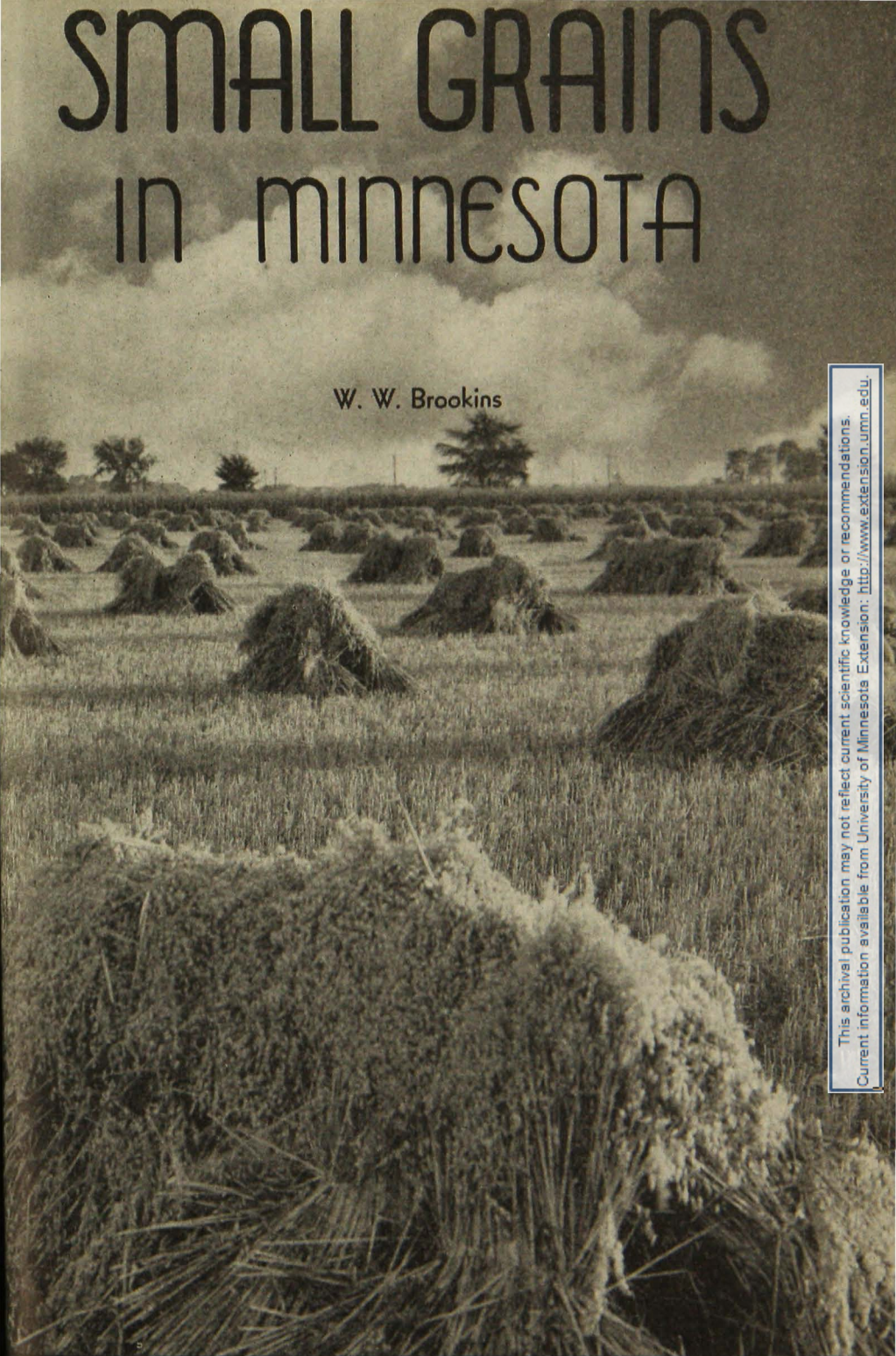
SMALL GRAINS IN MINNESOTA

W. W. Brookins



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Agricultural Extension Service
U. S. DEPARTMENT OF AGRICULTURE

