them.

DISEASES OF FLAX.

Real diseases of the flax were almost unknown in the past. In Europe several species of lowly organized fungi cause from time to time great injury. The rust of flax (*Melampsora lini Desm.*) is the most dangerous disease in Europe, but is as yet not found in Minnesota. Some wild species of flax in the Rocky Mountains prove, however, very plainly the presence of this rust in the United States, and we can not be too careful to avoid its introduction. The disease caused by this parasite is called in Belgium "le feu" or the fire, a very good name to express its effects upon the flax.

A second disease is indicated by the death of the upper part of the plant and by new branches starting from the lower stem at the point where the upper part disappeared. If the season is favorable the damage is but slight, but becomes very great in a dry season.

In another questionable disease the stems of the plant assume a yellow color at the base, a blackish one at the tip, and the leaves—and later the stems—die and disappear. Opinions vary as to the real cause; some blame deep plowing, others too frequent crops of flax in the same soil. The following report to His Excellency, Governor W. R. Merriam, who took great interest in this matter, will show the probable cause of the trouble. In many cases successive good crops were obtained, but as a very general rule it would be unwise to imitate such attempts and to run the risk of losing seeds as well as the whole crop.

REPORT TO HIS EXCELLENCY, GOVERNOR W. R. MERRIAM.

DEAR SIR:—One of the most important branches of farming in the State of Minnesota, at least in the more southern parts, is the cultivation of flax; not for its fibre, but chiefly for its seed, the raw material for linseed oil. Minnesota produces at present more flax seed than any other state of the Union, and this industry is steadily increasing. Many reasons could be given for this increase, but the leading one is the general failure of the wheat crop, due largely to the ravages of the Chinch-bugs. During the last five years the flax industry has suffered greatly in many regions from a mysterious disease of the plants, and grave fears are entertained for the future success of flax-culture. Many farmers, knowing the great interest you take in their welfare, applied to you for assistance, or rather asked you to have the matter investigated with the view of perhaps discovering some method to overcome or lessen this threatening evil. As I had some experience with this disease in 1889 you obtained the co-operation of the regents of the University, and appointed me early in May to investigate it in the infested region. I immediately proceeded to the region about Windom where some land badly infested could be rented, and where I obtained the intelligent assistance of a resident farmer, Mr. Emil J. Meilicke.

Several practical methods to investigate this trouble presented themselves. One, based upon the assumption that exhaustion of the soil by previous crops of flax was the cause of failure, led to the first series of experiments; another, that a specific disease caused the death of the plants, led to a second one. The results of both series of experiments proved beyond reasonable doubt that nothing practical can at present be advised to prevent losses. But during these two series of experiments many facts were observed, which, together with other observations made last year, indicated the real cause of the flax trouble, and necessitated a third series of experiments, which is now partly finished. Still, it will be necessary to continue these experiments, not in the field, but in the laboratory where all the surrounding conditions can be observed or kept under control. This will take some time, however, as the conclusion of each experiment requires about three months. The following report is therefore only a preliminary one, and only the leading facts as learned by field experiments will be given.

To carry out the first two series of experiments it was necessary to commence as early as possible, so that the soil could be prepared thoroughly. The land selected was admirably well adapted for the purpose. The soil was of good average quality, and had been twice seeded to flax. In 1888 a good crop was produced upon it, but in 1889 every plant of flax had been killed

I. Series of experiments to observe effects of fertilizers upon land exhausted by flax:

The plats, each $\frac{1}{16}$ of an acre in size, extended in one continuous row from east to west. Every third plat was left untreated, so as to make comparison easy with the adjoining plats, which were treated with fertilizers. Between the plats was left a passage three feet wide. The adjoining plats were devoted to experiments with the same fertilizer, only with this difference: One plat was seeded with flax-seeds grown upon the farm, or suspicious seed, the other with imported flax-seed from regions free from disease.

No. of Plat	*Kind of Seed*	*First Half of Plat*	*Second Half of Plat*
		Fertilizer	*Fertilizer*
1	Native	10 ℔ lime	20 ℔ lime
2	Foreign	10 ℔ lime	20 ℔ lime
3	Foreign	None	None
4	Foreign	20 ℔ acid phosphates	40 ℔ acid phosphates
5	Native	20 ℔ acid phosphates	40 ℔ acid phosphates
6	Native	None	None
7	Native	10 ℔ muriate phosphate	20 ℔ muriate phosphate
8	Foreign	10 ℔ muriate phosphate	20 ℔ muriate phosphate
9	Foreign	None	None
10	Foreign	10 ℔ salt	20 ℔ salt
11	Native	10 ℔ salt	20 ℔ salt
12	Native	None	None
13	Native	10 ℔ nitrate of soda	20 ℔ nitrate of soda
14	Foreign	10 ℔ nitrate of soda	20 ℔ nitrate of soda
15	Foreign	None	None
16	Foreign	10 ℔ super-phosphates	20 ℔ super-phosphates
17	Native	10 ℔ super-phosphates	20 ℔ super-phosphates
18	Native	None	None
19	Native	10 ℔ land plaster	20 ℔ land plaster
20	Foreign	10 ℔ land plaster	20 ℔ land plaster
21	Foreign	None	None
22	Foreign	10 ℔ ground oil cake	20 ℔ ground oil cake
23	Native	10 ℔ ground oil cake	20 ℔ ground oil cake
24	Native	None	None

Plats 49 to 60, seeded alternately with native and foreign seeds, were treated with a top dressing of the same material, after the young plants appeared above the soil.

The seeds germinated in due time in all the plats, whether fertilized or not, and the young plants soon coated the surface with their beautiful green leaves. But before long they commenced to shrivel up and all disappeared before reaching a height of three inches. The plants in plats 22 and 23, fertilized with ground oil cake, succumbed first.

These experiments plainly indicate that exhaustion of the soil by previous crops of flax can not be the cause of the disease, as all the materials formerly removed by the plants had been added again to the soil in the most soluble state. The uniformity in which the plants became diseased in all the plats was very remarkable.

