The University of Minnesota

AGRICULTURAL EXPERIMENT STATION

REPORT OF NORTHEAST DEMONSTRATION FARM AND EXPERIMENT STATION DULUTH 1922 AND 1923

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REPORT OF THE NORTHEAST DEMONSTRATION FARM AND EXPERIMENT STATION, DULUTH

1922 AND 1923

M. J. THOMPSON, Superintendent

INTRODUCTION

This report is a summary of the experimental work in progress at the Northeast Experiment Station, Duluth, for 1922 and 1923. It is the ninth in the series published since establishment of the station in 1912. Exclusive of press circulars, the publications are: Annual reports for 1915; 1916; 1917; 1918-1919; 1920; 1921; Bulletin 163, Investigations in Costs and Methods of Clearing Land; Bulletin 189, Forced vs. Delayed Systems of Clearing Stump Land. No formal report was issued in 1922, but instead a series of six articles was distributed through the press, each summarizing in a special field the work of the institution during the first decade of service.

WEATHER CONDITIONS AND INFLUENCES

The last two seasons have been quite similar. The winters of 1921-22 and 1922-23 were extremely severe following the mildness of 1920-21. The first was characterized by early and heavy snows, cold, and wind, and the second will be remembered for less snowfall but continuous northwest winds and intense cold, which continued into the last week of March. Both springs were late, followed by relatively cool summers as contrasted with the summers of 1919, 1920, and 1921, when corn ripened with no difficulty. Both summers have been dry followed by fine, open falls. October of both years has been drier than in any other year since 1895. The season of 1922 closed with extremely heavy rainfall in November followed by a cold December. November and December of 1923 were mild and dry, comparable to the falls of 1913, 1914, and 1918. Plowing, blasting, and stone picking were in progress until December 1, and such clearing operations as burning, brushing, and stumping in favored locations continued to December 27, when the first snowfall of any consequence occurred.

Statistics relating to weather are of little value unless interpreted in terms of crop production. Data for the winter months have been omitted from the table.

TABLE I
METEOROLOGICAL DATA, SUMMERS OF 1922-23

Month	Temperature: Maximum 1922	Maximum 1923	Minimum 1922	Minimum 1923	Mean: Normal	Mean 1922	Mean 1923	Precipitation: Normal	Precipitation 1922	Precipitation 1923
April	58	79	21	11	37.0	37.2	37.5	2.14	2.85	1.11
May	81	78	37	26	47.3	51.5	49.0	3.47	3.28	1.81
June	92	85	41	41	57.2	60.0	60.8	4.53	3.97	3.89
July	84	89	44	49	63.9	63.6	64.6	3.65	2.30	5.40
August	92	84	43	38	62.6	64.2	60.3	3.53	2.01	1.76
September	86	81	37	30	55.1	58.2	56.4	3.55	2.23	2.61
October	83	75	21	15	44.1	46.0	44.4	2.74	0.56	0.46
Mean Av. temperature, growing season					52.5	54.4	53.3			
Total precipitation, growing season								23.61	17.20	17.04

The table shows an excess of 566 degrees of temperature since January 1 for 1922; and a deficiency of 160 degrees for the same period in 1923. Both seasons show a deficiency of rainfall for the growing season of 6.41 and 6.57 inches respectively.

Fig. 1. Institute Hall, as Rebuilt in 1921

The hay, potato, and grain crops showed definite reactions to prevailing temperature and moisture conditions in both seasons. Moisture in May and early June is essential for a full hay crop. In 1922 the rains were copious, normal, and well distributed during this period and one of the best crops in years was harvested. In 1923, both April and May were very dry, the drouth extending to June 20. A partial hay crop resulted. On the contrary 1922 potato crop was poor; the 1923 crop, excellent. The 1923 crop had the advantage of drier planting conditions, but June temperature and rainfall were favorable both seasons. The potato crop requires moisture at setting time followed by cool weather. July, 1922, was normally warm but dry, followed by a hot dry August. Retarded growth, early maturity, a spread of such diseases as Mosaic, and a short crop, resulted. July, 1923, was normally warm and moist followed by a dry but cool August; the July

surplus of rain sufficed. A normal growth and maturity, scarcity of disease, and heavy yields resulted. The grain crops behaved in like manner. Oats and barley thrive in a cool dry season, with a dry seedbed. The spring of 1922 was wet, followed by a hot July and August with resulting short yields. But the spring of 1923 was dry, with an ideal seedbed, and normal to cool weather in midsummer. Heavy yields followed.

FIELD CROPS

Variety testing of the various field crops adapted to this district has now been carried on for nine years; and for five years beginning in 1919, on a given field. A five-year rotation is maintained, two years in grass, two in grain, and one in a cultivated crop. Where less than five-year averages are recorded the variety is a recent introduction or has been discarded.

TABLE II

YIELDS PER ACRE IN VARIETY TEST PLOTS OF GRAIN

Crop	Minn. No.	1919	1920	1921	1922	1923	Average
		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Wheat							
Marquis	1239	18.79	15.16	16.65	19.27	15.07	17.00
Preston	924	13.82	17.12	15.24	24.70	....	17.72
Mindum	470	26.73	8.46	20.40	20.69	21.28	19.51
Emmer	1165	....	10.00	15.60	17.14	14.00	14.19
Koda	2198	....	....	10.40	18.50	16.30	15.07
Oats							
Iowa	103	54.31	50.96	41.59	46.67	53.31	49.37
Iowar	670	....	58.88	56.15	67.59	50.76	59.84
Imp. Li owa	281	46.18	77.73	41.26	52.50	60.44	55.62
Victory	514	53.50	75.29	41.60	61.70	54.44	57.30
Minota	512	48.25	70.50	46.98	53.44	57.28	55.29
Selection	358	40.93	76.08	41.83	47.33	49.01	51.03
Silver Mine	506	45.68	68.12	45.84	....	56.80	54.11
Lincoln	505	47.69	73.45	44.41	44.33	....	51.47
Swedish Select	513	48.83	....	38.11	58.86	....	48.37
Rye							
Spring	61	32.00	21.98	12.93	9.53	....	19.11
Rosen	82	....	10.46	23.21	21.97	17.66	18.32
Wisconsin Pedigree	84	....	13.00	21.73	25.20	18.18	19.53
Swedish	2	....	13.87	22.69	28.05	19.60	21.26
Barley							
Imp. Manchuria	184	47.07	45.08	25.47	31.30	44.08	39.00
Minsturdi	439	42.64	40.08	29.04	21.17	29.19	32.42
Svansota	440	53.76	50.08	33.50	25.80	37.29	40.68

To date the variety of durum or macaroni wheat known as "Mindum" has given the greatest promise in yield and shown the least rust injury. Since wheat is not grown commercially in this district and is largely produced for poultry feed, the difficulty experienced in growing the spring bread wheats owing to rust attacks and frequent inability

to sow in April, is not a serious matter. The variety "Kota" so popular in North Dakota, does not yet equal Mindum, tho under trial for two years. "Java," a bread wheat but of high starch content, and recommended for poultry feed promises well on first trial. Winter wheat has not yet been a success at this station.

Victory, Improved Ligowa, and Iowar are the three outstanding varieties of oats at the Duluth station. Garton is a black oat which is not promising here. In a class with it is the side oat "White Tartar," which is very susceptible to smut. The season is too short for this variety to mature unless sown early. It requires about ten days longer to ripen than the usual mid-season variety. Gopher, just introduced, is an early strain that led all varieties here in 1923 and is yielding heavily all over the state.

Swedish rye, Minnesota No. 2, has established a definite lead over all competitive varieties in a four-year period.

Fig. 2. Svansota Barley (Minn. No. 440) in Rotation

The two-rowed Svansota barley retains its lead after five years' trial. This variety and Minnesota No. 184, a six-rowed Manchurian barley are in a class by themselves. Field peas were brought into the variety test plots in 1923. Brown Swedish, owing to early maturity, was the only variety of beans that entirely escaped the frost in September. Considerable attention was given to rod-row tests of oats and barley, plant breeding, and tests of rust-resistant varieties.