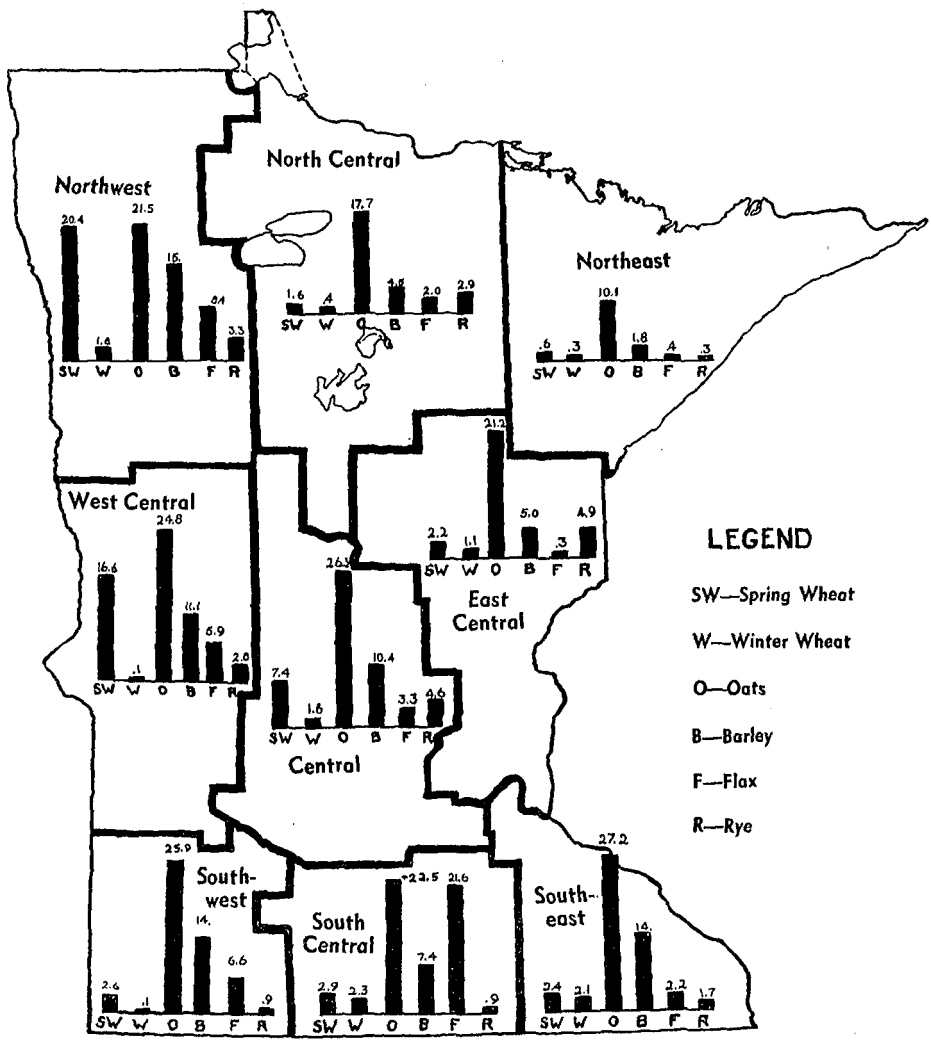

FIG. 1. PER CENT OF TILLABLE ACRES SOWN TO SMALL GRAINS IN DIFFERENT DISTRICTS IN MINNESOTA

Research data furnished in this bulletin were supplied by the Division of Agronomy and Plant Genetics, and previous publications from University Farm and branch stations. The writer expresses appreciation for data made available and for helpful criticisms and suggestions by the staff members of the Division of Agronomy and Plant Genetics.

Small Grains in Minnesota

W. W. Brookins

MINNESOTA farmers have sown annually over one half of their cultivated acreage to small grains during the ten-year period, 1931-40. Cultivated acreage refers to land seeded to wheat, oats, barley, flax, rye, corn, potatoes, and tame hay, which have averaged 17,396,347 acres annually for this period. On the basis of acreage, the oat crop is the most widely grown of the small grains in the state. Barley, wheat, flax, and rye follow in the order given. Grain yields at University Farm, branch stations, and on farms show that oats and barley are well adapted in all parts of the state. The oat crop is one of the easiest to grow, producing high yields when sown on the better soils. Barley, wheat, and flax are usually sown in the most fertile soils, leaving oats to the less productive fields. This latter fact may account for the impression that oats are not a profitable crop.

The relative importance of these grains in the nine districts of the state is summarized in table 1.

The percentage of total acres in cultivated crops sown to wheat, oats, barley, flax, and rye for the period 1931-40 in each of the nine districts is illustrated in figure 1.

Grain crops should become more profitable by reducing the cost of production, through the application of better cultural practices, stabilizing yields by overcoming hazards of drouth and disease, and by choice of better varieties and the use of high quality seed.

Table 1. Average Acreage of Major Crops in Minnesota by Districts For the Ten-year Period, 1931-40*

District	Crops and 1,000 Acres								
	Spring wheat	Winter wheat	Oats	Barley	Flax	Rye	Potatoes	Corn	Tame hay
Northwest	566.7	4.7	552.9	385.6	215.1	84.1	101.5	161.2	500.1
North Central	4.5	1.2	51.4	13.1	5.7	8.3	13.6	36.4	156.8
Northeast	.7	.3	12.2	2.2	.5	.3	6.4	.4	97.8
West Central	542.5	2.5	810.6	364.1	194.7	92.0	25.2	873.6	358.9
Central	207.8	41.7	725.3	287.2	91.7	128.2	39.3	848.4	385.5
East Central	20.0	10.0	190.7	44.9	2.9	44.6	67.9	211.5	305.3
Southwest	71.6	2.4	682.0	368.7	174.5	59.2	8.9	1,056.8	213.8
South Central	88.2	67.5	671.0	220.9	645.2	28.3	20.6	946.7	296.8
Southeast	45.0	40.1	518.3	266.3	42.7	33.1	14.0	506.7	439.7
Totals	1,547.0	170.4	4,214.4	1,953.0	1,373.0	478.1	297.4	4,641.7	2,754.7

* Minnesota Crop and Livestock Statistics, Kirk, Paul H., and Bodin, Roy A.

Selecting Adapted Varieties

INCREASING numbers of farmers are turning to their county agents and experiment stations for facts on which to base their judgment in the matter of variety choice. Three years of carefully conducted trials carried out in each of five or six localities in the state is considered a sound basis for determining adaptation of a new variety and its performance relative to standard recommended varieties. At an annual conference of agronomists, plant breeders, plant pathologists, and cereal chemists of the Minnesota experiment stations, the relative performance of varieties in these tests is studied. To be placed on the list of recommended varieties a new variety must have been tested for a three-year period and must be approved by a majority vote of all attending the conference. A similar vote is required to remove a variety from the recommended list.

Wheat

Spring wheats used in the production of bread flours are most successful in the northwest and central areas, while winter wheat is best adapted in southeast and south central counties. Over a period of years winter wheat has averaged 25 per cent higher yield than spring wheat in these areas despite occasional losses due to winterkilling. The spring varieties available are susceptible to scab and are not as dependable in southern counties as winter wheat. Stem rust resistance is extremely important in wheat varieties although winter varieties mature early enough so that they usually escape serious stem rust damage.

Durums of the better quality are obtained in northwestern and western Minnesota where lower rainfall and other conditions at harvest time favor the development of a hard textured grain. Hard texture is essential in the manufacture of macaroni, spaghetti, and other semolina products. Durums may give high yields in southern Minnesota, but the quality is not as satisfactory as in the grain produced in the northwest. Mindum has yielded about the same as other spring wheat in southern Minnesota. Milling qualities must meet requirements of the milling trade and should be carefully considered in selecting a variety.

Varieties Recommended

Thatcher.—The highest yielding spring bread wheat variety at all stations over a period of 10 years. Outyields Renown and Renown selections when leaf rust is not a factor. It is beardless, has very strong straw, and is the equal in milling and baking qualities to all varieties at present available. Thatcher is moderately resistant to stem rust and bunt, resistant to loose smut, but is susceptible to leaf rust and head blight.

Rival.—Has averaged somewhat higher yields in southern Minnesota and has been equal to Thatcher in northwest Minnesota for a three-year period. It is bearded, has weaker straw than Thatcher, and has a tendency to shatter. Milling and baking properties appear to be equal to Thatcher. It is moderately resistant to stem and leaf rust, resistant to bunt and loose smut, moderately susceptible to scab, and susceptible to black chaff. It is recommended for southern Minnesota only.

Mindum (Durum).—Has high yielding ability and when grown in the Red

River Valley excels in quality of semolina products. It is bearded, has amber seeds, and is moderately susceptible to stem rust and bunt, but resistant to leaf rust.