II. Series of experiments to observe the effects of Fungicides on plants grown upon infested soil:

The various fungicides experimented with are usually applied in a liquid form, the seeds of the plants to be protected being soaked for a longer or shorter period in such solutions. In the case of flax another method had to be applied, as its seeds cannot be soaked without sticking together, so that they can not be seeded in the usual way. To overcome this difficulty very dry soil from the plats themselves was carefully sifted and the fungicides were thoroughly mixed with this earth. Either 50 or 100 lbs. of soil were thus mixed with the fungicides for each plat, and this mixture was seeded by means of the drill with the flax-seed. This, of course, made the mixture rather stronger than simply an immersion would have done, and the fungicides remained for a longer time in contact with the seed, in fact surrounding it. Plats 25 to 48 were thus treated:

No. of Plat	*Kind of Seed*	*First Half of Plat*	*Second Half of Plat*
		Fungicide	*Fungicide*
25	Native	1.1 lb hyposulph. sodium 1.1 lb air-slaked lime	2.2 lb hyposulph. sodium 2.2 lb air-slaked lime
26	Foreign	1.1 lb hyposulph. sodium 1.1 lb air-slaked lime	2.2 lb hyposulph. sodium 2.2 lb air-slaked lime
27	Foreign	None	None
28	Foreign	0.6 lb sulphide of sodium	1.1 lb sulphide of sodium
29	Native	0.6 lb sulphide of sodium	1.1 lb sulphide of sodium
30	Native	None	None
31	Native	0.6 lb flowers of sulphur 0.6 lb air-slaked lime	1.1 lb flowers of sulphur 1.1 lb air-slaked lime
32	Foreign	0.6 lb flowers of sulphur 0.6 lb air-slaked lime	1.1 lb flowers of sulphur 1.1 lb air-slaked lime
33	Foreign	None	None
34	Foreign	0.6 lb sulphate of copper 0.6 lb air-slaked lime	1.1 lb sulphate of copper 1.1 lb air-slaked lime
35	Native	0.6 lb sulphate of copper 0.6 lb air-slaked lime	1.1 lb sulphate of copper 1.1 lb air-slaked lime
36	Native	None	None
37	Native	0.6 lb sulphate of iron 0.6 lb air-slaked lime	1.1 lb sulphate of iron 1.1 lb air-slaked lime
38	Foreign	0.6 lb sulphate of iron 0.6 lb air-slaked lime	1.1 lb sulphate of iron 1.1 lb air-slaked lime
39	Foreign	None	None
40	Foreign	0.2 lb corrosive sublimate	0.4 lb corrosive sublimate
41	Native	0.2 lb corrosive sublimate	0.4 lb corrosive sublimate
42	Native	None	None
43	Native	0.5 lb corrosive sublimate	1 lb corrosive sublimate
44	Foreign	0.5 lb corrosive sublimate	1 lb corrosive sublimate
45	Foreign	None	None
46	Foreign	1 lb sulphate of copper	2 lb sulphate of copper
47	Native	1 lb sulphate of copper	2 lb sulphate of copper
48	Native	None	None

With the exception of plats 43, 44, 46 and 47 all the seeds germinated, and the plants soon appeared. In above four plats the fungicide had been applied rather too liberally, and fewer plants made their appearance than in the other plats. But the plants, after reaching the height of about three inches, also became diseased, and gradually disappeared. Those in plats 40 and 44 seemed to last a little longer, but other causes may have been at work. At all events, every single plant succumbed.

These experiments seem to indicate that it is not a specific vegetable disease that affects the plants, because one or the other of the fungicides would have shown the effects of its application.

As soon as the disease appeared, affected plants were closely inspected with the microscope. Large numbers of dissections were made, and thin sections, stained in various ways, were studied. But a specific organism causing the death of the plants could not be found. The young plants, when reaching the height of three inches, and very often much sooner, would simply wilt, turn black, and drop. Their roots would be firm for a little time longer, no doubt simply owing to the moisture of the surrounding soil, but eventually they would also disappear.

A cure for the disease does not seem to be possible. So it remained to be seen whether prevention was not possible. The facts reported to you early in the spring, and the observations made since that time, all point to one thing—the disease, or whatever else it may be called, can be carried by means of water and by old straw of flax from infested land to soil not yet invaded. These seemed to be facts which became clearer and more certain with every additional observation. If facts, we can explain the cause of the trouble either by the assumption that a specific disease was at work, or that there is something in the flax straw itself which produces such symptoms of a disease. To settle this point a third series of experiments became necessary. These experiments are finished as far as they were made on a larger scale in the fields, but additional ones have to be carried on in the greenhouse. These experiments were planned not to cure a disease, but to produce it in an artificial way. If this be possible, in soils not affected with the disease, and with straw of healthy plants, it will go far to show that we have not to deal with a genuine disease produced by microscopic parasitic organisms, but by something entirely different. Such experiments were carried out both near Windom and also upon the grounds of the Experiment Station.

III. Series of experiments to show that the old straw of flax is the cause of the trouble.

It is well known in Europe that flax is a plant "unkind" to its own offsprings. By "unkind" is meant that flax will not succeed flax. But the cause for this strange behavior has never been ascertained, nor have any experiments been made to demonstrate such facts.

Sixteen plats of uniform size were selected upon good and rich land, upon which no flax had ever been grown. These plats were arranged in a double row after the manner of a checker board, so that each plat treated was bound by two plats not treated. The ground was thoroughly well cultivated and the seed was uniformly distributed over all, and carefully covered with soil. Between the plats was a path three feet wide.

Plat 1 was covered with 60 ℔ of dry healthy chaff of flax; this chaff was partly worked under the soil.

Plat 1a contained nothing but seed.

Plat 2 was moistened with an extract made by soaking 60 ℔ of old healthy flax chaff in cold water.

Plat 2a contained nothing but seed.

Plat 3 was moistened with an extract made by soaking 60 ℔ of old healthy flax chaff in boiling water.

Plat 3a contained nothing but seed.

Plat 4 was moistened with an extract maœe by soaking 120 ℔ of healthy green flax in boiling water.

Plat 4a contained nothing but seed.

Plat 5 was moistened with an extract made by soaking 15 ℔ of diseased fresh flax in boiling water.

Plat 5a contained nothing but seed.

Plat 6 was moistened with an extract made by soaking 15 ℔ of diseased fresh flax in cold water.

Plat 6a contained nothing but seed.

Plat 7 was covered with 60 ℔ of dry diseased chaff of flax; this chaff was partly worked under the soil.

Plat 7a contained nothing but seed.

Plat 8 was covered with 120 ℔ of green straw of healthy plants of flax cut into small pieces.