A rate-of-seeding test has been conducted for three years with rye and for two years with oats and barley. There was no material difference in yield whether 1.25, 1.50, or 1.75 bushels of rye were sown per acre. Barley has been sown at the rate of 1.5, 2, and 2.5 bushels per acre. In both years the two-bushel seeding has given the highest yields. Oats have been sown at the rate of 2, 2.5, and 3 bushels per acre. The

three-bushel seeding has outstripped the other two in both seasons.

A date-of-seeding test, also, has been conducted. Table III shows the results with rye.

TABLE III

YIELDS PER ACRE OF WINTER RYE IN DATE-OF-SEEDING TESTS

Date of seeding	4-year average, Bu.
Sept. 1	25.12
Sept. 10	22.23
Sept. 20	20.52
Sept. 30	16.85
Oct. 10	8.51

It would seem to be poor practice to sow rye later than September 20 in this latitude, and the nearer to September 1 the better. It is possible that rye sown late in October, when germination is delayed until spring, will outyield the early October and sometimes the late September seedings, for these seeds germinate and are injured by the thawing and freezing of late fall.

Oats and barley have been run in date-of-seeding tests for two years only. In both cases seeding has been done on May 1, 15, and 30. The two-year average yields for oats, for the respective dates, are 69.7, 46.2, and 37.1 bushels per acre. For barley the averages were 34.07, 34.05, and 23.6 bushels per acre, respectively. It would seem that rye should be sown not later than the middle of September, oats as near May 1 as possible, and barley not later than May 15.

Plowing is expensive. In order to reduce the cost of growing grain, the land is sometimes disked instead of plowed when grain follows a cultivated crop. In the report for 1920, the result of such a project is recorded. It was repeated in 1923, when oats followed sunflowers. The average of all disked plots for both years is 57.87 bushels per acre, and of all plowed plots for both years, 52.02 bushels. Disking was less expensive than plowing and increased the yield by 10 per cent.

It has been suggested that harrowing the grain crop after sprouting would improve the yield in dry seasons. It has also been asserted that top-dressing with manure is good practice. Both plans were tried in 1923, without positive gains. Smut is becoming very troublesome on oats. Side oats were found most susceptible, probably because they are late. Formalin, copper carbonate, and Seed-O-San treatments and the last two in combination, all dust except the first, were tested for smut control. The first and second seemed better than the others.

Thirty-six varieties of dent and flint corn were under test. They came from border states and Canadian provinces. The cool season was unfavorable for corn. Squaw flint, that ripened in 1919, 1920, and

1921, failed in 1923. Several strains matured grain but the outstanding variety was Howe's Alberta Flint, a yellow corn with ears six inches long. It was dry several days before the frost of September 13.

In two root crop series, flat turnips and rutabagas surpassed all other kinds in yield.

ROUGHAGE CROPS

Under roughage crops are included hay crops, and soiling crops, for green feeding during late summer.

New seedings of Grimm and Cossack alfalfa were made in 1921. The land was a level, heavy clay, requiring both liming and inoculation. The location would be considered a very severe test. The average annual yield of Grimm, two cuttings, for two years, is 2.34 tons per acre; of Cossack, 3.07. Both showed improvement in 1923 over 1922. Test plots of seven varieties were sown in May, 1923, and a series of date-of-seeding tests at two-week intervals from May 11 to September 1, both in triplicate plots. Part was sown with a nurse crop. This helped to control weeds, and altho the season was dry there seemed ample moisture for both alfalfa and the cover crop.

Seedings made after July 1 do not look promising, indicating that this is the seasonal limit for seeding. Seeding down Series 2 of the old fertilizer experiment, constitutes another test. Since half of this is limed, a comparison is made of the influence of lime and no lime. Altho seven years have elapsed, the effect of lime is still in evidence. The alfalfa was sown without a nurse crop and with a nurse crop of 1, 1.5, and 2 bushels per acre. There appears to be some advantage when no nurse crop is used.

Much attention was given to sweet clover in 1922 and 1923. Nurse crops of oats and barley were used in comparison with none. The second year there is practically no difference in the stand of the biennial white and yellow clover either with or without a nurse crop, which served principally to control weeds the first year. The second crop is harvested about June 20 of the year following the seeding, is cut just before it blossoms and when it is not less than 6 inches and preferably 8 inches high. This is assuming that a small crop was cut the first season. The seed crop follows in August. Hubam, the annual sweet clover, will produce about 1.75 tons per year here. The first crop (white biennial) of the second year was 1.25 tons per acre; and the second, or seed crop, was a trifle more than 2 tons. The corresponding yields for yellow sweet clover are not quite 1.25 tons and a trifle more than 1.5 tons per acre. In the humid portion of northeast Minnesota, the biennial white sweet clover, at least, has an uncertain future as a

hay crop, owing to the difficulty of curing it in June. This condition may be obviated by pasturing and thus delaying the hay harvest until the usual dry period sets in.

The third or seed crop has been fed as a soiling crop in August, and with excellent results. The cattle prefer the yellow-flowered variety to the white, both as pasture and as hay. The yellow-flowered variety leads in both quality and palatability and seed will mature in this district. The seed of the white-flowered biennial does not always mature. In two weeks the cattle consumed from 80 to 94 per cent, the waste consisting mainly of woody stems. Cut green for soiling, the yellow biennial produced 6.43 tons per acre and the white biennial, 8.58 tons.

In this project, other feeds were grown for both soiling and fodder purposes. The group included the following crops with the respective yields per acre of green forage: Sunflowers, 21.17 tons; millet, 9.72 tons; oats and hubam, 8.52 tons; corn, 7.12 tons; hubam, 7 tons; peas and oats, 6.72 tons. Sunflowers have been fed green, successfully, for two years. They are first run through a straw or silage cutter. The cattle eat them clean. When feeding was suspended, production dropped 4 pounds per cow per day. The great asset of sunflowers is the high yield. They have also been fed as fodder, the cows consuming 65 per cent of the gross weight. For this purpose they must be so cut as to preserve the leaves; even then they will probably rank below fodder corn. A local strain has been developed for seed purposes and early feeding. Cut on the same day, the local strain shows a greater content of ether extract, protein, and nitrogen-free extract and a smaller content of crude fiber than any other. Corn was consumed green equally well, but the volume was much less. Oats, oats and hubam, and hubam were secondary in feeding value tho fair in yield. Sudan grass and millet, both rather coarse feeds, were rated last. A dairy farmer feeding a producing herd on limited pasturage and with recurring dry seasons, will find soiling crops both cheap and efficient for maintaining the milk flow.

SILAGE CROPS

For several reasons, the silage work at the Duluth station has been concentrated on the sunflower plant. It has proved a safe crop for six years. No frost injury has been recorded and a longer growing season is available than for corn or other crops, as silage harvest can often be delayed until the middle of September. The late harvest simplifies the labor problem at a busy season. The yields far exceed competitive crops. Finally, the location of the station is typical of a large area where corn still has limitations as a silage crop.

Fertilization and rotation work with sunflowers are reported elsewhere under these particular heads. The following cultural projects are included here: Rate of seeding, date of seeding, fall vs. spring plowing, hills vs. drilled rows, corn vs. sunflowers, fodder and silage tests.

In "rate of seeding" we have three conditions: (1) Rows spaced 30, 36, and 42 inches apart; (2) sown with grain drill, plugging one or two intervening feeding spouts, thus making rows 6, 12, and 18 inches apart; (3) setting the grain drill at 4, 8, and 12 pecks of wheat per acre. A double-disk Van Brunt drill was used. The first subproject has been under way for three years, the total findings of which are given in Table IV.

TABLE IV

YIELDS PER ACRE OF SUNFLOWERS* IN ROWS SPACED AT 30, 36, AND 42 INCHES

Spacing of rows	1921	1922	1923	3-yr. Av.
In.	Tons	Tons	Tons	Tons
30	14.26	15.60	24.58	18.14
36	13.90	14.36	23.10	17.12
42	13.44	10.80	19.74	14.66

* Green material.

Each spacing was grown in duplicate each year, with one series discarded in 1923, hence the average is made up of five plots. The same general behavior was noted each year. While spacing 30 inches between rows produces an additional ton of silage and insures somewhat finer quality it is more difficult to cultivate. Yet for the farmer with a limited clearing, this extra ton, worth about six dollars, is a consideration not to be ignored. The 42-inch spacing apparently wastes land, altho the plants grow to greater size and coarseness. The 36-inch spacing is the most practical.