Minturki (Winter Wheat).—One of the most winter hardy and highest yielding varieties. Matures early and usually escapes serious stem rust damage. Produces flour with a yellow color. It is bearded, somewhat resistant to stem rust; moderately resistant to bunt, loose smut, and head blight; but moderately susceptible to leaf rust.

Marmin (Winter Wheat).—A bearded variety resembling Minturki in appearance. About equal to Minturki in yield, hardiness, and other characteristics, but produces plump harder grain. It is superior in color of loaf of bread to that produced from flour of Minturki.

Varieties Not Recommended

Renown.—Yields slightly less than Thatcher except in years of serious leaf rust epidemics. Resistant to stem rust and leaf rust, but the flour carries a slightly yellow color and produces a loaf of lower volume than Thatcher. It is higher in bushel weight and of better kernel appearance. Straw strength and time of maturity are similar to Thatcher.

Pilot.—Yields about the same as Thatcher, is resistant to stem rust, and moderately resistant to leaf rust. The flour produces a loaf of lower volume

Table 2. Average Yield of Wheat Varieties In 1/40 Acre Plots, in Bushels Per Acre And Per Cent of Thatcher

Variety	University Farm and Waseca		Morris and Crookston	
	Bu.	Per cent	Bu.	Per cent
Spring wheat average, 1935-1940				
Thatcher	27.7	100	24.2	100
Marquis	18.8	67	11.8	49
Ceres	19.6	71	15.6	64
Pilot	27.4	99	22.7	94
Mindum	24.5	88	19.9	82
Kubanka	.....	.....	20.0	83
Spring wheat average, 1938-1940				
Thatcher	29.2	100	25.9	100
Nordhaugen*	.....	.....	21.1	81
Rival	33.5	115	26.3	102
Winter wheat average, 1935-1940				
Minturki	34.9	100	.....	.....
Marmin	33.6	96†	.....	.....

* Not grown at Morris 1938.
† Marmin in per cent of Minturki.

Marquis Thatcher

FIG. 2. STIFF STRAWED, DISEASE RESISTANT VARIETIES ARE THE MOST PROFITABLE

than Thatcher. Not recommended on account of very weak straw.

Apex.—Tested three years and shown to be unadapted. Averaged 25 per cent below Thatcher in yield. Resistant to stem rust, moderately susceptible to leaf rust, and produces grain of lower test weight. Not recommended on account of low yields.

Nordhaugen.—Has averaged about equal in yield to Thatcher at Crookston for a three-year period and slightly lower at Morris for 1939 and 1940. Grain is lower in weight per bushel and inferior in milling and baking characters to Thatcher. It is resistant to stem rust but susceptible to leaf rust.

Kubanka (Durum).—Similar to Mindum in type and quality of grain. Has produced somewhat lower yields in Minnesota over a period of years. Is moderately resistant to stem rust.

The average yields of wheat varieties grown at Crookston, Morris, University Farm, and Waseca are given in table 2.

Oats

Extensive tests have shown that early and midseason oats are best adapted to Minnesota. Late oats usually do not develop fully, frequently producing grain with a high per cent of hull, and generally are more subject to drouth. Early maturing varieties are best suited to southern districts and midseason varieties to northern districts although early varieties yield well in the north. Varieties that are resistant to stem rust are available for all sections of the state. Certain varieties, now undergoing test, produced by oat breeders at Minnesota and in nearby states are resistant to the three important diseases of stem rust, crown rust, and the smuts although further test is necessary before placing them on the recommended list.

Varieties Recommended

Gopher.—One of the highest yielding varieties in central and southern Minnesota for the past 13 years. Yields somewhat less than Rusota at northwestern stations. Because of early maturity, it usually escapes stem rust and drouth. Stands up well and excels in straw strength on the heavier soil types, but it is not as well adapted to lighter soils. It is susceptible to crown and stem rusts and moderately susceptible to smuts.

Iogold.—Adapted to the same areas as Gopher. Has yielded about the same as Gopher in extensive tests. The variety is early in maturity but somewhat weaker in straw than Gopher. It is resistant to stem rust, susceptible to crown rust, and moderately susceptible to the smuts.

Minrus.—Is high yielding, stem rust resistant, and mid-early in maturity. It has produced higher yields than Gopher at the three northern stations with equal to better yields than the later varieties. Better suited to lighter soils than Gopher. It is susceptible to crown rust and moderately susceptible to the smuts.

Anthony.—One of the highest yielding varieties in northeastern Minnesota, the only section where it is now recommended. A midseason oat, resistant to stem rust, but maturing too late for southern Minnesota. The variety is susceptible to crown rust and smuts.

Rusota.—Similar in time of maturity to Anthony with somewhat higher yielding ability. It yields best in the Crookston and Duluth areas. Has weaker straw than Gopher. It is resistant to stem rust and susceptible to crown rust and smuts.

Nakota.—An early maturing hulless variety which has yielded well and appears to be well-suited in all parts of the state. It is resistant to stem rust and smut but susceptible to crown rust.

Table 3. Average Yields of Oat Varieties in 1/40 Acre Plots in Bushels Per Acre and Per Cent of Gopher for a Period of Years

Variety	University Farm and Waseca		Morris and Crookston		Grand Rapids and Duluth	
	Bu.	Per cent	Bu.	Per cent	Bu.	Per cent
			10-Year Averages, 1928-40*			
Gopher	65.3	100	62.0	100	55.3	100
Iogold	67.5	103	61.0	98	55.7	101
Minrus	68.2	104	62.2	100	59.5	108
Anthony	60.3	92	60.9	98	58.7	106
Victory	54.3	83	51.7	83	52.2	94
Rusota	62.8	96	61.8	100	57.0	103
	5-Year Averages, 1936-40		5-Year Averages, 1935, 1937-40*			
Gopher	69.8	100	62.8	100	49.1	100
Nakota†	66.7	96	59.0	94	45.1	92
			3-Year Averages, 1938-40‡			
Minrus	82.1	100	63.1	100	63.6	100
Rusota	74.2	90	60.2	92	56.6	89
Vanguard	80.5	98	62.8	99	58.2	91

* Years of crop failure omitted.

† Yields corrected for hull.

‡ Rusota and Vanguard in per cent of Minrus.

Vanguard.—In three-year trials, it has yielded about the same as Gopher at northern stations and somewhat lower at Waseca. It has good straw strength and matures between Minrus and Rusota. It is resistant to stem rust but susceptible to crown rust. The variety appears to be best suited to northern counties and has been placed on the recommended list for northwestern Minnesota only.

Varieties Not Recommended

Boone, Marion, and Hancock.—New varieties developed in Iowa. Boone is resistant to stem rust, crown rust, and the smuts; while Marion and Hancock are resistant to stem rust and the smuts but susceptible to crown rust.