Plat 8a contained nothing but seed.

Owing to contiguous dry weather the effects of these applications did not appear as soon as expected. The plants all commenced to grow until they had almost reached their full size, when the disease made its appearance. The plats not treated with anything did not show any disease only in some cases near the borders where the winds had drifted some of the old chaff. But in all the plats treated the disease became very manifest. The cold solutions caused the least numbers of diseased plants; the hot solutions had caused the death of nearly one half of all the plants; the dry chaff had killed all the plants, and the plats were almost denuded.

As these experiments were carried on in a region infested with the disease, it was prudent to make similar ones in a region perfectly free from it. So two plats in a garden with rich soil rented by the Experiment Station were devoted to this purpose. The ground was thoroughly cultivated and seeded with flax. As soon as the young plants appeared above the surface the letters M and E were staked out. After a hot and strong extract made of perfectly healthy fresh plants had cooled, it was applied with the spout of a sprinkling can along the lines forming the above letters. In this case also the disease did not appear until the plants had almost reached full size. But it did appear and killed every plant along the lines sprinkled with the extract, plainly proving that we have not to deal with a disease, but that the straw of flax itself is the cause of this trouble.

The experiments thus roughly outlined prove one thing very clearly: A prevention is possible, a cure not. Farmers must therefore not attempt to kill the goose that lays such golden eggs. A proper rotation of crops is the only help against this trouble. Flax should be followed, if possible, by some crops that have to be hoed or cultivated so that the old straw of the plants is removed, and that volunteer plants cannot survive. A proper rotation is very much more important in this State where the flax is not grown for the sake of its fibre. In other countries where the flax is pulled but little of the old straw and chaff remains upon the ground, yet even there it is well understood that flax should not be grown more than once every seven years upon the same field.

In closing this report it gives me great pleasure to state that the results of the expense which the State has so generously sustained through the prompt action of its efficient Governor and regents of the State Univerity gives promise of results valuable to the interests of agriculture; also it is a pleasure as well as a duty to state that the generosity of the officials of the St. P., M. & O. R. R. in giving me free transportation, greatly facilitated the work. Very respectfully yours,

OTTO LUGGER.

St. Anthony Park, October 3, 1890.

SCAFFOLDING OR "LÆNDERN" OF FLAX.

In consequence of wrong cultivation or injurious climatic influences, such as violent rains, it frequently happens that flax, instead of remaining erect, is beaten to the ground, and that it remains in that position. This is very injurious both for the formation of good fibre and seed. The fibre becomes weak and is not nearly so valuable as that from erect plants. Seeds from such plants do not mature well, and can only be used as food for cattle.

In Belgium a vast amount of flax is grown for very fine fibre, to be manufactured into the delicate French Batiste or Brussels lace. Plants to produce a fibre for this purpose are grown very close together, so as to form long stems of small diameters. When in flower such tender plants are mostly unable to retain their erect position, and the nececsary precautions must be taken to assist them. To prevent their falling down the so-called "Ländern" has been invented, which of course adds greatly to the expense of the fibre, but always brings rich returns, as fibre of this kind will bring twice the price of that of any other fibre. The raw material alone is frequently worth much more than the land upon which it grew, even in that country.

To prevent the laying of the plants they have to be supported, when about 6 to 8 inches high, by frames of wood upon which twigs are spread very uniformly. Twigs of young birch are best, but other small twigs are also used, after all the leaves have been removed from them. Forked uprights, 18 to 30 inches long and with a diameter of about 2 inches, are driven in the ground, and long poles are laid in these forks. If farmers are forced to use pine for poles they remove first the bark. Upon these frames are laid twigs which have been first compressed and flattened by means of boards or stones. These twigs form an elevated network over the field, and allow rain and air unobstructed access. Many other methods are in use, but all for the same purpose. The tender plants of flax soon find their way through this network of twigs, and are thus securely supported. Large fields are thus covered to produce an uniform result in fine fibre, and only plants growing near their edges contain less valuable fibre, as they are more exposed to the air and have, in consequence, thicker stems with coarser fibre. Of course such operations can only be carried out where labor is cheap.

ROTATIONS.

The question, "After what previous crops is it best to grow flax?" can not be answered very readily. We have to recollect that the soil must contain for flax rich sources of accessible food. As a general rule flax will do well after any well-manured and well-cultivated crop; in such a case the soil is also nearly free from weeds. After turnips and beets, however, flax will not succeed well. Oats, sown upon a freshly-broken field of clover, form an excellent crop to be followed by flax. Upon heavy soil flax succeeds well after wheat. After potatoes, in well-manured fields, flax is also generally very successful.

If flax is pulled early, or before the seeds are ripe, considerably less food is absorbed from the soil, and the succeeding crop of another plant is usually a good one; but if we allow the seeds of flax to ripen, the succeeding crop is more or less influenced and poor. Of course success or failure in either case depends greatly upon the character of the soil.

To give successful rotations the methods in vogue in some of the most favorable flax growing regions will be given.

In Belgium.—The International Congress of Flax Growers at Vienna passed unanimously this resolution: Of all the methods employed in flax culture, those in Belgium, but chiefly those in Eastern and Western Flanders, are best adapted to produce the greatest rewards.

The successful flax culture in Belgium is not so much dependent upon the quality of the soil and the nature of the climate, or upon the amount of labor and money expended, but upon a well directed union of all four elements. Such a combination of natural and artificial means is the general rule of flax growers in that country. Ireland, even better favored by soil and climate, though very successful, does not succeed as well as the energetic and skillfull flax growers of Belgium. "*Labor coronat opus*" (labor crowns the work), characterizes all Belgian agriculture.