Fig. 3. Sunflowers vs. Corn for Silage, August 4, 1923

It is unnecessary for the small grower to buy a corn planter to seed his crop. The grain drill can be used to advantage. One method is to sow with all feeding spouts open, making the rows 6 inches apart; another method is to plug alternate spouts making rows 12 inches apart; plugging two spouts, side by side, makes a spacing of 18 inches between rows. This work has been running two seasons.

TABLE V

YIELD PER ACRE OF SUNFLOWERS* SOWN WITH GRAIN DRILL WITH OPEN AND CLOSED FEEDING SPOUTS

Drill row spacing	1922	1923	Average
In.	Tons	Tons	Tons
6	11.65	13.01	12.35
12	11.03	11.97	11.50
18	11.34	15.52	13.43

* Green material.

Additional work must be done before conclusions can be drawn in this project. With close seeding, the growth is more slender, but this is secured at the cost of height. The lack of tillage causes drying out in late summer. Another reason why this method is limited in application is the difficulty of harvesting. A machine similar to a sled with cutting knife attached, or a brush mower equipped wtih a 3-foot bar can be used, but the stalks are loose and hard to handle.

The third subproject was begun in 1923. The Montana experiment station reports that by setting a Van Brunt grain drill for four pecks of wheat per acre, and filling it with sunflower seed, sufficient seed will be sown. At Duluth, the drill was set at 4, 8, and 12 pecks per acre. The average yields for this season ranged from 17.75 to 18.2 tons per acre, rather substantiating the Montana statement. This work will be continued for several years.

The date-of-seeding experiments have been in force for three years, beginning in 1921. For the last two years a July 1 planting has been included. All plantings are in duplicate, with only averages reported.

TABLE VI

YIELD PER ACRE OF SUNFLOWERS* IN DATE OF SEEDING PROJECT

Date of seeding	1921	1922	1923	Average
	Tons	Tons	Tons	Tons
May 17	19.35	16.10	16.50	17.32
June 1	16.79	9.61	13.34	13.24
June 15	15.64	5.03	11.89	10.85
July 1	....	7.14	6.86	7.00

* Green material.

The first planting not only produced an additional ten tons, or nearly two and one half times as much as the last planting, the surplus an

average crop in itself, but it was much better feed, containing less watery material, and was more mature. As in six years no trouble from spring frost has been experienced, we have followed the plan of planting the crop as soon as soil and weather conditions permitted. The earliest planting date on record is May 10.

Fall and spring plowing tests with sunflowers were first reported in 1921. The work was continued in 1922 and 1923.

TABLE VII

YIELD PER ACRE OF SUNFLOWERS,* FALL AND SPRING PLOWING

Time of plowing	1921	1922	1923	Average
	Tons	Tons	Tons	Tons
Fall	18.68	15.92	14.85	16.48
Spring	16.74	13.60	16.54	15.63

* Green material.

Altho the increase with fall plowing is small, there are certain indirect benefits. The work can be done more easily in the late fall when there is less other work. The need of fall plowing is especially urgent when we consider that very early planting insures heaviest yields. Finally, weather and soil conditions are usually better in the fall.

A two-year test has been conducted on the relative merits of check-rowing and drilling sunflowers. An average of 8.5 tons was harvested with the first practice and an average of 10.46 tons with the second. Check-rowing has this advantage: quack grass and other weeds can be eradicated; and the foliage does not wither so soon and seems less subject to disease, probably on account of beetter exposure to sunlight and air.

Among the miscellaneous studies conducted in 1923, was a comparison of corn and sunflowers for silage on the basis of yield per acre. The sunflowers produced about 65 per cent more than the corn. The proper time to cut sunflowers for silage is still debatable. They were harvested at 10-day intervals beginning August 26, and made into silage, large salmon casks being used as containers. However, the samples submitted for analysis were injured in transit, delaying the work one year.

A local strain, selected from early ripening heads in 1919, was grown in considerable quantity in 1923. The earliest plants in this field blossomed in the middle of July. This selection seems somewhat more free from disease than commercial strains. Its value for soiling purposes lies in its earliness, and for chicken feed in the ability to ripen every season. The principal diseases were leaf spot, which has been troublesome for some years, and rust, which appeared in appreciable amounts in 1923.

POTATOES

As indicated on an earlier page, the season of 1922 was very unfavorable for potatoes after the setting stage, while in 1923 weather and soil conditions were uniformly good. The potato experimental work begun in 1916 has been maintained continuously since, with considerable expansion in recent years. The projects now under way are: Varietey testing; level vs. ridged cultivation; drilling vs. check rowing; spacing of rows; date of planting; spring vs. fall plowing; spray tests; comparative yielding power of different strains of the same variety of certified seed stock from different sources; cold vs. warm storage; small vs. large seed; effect of cutting seed end, also the fertilizer work, which is discussed in a later section.

Variety testing has now been in force annually since 1918, except in 1920. The eight standard varieties for Minnesota have been grown. Yields for 1918, 1919, and 1921 have been previously reported.

TABLE VIII

YIELD PER ACRE OF POTATOES IN VARIETY TESTS

Variety	1922	1923	5-yr. Av.
	Bu.	Bu.	Bu.
Bliss Triumph	72.11	221.00	137.38
Early Ohio	125.77	172.30	181.33
Irish Cobbler	146.66	230.00	208.73
Green Mountain	166.52	309.70	241.18
Rural New Yorker	114.89	199.80	176.14
Russet	131.44	225.50	204.25
King	161.94	286.00	233.47
Burbank	164.38	231.00	221.58
General averages, all early varieties			175.81
General averages, all late varieties			215.32

Throughout the test period, Green Mountain has led in production with King second and Burbank third. Irish Cobbler is popular here. Being early, it yields less than the four late varieties, but it stands first in the early group. The Red River Valley Ohio, when grown here, becomes irregular in shape and color. A Bemidji selection of mosaic-free Triumph established a new production record for the variety at this station. The relative average production of early and late varieties, with a margin of 40 bushels between them is worthy of consideration by the prospective grower from other sections.

Ridging potatoes as contrasted with level culture has been under observation for five years at Duluth. Reports for 1919, 1920, and 1921 have been published.

The work of 1923 terminates this project. It has frequently been argued that in humid regions and with clay soils potatoes must be ridged to allow the water to escape. On the other hand, in drier sec-

tions, with lighter soil, level culture should be practised. It is quite evident, from an average of ten plots tested under each method for five years, that there is no material difference in yield under Duluth conditions and that the method practised is a matter of choice.

TABLE IX

YIELD PER ACRE OF MARKET POTATOES HAVING LEVEL AND RIDGED CULTIVATION

Culture	1922	1923	5-yr. Av.
	Bu.	Bu.	Bu.
Level	166.62	238.40	231.96
Ridged	142.18	247.50	228.17

In 1921 an experiment was begun in growing potatoes in check rows and in drills. The 1921 report contains the results of the first years' work.

TABLE X

YIELD PER ACRE OF MARKET POTATOES PLANTED IN DRILLS AND IN CHECK ROWS

Treatment	1922	1923	3-yr. Av.
	Bu.	Bu.	Bu.
Drilled	161.10	238.70	203.27
Check-rowed	118.93	245.80	203.71

The potatoes in the drilled plots are in rows 3 feet apart, and about 16 inches apart in the rows. In the check-rowed plots, just half as many seed pieces are dropped, allowing cultivation both ways. Check-rowing is desirable if the land is very weedy. While the number of hills is less, the increased yield per hill tends to equalize the yield.

The 1921 report also included the results of the first years' study of the spacing of potato rows. The object of this experiment is to determine what spacing is most practical, especially for small fields.

TABLE XI

YIELD PER ACRE OF MARKET POTATOES IN ROWS AT VARYING DISTANCES APART

Distance apart	1922	1923	3-yr. Av.
In.	Bu.	Bu.	Bu.
30	160.05	276.10	240.48
36	150.74	235.10	214.25
42	101.73	205.60	171.41

Rows 30 inches apart can be cultivated with a horse cultivator with little trouble. Owing to the marked increase in yield, over a three-year period, this would seem a desirable practice. Duplicate plantings were made each year, so the averages are made up of the yields of six plots.