Vicland.—Selected in Wisconsin for resistance to the rusts and smuts.

In accord with the plan followed in Minnesota, these varieties have not been tested long enough in the state to be eligible for recommendation.

Yields of varieties tested in 1/40 acre plots for periods of 3 to 10 years are given in table 3. Yields given are averaged for University Farm and Waseca, Morris and Crookston, and Grand Rapids and Duluth. Years of crop failure have been omitted.

To summarize, Gopher and Iogold are desirable early varieties, Gopher having somewhat stronger straw and therefore better adapted to productive land in sections where early oats are desired. Rusota and Minrus are recommended varieties of midseason oats for sections where midseason oats are best adapted. Vanguard is recommended for northwestern Minnesota only and Anthony only for northeastern Minnesota.

Barley

The greater part of the barley produced is consumed by livestock on the farm. About 25 per cent is sold annually for the production of malt and by-products, and the remainder not used on the farm is sold into feed channels.

Rough bearded types have been largely replaced by smooth-bearded varieties in the last few years. The crop consists principally of the six-row

type, very little two-row being grown owing to a limited market and the possibility of mixing six-row with two-row varieties thus endangering the use of six-row varieties for malting purposes. Resistance to scab is one of the greatest needs in varieties because a large volume of grain is frequently rendered unfit for hog feed and malting purposes as a result of scab epidemics.

Varieties Recommended

Barbless (Wisconsin 38).—Popular for its high yield and smooth awn; the variety produces a large, plump, soft-textured kernel under favorable conditions, and is considered satisfactory for malting. It lodges badly on heavy or rich soils and matures five to six days later than Velvet. It is moderately resistant to barley stripe but susceptible to loose smut and scab.

Velvet.—Has produced slightly higher yields than Manchuria over a period of 10 years at all but the Duluth station. The variety is well-liked by maltsters, and produces a smaller berry but stiffer straw than Barbless. It is susceptible to loose smut, scab, and barley stripe.

Peatland.—A rough awned variety well-adapted to peat soils. It has yielded well on mineral soils and appears to be best adapted to northeast Minnesota. Peatland is resistant to stem rust, loose smut, moderately resistant to scab but susceptible to stripe.

Varieties Not Recommended

Glabron.—Similar in type of awn and yield to Velvet. The straw is somewhat stiffer than in Velvet or Barbless and about one fourth the kernels are blue beneath the hull. It is not suitable for malting. The variety, Glabron, is moderately resistant to stripe, but it is susceptible to scab and loose smut.

Manchuria.—Yields less than Barbless, but has yielded as well as Velvet in northeastern Minnesota with lower yields than Velvet in other parts of the state. Under certain conditions some strains have a high per cent of kernels blue beneath the hull. Matures about the same time as Velvet, but has rough beard and weak straw.

Oderbrucker.—Similar in type to Manchuria; an excellent malting variety, but the lowest yielding variety in all parts of the state.

Table 4. Average Yields of Barley Varieties in 1/40 Acre Plots in Bushels Per Acre and Per Cent of Barbless for a Period of Years

Variety	University Farm and Waseca		Morris and Crookston		Grand Rapids and Duluth	
	Bu.	Per cent	Bu.	Per cent	Bu.	Per cent
			10-Year Averages, 1931-40			
Barbless (Wis. 38)	51.2	100	43.2	100	35.8	100
Velvet	42.4	83	35.5	82	28.0	78
Peatland	42.2	82	37.0	86	32.1	90
Manchuria	37.7	74	32.3	75	28.0	78
Glabron	43.3	84	35.1	81	27.1	76
Trebi	51.4	100	43.4	100	34.8	97
			3-Year Averages, 1935, 1937, and 1938*			
Barbless (Wis. 38)	55.8	100	49.1	100	28.1	100
Velvet	47.0	84	39.1	80	22.9	81
Oderbrucker	37.8	68	32.6	66	19.5	69

* Years of crop failure omitted.

Trebi.—A rough-awned feed type barley which has yielded about equal to Barbless, but it is of very poor malting quality. The high yield is probably not sufficient to warrant the use of Trebi in areas where malting barley is produced because of the danger of mixing varieties and endangering the malting barley market.

Yields given in table 4 illustrate behavior of these varieties with averages at University Farm and Waseca, Morris and Crookston, and Grand Rapids and Duluth.

Flax

Practically the entire flax crop, excepting grain for seed, is sold to processors in the drying-oil industries. Linseed meal, which remains after the oil has been extracted from the seed, provides an excellent high protein feed for livestock. Recently a limited market for flax straw for the manufacture of cigarette papers and other fiber uses has developed and offers a small additional income to growers. Wilt-resistant varieties are essential for successful production. Varieties possessing resistance to wilt and rust and combining high oil content and oil quality with high yield per acre are greatly needed.

Varieties Recommended

Redwing.—Yields somewhat better than Bison in southern Minnesota and matures two to six days earlier. The seed is medium size, but the oil produced is superior in drying properties. It frequently has shorter straw than Bison and is less likely to lodge on heavy fertile soils. It is somewhat less wilt-resistant than Bison and is moderately susceptible to rust.

Bison.—Produces higher yields than Redwing in the Red River Valley. The seed is large with about 2 per cent higher oil content than Redwing, but it has an oil of lower drying qualities. It is resistant to wilt but susceptible to rust.

Biwing.—A new variety produced at University Farm. It is equal or better in yield to Redwing or Bison. Seed size approaches that of Bison with an oil quality equal to Redwing and superior to Bison. It is resistant to wilt and somewhat less susceptible to rust than Bison and Redwing.

Buda.—Has yielded equally as well as Bison at Crookston and appears to be best suited to the Red River Valley. The variety is mid-late in maturity, seeds medium-small to small with an oil of good drying quality. It is resistant to wilt and moderately resistant to rust.

Table 5. Average Yields of Flax Varieties in Bushels Per Acre and Per Cent of Bison at Four Stations for a Period of Years

Variety	University Farm and Waseca		Morris and Crookston*		Morris and Crookston*	
	Bu.	Per cent	Bu.	Per cent	Bu.	Per cent
	1/40 Acre Plots	10-Year Averages, 1931-40			5-Year Averages, 1934-38	
Bison	13.2†	100	11.5	100	12.7	100
Redwing	13.5†	102	11.7	102	10.4	82
Buda	.....	.....	.....	.....	11.3	89
	Rod Row Plots	5-Year Averages, 1936-40				
Bison	13.4	100	15.2	100	.....	.....
Redwing	18.0	134	16.0	105	.....	.....
Biwing	16.7	125	16.4	108	.....	.....

