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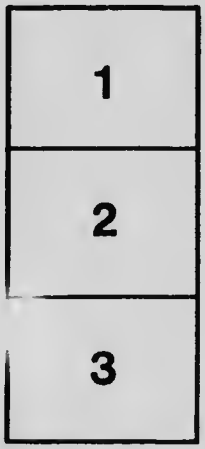

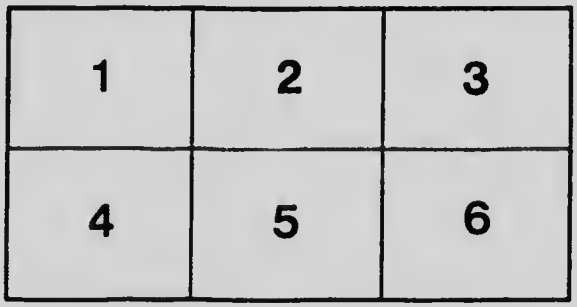

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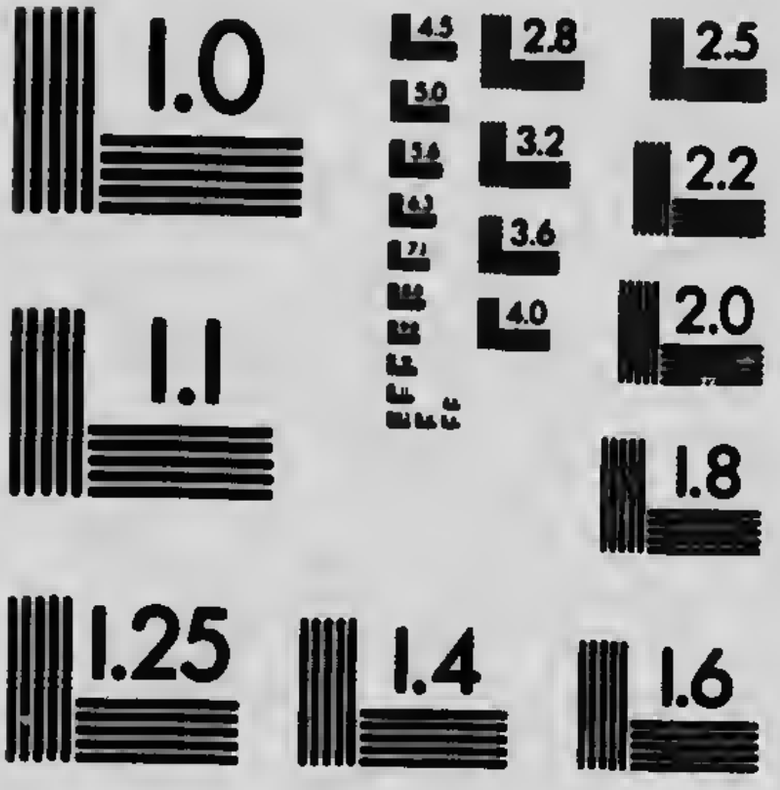

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'09

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE.

Farm Underdrainage: Does It Pay?

By W. H. Day, B.A., Professor of Physics.

Underdrainage has been known and practised in Ontario to some extent from the days of the early settlers, when the only materials at hand for pipes were slabs and stones. As the wooden pipes decayed and the stone ones filled with sediment, they gave place to clay tile, and for many years these have been laid in comparatively large numbers, and usually with gratifying results, as is shown by the fact that the most enthusiastic advocates of tile drainage to-day are those who have done most of it. Yet, despite this success, the practice of underdrainage has spread comparatively slowly. To be convinced of this one has only to travel over the province in April, May, and sometimes June, and note the thousands upon thousands of farms in well-settled districts, amounting to millions of acres, that are so wet in whole or in part that seeding operations are delayed from two to six weeks, and then travel again in August and see these same large areas producing only one-quarter to half a crop, while dry land in the same vicinity yields a full crop. In several cases practically whole counties need underdraining, and there are some counties where tile are not yet manufactured, and where practically no underdrainage whatever has been done. With these facts before us, and being ever more strongly emphasized by widening experience and by accumulating data, and knowing at the same time that many farms and various districts once wet and useless have been transformed by underdrainage into the most productive in the land, one cannot but wonder why the practice has not spread more generally into other wet districts. Contact with the people tells us why. To begin with, the results of underdrainage are not generally known, the immensity of which truth only an intimate knowledge of the facts will reveal. Secondly, the critical operations of drainage are even less understood than its benefits—farmers, generally, have no way of telling whether they have fall enough for underdrainage, what the grade of a proposed drain should be, nor any method of digging to a grade, or planning a general drainage system; and, fearing disaster in undertaking to drain by guess, they leave it strictly alone. Thirdly, there is an impression abroad that a poor man cannot afford to drain, as the cost is so great. And, lastly, the

scarcity of labour is preventing many men from draining who are fully impressed with its value. Four years of contact with hundreds of farmers eager for knowledge on drainage has led us to these conclusions; it has also shown us the need of literature to spread information and dispel illusions concerning drainage. It is hoped that this bulletin, and its sequel, No. 175, will contribute to these ends.

As the farmer is pre-eminently a practical man it is the writer's first aim to treat the subject from the practical side.

RESULTS OF UNDERDRAINAGE.

In the spring of 1909 the Department of Physics, which for several years has been making drainage surveys for farmers in all parts of the Province, wrote a large number of the men for whom surveys had been made in 1906, 1907, and 1908, asking them if they had put in any of the

Fig. 1. Cutting wheat on the farm of Mr. J. A. Fletcher, Fletcher P.O., Kent. Farm was a "mud pond" before it was underdrained. (See page 3.)

drains surveyed by the department, and, if so, to give their experience, paying special attention to cost of drains, difference in dates of seeding, difference in growing crops, and increase in yield. A few others who had done drainage in earlier years were also written to. Perhaps the most effective way of presenting their reports is to give first quotations from a few of their letters under their own names, and then summarize all the reports. In this way farmer can talk to farmer at first hand through this College bulletin, even though hundreds of miles apart.