Growing potatoes on fall-plowed and on spring-plowed land was begun in 1921 and continued through 1922 and 1923. When fall plowed, the land is top-dressed in the winter and the manure is disked in the following spring. When spring plowed, the manure is spread and plowed under.

TABLE XII

YIELD PER ACRE OF MARKET POTATOES IN TEST OF FALL VS. SPRING PLOWING

Time of plowing	1922	1923	2-yr. Av.
	Bu.	Bu.	Bu.
Fall	125.50	243.10	184.60
Spring	146.66	278.80	212.70

The complete fertilizer series, operated for three years, has always been spring plowed. All other experimental work has been done on fall-plowed land. The average yield of the phosphate plots on spring-plowed land was 165 bushels; on fall-plowed land, 170 bushels.

This apparent advantage of spring plowing can probably be explained. With the prevailing heavy type of land, the soil does not have time to pack, as often happens with fall breaking. However, the land itself is usually in better condition for plowing in the fall and more time is available; and for sod land it is almost necessary, as a tough green sod in spring makes seedbed preparation expensive. Spring breaking tends to shorten the season and to retard early planting, which insures the highest yields.

Alternate plots of Green Mountain potatoes were sprayed with bordeaux mixture in 1922, using an ordinary one-horse barrel sprayer. The sprayed plots returned an increase of 42.6 per cent.

A more extensive experiment was planned for 1923. Four sprayings were used, on July 9, 17, 24, and August 1. An insecticide, lead arsenate, was combined at all times with a fungicide. A sprayer, providing a pressure of 200 pounds per square inch was used. (1) Home-made bordeaux alone; (2) in combination with a casein spreader to make the spray adhere better to the foliage; (3) pyrox; (4) commercial powdered bordeaux, were used; (5) a check plot was left untreated. The average respective yields were 305.1 bushels per acre; 325.5 bushels; 331 bushels; 328.5 bushels; 315.7 bushels. The spray produced no gains this season. Conditions were unfavorable for the spread of disease and frost came in the middle of September, killing the foliage and checking the possible action of the spray in delaying maturity.

Seventy-eight lots of certified seed of four varieties were assembled from various parts of the state and grown side by side in triplicate plots to determine whether or not there is any difference in yield of different strains of the same variety, to the end that high-yielding strains could be isolated and their propagation encouraged.

The range in production of different strains within a given variety is extreme, altho all seed has been certified. The purchaser of potato seed stock as of livestock, must be concerned not alone with registration, indicating purity of stock and freedom from disease; he must consider

producing power as well. Other projects of cultural character will be reported later, owing to their recent origin.

TABLE XIII
VARIATION IN YIELD PER ACRE WITHIN GIVEN VARIETIES OF POTATOES

Variety	No. of growers	No. of samples	Range in yield
			Bu.
Irish Cobbler	40	40	115-247
Burbank	6	6	168-244
Russet	14	14	177-265
Rural New Yorker	18	18	167-290

DATE-OF-PLANTING TESTS

A date-of-planting test has been under way for two seasons. In both years the first planting was made as near the middle of May as possible, the date for 1922 being May 20 and for 1923, May 17. The second plantings were made on June 1, and the third on June 15. In 1923 a fourth planting was made on July 1. In both seasons the yields declined progressively with later dates of planting. In 1923, the following average yields from triplicate plots were harvested: May 17, 401 bushels per acre; June 1, 232 bushels; June 15, 175 bushels; July 1, 94.1 bushels.

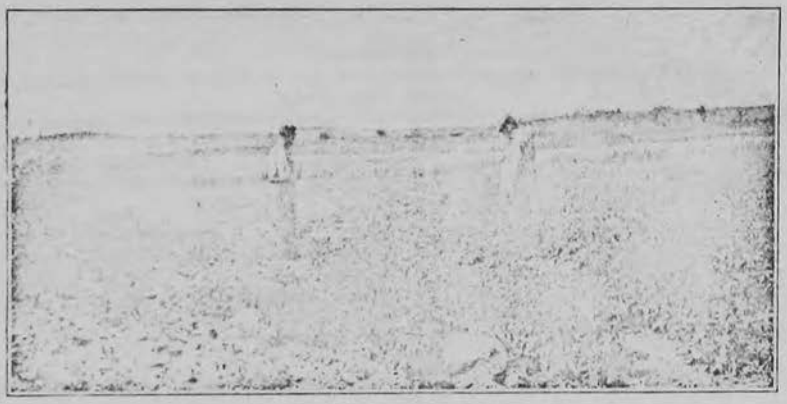

Fig. 4. Plant Potatoes Early

The three rows behind the man on the right were planted on June 1; the yield was 232 bushels per acre. The three rows between the men were planted on June 15; the yield was 15 bushels. The three rows behind the man on the left were planted on July 1; the yield was 94 bushels. The rows on the extreme left were planted on May 17; the yield was 401 bushels.

CROP ROTATIONS

In 1919, a series of 36 plots, each one-tenth acre in size, was set apart for the study of crop rotations adapted to the heavy clay timbered soils of northeastern Minnesota. Nine plots are allotted to a three-year rotation of barley, hay, and sunflowers in triplicate; twelve plots to a

four-year rotation of barley, hay two years, and sunflowers; fifteen plots to a five-year rotation of barley, hay three years, and sunflowers. These studies are concerned with relative yields, relative costs, relation to livestock needs, and system of farming.

The grain stubble is manured once in the rotation at the rate of two tons of manure per acre per year. For example, the three-year rotation requires six tons spread over the barley stubble. The work is now five years old. The second cycle of the three year rotation will be completed in 1924; the first cycle of the four-year rotation was completed in 1922, and of the five-year rotation, in 1923.

TABLE XIV

YIELDS PER ACRE OF BARLEY IN VARIOUS CROP ROTATIONS

Rotation	1922	1923	5-yr. Av.
	Bu.	Bu.	Bu.
3-year	26.73	45.13	34.20
4-year	30.41	35.71	31.65
5-year	25.27	37.12	29.83

TABLE XV

YIELDS PER ACRE OF HAY IN VARIOUS CROP ROTATIONS

Rotation	1922	1923	4-yr. Av.
	Tons	Tons	Tons
3-year	1.70	2.81	2.23
4-year	1.91	1.75	1.94
5-year	1.94	1.62	2.02

TABLE XVI

YIELDS PER ACRE OF SUNFLOWERS IN VARIOUS CROP ROTATIONS

Rotation	1921	1922	1923	3-yr. Av.
	Tons	Tons	Tons	Tons
3-year	15.65	9.77	11.56	12.33
4-year	11.76	9.33	8.78	9.96
5-year	13.69	9.29	8.64	10.54

The three-year rotation has demonstrated its superiority in point of yield in the production of all three classes of crops. The manure is more effective on the principle that a small amount applied frequently accomplishes more than a large amount spread at longer intervals. Again, there is more frequent tillage, as one third of the land is broken annually instead of one fourth or one fifth. The higher yields of hay are probably accounted for by the fact that the crop from only the first seeding is harvested. This is usually the heaviest. But this type of rotation is more expensive because more plowing is involved, as already indicated. Morever, for livestock farming too great a proportion of the land is devoted to cultivated crops unless there is permanent meadow to balance it. The five-year rotation has done as well as the four-year.

The higher yield of hay may be partly explained by the fact that clover largely drops out of the rotation in the second year and returns in part in the third. With the small percentage of ground to break annually and the large tonnage of hay, the five-year rotation is well adapted to livestock farming.

SOIL FERTILITY INVESTIGATIONS

The phosphate experiments, begun in 1916, constitute the first organized work of this character done at Duluth. In that year potatoes and rutabagas were grown; oats followed in 1916, and hay in 1917. Seven crops of potatoes and rutabagas, and six of hay and oats, have been harvested. The work has now been suspended and the three series of eighteen plots are being devoted to alfalfa and sweet clover experiments. As previously reported, the west half of each series was limed in the fall of 1916 at the rate of three tons per acre. At the same time the raw crushed rock phosphate was spread at the rate of one ton per acre on the designated plots. Manure has been spread at the rate of ten tons per acre on the grain stubble, and the acid phosphate, 360 pounds per acre, at the time of planting the cultivated crop. Plots are one-tenth of an acre in size.