* Crop failure at Crookston 1936—data omitted.

† Varieties compared at University Farm 1931-1940, at Waseca 1938-1940.

Table 6. Average Yields of Rye Varieties in 1/40 Acre Plots in Bushels and Per Cent of Dakold for a Period of Years

Variety	University Farm and Waseca		Morris		Grand Rapids		Duluth*	
	Bu.	Per cent	Bu.	Per cent	Bu.	Per cent	Bu.	Per cent
				5-Year Averages, 1936-40				
Dakold	43.0	100	25.3	100	31.0	100	16.8	100
Wisconsin Ped. 6	47.5	110	27.9	110	36.0	116	25.1	149
Emerald	45.2	105	27.3	108	35.4	114	23.0	137
	1929-33 University Farm		1930-32† Waseca					
Dakold	35.3	100	31.5	100	.....	.....	.....	.....
Rosen	31.6	89	37.9	120	.....	.....	.....	.....

* 3-year average (1938-40).

† 3-year average.

Varieties Not Recommended

Golden seeded varieties.—B. Golden and Viking are similar varieties. B. Golden has large yellow or golden seeds, with too short a straw to be generally satisfactory as a farm variety. It is moderately resistant to wilt and immune from the rust races commonly found in the United States.

Walsh.—A large brown-seeded flax which has not yielded higher than Bison. It is moderately resistant to wilt and has similar immunity to rust as B. Golden and Viking.

The flax crop is largely produced in the northwest, west central, southwest and south central counties. Yield figures in table 5 are given for the stations which most nearly represent these areas.

Rye

On lighter soils and less productive fields, rye has a definite place among the grain crops of the state. In the sandy soils of the central and east central districts, rye can be raised more economically than other grains. It supplies feed for livestock and finds a market in the milling and distilling industries. The crop exhibits a wider range of adaptation than winter wheat and may be grown in more northern areas if snow cover is adequate. Resistance to cold injury along with good production and quality in the grain are essential qualities for Minnesota conditions.

Dakold.—Has yielded slightly less than Wisconsin Ped. 6 and Emerald over a period of five years. Grain is usually smaller than Rosen, mostly brown, lacking the attractive slate grey color and appearance of Rosen.

Rosen.—An old standard variety fairly well adapted to southern parts of the state. It yields better than Dakold when winterkilling is not a factor.

Emerald.—A high yielding variety which appears well adapted to all parts of the state when not subject to severe winterkilling. No seed is available for growers' use at present.

Wisconsin Ped. 6.—Has yielded about equal to Emerald and slightly higher than Dakold over a five-year period. Appears well adapted to all parts of the state when winterkilling is not severe.

Selection of Seed Important

Purity of Seed

Small grain varieties may soon become mixed with other varieties and classes of grain grown nearby. Mixtures and accumulative diseases transmitted through the seed frequently reduce yield and may explain the "running out" of a variety referred to by farmers. With reasonable care in harvesting and storing the seed, reasonable purity may be maintained at little cost with a seed plot of at least 5 acres sown to registered seed once in every four or five years.

Grain crops such as wheat, oats, barley, and flax are commonly self pollinated, and crossing of varieties under field conditions occurs only rarely. Natural crossing takes place generally between rye varieties, and mixtures due to crossing may occur where two varieties are seeded close together. The regular use of the seed plot is necessary if reasonable purity is to be maintained with these crops.

Weeds are commonly spread in the seeds of small grain crops, reducing yields and increasing the hazards of growing the crop. Grain as threshed is seldom clean enough for seed purposes and should be properly cleaned before seeding. Of all grain samples tested for farmers, over a five-year period, the State Seed Testing Laboratory reports that 53 per cent contained lamb's-quarters, 63 per cent green foxtail, 32 per cent yellow foxtail, 17 per cent lady's-thumb, and 34 per cent wild buckwheat. Other weeds have been found less frequently.

Flax does not compete with weeds as well as other small grains. Owing to the small seed size, the grain is more difficult to clean properly on the average farm fanning mill. Additional equipment is necessary to make the close separations of seed sizes typical of the weeds found in flax. The State Seed Testing Laboratory found that 61 per cent of farm flax seed samples

FIG. 3. A SEED PLOT, USING REGISTERED SEED, SHOULD BE ESTABLISHED EVERY FOURTH OR FIFTH YEAR TO RETAIN REASONABLE PURITY

contained green foxtail, 57 per cent wild buckwheat, 54 per cent yellow foxtail, 23 per cent wild mustard, and 5 per cent false flax.

Weeds in the harvested crop may be reduced by the use of clean seed and better methods of production. The previous crop, seedbed preparation, and time of seeding among other factors affect the weed content of the resulting crop. The amount of weeds in seed and crop harvested has varied from a trace to 32 per cent for flax and a trace to 22 per cent in barley in recent studies made with these crops. These facts emphasize the need for seed cleaning and more care in production practices. For the more difficult seed cleaning jobs, commercial equipment should be used which has a reputation for thorough work.

Disease Resistant Varieties

One of the most practical methods for controlling small grain diseases is the use of resistant varieties. Certain seed borne diseases may be controlled by seed treatment. In view of the low cost of application, the improvements in stand, and increases in yield which frequently result, the practice is generally recommended.

Remove Crop Residues

Crop residues commonly harbor diseases and, when left on the field surface, provide a source of infection to the growing crop. Blight and scab on barley are commonly spread by this means from corn stalk and stubble residues, and rust on flax may be spread from flax stubble remaining from a previous crop. Ordinary good farm practice of plowing under crop residues, planning to avoid a crop succeeding itself in the rotation, and applying recommended disease control measures may be expected to increase the returns from small grain crops. For recommended disease control practices, growers should refer to publications available in the office of their county agent or in the Bulletin Office at University Farm.

FIG. 4. THE BEST GRAIN SHOULD BE THRESHED INTO SACKS AND STORED FOR SEED

Preparation for Seeding

Good Rotation Essential

Establish a rotation of crops that provides adequate supplies of good quality hay, pasture, and grain for feed according to the livestock or cash crop needs for efficient operation of the farm. Legumes, grasses, or legume grass mixtures are important crops in the rotation and should occur regularly.