A great part of that land is composed of alluvial soil, formed by the recession of the ocean, or by the gradual elevation of the land. Numerous large rivers emptying their muddy waters into the ocean have also formed larger or smaller deltas composed of alluvial soil. This soil, although very good, is in Belgium of less influence upon flax culture, as the enterprising farmers have succeeded to transform even sandy regions into excellent flax fields. Such sandy regions are first reclaimed by growing upon them oats, rye and broom. The two former as well the tips of the latter, are used as fodder. After three years all the plants are plowed under to form humus and thus improve the land. If the farmer can keep a cow, which he feeds with turnips and clover, the progress is quicker, and he soon transforms the sandy soil into productive fields, by carefully using both the solid and liquid manures of his animal or animals. Farms in Belgium are usually small, but few consisting of more than fifty acres, whilst the great majority contain but five to eight acres. The production of fibre upon small farms compares favorably with that of larger ones. Agriculture is carried on with a diligence found nowhere else, with, perhaps, the exception of some portions of England and the Lothians of Scotland. Cleanliness of the whole farm, deep and uniform culture, careful rotation of crops, proper husbandry and application of manure, and consequent rich returns distinguish Flemish farms from all others in Europe. Many of these farmers succeeded without being much educated, with simple tool, just by following the best of all teachers—long experience. They learned, forced by very unfavorable conditions, to make the best use of such teachings. Even to-day almost the only tool used by these farmers is the spade. The leading feature of Flemish farming is deep culture; the soil is gradually worked to a depth of 20 inches and more, and if sowed with flax it is divided in beds six feet wide, the beds being separated by deep ditches 12 inches wide. In the succeeding season a piece of soil 12 inches wide, is taken from the bed and filled in the ditch, and a new ditch is thus formed. This being done every year a thorough and deep culture, enriched by careful manuring, is the consequence, and the whole field looks like a well-cultivated garden. A deep and rich soil forms the best home for a rank vegetation; the atmospheric gases can penetrate most rapidly, and the water, instead of remaining and evaporating upon the surface or close under it, percoleates without resistance, thus leaving behind all valuable properties. Not all plants require a very deep soil, but the flax plant does, and it is not an exageration to say that the tap root of flax is as long below the surface as the stem is above the same. The aim of the Belgian farmer is to produce a deep and loose soil, perfectly uniform in texture and in the amount of food for the plants. Before the ditches mentioned above are filled the collected material in them is carefully removed with a spade, and is uniformly distributed over the beds. The manner in which sub-plowing is carried on is also peculiar. As soon as the plow has made the first furrow laborers, with spades, dig up the soil exposed in the same and deposit it upon the plow ridge, where the lumps of earth remain until dissolved by the atmosphere. The next operation with the plow fills up the depression, the spade again comes into action, and thus the whole upper surface of the field is brought below and the lower layers are brought on top. This operation is considered of equal value as an application of manure. Of course such operations are not carried out in soils composed of clay. The Belgian method of drainage is also peculiar, but it is not necessary to describe it in this relation.

The rotations adapted are based upon long and practical experience, and are not always based upon exact scientific deductions. The farmer knows that all plants absorb certain substances from the soil, and that the art of applying manure consists in replacing such substances that were taken away by any crop. They have learned in the course of many generations what they can expect to produce by following certain rotations. If the farmer is an intelligent man—and most Belgian farmers are—he surely knows the exact qualities and conditions of his land, and he knows also which crops he can grow most successfully, for which crops there is a demand, and what kind of manure it is best for him to apply to obtain any desired effect. His aim is to produce the biggest crop with the least expense and injury to his land.

Below are some of the rotations in general use in the flax-growing regions of Belgium:

In a soil of good quality, upon which wheat can be grown successfully, the following rotation is in general use:

1, wheat; 2, rye or turnips; 3, oats; 4, flax; 5, clover; 6, rape seed; 7, potatoes.

Upon a stiff soil the following rotation is in use:

1, potatoes; 2, wheat; 3, beans; 4, rye; 5, wheat; 6, clover; 7, turnips; 8, flax; 9, wheat; 10, oats; 11, fallow; 12, tobacco; 13, rye; 14, oats.

Upon a good and strong soil they have this rotation:

1, potatoes; 2, wheat; 3, flax; 4, clover; 5, rye; 6, oats; 7, buckwheat. In this rotation manure is applied every season excepting the last.

Upon rich clay this rotation has been found the best one:

1, turnips; 2, oats and clover; 3, clover; 4, wheat; 5, flax; 6, wheat; 7, beans; 8, wheat; 9, potatoes; 10, wheat; 11 oats. In this rotation they have in eleven years four times wheat; the clover, occurring twice, is the only enriching crop. Manure is given in the 1st, 3d, 4th, 7th and 9th years.

The system of flax-culture in Belgium is not excelled by any other used elsewhere. It varies, of course, with the varying qualities of the soil.

Other practical rotations followed in Belgium are here given:

Upon poor and sandy soil:

1, buckwheat; 2, carrots; 3, potatoes; 4, barley; 5, flax.

1, flax; 2, rye; 3, rye; 4, potatoes; 5, oats; 6, clover; 7, rye or barley; 8, rye; 9, flax; 10, rye.

1, turnips; 2, buckwheat; 3, potatoes; 4, oats; 5, flax.

1, rye; 2, clover; 3, rye; 4, rye; 5, oats; 6, potatoes; 7, turnips; 8, flax; 9, clover.

1, clover; 2, oats; 3, rye; 4, rye; 5, buckwheat or potatoes; 6, barley; 7, oats; 8, rye; 9, flax.

Upon best kind of light soil:

1, wheat; 2, rye; 3, rye or barley; 4, potatoes; 5, wheat; 6, rye; 7, flax; 8, clover.

1, potatoes; 2, wheat; 3, rye or barley; 4, oats; 5, flax; 6, rye; 7, clover.

1, oats; 2, rye or barley; 3, potatoes; 4, wheat; 5, rye; 6, barley or oats; 7, flax; 8 clover.

1, barley; 2, rye; 3, potatoes; 4, wheat; 5, rye; 6, flax; 7, oats; 8, clover.

Upon a good clayey or stiff soil:

1, oats; 2, beets; 3, wheat; 4, rye; 5, potatoes; 6, wheat; 7, rye; 8, flax.

1, beans; 2, wheat; 3, rye; 4, potatoes; 5, beets; 6, flax.

1, clover; 2, barley; 3, beets or beans; 4, wheat; 5, rye; 6, potatoes; 7, rye or wheat; 8, oats; 9, flax.

1, wheat; 2, barley; 3, beans; 4, wheat; 5, rye or turnips; 6, potatoes; 7, rape seed or turnips; 8, oats or flax.

1, rape seed or turnips; 2, wheat; 3, rye; 4, oats; 5, clover; 6, wheat; 7, rye or barley; 8, oats or flax.