TABLE XVII

AVERAGE YIELDS PER ACRE OF POTATOES AND RUTABAGAS IN PHOSPHATE-MANURE EXPERIMENT, 1922-23

Plots (averages)	Treatment	Potatoes		Rutabagas	
		Marketable	Total	Roots	Leaves
		Bu.	Bu.	Tons	Tons
1- 7-13	None	118.74	136.74	10.01	5.08
2- 8-14	Rock phosphate	124.84	139.85	17.88	4.25
3- 9-15	Rock phosphate and manure	160.83	178.63	9.46	4.82
4-10-16	Manure	140.70	158.39	10.82	4.67
5-11-17	Manure and acid phosphate	151.35	170.00	12.03	4.06
6-12-18	Acid phosphate	117.72	140.60	10.49	6.79

As 1922 was a poor potato year, yields were lower than normal. The effect of manure and rock phosphate is more marked than ever before as compared to other plots, indicating a greater availability of the phosphate and perhaps a cumulative effect of manure. Both rock and acid phosphate alone, continue to be little better than the check, which holds up extremely well, with no fertilization except the grass and clover sod.

Rutabagas were a fair crop in 1922. Heavy crops were harvested only in 1916 and 1919, with poor stands in 1917, 1918, and 1921. The effect of manure is very marked, in combination with phosphate, on both roots and leaves. On the other hand, the effect of acid phosphate is very slight when used alone, owing in part probably to the dry season.

which prevented the crop getting the full effect from it. As with potatoes, there is some indication of greater availability of the rock phosphate and cumulative effect of repeated manure applications.

TABLE XVIII
AVERAGE YIELDS PER ACRE OF OATS, PHOSPHATE-MANURE EXPERIMENT, 1922-23

Plots (averages)	Treatment	1922	1923
		Bu.	Bu.
1- 7-13	None	28.80	46.80
2- 8-14	Rock phosphate	29.00	51.00
3- 9-15	Rock phosphate and manure	32.05	55.83
4-10-16	Manure	33.43	60.60
5-11-17	Manure and acid phosphate	41.23	68.61
6-12-18	Acid phosphate	42.85	65.47

The winter of 1921-22 was one of heavy snows and high winds. Snow fences were placed lengthwise of the series of plots to be in grain in 1922. The fences gathered the snow and held it in deep piles which melted slowly and kept the ground wet. As a result the crop went in late and under wet soil conditions. The middle block was discarded. A hot summer following a wet spring produced much rust and low yields on the other two blocks.

A like condition existed in the winter of 1922-23, again followed by slow melting of the snow and late seeding. But the spring rains were light so the soil was in good shape for seeding. With dry cool weather extending through the growing season yields were excellent.

In both seasons the experience of previous years has been borne out in that acid phosphate, especially in combination with manure, has given the best return, altho the manure has been applied two and one half years before and the phosphate one year before. Rock phosphate alone still makes a poor showing compared to the unfertilized plots and whether alone or in combination is inferior to the acid phosphate for oats.

TABLE XIX
AVERAGE YIELDS PER ACRE OF HAY, PHOSPHATE-MANURE EXPERIMENT, 1922-23

Plots (averages)	Treatment	1922	1923
		Tons	Tons
1- 7-13	None	1.65	1.26
2- 8-14	Rock phosphate	1.77	1.36
3- 9-15	Rock phosphate and manure	2.47	2.86
4-10-16	Manure	2.38	2.16
5-11-17	Manure and acid phosphate	2.57	2.49
6-12-18	Acid phosphate	1.78	1.71

The season of 1922 was very favorable for hay. A winter of heavy snows was followed by a wet spring and early summer. The result is reflected in the 1922 yields. But the drouth of late summer and fall

injured the spring seeding; the moderate snowfall of the winter of 1922-23, was piled in the roads, leaving the fields very bare. The spring of 1923 was dry until June 20. Somewhat poorer yields of hay resulted. The middle block of hay was discarded entirely on account of poor catch in 1922, with resulting irregular stand. The table indicates three things: The decline in yield of check plots; the low yield with fertilizers in absence of manure; and the uniformly heavy yield with manure alone or in combination in spite of an unfavorable season. But the yields with manure as compared to former years are so pronounced in 1923 that one is led to conclude that it is due in some degree to the cumulative effect of former applications as in the case of both grain and cultivated crops.

TABLE XX

SUMMARY OF SEVEN YEARS' WORK, PHOSPHATE-MANURE EXPERIMENTS, 1916-23

Plots	Treatment	Potatoes, market	Rutabagas	Hay	Oats
		Bu.	Tons	Tons	Bu.
1- 7-13	None	168.43	9.83	1.57	45.70
2- 8-14	Rock phosphate	176.83	10.35	1.64	49.93
3- 9-15	Rock phosphate and manure	196.97	11.39	2.28	52 67
4-10-16	Manure	187.90	12.17	2.03	53.51
5-11-17	Manure and acid phosphate	197.94	12.03	2.12	57.22
6-12-18	Acid phosphate	170.67	11.09	1.75	56.29

The table provides a good study in rotations, as the check represents average yields on clover-grass sod in the absence of manure or fertilizer. As the project is to be discontinued, the influence of each treatment on each crop can be somewhat better understood if presented in percentage form, for the seven-year period.

TABLE XXI

AVERAGE PERCENTAGE INCREASE FROM USE OF PHOSPHATE AND MANURE

Treatment	Potatoes	Rutabagas	Hay	Oats	Average
	Per cent	Per cent	Per cent	Per cent	Per cent
None	.....	.....	.....	.....	.....
Rock phosphate	4.99	5.29	4.46	9.19	5.98
Rock phosphate and manure	16.98	15.97	43.95	15.10	23.00
Manure	11.58	23.80	29.30	17.07	20.44
Manure and acid phosphate	17.52	22.38	35.03	25.16	25.02
Acid phosphate	1.36	12.82	11.46	22.97	12.15

Manure alone is the most effective single agency, but in combination with phosphate an increase is realized. But the small increases of 6 and 12 per cent of harvested crops when phosphate is used alone in comparison with the untreated check plot, and the small increase realized when used with manure, would lead to the conclusion that until our soils grow older at least, the use of either form of phosphate will not pay. The continued relatively high production of the check plots should not be overlooked.

These plots were also treated with lime, on the west half of each. Special records have not been taken since 1919. To quote the 1917-19 report: "In 1917 and 1919, the limed portion of the plots (potatoes) outyielded the unlimed by 9.5 and 12.4 bushels per acre respectively but in 1918 this condition was reversed." The variation is so slight it may be ignored. To quote further: "The first hay crop was harvested in 1918. The 1919 crop was very heavy. The limed half exceeded the unlimed by not quite 18 per cent in 1918 and 8 per cent in 1919." The series was sown to alfalfa in May, 1923. General observations indicate a much better stand on the limed half of the series even tho seven years removed from application.

CLOVER UTILIZATION EXPERIMENT

The clover utilization experiment covers a period of six years, beginning in 1918. Plots 1 and 4 are pastured in late June and early July. The grass consumed is partly returned to the land through the droppings of cattle on pasture; Plots 2 and 5 are plowed down with the entire grass crop about July 1. The hay crop is harvested off plots 3 and 6, and nothing is returned to the land to balance the material removed. Potatoes and sunflowers follow the grass crop, to be succeeded in turn by grain, with clover and timothy. The object is to determine the effect of each treatment on succeeding crops. Two cycles of the rotation have now been completed.