Sow small grains after cultivated and legume crops. The grains benefit from barnyard manure and the phosphate and potash in commercial fertilizers applied to the cultivated crops and from the effect of the legumes. Studies conducted at University Farm over a period of 25 years clearly showed that grain yields were increased when small grains were grown in rotation. The yield of wheat was 28 per cent higher and of oats 34 per cent higher in a rotation of wheat, hay, pasture, corn, and oats than where wheat and oats were alternated. Where alfalfa, red clover, and sweet clover preceded wheat, oats, barley, and flax in similar five-year rotations, yields of these grains were 33 to 36 per cent higher than where timothy was used as the hay and pasture crop. Three- and four-year rotations have in general proved about equal to 5-year rotations in increasing small grain yields at University Farm and Crookston.

At the Morris Station, wheat and barley were more successful as the third or fourth crops than immediately following alfalfa in rotation with corn and alfalfa. With limitations on corn acreage, it will frequently be necessary for small grains to follow alfalfa or clover immediately in the rotation. This appears to be a necessary practice, and good returns can be expected at least in seasons of sufficient rainfall.

If grain yields are to be maintained in erosion areas, rotations which include from 40 to 75 per cent or more sod land may be necessary.

Each farm is a separate rotation problem and the following rotations are suggestive of the place for small grains. For additional rotations see Agricultural Extension Pamphlets 43 through 50, "Farm Planning," University of Minnesota.

I. (1) Small grain, (2) sweet clover, (3) corn

II. (1) Small grain, (2) hay or pasture, (3) pasture, (4) corn

III. (1) Small grain, (2) small grain, (3) hay or pasture, (4) cultivated crop

Rotations I and II are suitable for central and southern Minnesota where an abundance of pasture crops is highly desirable. In areas requiring a higher proportion of cash grain crops, rotation III is suggested.

The type of rotation used is dependent to a large extent upon farm management problems. Factors such as weeds, insects, and disease control are important in determining the length of the rotation. The proper rotation system may be based on certain general principles, but it is also determined to a large extent by local conditions.

Legume and grass crops used regularly in rotations and barnyard manure provide the cheapest means of maintaining soil fertility and yields of small grains. Where lime has been applied on soils needing lime for alfalfa and sweet clover and a more luxuriant growth of the legumes results, higher grain yields may follow.

Barnyard manure is best applied to some other crop in the rotation rather than to small grains. The manure should be well rotted as rotting tends

to reduce the viability of the numerous weed seeds in the manure. Less danger from weed infestation may be encountered if the manure is applied to pastures and cultivated crops preceding in the rotation.

For recommendations on the use of commercial fertilizer for small grains, growers are referred to folder 101.

Crop Selection for Soil

Small grains produce their best yields and quality on well-drained, fertile, silt loam and clay loam soils. These crops are benefited by the same soil conditions that favor the clovers.

Peat Soils

On most peat soils, small grains do not produce satisfactory yields unless the necessary fertilizer is applied. Grain crops are more subject to injury by frost on peat than on mineral soils. Rye is a safer grain on peat than winter wheat, and Gopher and Minrus oats are fairly well adapted. Flax also does fairly well. Spring wheat is generally a hazardous crop. Peatland barley produces better yields than smooth awned varieties although lodging may sometimes occur.

Sand

Rye is the outstanding grain on sand and has given the highest yield of all the grain crops on the lighter soils. Although they prefer heavier soils, oats produce fair yields on these soils if fertility is maintained. Minrus oats and Peatland barley appear to be better suited than other varieties of these two grains. Flax is a very unsatisfactory crop on sand.

On the heavy fertile soils, the lodging of grains is a big problem. The most effective method of reducing lodging is through the use of stiff strawed varieties.

Preparing the Seedbed

A firm seedbed encourages rapid germination and an extensive deep root system. Satisfactory yields of spring grains have been obtained on loosely prepared fields, but these are usually the first to show the effects of drouth unless situated in low spots where the water table is close to the surface. Small grains are frequently used as companion crops to grasses and legumes although these crops require a firmer seedbed to establish a good stand than small grains alone.

The success of different methods of preparing the ground for a grain crop depends upon many factors including locality, slope of the land, soil, rainfall, requirements of the crop, and weed content of the soil.

Fall Plowing

Plow early in the fall so that weed seeds brought to the surface will have an opportunity to sprout and may be exposed to killing frosts of the fall season. Fall plowing also aids in the control of insect pests. The mellowing effect of freezing and thawing in the fall and spring and the packing which results from moisture during this period reduces the amount of labor required in the spring in preparing a good seedbed. With shallow disking and harrowing in the spring, the seedbed may be prepared quickly as soon as the ground can be worked, and early seeding may be accomplished.

Spring Plowing

Spring plowing usually leaves heavy soils in a loose cloddy condition to the depth of plowing. After disking and harrowing, it is frequently necessary to roll or pack the soil in order to reduce the air spaces and bring the surface soil in close contact with the moist soil beneath. Various types of

packers which will do this are available on the market. Other methods of packing which are less effective include further disking with the disks set straight, repeated harrowing with a spike tooth harrow, or dragging with a weighted plank drag. Oat yields at University Farm have averaged 5 per cent lower for spring than fall plowing. Spring plowing cannot be recommended as a general practice except where previous crop residues must be left to reduce wind and water erosion.

Summer Fallow

Farmers in northwestern Minnesota use this practice in controlling weeds in preparation for crops of wheat and flax. Soil blowing on the lighter soils and erosion on the slopes of rolling land is a danger, and the practice must be used with caution. In southeastern Minnesota and areas of similar rainfall, fallowing during the entire summer is of doubtful value except where necessary to control serious weed infestations.

Disking Cornstalk and Stubble Land

Another method of securing a firm seedbed is to disk cornstalk and stubble land in the spring, working the broken stalks and stubble into the soil until well covered, harrowing, and then packing. An excellent seedbed for flax or oats may be prepared in this way on land where only the stubble remains. Oats yielded 4 per cent higher on double disked corn ground than on spring plowing at University Farm. On fields in which the corn stalks are left over winter as a snow catch, the stalks may be broken off close to the ground early in the spring while the stalks are still brittle. A heavy iron rail or a sled equipped with a heavy blade driven down the corn rows will break off the stalks so they can be cut up later with the disk.

Crop residues should be worked into the soil rather than raked off and burned. Burning is wasteful and robs the soil of necessary organic matter. The presence of these materials improves the workability or tilth of clay soils and the water holding capacity and productiveness of sandy soils.

Soils and crops men agree, however, that burning of cornstalks may in some cases be done. This practice may be followed only on rich, fertile soils well supplied with organic matter where a good rotation provides for the regular replacement of legume crop residues. Lack of decomposing plant material is a frequent cause of wind and water erosion, but the loss of these residues on peat soils and rich bottom lands is not as serious as on the lighter uplands and slopes subject to erosion.