QUOTATIONS FROM REPORTS BY MEN WHO HAVE DRAINED.

WILLIAM BELL, Washago, Simcoe: "I drained eight acres you surveyed for me in 1907. It had produced nothing previously. Last year I grew a fairly good crop of oats on it, which yielded 33 bushels per acre. Following is a statement of outlay and results:

Cost of draining 8 acres, $290.90—$35.11 per acre, including a 6-inch main to drain other land as well as this.

Returns—33 bushels oats at 45 cents—$118.80, nearly half cost of drainage, and straw yet to be accounted."

T. S. BIGGAR, Manager, Walker Sons, Walkerville, Essex: "On our drained land this year, 1909, we had 80 bushels of shelled corn per acre, while the undrained gave us only 56 bushels. Of oats we had 66 bushels on drained and 37 on undrained. In 1908 the drained land gave us twice as much as the undrained. We have tiled 87 acres this year, and purpose tiling much more next year."

J. H. CLARE, Chapman, Hastings: "Fields that previously were unfit for crops at all can now be seeded on even date with high land; and, while before they grew nothing but coarse grass, now they yield per acre:

Hay—2 to 3 tons.
Barley—30 to 50 bushels.
Oats—40 to 100 bushels.
Corn—14 feet high."

JAMES CLAYTON, Cedar Springs, Kent: "In 1901 I drained 8 acres, at a cost of $112, or $14 per acre; 8 acres right across the fence was not drained. In 1902 both fields were sowed to beans; 8 acres drained land gave 302 bushels, which sold for $456; 8 acres undrained land gave 24 bushels, which sold for $37.

"Gain, $419, nearly four times the cost of drainage.

Author's Note: This example shows the value of underdrainage in specialized agriculture.

"In 1903 both fields grew fall wheat. Eight acres drained land gave 45 bushels per acre; 8 acres undrained land gave 25 bushels per acre. Gain, 20 bushels of wheat per acre. 1904—There was drained land on both sides of that fence."

W. J. COHOE, New Durham, Brant: "About two-thirds of the oat field was drained last fall, and this went in in good condition, April 30th. The rest of the field is porous soil, but rather level and higher than the drained part, and we sowed it three weeks later; and I must say it was not really fit then, but, anxious to get it sowed we 'mudded it in.'"

NATHAN DAY, Powles' Corners, Victoria: "I drained a 10-acre field some fifteen years ago, at a total cost of $145, or $14.50 an acre, the drains being four rods apart and two and a half feet deep. It was a muck soil, from a foot to a foot and a half deep, underlaid with a heavy clay. Before draining it was the wettest field on the farm, and would grow only hay and oats, and never more than a half crop of them, and often not that, and was never sowed before June. Since draining it is the second driest field we have, and will grow a full crop of anything that can be grown on the high land of the farm. It has been sowed in April every year but one since it was drained. The drains paid for themselves in two years. If I were draining this field again I would put a drain every two rods, for the crops are always better right over the drains than halfway between."

J. A. FLETCHER, Fletcher, Kent: "This section of the country (Tilbury East Township) is on a fair road to improvement. Farmers are beginning to realize in hard cash that they cannot farm without drainage. I have enclosed a photo (Fig. 1), taken on my farm (cutting wheat), which shows the advantage of thorough drainage. This farm of mine was practically a mud-pond

seven years ago, when I bought it, and to-day I completed harvesting one 18-acre field of corn, which gave me the handsome return of over 3,000 bushels."

F. W. HUNTLEY, Sutton, York: "We drained part of the land surveyed, and this year a fine crop of fall wheat is growing on land that formerly was counted too wet for anything but meadow."

WILLIAM LAMB, Brantford, Brant: "I think underdraining the best investment I can make on my farm."

JOSEPH LAPP, Cedar Grove, York: "I drained five acres, with drains 120 feet apart (110 rods on five acres). Drained another field, with drains 30 feet apart and 3 feet deep. In each case the gain in the first crop paid the full cost of the drainage.

"My general conclusion is this: Where drainage is at all required, its entire cost will be repaid by the increase in the first two crops, but in most cases by the increase in the first crop alone. Our own experience is the latter."

A. LEACH, Farm Manager for W. F. Maclean, M.P., Donlands, York: "The cedar swamp field south of the barn, which you surveyed, and which, as you will remember, was so wet, even in the driest part of the summer, that one could not walk on it without getting wet, was drained last fall; and this year, in spite of the heavy rains which delayed all spring farming operations, it was the driest field we had when we came to cultivate it, although much of our land is high and rolling. The crop sowed on it is coming on fine, and gives every indication of good, stiff, strong growth."

JAMES MARSHALL, Hamilton, Wentworth: "In fifteen years I have put in over twenty miles of drains on my farm, and my only regret is that I have not used more of my spare time and attention to complete the underdraining and bring the whole farm into a better state of cultivation. In 1897 I drained a 12-acre field, at a cost of $460, almost $40 an acre, drains being 25 to 30 feet apart and 3 feet deep. The next year this field yielded 80 bushels of oats per acre, while the adjoining field of similar soil, but not drained, yielded only 45 bushels per acre, thus gaining 35 bushels of oats per acre by drainage."

Author's note: Price of oats by to-day's paper, 44 cents. Value of 35 bushels at 44 cents, $15.40, considerably more than one-third price of drainage, and the increase of straw yet to be counted.

"Another year I got the following results: 45 bushels wheat on drained; 25 bushels wheat on undrained, thus gaining 20 bushels."

Author's note: Wheat to-day, price $1. Value of 20 bushels, $20, over half cost of drainage, and straw yet to be accounted.