The principle upon which these rotations are based is not easy of explanation, as they are determined entirely upon observations and experience. The necesssity of a rotation is proven beyond any doubt, but the order of succession must depend upon local conditions. At all events crops of the same kind must not succeed each other, and the interpolation of a hoed or cultivated crop is necessary to take the place of a fallow. Crops consumed upon the farm are of double value, as they serve as food for the animals and produce manure as well.

Rich and heavy soils are usually plowed in fall, again in spring, and a third time before sowing. In other cases the land is plowed in November and again in March, while in still other cases the land is not plowed at all, but spaded.

In Courtrai-Plock and the Tournai districts, where the best flax for fibre is grown, the land is used for flax but once in eleven years, usually following a crop of wheat or oats. Land intended for flax is heavily manured as soon as the previous crop is removed. Twenty-five to thirty wagon-loads of manure per acre is the usual amount: this manure is carefully spread and is plowed under to a depth of 4 to 5 inches. The fields remain in this condition for 3 to 4 months; later it is plowed again, but a little deeper, so as to turn the manure. While this plowing is in operation 7 or 8 men follow with spades and make the furrow about six inches deeper, thus bringing the exhausted soil deeper and the enriched soil nearer to the surface. The land remains so over winter, and is thoroughly harrowed in the spring. The next operation is to enrich the soil just before sowing, with fluid manure, about 2,500 gallons per acre. The quantity of seed used depends upon the quality of the soil. The Belgian farmer uses much seed (about 160 lbs. per acre), with the view of producing very fine fibre. After sowing the land it is harrowed and rolled. When the young plants have reached the height of several inches children and women remove carefully all weeds. As soon as the stems of the plants, near the roots, turn yellow, they are pulled, if it is the purpose to obtain the very fine fibre for lace, etc. If coarser fibre is desired the plants are left for a longer time to mature, and still longer if the seeds are the only desired product.

In Luxemburg.—To show how opinions differ in regard to flax-culture the methods used in that country will be given. Mons. Mahaux says that the soil should be prepared in the same way as for oats, but should be fertilized with lime at least one year previous to the sowing of flax. Experience had shown that wherever good oats could be grown flax would also succeed. He thinks it necessary to prepare the soil specially for flax, but the fields plowed in fall should be thoroughly harrowed in spring. About 132 to 141 ℔ of seed per acre are sown; after the use of a light harrow a heavy iron roller should be employed. The best time for sowing is from April 20 to May 1. In case weeds become numerous sheep should be utilized during June, or before the young plants have a greater height than 9 to 10 inches. Weeding by hand he considers not necessary, excepting if thistles should appear. It is claimed in Luxemburg that the best and most flax could be harvested upon new breakings which had for several years been used as a pasture. This is no doubt very true if the seed of flax is the principal crop.

In pulling the stems great care should be had not to bend them, but to keep them as straight as possible; if bent the stems would dry and produce a poor fibre. The pulled flax should be left upon the ground for 14 to 20 days; should then be gathered into small shacks which would allow a free circulation of air. When perfectly dry the straw should be housed; if heated the fibre would spoil.

In Luxemburg an average crop amounts to about 3,520 ℔ of flax to 440 ℔ of seed per acre. It is considered there absolutely necessary to change the seed every year.

THE PRODUCTIONS OF GOOD FLAX SEED.

At the International Congress of Flax Growers held in Vienna it was claimed again and again that good flax-seed could and ought to be grown by every farmer for his own needs. It is well known that flax grown for fibre does not produce seed that is perfect enough for seeding purposes, and that the latter must be grown specially and with great care. To produce good seed any soil fit for flax will be good enough, but it is best if the soil is not too rich. We can, of course, not expect to produce seed of equal value as the best obtained from Riga, because we lack the peculiar favorable climate of the Baltic provinces of Russia, but if we carefully imitate the method used there we can at least produce seed approaching it in value.

Pinkert gives the following rules to produce good flax-seed:

1. We should select new land and fertilize it with wood ashes. Or, we should select a clean, sandy and exposed soil made rich by manuring. (An exposed soil because seed grown upon poorer soil in a colder region will succeed very well if later sown upon better soil in a warmer region.)

2. The soil selected should have never produced flax before, or at least not during the previous 15 years.

3. The soil must be thoroughly well prepared, and the seed should be sown very early in spring (towards the end of April), so that the plants mature and ripen their seeds during still warm weather.

4. Drilling is best to produce good seed.

5. The plants must mature perfectly, and should not be harvested until the seed capsules turn brown, and the leaves commence to drop.

Many experiments made to test the possibility of producing good seed have shown that it can be done, or that at least such seeds do not degenerate for the first two seasons. But drilling was shown as a very general rule to produce inferior seeds than those produced by sowing broadcast, and the general opinion of flax growers at the International Congress was to the effect that sowing by means of the drill could not be encouraged for this purpose. A careful weighing of seed demonstrated the fact that more and better seed was produced by sowing broadcast than by any other method. Moreover the fibre of flax sown by the drill is always inferior.

Very important are the experiments made to solve the questions of what influence were time of harvesting and method of keeping seed upon its quality. Many trials have shown that seed kept in capsules have a greater specific weight than threshed seed. Other trials proved that only perfectly ripe plants produced good seed, and that seeds taken from unripe ones would already degenerate in the first generation.

As soon as the plant has passed the time of flowering the lowest leaves drop, the lower part of the stem commences to turn yellow, and the seeds in the capsules are milky white. This is the first degree of ripeness. The yellow color, the wilting and dropping of leaves gradually extends upward, and eventually reaches the seed capsules, and the seed becomes partly colored. This is the second degree of ripeness. If later the stem assumes a brownish color, if the seeds rattle in the capsules, and have absorbed the last sap from the stems, are bright brown in color and hard, then the plant has reached the third degree in ripeness. Whenever we wish to obtain good flax seed the plants must be pulled in the third degree, but if we wish to obtain both seed and fibre we have to pnll the flax when the second degree of ripeness has been reached. Seed harvested at that time will grow. Poor seed is not so much the result of pulling the plants at the wrong time, but of wrong manipulations carried on later. Pulled flax is usually left upon the soil, where it is spread out to dry. This spreading is very injurious to the seed, as its quality is greatly influenced by light and moisture. Capsules laying directlv upon the soil produce an inferior seed than those in capsules remaining not in contact with the same. If the pulled plants are at once put together in small stacks all the capsules obtain an equal amount of light and are uniformly dried. The removal of the seeds from the capsules by thrashing soon after being pulled is a very faulty operation; experience has shown that if the seeds are not perfectly ripe at that time they will ripen later, if left undisturbed in the capsules. The most intelligent flax growers all agree that it is best to leave the seeds in the capsules, and to keep them in a perfectly dry space. In this manner nearly all seeds of weeds are also prevented to be mixed with flax seed. These can be threshed later, or when required for seeding.