Seedbed Requirements for Winter Grains

Conditions are similar as for spring grains. Disk corn stubble or soybean ground to level the surface and work residues of previous crop into the soil. Meadows or pastures to be used require plowing in late summer but early enough to permit working down the soil to a firm condition by mid-September. Grain stubble may be shallow plowed or thoroughly disked immediately after the crop has been removed. Working the soil at intervals until seeding time will assist in reducing the weed problem and putting the ground in a good state of tilth.

Seeding the Small Grain Crop

Rate and Time

Sow grains at sufficient rate to provide a good stand which will compete with weeds and at the same time permit tillering in the crop. Tillering is less in heavy seedings than at lower rates but is dependent upon environmental conditions to a great extent. Variations in rate of seeding are necessary to compensate for differences in germination, seed size, and method of seeding. The following rates per acre are recommended for general use:

Wheat	**1¼-1½ bu.**
Common oats	**2 bu.**
Hulless oats	**1 bu. (45 lbs. per bu.)**
Barley	**2 bu.**
Rye	**1¼-1½ bu.**
Flax, Southern Minnesota	**3-4 pecks**
Flax, Northern Minnesota	**2-3 pecks**

In seeding hulless oats with a drill, the oats have a tendency to bridge over above the seed cups in the drill box. The grain should be stirred occasionally to insure a more even feed. The smaller seeded flax varieties may be sown at the lower rates. These rates are based on clean seed, sown with a drill. For broadcast seeding, increase the rate for oats and barley to 2½ or 3 bushels per acre and other grains in proportion. This is found to be necessary owing to the failure of many seeds to sprout due to insufficient covering and losses from birds and rodents in the field.

Spring Grains

Wheat and flax develop best under cool moist growing conditions and should, therefore, be seeded as soon as the ground can be prepared. Spring wheat is one of the first grains to be sown in spring chiefly because experience has shown that best yields and quality are thus obtained. Barley, oats, and flax have followed wheat in time of seeding as a matter of convenience and habit. These grains are relatively resistant to cold injury, and where early seeding is practiced, they are usually not seriously injured by frost.

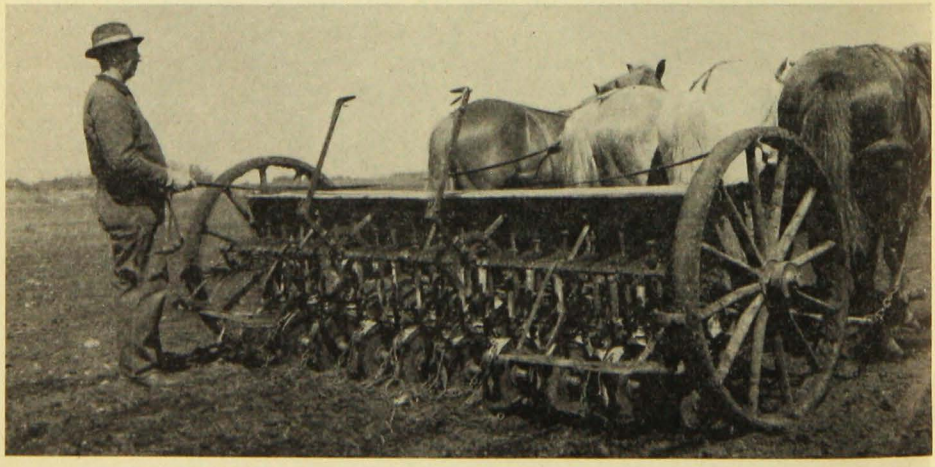

FIG. 5. SEEDING WITH A DRILL AIDS IN SOWING GRAIN AT THE PROPER RATE AND DEPTH

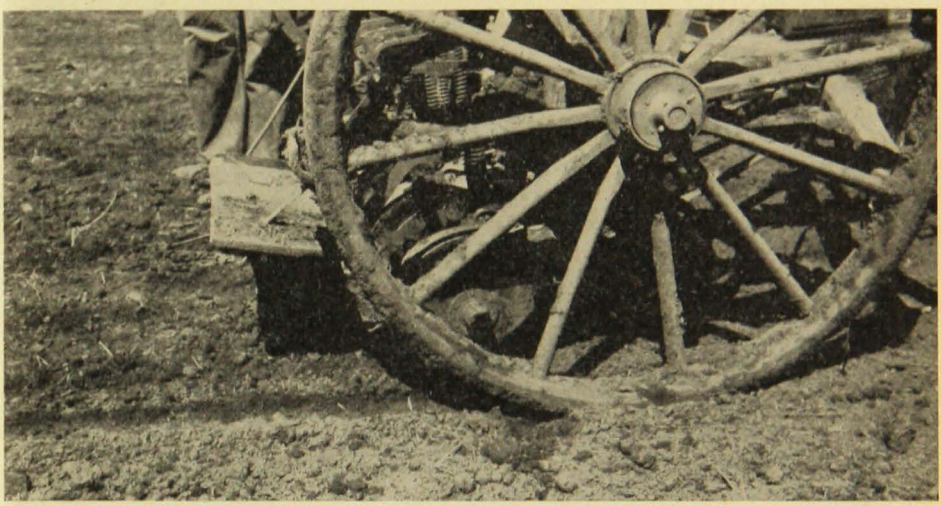

FIG. 6. A WELL-PACKED, FIRM SEEDBED IS INDICATED BY THE SHALLOW WHEEL MARK OF THE SEED DRILL

Frosts, which occurred during April and May in 1940 on early seeded flax, were observed to have reduced such weeds as green and yellow foxtail, barnyard grass, and pigweed and little or no injury to flax has been reported. Temperatures of 26° F. are not injurious, pronounced injury occurring below this point. The flax crop is most easily injured in the two-leaf stage just as it emerges, but very soon it develops beyond this point.

Winter Grains

In southern Minnesota winter wheat is best seeded about the first or second week of September when moisture conditions are frequently more favorable for sprouting. Late September seeding frequently does not permit adequate development of roots and top growth before freeze-up. Good top growth serves as a snow catch to provide winter cover. In extreme northern counties, it is desirable to seed in early September as soon as moisture conditions are favorable for germination. In the northern counties, winter wheat should be restricted to fields protected by natural wind barriers where snow provides adequate cover.