R. H. MCCURDY, Vienna, Elgin: "Last fall I drained [illegible] acres that formerly would grow nothing. They were low spots in a field. Cost $17.50 an acre. This year I had 30 bushels of fall wheat per acre on them, while the higher land gave only 15 bushels. The drains more than paid for themselves with this one crop. The whole 30 bushels was gain, as those spots would grow nothing before." (See Figures 2 and 3.)

Author's note: Value of 30 bushels at to-day's market price, $30.

JOHN MCINTAGGERT, Brechin, Ont.: "Last fall I drained the lowest of the land you surveyed, putting in over 500 rods of tile drains. Other years I was unable to work on it till the last of seeding, but this year it was the first ground I could work on, and was all of a month ahead of high land." (See Figs. 4 and 5.)

Author's note: With regard to Mr. McIntaggert's case, a very interesting fact came to my knowledge recently. His drains, about five miles, on fifty acres, were laid out by the Department in June, 1908, and [illegible] the

conclusion of the survey a drainage demonstration was held, at which many of the neighbours were present, one of whom applied for a survey of his farm, but it could not be undertaken then, and was later turned over to Mr. J. H. Hare, District Representative of the Department of Agriculture for the county of Ontario. In June of the present year Mr. Hare went to the locality to make the said survey, and in the mean-

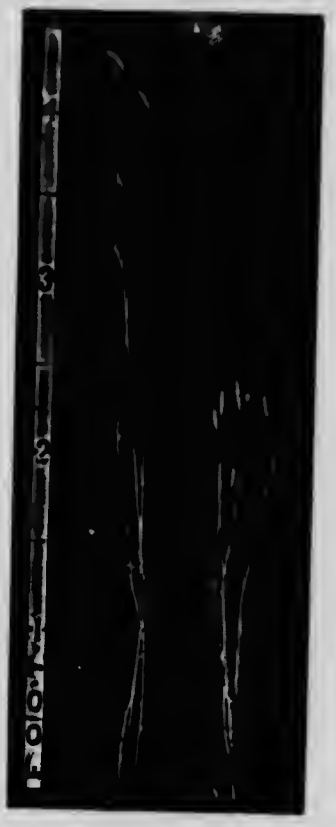

Fig. 2. Fall wheat on drained and undrained land.

Fig. 3. Corn on drained and undrained land.

Specimens sent by Mr. R. H. McCurdy, Vienna, Elgin County.

time Mr. McIntaggert had put in two and a half miles of tile on about twenty-five acres, and the neighbours had been watching the results. What they thought may be judged from the fact that Mr. Hare had to make *nine surveys instead of one* before leaving the community, and we may also infer that the samples sent by Mr. McIntaggert, and shown in Figures 4 and 5, do not show any more difference or speak any more emphatically when singled out than did the crops as a whole from which they were chosen.

J. P. McKim, Caledon, Peel: "I have drained some mud-holes, which were always so wet that we had to sow around them even in a dry spring. This year they were the first of the field ready to sow. I cannot compare dates, as I never could sow them before."

John A. McMahen, Petrolea, Lambton: "This year (1909) I had barley sowed on drained and on undrained land. The drained land yielded 15 bushels more per acre than the undrained, and twice as much straw." (See Fig 8.)

Peter W. Scott, Belgrave, Huron: "The lowest field on my farm has drains 100 feet apart, and this spring it was the driest field and ready to cultivate the earliest. I consider in a year like this thorough drainage doubles the value of land for cultivation." (See Fig. 6.)

Smart Bros., Collingwood, Simcoe: "We put down some 17,000 feet of tile drains last fall, according to your survey, and everything worked out perfectly. The cost was $973. The greater part of the land drained had never been cropped before, on account of being too wet, but this year we have tomatoes planted on some of the lowest of it; also carrots, beets, parsnips, etc. We would not think of working undrained land in our business.

"We cannot say too much in praise of the drainage work of your department, as we have done considerable tile draining before, and therefore know the advantage of your system."

J. C. Thomas, Blytheswood, Essex: "Part of my seed-corn plot this year was on drained land and part on undrained. The results were as follows: Stalks, per acre, 4,000 lbs. on drained and 2,320 lbs. on undrained. Shelled corn, per acre, 32 bushels on drained, 29.7 bushels on undrained. In my general corn crop I got the following results: Stalks, per acre, on drained 2,970 lbs., on undrained 1,420 lbs. Shelled corn, per acre, 53.3 bushels on drained and 18.9 bushels on undrained."

Difference in Dates of Seeding.

Twenty-six of our correspondents gave us the difference in dates of seeding their drained and undrained land. A summary of their reports is given in the following table:

TABLE I.—Table showing difference in dates of seeding drained and undrained land as reported by 26 farmers who have drained:

Difference in Seeding Time.	Number reporting each Difference.	Per cent.
1 to 2 weeks.	5 out of 26	19.2
2 to 3 weeks.	4 out of 26.	15.4
3 weeks or over.	17 out of 26.	65.4
4 weeks or over.	13 out of 26.	50.0
5 weeks or over.	8 out of 26.	30.8
6 weeks or over.	6 out of 26.	23.1
A whole season.	4 out of 26.	15.4

It is worthy of note that half our correspondents were able to sow their drained land four weeks or more earlier than their undrained, while nearly two-thirds of them gained three weeks or over.

3 2 1

Fig. 4. Oats on drained and undrained land.

1 2 3

Fig. 5. Barley and spring wheat on drained land, and barley on undrained.

1 2 3

Fig. 6. Peas on drained and undrained land.

Specimens sent by Mr. John McIntaggert, Brechin, Ont.

Specimens sent by Mr. Peter W. Scott, Belgrave, Huron Co.

Difference in Growing Crops.

Many of those who reported had just this spring sowed their first crop on drained land, and so were unable to give any results as to yield. These and others were asked to select average samples of growing grain from their drained and undrained fields and send them to us. They were photographed and mounted for preservation. Since harvest we again wrote the senders of samples, asking them to report on the yield of the fields from which they were chosen.