STRUCTURE OF THE FLAX STEM.

(Prof. H. Leslie Osborn, Ph. D., of the Hamline University, has kindly prepared this chapter.)

Any of the higher members of the plant or animal world are known now to be composed of vastly numerous units called cells. The variety in shape and color of plants or animals is due to the action of these cells, and the body of living things is the production of these cells, which, together, compose it. Sometimes the cells themselves are welded together into an organ as for example in the human finger nail or hair, or the spines of the nettle, in other cases the cells manufacture substances which they pour out and their aggregate accumulation is very extensive, as for example in the case of the "milk" of the milkweed and the "blood" of blood-root, the pitch of pines and the gums of many fruit trees.

These ultimate units or cells may be compared with a pile of bricks or a pile of cord-wood, or a honey-comb—they were first noticed in plants where they are comparatively large and clearly visible because of their very heavy boundary walls and can be seen in the pith of corn-stalk if a thin shaving be taken and examined with a lens of moderate power. All animal and plant bodies are composed of portions called "tissues," which are comparable with piles of bricks or sticks, being made of large nnmbers of cells all much alike and all arranged in accordance with a law or plan which we can discover if we are sufficiently patient and skillful.

Cells, though they are very various in shape, size and other respects all agree in presenting two portions, known respectively as the cell-wall or boundary substance, and the cell-contents. The cell-content is the only really living part of any plant and all its vitality resides here. Only a certain portion moreover of the cell-content of most grown cells is alive, and this substance is known as *protoplasm*. It is the most mysterious substance known to man. Protoplasm is a thin jelly of a grayish color and not perfectly clear but "granular," that is appearing as if made of very many extremely fine grains scattered through a clear fluid. A certain portion of the protoplasm often in the center is denser than the rest and is bounded by a very thin wall, this is called the *nucleus*. The protoplasm as before observed is the portion of the plant which is alive; it is moreover the only living portion, and in a large plant, such as a tree, the bulk of the body is dead and only a certain few of the cells, those containing protoplasm, possess life. It is the powers of protoplasm which make it the most wonderful substance at present known. It can be analyzed by the chemist and he can take its elements and compound them, but the compounds posesses none of the peculiar powers of living protoplasm. It is because of the possession of these powers that protoplasm is such a wonderful substance. Through their agency it can find in the air and water and earth that from which to construct food to support the animal creation. One of its powers is that known as *secretion*. By virtue of this it can take ammonia and carbonic acid and water, all of which abound in the atmosphere or soil which bathe the leaves, stems and roots of plants, and by the help it can get from the sun's heat and light, it can analyze and combine them into sugar or starch, or gluten or oil, and can make a vast number of varieties of these products. Let us imagine ourselves in a chemist's laboratory; he takes some of this fluid and a little of that, and pours them together into a tube. As we look a solid sediment spreads through the fluid and then settles to the bottom. He tells us that the sediment is the result of the reaction between the chemicals. This illustrates to us the power of protoplasm; it brings carbonic acid together with water, and after several reactions a product is formed which is sugar or starch or some of their kind.

Protoplasm, besides possessing this marvelous power of directing chemical reactions, has the further remarkable ability of increasing thereby its own substance, which power is termed the power of growth. In connection with this power is the further power of dividing itself into two portions, each one of which can grow and in its turn divide again. Each cell can thus divide and the two grow and in turn divide. There can thus be formed from a given number twice as many, and from these four times the original number, and from these eight times the original number. The speed with which these powers are put forth is dependent on a variety of circumstances, among them warmth, hence the rapid growth of plants in warm weather and their retardation by cold. The nucleus of the protoplasm seems to be especially concerned in causing the numerical increase in the cells while the remainder of the protoplasm seems to be the part which produces an increase in the amount of protoplasm.

The protoplasm as above remarked is the vital part of the cell, and all the rest is a product which it constructs, but the cell-wall appears so early, being one of the first results of its constructive activity, that it is usually spoken of as if it were of equal importance with the protoplasm. The cell wall is a peculiar chemical compound called *cellulose*, which is a substance very much like starch and sugar. Cellulose is made by the protoplasm by virtue of its power of superintending chemical reactions, and poured out around itself so that it forms an outer shell coating the entire cell and having its shape. The cellulose is at first rather soft and plastic, and can share in all changes of shape which the cell assumes; but later it becomes thicker, as more and more accumulates, and it becomes comparatively rigid and thus hinders any change by shape which the cell might tend to make. After cells have grown to their final full-grown shape the protoplasm often plasters on the inner side of the cell wall layer after layer of matter which causes the wall to become very thick and firm. One substance thus made by the protoplasm is wood or *lignine*; this strengthens the plant very much, and being very durable may last unchanged for many generations. Some trees are hundreds and perhaps thousands of years old, and the wood of others only slightly affected by heat, is found as lignite—a variety of coal—in the earth, and geologists tell us that it is hundreds of thousands years old.

In addition to producing cell-wall, substances of a greater variety of shapes and composition are also made. One of the simplest cases of this is seen in the potato. Here the pith cells of a stem beneath the ground receive various chemicals from the juices which were first constructed by the cells of the leaf and then caused to circulate as sap through the plant, something as blood circulates through the animal body. These pith cells thus supplied with materials from the sap set themselves to work and construct starch, and thus they go on making it in so gluttonish a fashion as to literally kill themselves, but like misers they leave their wealth behind them within the cell-walls. And thus the potato is a valuable food for animals who need starch in their diet. This case resembles that of the turnip and beet and the apple and pear, indeed, all the vegetable fruits are cases under this general head. The wonderfully varied directions in which this capacity is exercised is as remarkable as the power itself. The substance of wheat called gluten, entirely unlike that of the potato, the varions oils and resins, the numerous secretions which are medicine, such as aconite, the nicotine of the tobacco plant, all of these and hundreds more are secretions made by protoplasm, and stored in the cells of the leaf, stem or root, whence they are taken and used by man in various ways.