TABLE XXII

AVERAGE YIELDS PER ACRE OF CULTIVATED CROPS IN CLOVER UTILIZATION EXPERIMENT, 1922-23

Plots (averages)	Treatment of clover	1922		1923		6-yr. Av.	
		Potatoes	Sunflowers	Potatoes	Sunflowers	Potatoes	Sunflowers
		Bu.	Tons	Bu.	Tons	Bu.	Tons
1-4	Pastured	70.01	6.28	233.56	11.76	180.06	9.90
2-5	Plowed under	68.74	5.57	197.83	10.30	167.83	9.52
3-6	Harvested	69.66	6.41	215.04	9.35	171.50	9.09

TABLE XXIII

AVERAGE YIELD PER ACRE OF HAY IN CLOVER UTILIZATION EXPERIMENT, 1922-23

Plots	Treatment of clover	1922	1923	7-yr. Av.
		Tons	Tons	Tons
3	Harvested	2.17	0.98	
6	Harvested	1.80	0.70	
Av.		1.99	0.84	1.47

TABLE XXIV

AVERAGE YIELD PER ACRE OF OATS IN CLOVER UTILIZATION EXPERIMENT, 1923*

Plots (averages)	Treatment of clover	1923	4-yr. Av.
		Bu.	Bu.
1-4	Pastured	48.10	52.67
2-5	Plowed under	39.20	49.17
3-6	Harvested	44.60	51.42

* The 1922 yields were discarded because of water injury.

Pasturing the crop, with a return to the field in the form of manure, has proved slightly better in all cases. Plowing under the crop appears to be poor practice thus far in the test. The feed is lost with no compensating gain. Judged from yields following harvesting of hay crop, if the aftermath alone were plowed under, practically as good yields could be expected, with the hay crop a net gain. Failure of the green manure crop to make a showing is partly due to the failure of the land to pack, and to the drying out of the land following plowing. Green material decays very slowly. In comparing the first and third methods of disposition of grass and clover, it must be remembered that the 1.43 tons of hay harvested must pay not only for the labor cost of harvesting, the difference in tonnage of succeeding crops harvested, but also the value of the pasture crop. The yields of potatoes and sunflowers in 1922, under unfavorable temperature and moisture conditions, were apparently less than when manure is applied regularly in the rotation.

The average yields for a six-year period, indicate what yields may be expected in the absence of livestock, omitting from consideration the pasture plots.

ROTATION WITHOUT CLOVER OR MANURE

This experiment has also been running since 1917, completing two cycles of a three-year rotation. The rotation consists of cultivated crops (sunflowers and potatoes) barley, and oats. No clover has been sown on this land and no manure or commercial fertilizer applied. No grass sod has been formed. The object is to determine the cause of the progressive decline in yield without constructive soil management and with exploitive potato cropping.

TABLE XXV

AVERAGE YIELDS OF CROP IN ROTATION WITHOUT CLOVER OR MANURE, 1917-23

Crop	1922	1923	1917-23
Barley, bu.	.....	12.39	8.73
Oats, bu.	.....	28.50	34.60
Sunflowers, tons	4.58	5.36	6.43
Potatoes, bu.	46.75	126.70	114.70

It is usually assumed that a single-cropping system is confined to the prairies. But even in the timbered country it is not uncommon to see a meadow unbroken for years or several crops of potatoes grown on the same soil. This group of plots is becoming badly infected with quack grass and Canada thistle; the soil is lifeless, cloddy, inert. It bakes, cracks, and puddles, for the life-giving properties of the original humus content have been exhausted. The experiment teaches this lesson: The soils of this region will permit of no exploitation; but they

will improve from year to year under constructive management and with the use of clover or manure in the rotation, beginning with the first crop.

RATE OF MANURING

The rate-of-manuring experiment was begun in 1917, and is now seven years old. The object is to determine what quantity of manure is the most profitable for staple farm crops. Duplicate crops receive respectively 5, 10, and 20 tons of manure on the grain stubble once in the three-year rotation of oats, hay, and cultivated crops. Two lots receive five and ten tons, respectively, on the grass sod. It will be seen that in the first group the hay crop is first benefited, then the cultivated crops, and finally the grain crop; in the second group the cultivated crop has the advantage.

TABLE XXVI

AVERAGE YIELD PER ACRE OF CULTIVATED CROPS IN RATE-OF-MANURING PLOTS, 1917-23

Plots (averages)	Treatment	1922 Potatoes	1922 Sunflowers	1923 Potatoes	1923 Sunflowers	1917-23 Potatoes	1917-23 Sunflowers
		Bu.	Tons	Bu.	Tons	Bu.	Tons
7-13	None	90.93	5.77	170.00	8.02	131.44	7.67
8-14	5 tons manure after oats	87.45	7.01	221.16	9.08	155.12	8.70
9-15	10 tons manure after oats	99.18	10.13	208.98	11.77	161.14	11.15
10-16	20 tons manure after oats	118.43	9.81	275.59	14.39	175.39	11.62
11-17	10 tons manure after hay	92.21	9.10	209.00	14.88	143.05*	11.37*
12-18	5 tons manure after hay	100.10	8.68	246.97	13.97	168.35*	10.33*

* These were check plots until 1920. Manure treatment began that year.

TABLE XXVII

AVERAGE YIELD PER ACRE OF OATS IN RATE-OF-MANURING PLOTS, 1917-23

Plots (averages)	Treatment	1923	5-yr. Av.
		Bu.	Bu.
7-13	None	50.15	44.00
8-14	5 tons manure after oats	50.10	44.70
9-15	10 tons manure after oats	64.51	49.53
10-16	20 tons manure after oats	73.81	57.00
11-17	10 tons manure after hay	70.00	52.40
12-18	5 tons manure after hay	67.86	48.80

TABLE XXVIII

AVERAGE YIELDS PER ACRE OF HAY IN RATE-OF-MANURING EXPERIMENT, 1917-23

Plots (averages)	Treatment	1922	1923	5-yr. Av.
		Tons	Tons	Tons
7-13	None	...	...	...
8-14	5 tons manure after oats	1.53	0.79	1.38
9-15	10 tons manure after oats	1.77	1.76	1.73
10-16	20 tons manure after oats	2.17	2.47	2.16
11-17	10 tons manure after hay	2.29	2.51	2.24
12-18	5 tons manure after hay	2.37	1.89	1.89
		2.25	1.29	1.75

As this experiment becomes older, the same behavior is noted as elsewhere—an increased effect from manure. The application of five tons is still the most effective for potatoes, altho a 20-ton application produces 20 bushels more per acre. Sunflowers have never shown much response to 5 tons spread on grain stubble, the yield being only slightly above the unfertilized plot. On the other hand, 20 tons, measured by returns, is a waste of fertilizer. Ten tons, whether put on grain or grass stubble continues to be the most economical quantity for most crops. Oats react like sunflowers to the 5-ton application on grain stubble. They do slightly better when the manure is applied on grass stubble, as the manure has come on one year later. There is a gradual increase with amount and nearness of application showing that the effect of the manure is largely residual. The oat crop takes what has been left behind by the hay and cultivated crops. Ten tons of manure on grain stubble has produced the largest return of hay per ton of manure applied.

COMPLETE FERTILIZERS FOR POTATOES

Thus far experimental work with commercial fertilizers as reported, has been confined to phosphate. But in 1921 a series of 20 plots was set apart for tests of complete fertilizers in various combinations on potatoes. These plots were one-fortieth acre in size. This work was continued through 1922 and 1923. Three-years' data are now ready for publication. One crop of oats following the potatoes has been grown, and no hay crop has been harvested. Data for potatoes only will be reported here.

TABLE XXIX

AVERAGE YIELD PER ACRE OF MARKET POTATOES IN COMPLETE FERTILIZER TESTS, 1921-23

Treatment	1921	1922	1923	Av.
	Bu.	Bu.	Bu.	Bu.
Checks	229.70	102.37	191.5	174.5
Potash	251.20	137.92	186.0	191.7
Phosphorus	208.10	114.64	178.7	167.2
Nitrogen	249.32	111.92	187.5	182.9
Potash and phosphorus	237.00	114.08	170.8	174.0
Nitrogen and potash	258.90	121.05	244.6	208.4
Nitrogen, phosphorus, and potash	265.30	177.60	226.3	223.1
Nitrogen and phosphorus	242.00	147.01	246.1	211.6

These tests have been conducted on almost virgin soils from which one crop of grain or a crop of grain and of hay have been removed. Applications were heavy, one-half ton per acre. The largest gain was 48 bushels, which at 50 cents per bushel would cover the fertilizer cost. On the newer soils, then, it would seem that unless prices were very high, commercial fertilizers are hardly profitable. However, on soils

that have been cropped for several years, and on which the original stock of nitrogen, phosphorus, and potash has been reduced, a different experience might be recorded for the first and third minerals. Phosphates seem to act uniformly on the new and the somewhat older soils in this district. (See Table XVII.)