Mr. McCurdy, in commenting on his samples (Fig. 2), said: "The tall wheat, 4½ feet high, is from drained land which would grow only swamp grass before being drained; the short one, 2½ feet, is from undrained land. Both were sowed on September 14th, 1908, and pulled on July 3rd, 1909. Water-furrows were run through the undrained land." Reporting on the yield in September, Mr. McCurdy says the crop on the drained land yielded 30 bushels, and that on the undrained only half as much. The straw, too, was in about the same ratio, as may be seen from the figure.

The corn on the drained land (Fig. 3) was planted on May 20th, that on undrained, June 9th. Both samples were taken July 3rd.

Fig. 4 shows three samples of oats, No. 1, 2½ feet high, from low, flat, heavy clay *sod*, drained and fall-ploughed; No. 2, 1 foot 3 inches high, from high, loamy, undrained *sod*, spring ploughed; and No. 3, 1 foot high, from high, loamy, undrained *sod*, fall ploughed. Mr. McIntaggert, in commenting on the samples, says: "Other years I was unable to work the low land till the last of seeding, but I drained it last fall, and this year it was the first land I could work. I sowed it on May 13th, while the high piece from which sample 2 was taken was not sowed till May 26th, and the other piece on June 1st."

Fig. 5 shows barley and wild goose wheat from low, flat, heavy clay, drained and fall ploughed, and barley from same kind of land undrained, and summer fallowed last year, lying right across the fence from the field which gave sample No. 1. No. 1 was sowed on May 13th, No. 2 on May 19th, and No. 3 on May 28th.

On October 18th, Mr. McIntaggert, reporting on the yields, said: "June was very dry here, and July showery, favouring the late-sown crops, for the early ones were too far advanced to benefit by the July showers; still my oats on drained land yielded 50 bushels per acre, and those on the undrained 31. As for the straw, there was not such a difference, both lands averaging about two-thirds of a ton per acre. My spring wheat on drained land was good, yielding 25 bushels per acre and a ton of straw, while that on undrained land yielded 15 bushels per acre and about two-thirds of a ton of straw. Barley on drained land yielded 50 bushels per acre and nearly a ton of straw, that on undrained 30 bushels and half a ton of straw. My crop on the drained land looked so promising that I ordered another car-load of tile and put it in this summer, so that now I have all the wet, flat part of my farm drained."

Sample No. 1, Fig. 6, peas 1 foot 9 inches high, land drained and manured, sowed May 5th; No. 2, land drained only, sowed May 5th, 11 inches high; No. 3, from land not drained, sowed April 27th, 7 inches high. The dates are worthy of note in this case, as the peas on the undrained were sowed a week and a half earlier than those on the drained,

Fig. 7. Barley on drained and undrained land. Specimens sent by Mr. H. Clare, Norwich, Oxford County.

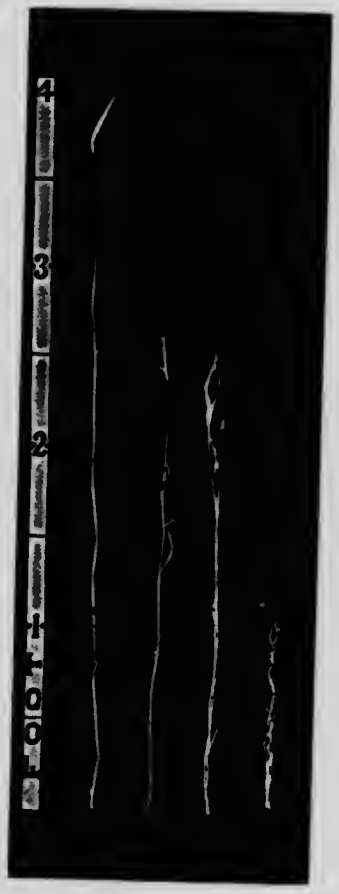

Fig. 8. Barley on drained and undrained land. Specimens sent by Mr. John A. McMahen, Petrolea, Lambton Co.

still the latter were much ahead on June 28th, when the samples were taken. Mr. Scott says there were twice as many plants on the drained as on the undrained. Reporting on yield, October 13th, he says: "On drained land the yield was 25 bushels of grain and 1½ tons of straw; on

undrained, 15 bushels and 1 ton. The manured land gave the same yield of grain as the unmanured, but almost twice as much straw. The oats on drained land, of which I sent you a sample, yielded 50 bushels and 1¼ tons of straw, but those on the undrained gave only 10 bushels and ½ ton of straw."

Fig. 7 shows two samples of barley, No. 1, 2½ feet high, and No. 2, 1 foot 3 inches, or only half as high. Both were sowed on the same day, May 18th, and pulled on July 3rd.

No. 1 from the drained, and No. 2 from the undrained (Fig. 8), represent the *best samples* in the two fields. They were pulled June 28th. Nos. 3 and 4 are *average samples,* but they were pulled on June 14th, two weeks earlier than 1 and 2. The drained land was sowed on April 10th, and the undrained April 11th. Reporting on the yield later, Mr. McMahen stated that he had 15 bushels more on the drained land than on the undrained, and twice as much straw.

Difference in Fruit Trees on Drained and Undrained Land.

The foregoing illustrations show in a very striking manner the superiority of grain crops grown on drained land. The difference in fruit

Fig. 9. Peach trees killed by lack of drainage, south side of flat.

trees is even more marked. In the Niagara district I recently examined a peach orchard planted in 1905, through which a broad flat extended, on either side of which the trees were large and thrifty, about 10 to 15 feet in height, I should say. In the flat, however, 12 rows were lacking, and small pear trees filled the places. In the middle of the low

land some of these were dying. The owner told me that the whole field had been planted with peaches at the same time, but that every tree in the flat had died. One or two tile drains would have made it produce just as good trees as the knolls did. Fig. 9 shows the south and Fig. 10 the north side of the flat. In the fruit belt between Hamilton and St. Catharines one may see hundreds of views similar to these.