Having noticed these facts in regard to the units of plant structure, the cells, we are now prepared to examine the stem of the flax plant, giving our especial attention to the structure and position of the cells which make the plant of such great importance to the agriculturist, the flax fibre. In the stem of such plants as the flax there are three distinct zones—the pith, the wood and the bark. These fit on each other like three successive cylinders, the two outer ones hollow. The stems vary very much with age in regard to the relative sizes of these cylinders, and in the earliest state the entire stem except the outermost surface would be found to be composed of one kind of cells only, the pith cells. In the history of the stem the various pith cells have different destinies, and acquiring different shapes, and cell-walls of various thickness, they finally present the appearance shown in the illustrations, and undergo no further change.

For the actual demonstration of the facts learned from microscopical examination of the flax stem it is necessary to cut very thin slices or "sections" across the stem and lengthwise through the center; these are then "mounted" upon a glass plate and covered with a second glass plate, and then enlarged by means of the microscope. Two enlargements of each sec-

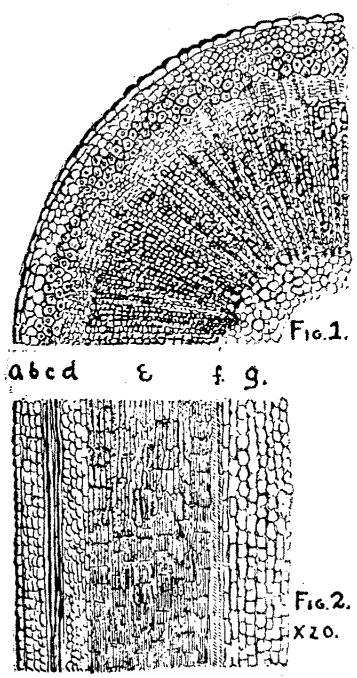

FIG. 1. Cross-section of a fourth of the stem of a flax-plant 18 inches high, showing the situation of the bast and its relative amount.

FIG. 2. Longitudinal section through the same stem.

tion are given. Figs. 1 and 2 are enlarged 20 times; the former showing a cross section, the latter a longitudinal one. Fig. 3, enlarged 340 times, shows the individual cells, which were too small to be clearly seen by an enlargement of 20 times. From an examination of these illustrations much can be learned. In the first place, figures 1 and 2 show a small hollow spaee in the center, surrounded by pith (*g*), then a zone of considerable width, the wood zone (*e*), outside of this a zone consisting of several layers, the central one of which (marked *c*) is the layer of "flax fibre cells." The relative position of flax fibre is thus shown.

By careful study of figures 3, 4 and 5 we can ascertain the peculiarities of the cells of each tissue. These sections do not extend inward to the

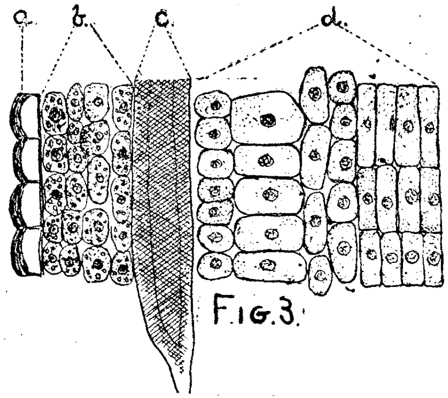

FIG. 3.

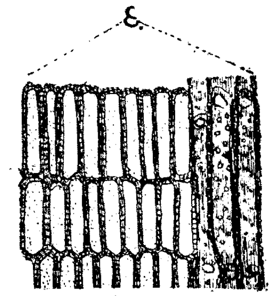

FIG 4.

FIG. 3. Enlargement 350 times of Fig. 2, from the epidermis to the wood.
FIG. 4. Enlargement 350 times of Fig. 2, of the wood zone.

pith. They show us that the plant is covered externally with a layer of cells called the *epidermis* (*a*), that these cells fit each other tightly (except at certain air-holes, not shown in the figure, which holes are guarded so as to control the passage of air); that the outer walls of these cells are much thicker than the inner walls (by deposition of cellulose when the cell was alive). These heavy-walled cells (*a*) protect the soft delicate cells just beneath them from injury, both against crushing from pressure on the outside and from drying, to which the stem would otherwise be exposed. The

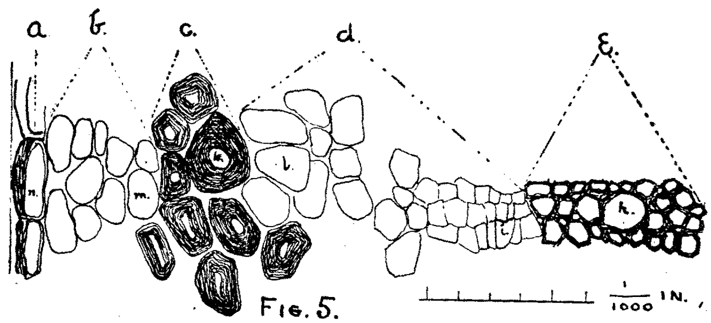

FIG. 5.

FIG. 5. Enlargement of Fig. 1: *a*, epidermis; *b*, parenchyma; *c*, bast; *d*, phlöem or cambium; *e*, xylem or wood; *f*, fibro-vasculat tissue; *g*, pith.

epidermis (*a*) still further protects the cells beneath by being spiny, or by being covered with sticky "glandular hairs."

Just beneath the epidermis (*a*) are to be found several rows of cells which are shaped much like a sack of salt would be if it had no corners. These cells (*b*) are extremely small, as can be seen from the scale which is shown below figure 5; they are about 1-1000 inch across, and are twice as long as wide, 1,000 could thus stand in a row an inch long, and 500 in a pile one inch high. These cells in the growing plant are very thin-walled and filled with protoplasm (see fig. 3). They are not close packed, and the air which is let in at the air holes of the epidermis circulates through the spaces between the cells, and carries carbonic acid gas to them, from which they manufacture chemical material.