Fig. 5. Bearing Apple Tree in the Old Orchard
This tree was one-year-old stock when set in 1915.

GARDEN FERTILIZATION

In 1922 a beginning was made in organized vegetable gardening work at this station. Part of the work was devoted to variety testing in a small way, but the major project is one of soil management in view of the problem of securing fertilizer near the cities. The standard root crops, as beets, carrots, onions, rutabagas, and parsnips, make up test

plots, with smaller quantities of cabbage, cauliflower, and lettuce representing the leaf crops. Duplicate plots of each crop are treated as follows: no fertilizer; 30 tons of manure per acre; 15 tons; 15 tons of manure and a half ton of commercial fertilizer; 1 ton commercial fertilizer.

Three years' results will be available in 1924. Information is insufficient to draw conclusions, but present yields indicate a margin in favor of the combination treatment.

FERTILITY TESTS ON BURNED VIRGIN (MINERAL) SOIL

Following the great fire of October 12, 1918, there was much discussion as to whether or not the soils had been injured for crop production. As the fire extended to all parts of the station farm, it was decided to make some investigations as to the effect. Two tracts of land were selected, both upland, and both heavily burned. They represented average conditions, as one maintained heavy and the other a light growth. The results of the 1920 and 1921 work have been reported (see station report for 1921).

Conditions of soil were as follows: (1) Upland soil, severely burned; (2) Unburned land, cleared, cropped at once without clover or manure (see Table XXV); (3) Unburned upland, pastured in advance of stumping, and reinforced by clover-grass sod. This is listed in 1921 report as Delayed Clearing Plots. A comparison of the three, as given in Table XXX, shows to some degree the effect of fire on crop production.

TABLE XXX

AVERAGE YIELD PER ACRE OF CROPS ON BURNED AND UNBURNED SOIL, 1922-23

Treatment	Length of period	Oats	Hay	Potatoes	Sunflowers
		Bu.	Tons	Bu.	Tons
(1)*	2-yr. Av.	30.05	1.59	94.48	7.39
(2)*	7-yr. Av.	34.42	...	114.70	5.93
(3)*	4-yr. Av.	46.00	1.53	138.94	7.02

* See paragraph above.

To equalize conditions with (3), the burned plots each had two tons of manure per acre per year. As clover and grass seemed to thrive in the ash, the showing of hay is fair. The same holds true of sunflowers, which have not produced well either in (1) or (3) owing in part to the absence of manure and in part to the heavy clay, low in organic matter. The extremely low yield of oats, and of potatoes, inferior to even that in continuous-cropping plots, would indicate some injury from fire.

In summarizing the soil fertility work for 1922-23, we find the returns from phosphates unprofitably low; the influence of lime on

legumes evident seven years after application. The 10-ton application of manure is generally most effective, with cumulative effect over several years. Complete fertilizers on upland soils have not as yet justified their use by increased production.

Fig. 6. Work of Sheep in Brush Control

GRAZING HEIFERS ON STUMP PASTURE

For the eighth consecutive season, grazing records of young stock have been made. During recent years all the timber and heavy brush have been removed, but shelter was provided in an open shed against flies and spring and fall storms. The range was partly open meadow but mostly stump land with tame grass between the stumps. Table XXXI is a summary for eight years.

TABLE XXXI

GRAZING RECORDS OF HEIFERS ON STUMP PASTURE FOR EIGHT YEARS

Year	Continuous pasture began	Continuous pasture ended	Total days	Number of cattle	Average age of cattle	Average total gain	Average daily gain
					Mo.	Lbs.	Lbs.
1916	June 12	Oct. 17	103	10	17.2	161.6	1.56
1917	June 1	Oct. 17	138	..	....	74.0	0.53
1918	June 1	Oct. 18	128	6	19.0	175.0	1.36
1919	June 3	Oct. 27	146	8	10.5	172.0	1.18
1920	May 25	Oct. 27	155	9	15.5	168.0	1.08
1921	May 25	Nov. 2	161	8	15.0	162.0	0.98
1922	May 24	Nov. 1	161	8	11.3	189.0	1.17
1923	May 28	Oct. 20	146	10	14.8	230.0	1.57

Altho the stock was removed from day-night pasture on October 20, they continued on day range until the middle of December. Sheep remained on range through the month. The fall, like the spring, of 1923 was dry. This affected fall feeding in spite of good weather.

Yet the cool summer and well distributed mid-summer rains produced one of the best grazing seasons in the history of the station. The heat and drouth of the summer of 1922 were reflected in the poorer gains recorded.

LIVESTOCK

Twelve grade Hampshire ewes, purchased in the fall of 1919, have increased to more than 50 females in four years. The sheep have been used exclusively as an agency of development. They have been shifted frequently, but forced to pasture close. As a consequence the fields cleared this summer following the sheep have been sodded over and were entirely free of brush growth. There has been some trouble with dogs, but little with wolves. The fleeces run about 7½ pounds, and the four crops of lambs have averaged about 80 pounds in weight and have brought $7.50 or more at the farm each season. With tame pasture and less brushing work, the weight of both fleeces and of lambs would doubtless increase.

The dairy herd consists of 26 milking cows and 11 heifers. Of this number, 10 are purebreds, 6 cows and 4 heifers. Of the milking herds, 21 are mature cows that have finished one or more lactation periods, the remaining 5 being heifers in first lactation. The production records of the 21 cows follows:

TABLE XXXII
BUTTERFAT PRODUCTION OF DAIRY HERD

Name	Kind	Production of butterfat Lbs.
Antona	Reg. Guernsey	393.06
Antonette	Reg. Guernsey	298.99
Angeline 1	Grade "	371.82
Angeline 1-1	" "	356.68
Angeline 1-2	" "	292.90
Climax 1-1	" "	341.25
Climax 1-1-1	" "	329.08
Climax 1-1-2	" "	300.86
Dolly	Reg. Guernsey	296.89
Genevieve 1	Grade "	394.71
Genevieve 1-2	" "	313.58
Jewell 2-1	" "	256.21
Jewell 2-1-1	" "	374.93
May 1	" "	377.93
May 1-1	" "	395.69
Mimosa	Reg. Guernsey	415.46
Merry Maid	" "	370.35
Nellie 1-1	Grade "	399.17
Nellie 1-1-1	" "	317.98
Nellie 1-1-2	" "	401.89
Star 1-1		272.86
Average		345.82

Two of the three grades under 300 pounds of fat, will graduate into that class this season. One 400-pound record has been made by a heifer this year. This herd is maintained under farm conditions. All cows are kept in stanchions, and milked twice daily. No testing work for advanced registry has yet been begun. The herd is given reasonable care and proper feeding. Aside from cleaning the barn and milking, one man handles the herd with one half-time assistant during the winter months. He also cares for the hogs and the milkhouse. The cows consume on the average 17 pounds of hay and 30 of sunflower silage daily. During heavy winter production a grain ration of 1 to 2.5 is fed. A light grain ration is fed during summer and soiling crops are fed after August 1. Aside from a few foundation cows, the herd is farm-bred. No females have been introduced since 1914. The station herd has been on the accredited list for seven years.

POULTRY

The poultry work has been limited to the Single Comb White Leghorn and Rhode Island Red breeds, numbering about four hundred birds. The former breed has been developed for size and production, using pedigreed cockerels of known production in the breeding pens. No difficulty is experienced in disposing of surplus cockerels and hatching eggs, and the regular egg product is sold to near-by trade. In the fall of 1923 plans were developed for a considerable expansion of the experimental poultry work. An egg-laying contest has been started, co-operatively with the St. Louis County Club, in a special building erected for that purpose. Housing and temperature studies are under way and feeding work will soon be started. These projects will be reported upon in later bulletins.