Under-drainage will vastly increase the fruit area of Ontario, as by its aid heavy clay land becomes good fruit land. Fig. 11 shows Crawford peach trees eight years old, 16 feet apart, on heavy clay, well under-drained, on the farm of Mr. James Marshall, on the mountain, south of the city of Hamilton. Altogether there are 3,300 peach trees on the farm, some of which have now borne their eleventh crop.

Difference in Yield.

Table II. shows the difference in yield for various crops on drained and undrained land as reported by our correspondents. These figures are not averages, but reports of one particular crop in each case, usually the first after the drains were put in. These men were anxious to learn if "under-drains pay," and so went to some trouble to ascertain the

Fig. 10. Peach trees killed by lack of drainage, north side of flat.

yields per acre of the first crop. Only a few mentioned the straw at all, but those who did had about twice as much from their drained as from their undrained land. After the first season it became an old story with those who had drained years ago to see these fields producing bumper crops year after year, and in only a few cases were later records kept. These few show that the advantage of the drained land continues without interruption.

TABLE II.—Difference in Yield.

Grain.	Difference in Yield.			Persons reporting.
	Drained.	Undrained.	Difference.	
Barley	30-50	0	30-50	J. H. Clare, Chapman.
Barley	.....	.....	20	Jos. Lapp, Cedar Grove.
Barley	50	30	20	John McIntaggart, Brechin.
Barley	40	25	15	John A. McMahen, Petrolea.
Oats	35	0	35	Wm. Bell, Washago.
Oats	40-100	0	40-100	J. H. Clare, Chapman.
Oats	50	31	19	John McIntaggert, Brechin.
Oats	80	45	35	Jas. Marshall, Hamilton.
Oats	50	10	40	Peter W. Scott, Belgrave.
Oats	50	35	15	J. E. Tovey, Perth.
Peas	25	15	10	Peter W. Scott, Belgrave.
Wheat, Fall	45	25	20	Jas. Clayton, Cedar Springs.
Wheat, Fall	.....	.....	30	R. H. McCurdy, Vienna.
Wheat, Fall	45	25	20	Jas. Marshall, Hamilton.
Wheat, Spring	25	15	10	John McIntaggert, Brechin.
Straw	.....	.....	About doubled.	Several correspondents.
Hay	2-3 tons	0	2-3 tons	J. H. Clare, Chapman.
Corn	80	56	24	T. S. Biggar, Walkerville.
Corn	.....	.....	15-20	W. J. Dolson, Chatham.
Corn	.....	.....	*33⅓	Jas. Martin, Amherstburg.
Corn	.....	.....	*33⅓	J. B. Rhodes Chatham.
Corn	.....	.....	...	W. H. Winter, Chatham.
Beans	38	3	35	Jas. Clayton, Cedar Springs.

* 33⅓=about 20 bushels per acre.

Value of Increase in Crops.

The following quotations taken from daily papers one day in October represent fairly well the prices this year: Wheat, $1.00; barley, 58 cents; oats, 47 cents; peas, 90 cents; corn, 75 cents; hay in Toronto, $16 to $20 a ton; in Guelph, $14.50; straw in Toronto, $8; in Guelph, $8. If the reader will compute the value of the increases, allowing a gain of half a ton of straw per acre, he will find it to range from $11.05 to $36.25 per acre, the average being $21.65, not counting the beans, which do not constitute a general farming crop. That is, each acre drained on the farms of these men has produced at this year's prices, $21.65 more than if it had not been drained. The average will rise or fall with the market.

UNDER-DRAINAGE AS AN INVESTMENT.

Drainage as an investment has been touched indirectly in the quotations already given. Some have stated that their drains paid for themselves in one year, some in two years. Even where the drains were put less than two rods apart and the cost ran up to $40 an acre, they paid for themselves in two crops. Has the farmer any other place where he can invest his money and have the principal returned to him every year, or

every two years? But, says someone rendered poor and kept so by the wetness of his land, we haven't the principal, and how can we invest it? For such cases the Province has long since made provision in the Tile, Stone and Timber Drainage Act (R.S.O., 1897, chapter 41; revised in chapter 22, 9 Edward VII., 1909), by which any township is authorized to borrow money from the Province to lend to farmers for under-drainage purposes. When an individual wishes to borrow money in this way he applies to the township council, and if they approve of the loan to him they pass the necessary by-law, if one has not already been passed, and issue debentures which the Province buys from the Consolidated Revenue Fund, and lend the money to the applicant, who pays it back on

Fig. 11. Crawford peach trees, eight years old, sixteen feet apart, on heavy clay, well underdrained, on Mr. James Marshall's farm, on the mountain south of Hamilton. Picture taken July, 1908.

the instalment plan, $7.36 per year for twenty years on every $100 borrowed. Now tile drainage to-day costs about $14 to $40 an acre, depending on depth, distance apart, size and price of tile, kind of digging, etc., say $25 average; hence the sum of $100 would drain about four acres, and if borrowed under this Act, the total annual payment would be only $7.36, or $1.84 per acre, while, as pointed out above, the annual increase in crop reports by men who have put in drains is worth $11 to $36 an acre. Surely a man is safe in borrowing $1.84 to get back $11 to $36? Surely that's a good investment? Surely even the poorest "can afford to under-drain" with this assistance. The writer knows of at least

one man who, with very little capital, bought a large wet farm under heavy mortgage, and at once under-drained it with money borrowed under the Tile, Stone and Timber Drainage Act. To-day he is well off, and still not much beyond his prime.

Drained Land Easier to Work.