Early fall seeding of winter rye has generally produced higher yields than later seedings. Winter rye sprouts quicker and attains the same development in a shorter time than winter wheat and, as occasion requires, may be seeded from September 1 to October 1.

While early seeding is desirable in all grains, there is little to be gained by seeding in dry soil.

Late Seeding Lowers Yield and Quality

In seeding barley, a delay of 20 days after the ground could be worked resulted in a 16-bushel reduction in yield at University Farm. A loss of 36 per cent in yield of spring wheat by a delay of 10 days was found at Crookston.

Flax yields decreased 50 per cent when seeding was delayed two to three weeks, and winter wheat yielded 8 per cent less for September 30 seeding than for September 10 at Waseca.

Early seeding takes advantage of that part of the season best suited to the crop, while hot dry weather frequently catches the late seeded crops before they are well-developed. Premature ripening often reduces the yield of flour in milling wheats, lowers the starchiness of barley, and increases the hardness or texture; flax grain remains thin and shrivelled with a reduction in oil content; the feeding value of oats is reduced with the increase in per cent of hull which results. These are some of the direct evidences of loss of quality which can be avoided in part by early seeding.

Proper Depth

Drill Seeding

On a well prepared seedbed, grains sown with a drill can be put into moist soil beneath the dry surface layer at a uniform depth. This is of considerable value in dryer seasons as quicker and more uniform germination results than with broadcast seedings. Seeding 1½ to 2 inches deep is recommended for all grains except flax. In heavy moist soils, shallower seeding may prove satisfactory, but seeding at greater depths leads to unsatisfactory emergence of the seedlings. Flax is best seeded ¼ to ½ inch deep.

Difficulties of regulating the depth of seeding may usually be attributed to a loosely prepared seedbed, failure to work down the ridges on a corn field, and excess trash left on the surface. On loose soil, the spring tension on the disks of the drill may be released in order to seed shallow, provided the adjustment for regulating disk depth does not accomplish it. This is sometimes necessary in seeding flax.

Broadcast Seeding

This is better adapted for sowing legume and grass seeds and shallow seeded crops although it frequently is used for the larger seeded grains.

After the seed is spread, the grain must be covered by harrowing, but it is often difficult to cover uniformly with soil to the proper depth. Broadcast seeding thus requires a well-pulverized surface layer to aid in covering the seed.

Harvesting the Grain Crop

WELL-MATURED grains possess a higher market value than those harvested before they are fully developed. The result of harvesting immature grain is much the same as the effect of premature ripening due to drouth. Lower weight per bushel, shrivelled kernels, loss of yield, and high moisture content in the grain are frequent evidences of cutting and threshing grains before they are ripe. Early harvesting is sometimes justified in order to avoid losses due to hail, insect injury, and shattering by some varieties.

Wheat

Wheat may be cut in the dough stage but it is best to cut when well matured. Harvesting 13 days before mature has resulted in a 15 to 17 per cent reduction in yield, a 20 per cent decrease in weight per bushel, and a 40 per cent decrease in hard vitreous kernels. These losses are reduced proportionately as harvest approaches three or four days of maturity.

Oats

Oat yields increase with approaching maturity as with wheat. Losses of 29 to 41 per cent in yield can be expected where oats are cut in the milk stage 10-13 days before maturity with a corresponding loss in weight per bushel of 27 per cent. Harvesting three to four days before mature cuts down these losses in yield and quality. In general, the smaller the hull per cent, the greater the value of the oat for feed or milling purposes. The percentage of hull is increased by as much as 30 or 40 per cent by harvesting the crop eight to ten days before maturity.

The results of studies on time of harvest indicate that similar response may be expected in other grains.

Preserve Quality

Combine harvesting and shock threshing of grain has largely replaced the more expensive and laborious method of stacking before threshing. Stacked grain frequently may be of better quality and color than combined or shock threshed grain and may be justified for special crops.

Much of the grain in southern Minnesota is still harvested with a binder although the small combine has been introduced in a number of localities. Grain which has a tendency to shatter may be cut with the binder while damp with dew and placed in well built

FIG. 7. CAPPING SHOCKS MAY REDUCE WATER DAMAGE

shocks until threshed. Capping the shocks requires extra labor, but some protection is afforded against weathering and discoloration of the grain. Reset shocks which have blown over as soon as possible because the bundles absorb moisture from the ground and may damage many bushels of grain if the damp bundles are threshed with the standing shocks.

Owing to the nature of flax straw, drying is slower than for the other grains. The shocks should be built longer and narrower than is the common practice with wheat, oats, and barley.

Grain to be combined must be well-matured and dry. As the grain is binned directly from the machine, the moisture content must be low enough for safe storage. Fields heavily infested with weeds are difficult to combine as the leaves and broken green parts of the weed plants are not easily separated from the ripe grain. By cutting the grain in windrows and later picking up off the stubble with the combine, some of these difficulties can be avoided. Grain should not be combined while the grain is damp with dew in the early morning or in late afternoon when it again begins to absorb moisture.

Care in threshing is necessary to avoid cracking of wheat and other grains and skinning in barley. Durum wheats are frequently seriously damaged in threshing if the grain is dry and brittle and too high a cylinder speed is used or if too many concaves are left in the machine. The hull on barley is frequently removed by too close threshing, damage sometimes running as high as 25 and 30 per cent. Split and cracked flax kernels are commonly found in seed grain, and represent losses which can be avoided by a little more care in threshing and more attention to proper adjustment of the machines.

Grain Storage

Well-matured grains require little attention during storage. A moisture content of 12 to 13 per cent is considered safe for storage of wheat, oats, barley, and rye, while flax should not exceed 10 to 11 per cent. Musty, sour and bin-burned grain generally results from binning with too high a moisture content. It is necessary to shovel such grain during storage to cool and air it out, otherwise it rapidly goes off condition. Hulless oats, such as Nakota, should be spread shallow in the bin to permit thorough drying before storing in large quantities.

Storage bins require a once over inspection every year to locate the knot holes, cracks, and holes in the partitions made by small but troublesome rodents that infest granaries. Lath, slats from berry and peach crates, or tin tacked over these holes will avoid a great deal of unnecessary loss, waste, and mixing of grain from adjoining bins. Flax bins may be lined with building paper or cheesecloth on the floor and sides. Flax seed runs out the smallest openings, and in a few hours several bushels of the best grain may be lost in water and dirt under the floor of the granary. See that windows or openings above the bins are protected with glass or other suitable covering to prevent rain or snow from blowing in on top of the grain. During rainy weather inspect the roof for forgotten leaks and repair them promptly with tar and roofing paper or replace shingles as the case requires.

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