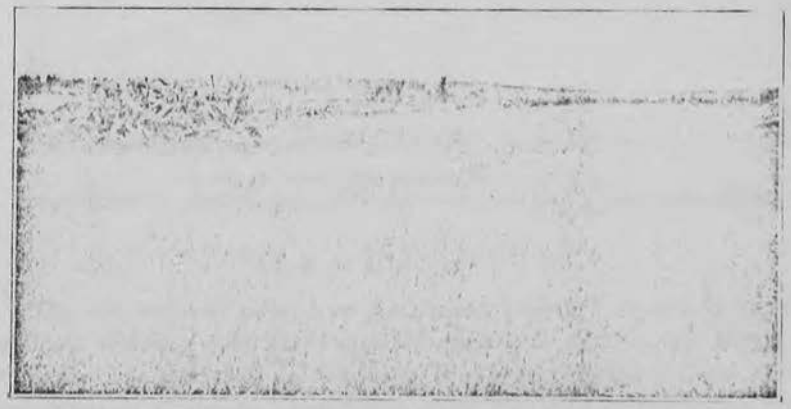

Fig. 7. Brushed by Sheep, Stumped by Tractor in Contest with Horses Costs, following the fire, were reduced to $20 per acre.

LAND CLEARING PROJECTS

Several experimental projects in land clearing were under way in 1922-23.

(1) Clearing costs on burned land. This work is supplemental to data published in 1921. A five-acre tract, brushed and logged in 1915, seeded in 1916 and pastured since, was stumped in June 1922. It required approximaely 43 man hours and 40 horse hours per acre up to the burning stage. The loose stumps were pulled, leaving about 23 per acre to blast, or 10 per cent of the original stand. To remove them required 45 sticks of picric acid, 30 feet of fuse, and 25 caps. Using the unit prices of 23 cents per hour for man labor (by month), 11.5 cents for horse labor, 3.66 cents per stick of picric acid, 1 cent per foot for fuse and 2 cents per cap, the acre cost of clearing a five-acre tract up to the breaking stage was $17.14. Allowing liberally for supervision, the cost still remains under $20 per acre for conditions of soil, stumpage, and vegetation as found at the Duluth station.

(2) It is said that late May and early June is the best time to blast, but that most clearing is done in October. In 1923 a six-acre field was divided into three tracts. One was stumped in late May; one in late June, and one in October. Allowing $1 per acre for burning, the respective costs were $19.71, $19.07 and $16.85, very close to the 1922 costs under like conditions. Spring and fall costs are very similar, because (1) both seasons were very dry; and (2) very little blasting was required. It is blasting in dry soil that increases the cost of clearing.

(3) A third stumping project, horse vs. tractor power, was begun in June. Two men and a Fordson tractor cleared one tract in 6.5 tractor hours and 11 man hours. Two men and a team on the other required 13 horse hours and 13 man hours. Both were ¾ acre in size. Two additional hours were needed for picking up on the first, and three man hours and 3 horse hours on the second.

Fig. 8. Heater Wood (left) Salvaged from Stump Pile (right)
This stump and root wood is frequently superior to the trunk and limbs for heating.

This work was duplicated in the fall. The team cleared tract required 44 man hours and 44 horse hours per acre; the tractor cleared tract, 42.4 man hours and 14 tractor hours per acre.

(4) Swamp clearing. A tract of swamp land was cleared by contract in October, 1923.

This is an old cedar swamp, with scattered dead pine stumps, and with balsam and birch in spots. There seemed to be as much wood beneath the ground as above it. The tract was green before the fire, and all but the stumps was removed two years ago. The soil is of organic deposit, ranging from a fairly well decayed peat to muck, and from 2 to 5 feet deep, underlaid with clay. The peat usually occurs in pockets. This tract is the hardest clearing on the farm, but it also contains the best soil. It required 1710 man hours to grub, stump, and pile the debris on a five-acre tract. Burning is being done this winter.

Fig. 9. Jack Pine Planted Since 1918 Fire
Note the growth made in 1922. Reforestation of waste lands should not be delayed.

THE STATION ORCHARD

The old orchard located on the "north eighty," set out in 1915 on new soil and in a cold location, was severely injured by the forest fire of 1918. In spite of these handicaps it is gradually improving. Excellent crops of Compass Cherry and some De Soto and seedling plums have been produced on numerous trees. About fifty apple trees bore

fruit in 1923. Most of this was Hibernal, with a few Duchess and Wealthy, one tree of Greening, and several Florence Crabs. The orchard was thoroly disked with a roller harrow, tractor-drawn, in November, 1923. This proved an excellent means of cutting sod where plowing was impossible.

The new orchard, located at the southeast corner of the station and just south of the superintendent's cottage, has every advantage. The land was broken, cropped, again plowed in 1922, and thoroly tilled in advance of planting in 1923. With the exposure to the southeast, south, and southwest, a sandy loam soil, and excellent air and water drainage, it is the best location on the place. This orchard of about three acres will include both tree and small fruits. Planting will be completed in the spring of 1924.

DEVELOPMENT OF STATION PLANT AND EQUIPMENT

With long dry falls, land clearing proceeded rapidly in 1922 and 1923. On January 1, 1924, less than 40 acres of stump land remains on the 250-acre tract. The piled stumps remain on a part of the cleared area, as wood is removed from the stump pile and sawed before the coarse and decayed parts are burned. This delays breaking but it conserves the fuel supply. There is but one crop of wood. A large open ditch was run through the "north eighty" in 1922, to be followed by tile in 1924. Clearing has been begun on this tract, which is the future garden area of the farm. The poultryman's cottage has been remodeled to house two families, and a power unit and pump have been installed. A new Minnesota model poultryhouse was built in October, 1923, 18 by 32 feet, for trapnesting, egg-laying contests, housing and temperature studies. A workshop was built at the main farmstead and equipped for winter use in overhauling machinery. The first sidewalks were laid in May, 1923, and additional cement work included a new horse barn floor, and outside permanent stairways to two dwellings. The new all-concrete root cellar, built in 1922, 12 by 40 feet in size, has proved a valuable addition to the equipment of the institution preparatory to more extensive gardening. Windbreak plantings have been extended. April 1 marked the close of the first decade of operation at the Duluth station. The period of development is approaching a close and with it will come certain modifications in the management and investigational work of the institution.

SUMMARY

1. Both 1922 and 1923 were slightly above normal in summer temperature but below normal in moisture.

2. The year 1922 was favorable for hay, 1923 for grain and potatoes.

3. The highest yielders of the four principal field crops, over a five-year period are: Mindum, a macaroni wheat; Victory, Minn. No. 514 oats; Svansota, Minn. No. 440 barley; Swedish rye, Minn. No. 2.

4. Date-of-seeding tests indicate that winter rye should be sown about September 1; oats, about May 1, and barley, about May 15.

5. In the rate-of-seeding tests, 3 bushels of oats and 2 bushels of barley produced best. There was little difference between rates with rye.

6. Disking following a cultivated crop produced 5 bushels more than plowing.

7. Howe's Alberta Flint corn is a promising variety for cold districts.

8. Spacing rows at 30 inches, produces the largest yield of sunflowers.

9. Plant both sunflowers and potatoes as near May 15 as possible for heaviest production.

10. Fall plowing increased the yield of sunflowers.

11. Setting a Van Brunt drill at the 4-peck mark for wheat is fair for sunflower seeding.

12. Cattle consumed 100 per cent of sunflowers and from 80 to 94 per cent of sweet clover in soiling tests.

13. A five-year test discloses no choice in the matter of ridging vs. level culture of potatoes.

14. A three-year test discloses no difference in yields, as between drilled and check-rowed potatoes.

15. Potato rows spaced at 30 inches produce much heavier than those at 36 or 42 inches.

16. Spring plowing was followed by a slight increase in yield of potatoes.

17. In dates of planting tests, ranging from May 17 to July 1, yields declined from 401 to 94 bushels per acre.

18. Spraying for disease affected potato yields slightly in 1923, but yields were increased by 42 per cent in 1922.

19. There is extreme variation in yield of different strains within the same variety of potatoes, as indicated in tests with certified seed in 1923.

20. The three-year rotation, in a five-year average, surpasses both the four-year and the five-year rotations in yields of hay, grain, sunflowers.