Aside entirely from the increase in crops, there are other matters that must enter into the consideration of drainage as an investment. For instance, drained land is more easily worked than undrained. All soils contain a certain amount of cementing materials, and the closer together the particles are the more strongly the cements act, just as a postage stamp pressed tightly to the envelope adheres more firmly than one put on loosely. Undrained soil is much more compact than the drained, and therefore its particles are more firmly cemented together, hence when it dries it bakes, so that it is almost impossible to plough it, and even if it can be ploughed, it breaks up in lumps that defy the harrow, disc and cultivator, and sometimes even the roller, so that whether wet or dry it is stiff, stubborn and hard to till. Drained land, however, whether naturally or artificially drained, is the opposite; it is loosely cemented, does not bake so hard, and crumbles readily into a fine seed bed under even a light implement like the harrow. During seeding time, when even hours are precious, this is a very important consideration, for tillage costs money.

Drained Land is Easier on Machinery.

Then again, the old-time deep water-furrow is unnecessary on drained land, and the implements, instead of trundling over lumpy, hard-baked earth, and every now and then dropping into one of these nerve-straining, body-bruising, machine-racking furrows, and almost stopping at every drop, move steadily forward on smooth ground that is soft and yielding. As a horse will last longer on a soft clay than on hard city streets, so will machinery last longer on drained than on undrained land.

HOW UNDER-DRAINS PRODUCE SUCH GREAT RESULTS.

It will be of interest to consider next the principles that underly the practical results above noted.

More Air in Drained Soil.

What are the physical differences between a drained and an undrained soil? First of all, the drained soil is the more porous, a fact which any farmer can prove for himself. Let him take a cubic foot of soil from drained land, and also a cubic foot of the same kind of soil from undrained land, and dry the two samples completely and then weigh them. He will find the drained to be much the lighter, and consequently it must contain much more pore space, a very important fact, for a porous soil with drains below gives a ready escape for excess water, and air follows into the soil and aids the germination of seeds and the growth of plants, for air about

the roots is just as essential to the life of plants as air in the lungs is to the life of man. A compact soil, on the other hand, retards such downward escape of water, and the soil becomes saturated, its particles run together even more closely than before, and the excess water flows away over the surface or lies in ponds till dried by evaporation.

Better Ventilation in Drained Soil.

In the meantime air is almost entirely excluded, for the pores are full of water, and neither germination nor plant growth can proceed in a healthy manner, because this small amount of air soon becomes impure, since the roots give off poisonous substances, and the exchange of impure for fresh air is slow, owing to the minuteness of the pores. But the ventilation of the drained soil with its larger pores is much more rapid and the soil air much more pure.

More Water in Drained Soil.

But there is another important result of the increased porosity that drainage gives; a drained soil, when ready to work, has more water in it for the crops than an undrained when it is ready to work. Strange as this may at first appear, it seems quite natural on second thought, for there's more room for water, more pore space in the drained soil. By actual test of a sample of loam brought in from the field, and one part packed like undrained soil, and the other left loose and porous like drained soil, I have found the latter, after being saturated and allowed to drain, to retain 28 per cent. more water than the former after being treated in the same manner. We must conclude that between drained and undrained land the difference in water-retaining power is somewhat similar. Let us see what this means: Loams, compact, have been proven to retain, after saturation and drainage, from four to five inches of water in the first foot of soil (they are about 50 per cent. pore space), and nearly as much in the second and third. Twenty-eight per cent. of four inches amounts to 1.12 inches, hence drainage, by rendering a loam more porous, makes it retain about one inch more of water in each foot of soil; and if the drains are three feet deep, this would mean three inches more of water than if the soil was not drained. Now at Guelph the average rainfall for the summer months is as follows: April, 1.57 inches; May, 2.30; June, 2.94; July, 2.96; August, 2.18; September, 2.21; not three inches for any month, and in no place in Ontario does the monthly precipitation much exceed three inches, hence the water saved in the soil by drainage three feet deep is about equivalent to one month's rain. And this difference is maintained as late in the season as there is sufficient rain to saturate the soil, and a similar saving occurs at every heavy shower afterward. Two things prevent rain from sinking *rapidly* into undrained soil—first, the scarcity of pore space; and, second, the air escaping upward (there's no other outlet for it); half the surface pores must be full of escaping air, while the other half are full of descending water. In drained soil the air can and does escape downward through the drains as the water presses from

above, and thus all the surface pores, instead of half, are absorbing water, and, besides, the pores are larger than in the undrained. It follows, then, quite naturally that drained land must absorb water much faster than undrained, and, therefore, that run-off and consequent loss cannot occur as early on the former as on the latter, and, therefore, that the drained land effects a considerable saving of water at every heavy shower.

Fig. 12. Pine stump with deep roots. Grew on high, well drained land.

Now, this saving and storing of water is a very important matter, as we shall see. If the reader will refer to page 15, and add the rainfall for the growing season, April to August, he will find it amounts to about 12 inches, and part of this is lost in run-off and drainage, say, three inches, leaving only nine inches for use by the crops. Tests conducted at this College have shown, however, that under our conditions ordinary field crops use, together with evaporation from the soil, from 18 to 24 inches of water. The difference between nine inches available

rainfall and the 18 to 24 inches needed indicates the amount of water that must be drawn from the great storehouse in the soil. Only when we know that the summer rainfall is only half sufficient for our crops do we realize the importance of having great quantities of water stored in the soil. Every inch of water saved and stored adds an inch for the crops in the droughts of July and August.

Fig. 13. Pine stump with shallow roots. Grew on flat, poorly drained land.

Drained Soil Brings up More Water from Below by Capillarity.