The layer *d* is also a layer of thin-walled and living cells called *cambium*. They form the zone which comes between the bark and the wood, and which is so full of sap in the spring that it lets the bark readily pull away from the wood in such trees as the willow, as every boy fond of music and whistles understands very well. The layer *d* is destroyed when trees are girdled, and this accident to the tree is followed by its death, because the living roots and the living tops are separated by a dead line across which no life can pass. These cells (*d*) are of two kinds known as the wood cells and the bark cells, and the growth of both layers takes place from them, those of the inside, known technically as the *xylem*, acquire the shape of wood, and then the wall is thickened by internal deposition. Others, the *phloem* become the ultimate bark of which the *bast-cell* or the flax fibre cell is one variety.

The layer *e* is a layer of wood; it arises from the cambium, becomes very dense, and the cells are very compactly wedded together so that they adhere in one mass. These cells are very beautiful to examine as objects for the microscope, because of the wonderful markings on the cell-walls due to the way the material has been plastered on the inside by the cell protoplasm when it was alive.

To the agriculturist the most interesting part of the flax stem is the portion indicated at zone *c* in the figures. This is the location of the fibre which gives to the flax its value for man's use. An examination of figures 3 and 5 will show much about the flax. Here as at *k* fig. 5 are numerous very thick-walled cells somewhat angular by having been flattened against each other, with almost no central space within; the cells are very long and taper pointed. Only a small portion of one cell shows in the cut lengthwise of the stem at *c* in fig. 3. The thick wall of this cell and the narrow cavity within can be seen. The walls of these cells present certain markings as if made by a spiral of substance wound around first one way and then a second spiral across the first. This appearance doubtless corresponds with the actual way in which the protoplasm plastered on the substance of the cell-wall when it was being made in the young stem and it probably contributes to the toughness, which is so important to us. The length of the single cells is too considerable to be shown in a single section. They are stated* to be from $\frac{0.78}{1000}$ of an inch long to $\frac{1.56}{1000}$ of an inch long.

The figure further shows that these cells lie among very thin walled cells, the green colored parenchyma cells at *b* are living cells containing protoplasm and their envelope is very thin and delicate, as generally in living and active cells. In the layer *d*, also, the cells are either thin walled living phlöem destined to grow into bast, if the plant should keep on grow-

*Goodale. Physiological Botany, p. 90.

ing, or also equally thin-walled living cambium, the young stage of xylem or wood. This zone *b* forms a fine example of what biologists call "undifferentiated tissue" or tissue which can grow into any of several different tissues, but has not done it yet. These soft cells around the bast make it possible by retting the stem to clear the bast from the other cells and separate them.

But their thickness of wall and situation among soft cells are not enough to make the bast cells of *Linum usitatissimum* useful to man. Nature must help us at one further point and this she does. The cells of the bast are not only tough walled and easily separated from their neighbors but they are so compactly welded together that if you get hold of one you can pull the entire string. The separate minute cells are connected end to end fitting by the tapering ends in a sort of bevel joint. They are thus welded together in long rows which are welded to each other into long strands called fibers. These fibers run the length of the plant, they are sometimes 6 feet long or thereabouts. It is the combination of these three qualities, shape, toughness, situation and the union of cells into a fibre which makes the flax one of the most useful of our cultivated plants.

CONCLUSION.

In the previous chapter the minute structure of the stem has been shown, and the parts composing it have been illustrated. In a cross-section we observe a number of rings, each of a different structure. To transform the straw of flax into a saleable article it is necessary to separate the long fibres, which are connected together by a sort of glue, the Pectose, and also with another kind of glue to the other layers. The outer layer, the epidermis, is easily removed, but the separation of the fibre from the wood is not so easy, as the greenish-yellow glue is very tenacious. By the process known as retting both separations are performed.

Dry stems of flax contain from 73 to 89 per cent. wood, and from 20 to 27 per cent. bast. The former substance contains 69 per cent. woody substance, 12 per cent. parts soluble in water, and 19 per cent. parts soluble in alkalies. The bast contains, on an average, 58 per cent pure fibre, 25 per cent. other substances soluble in water, and 17 per cent. soluble in alkalies.

The question is frequently asked: Is it necessary to ret? It is well known that retting has the very greatest influence upon the quality of the fibre, and that not unfrequently the best straw is destroyed by ignorance or inexperience. Retting requires considerable experience, and without it comparatively few farmers will succeed in performing that process at home. The erection of factories to do this work is absolutely necessary to assure success.

Mr. Charles Richards Dodge has recently published an excellent report upon flax, the methods employed in Europe to separate the fibres, and upon the present status of the fibre industries in the United States. As his paper, published as Report No. 1 of the new series of miscellaneous papers of the Division of Statistics of the U. S. Department of Agriculture, can be obtained upon application, it would be useless to describe, at this time, the various processes so well illustrated in that report, and those interested in flax-culture and flax-industry are advised to obtain for themselves a copy and study it carefully.

Mr. E. Bosse, formerly of Green Bay, Wis., but now living in this state, had considerable experience in Europe as well as in Wisconsin and Minnesota. His instructive letter to the Department of Agriculture, published upon page 62 of the Report No. 1 of Division of Statistics mentioned above, will be read with considerable interest by all those engaged in flax-culture. During some conversations had with Mr. Bosse he stated his belief that flax for fibre could be produced almost everywhere, even in dry regions, provided the flax-grower would plow as deep as twelve inches, and perform this labor during the fall. In Green Bay he plowed eight inches, and in Minnesota seven inches, but said that in future he would always plow at least eight inches deep, as the results were plainly so much better. He said that plowing ought to be done in fall. Early in spring, or as soon as the ground was dry enough for the team, he advises to cultivate as deep as possible, and to repeat this operation a few days later. After a few days the harrow should be used very thoroughly so as to kill as many weeds as possible. Immediately before sowing, which ought to be done as early as possible, the ground should be again slightly harrowed. He thinks the best time for sowing is from April 10 to April 20. Mr. Bosse uses 1½ bushels of home-raised seed per acre, and 2 bushels of imported seed, because the latter is so much larger. Retting, he thinks, should not be performed by the farmer himself, as it requires considerable experience and time, and neither are always at the command of the average farmer.

There is no reasonable doubt that our State can produce successfully a large amount of fibre, and if we commence to manufacture at first only the coarser articles, success will be sure. As our flax-growers gain in experience the better qualities of fibre can also be produced. In our large State, in which so many different conditions exist, and in which so many kinds of soil are found, there is no doubt that regions will be found as excellent for flax-culture as the most famous ones in Europe, and once found the finest fibre can and will be produced.