Now the upper layers of the soil, where the roots feed, are not capable of storing enough water for the crops, even when aided by the summer rains. But deeper down in the soil, three, four, five and six feet, there are large quantities of water, which travel slowly upward and gradually reach the roots. To some this may seem a new idea, and more or less doubt may be aroused. Let the doubter take a lamp chimney, tie a piece of cheese cloth over one end, invert it, fill it with dry earth, and then set it in shallow water. He will see the water travel upward through the soil as tea will travel upward through a lump of sugar, or water through a sponge. This movement of liquids upwards

or sidewise through porous bodies is known as capillary action or capillarity. Liquids move downward by the same process, as well as by the more rapid action of gravity. And when a soil has been saturated and all the water that will has drained away, it is this same power of capillarity that holds a large amount still in the soil. The difference between the capillary retaining power of drained and undrained land has already been emphasized. And, after all, capillarity is not a new idea. From childhood we have seen coal oil lamps with the oil travelling up the porous wick by capillarity to supply the flame at the top. The same thing takes place in the soil. As the dry weather advances and the roots use up all the available water in their vicinity and call for more. as the flame calls for oil, capillarity steps in and, by slow degrees, rais. a constant supply from the moister soil below, as the wick raises the oil, and so the plants thrive on into the drought. By and bye they begin to wilt and turn pale, just as a lamp flame grows dim when the supply of oil is checked. Now, drained soil has greater capillary power than the same soil undrained, because it is more porous; and, consequently, it continues to bring up water from below and keep its large plants fresh and green long after the undrained has failed to supply enough for its small ones. The reader will readily recall that in the dry weather of August the driest parts of his farm are those that in the springtime were the wettest; and, further, that the crops on these portions are the first to suffer from drought, results easily explained when he knows that these soils contain really less water when fit to till; that they bring up less by capillarity, and that they lose more by run-off, and also more by evaporation, as we shall see later.

More Root-space in Drained Soil.

But there is another reason why capillary action is slower in the undrained soils. Let me illustrate: Figs. 12 and 13 represent two pine stumps, with characteristic root developments.

Those who are familiar with pine know that the deep-rooted one grew on high land, naturally well drained, while the shallow-rooted one grew on flat, wet-bottomed land; and they know, further, that where the roots go deep, as in Figure 12, the stand is much thicker than where they have to spread out laterally; and, further still, that if the land is too wet, pine will not thrive at all. The same thing occurs with grains. If sowed on well-drained land, where the water-table does not come within three or four feet of the surface except for a day or so at times of rain, the roots strike deep and strong, going down from two to four feet, as shown in Figs. 14, 15 and 16, which are reproduced by courtesy of Prof. F. H. King, of Wisconsin Agricultural College. Roughly speaking, the root development is about equal to the top, or, better, the top is about equal to the root, for the root controls. But if sowed on undrained land, where the water stands within a few inches of the surface for a month or so, the roots do not enter the water, but attempt to spread

sidewise as with the pine in Fig. 13, but the stand is too thick for that, as the drills are only eight inches apart and the seeds an inch or two apart in the drills; it follows that each plant has very little room to spread its roots, and, consequently, a small, shallow root system is developed; and this, coupled with other unfavourable conditions, produces plants that are small, sickly, and stunted. And, therefore, when the dry weather does come and the water-table recedes rapidly, owing

Fig. 14. Showing the total roots of one hill of corn. Note one of the stalks, doubled beside the measuring stick.

to evaporation, the plants are unable to recuperate and send their roots deep before the lack of water begins to be felt, and again the stunting process goes on, the roots stay near the surface, and capillarity has farther to bring water to them than it has in drained land, where the roots go down nearer the water table; and the farther it has to act the less it will deliver, just as a man pumps less water from a deep well than from a shallow one.

Drained Soil is Warmer in Spring.

Moreover, in the springtime a drained soil is warmer than an undrained by from 5 to 12 degrees, according to measurements made by Prof. King, of Wisconsin, a very important fact indeed, for the warmer the soil the more quickly and completely the seeds will germinate and the thriftier the young plants will be. "A good start is often half the battle" is especially true of plants.

Fig. 15. Showing oats and their total roots.

The heat received from the sun is used in three ways. Some of it evaporates water from the soil, some heats the surface layers or seed bed, and the remainder is conducted to lower layers. That evaporation uses heat the reader may easily prove. Let him take two thermometers and put a dry linen or cotton gauze over the bulb of one. He will note that the two in this condition indicate the same temperature. Now, let him moisten the gauze with warm water and watch results. In a short time the wet bulb reads several degrees lower than the dry bulb, showing

that heat is being used by evaporation. As soon as the gauze becomes dry and evaporation ceases the two indicate the same temperature again. Few realize how much of the sun's heat is used in evaporating water from the soil. As long as the latter looks wet on the surface evaporation is going on about as rapidly as from free water, and the amount of heat used by it runs from 25 to 50 per cent. of the total amount received from the sun. This, at a time when warmth is needed to germinate the seeds, is a serious loss. As soon as the soil begins to look dry on the surface the rate of evaporation falls off materially, and much of the heat formerly used in turning water into vapour is available for heating the surface layers. Now, a loose, porous soil will look dry on the surface much more quickly than a compact one. Every farmer knows this, though he may not be conscious of it. After the final stroke of the harrow has been given a field, the compact soil in the teamster's foot-prints stands out dark and moist for several days after the rest of the surface is dry. Every farmer has seen this. It is often taken as an indication that rolling saves moisture, but if towards the end of the second day after harrowing the farmer will carefully scrape off the dry layer beside the foot-print he will find the soil below to be far more moist than that in or below the print itself, and he must conclude that evaporation from the loose layer has been checked, while from the compact it has continued at a rapid rate. In a similar manner, undrained soil, being the more compact, remains moist on the surface, and evaporation from it continues at full speed long after it has been checked on the porous, drained land. Moreover, loose soil is a poorer conductor of heat, and hence carries less of it down to the lower layers. The difference arising from these conditions is accentuated by another cause: Water is the hardest known substance to heat, and since during most of the time it is too wet, the undrained soil has more water in it than the drained, it follows that it must be colder. With the drained land saving heat because evaporation is checked, conducting less to the lower layers, and at the same time being easier to heat, the temperature of its seed-bed is easily maintained from 5 to 12 degrees higher than that of the undrained.

Seeds Germinate Better in the Drained Land.

The first, and one of the important results of this difference in temperature is that the seeds germinate better in the drained land. Every kind of seed has a temperature at which it germinates better than at any other. At too low temperatures many of the seeds will not germinate, and those that do grow very slowly. Drainage overcomes this slow, incomplete germination.

Bacteria Thrive Better in Drained Land.

From the higher temperature, coupled with the presence of more fresh air, the drained soil is superior in another way. Soil is alive with bacteria. These little organisms are to the plant what the cook is to the

family—they prepare the food, make it edible to the plant, so to speak. By their agency manure and clay and sand, which the plant cannot use as such, are changed into salts, which dissolve in water, and with it pass into the roots to sustain the plant. These bacteria need fresh air as much as plants or animals do. In the drained land there is plenty of it. Moreover, a congenial temperature is needful as much to them as to man, and this, too, they find in the drained soil. Here, then, they thrive

Fig. 16. Showing clover and its total roots.

and flourish, combining the elements of the air with those of the soil, and give to the plant abundance of food made to its very liking. In the undrained soil, however, the scant supply of air becomes impure, and this, with the cold, renders most of them so inactive that but little food is prepared; and one of the varieties is so constituted that when air is scarce it lives on the food already fitted for the plant.

Drained Land has more Plant Food than Undrained.

From which it follows readily that the amount of plant food available in drained land far exceeds that in the undrained. And the more extensive root systems in the former enable the plants to make full use of this advantage.

Recapitulation.

Now, if underdrainage will move the seeding time ahead three or four weeks, if it will lessen the labour of tillage by a half, if it will give barley, peas, oats, hay and corn twice as high and twice as thick on the ground the first week in July as on undrained land in the same farm, at the same date and under the same tillage; if it will give fruit trees where otherwise they would not grow; if it will practically double the yield of grain, straw and hay; if on the average it will make every acre that is drained produce $21.65 more than before; if it will repay the cost of drainage every year, or two years at the most, all of which our correspondents say it has done for them; if it will give ideal soil conditions for plant growth, then is it not high time that underdrainage become a general practice in all the flat, wet parts of the country, as general, forsooth, as the practice of tillage.

THE VALUE OF UNDERDRAINAGE TO THE PROVINCE.

Learning that each acre that has been drained produces on the average about $20 more per year than undrained led us to enquire how much land is being drained annually. The Bureau of Mines, Toronto, has for many years been keeping a record of the number of tile manufactured in Ontario. From their reports we learn that the number in 1900 was 19,544,000, and that this gradually dropped to 15,000,000 in 1905, but it has risen since then to 24,800,000 in 1908. Reports for 1909, which the tile manufacturers have sent us direct, indicate that this year the output is approximately 29,000,000, or almost twice what it was when we began our drainage campaign in 1905. Is it too much to claim that, in the main, the accumulated increase in tile output since 1905 represents the benefit that the Ontario Agricultural College has been to the farmers of the Province, directly and indirectly, on this one line of farm drainage? In view of the previous falling off in drainage, we think not. If this ground is well taken, let us see the result. The accumulated increase since 1905 amounts to 27,078,000 feet of tile, which would drain about 53,178 acres more than if the rate had continued as in 1905; and the annual value of the increased crop on this area, at $20 per acre, would be $1,063,560.

The total number of acres drained during the years 1905-1909 is 193,436, the product of which, at $20 increase per acre, would be worth $3,858,720 more each year than before being drained. All these estimates are based on reports from farmers and tile manufacturers.

To gain a comprehensive view of what underdrainage may mean, we must consider the Province as a whole, and estimate what proportion of it needs drainage. As a result of careful enquiry and statements of our drainage advisors, based on examination of many sections of the Province, I have made the calculation that at least one-third of the cleared land of the Province, or 4,710,000 acres, is in urgent need of underdrainage. If that were all drained and each acre produced $20 more than it does now, the increase in crop would be worth $94,200,000 annually. The value of all field crops in Ontario in 1908, according to the latest report of the Bureau of Industries was $164,077,000. Thus drainage of all the cleared land needing it might increase Ontario's field crop about 57.4 per cent. At the present rate it would take 100 years to complete the drainage.

But that does not tell the whole story of the possibilities of underdrainage. Ontario has 2,250,000 acres of slash land and 2,750,000 acres of swamp, marsh and waste land, or 5,000,000 altogether, much of which remains in this comparatively useless state only because it would be too wet for cultivation. On much of the slash and marsh a comparatively small amount of labour would do the necessary clearing, and underdrainage would reclaim the land and make it equal to the best. The swamp, too, when cleared, would yield to drainage in the same way. Thus an immense area could be added to the arable land of the Province.

CONDITIONS ON WHICH DRAINAGE SURVEYS ARE MADE.

The reader's attention has already been drawn to the fact that the Department of Physics is in the habit of making drainage surveys for those who apply for such assistance. It may not be out of place before leaving this part of the subject to state the conditions on which these surveys are made. There is no charge for the services of our drainage advisors, their salary being paid from a special drainage appropriation, but their travelling expenses, consisting of railway fare at a cent a mile each way for this work, meals on the way, if any, and cartage of instruments, if any, must be paid by the parties for whom surveys are made. They must be met at the station and returned to it, accommodated while on the job, and furnished with the necessary assistance for the work. As several surveys are usually made on one trip, the actual cash outlay for any one farmer is not likely to exceed $2. It may be even less; or, in exceptional cases, where farmers live in remote sections, it might amount to $5.

Those wishing surveys made should write the Department of Physics, O. A. C., Guelph, whereupon regular application forms will be sent.

CONSTRUCTION OF DRAINS.

Bulletin No. 175, on "Farm Drainage Operations," is issued as a sequel to this one, and may be had on application to the Department of Agriculture, Toronto.