THE EFFECT OF VARYING ROW SPACINGS ON THE AGRONOMIC AND QUALITY CHARACTERISTICS OF CEREALS AND FLAX

by

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ABSTRACT

The Effect of Varying Row Spacings on the Agronomic and Quality Characteristics of Cereals and Flax

During a three year study (1957-1959) at three Manitoba locations, agronomic and quality characteristics of Selkirk wheat, Garry oats, Swan barley and Raja flax were studied when crops were seeded in rows spaced 6, 12, 18, 24 and 30 inches apart. Within crops the same seeding rate per row was used for all spacings.

As row spacings increased from 6 to 30 inches, yields of all crops gradually declined whereas tillering and seed return increased. The 1000-kernel weight of barley increased substantially with wider row spacings but in wheat and flax the lowest 1000-kernel weights were recorded at the widest spacing. The 1000-kernel weight of oats and the bushel weight of all crops were not affected noticeably by row spacing. Wheat from 30-inch spacings contained an average of 3.2% higher protein than from 6-inch rows. Protein in barley and flax also appeared to increase at wider row spacings, but not as sharply as in wheat.

Average soil moisture content between 30-inch flax rows was higher at the time of boll formation than between 6 and 18-inch rows. A similar trend was found in wheat at time of heading.

Wheat variety by spacing interactions were studied in one

test in which Lerma, Lee, Thatcher and Selkirk wheats were seeded in rows spaced 6, 12, 18, and 30 inches apart. No significant interactions were observed in tillering and protein content, whereas interactions in yield and 1000-kernel weights were highly significant.

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INTRODUCTION

Inter-row[1] spacing may well affect development and quality of grain crops to a greater extent than past research on this subject has indicated. Recent studies (1, 37, 39, 54) have shown that the micro-climate may be altered considerably by changing row spacing in certain grain crops.

In the last century, and particularly in the last two decades there has been a rapid change in the varieties of grain crops grown in Western Canada. Information on optimum seeding dates and seeding rates have been made available with the release of each new variety. However there has been very little information on the response of any new variety to various row spacings.

Professional seed growers have used wider row spacings in the increase of new varieties when seed is scarce and price is high because experience has indicated a greater return of seed per bushel sown. But again there is no experimental evidence to indicate the optimum spacing for maximum return.

Any radical departure from established grain production practices should be carefully evaluated for its effect on the quality of the grain. The importance of protein content of Canadian wheat in international trade is common knowledge in agricultural circles. But

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[1]Hereafter referred to as row-spacing.

no published reports have been found concerning the effect of row spacings on protein content.

This investigation was undertaken to determine:

a. The effects of varying row spacings of wheat, oats, barley and flax on tillering, seed yield, rate of seed increase and various aspects of seed quality.

b. The interactions in tillering, yield, 1000-kernel weight and per cent protein of 4 contrasting varieties of spring wheat seeded at 5 row spacings.

REVIEW OF LITERATURE

Where moisture is a major limiting factor in the production of grain crops, a number of workers have observed agronomic advantages from increasing, beyond the conventional 6 inches, the spacing between rows of grain (11, 12, 13, 14, 16). At the Western Canadian Society of Agronomy meetings held in Winnipeg in 1921, Champlin (11) advocated that a number of grain farmers in Western Canada seed trial acreages of grain drilled in double rows 36 inches apart and in triple rows 30 inches apart. He emphasized that these fields would require inter-row cultivation. Such a practice, Champlin suggested, would reduce seed requirements, produce plumper grain of higher quality than from solid seeding, reduce fall tillage requirements and serve as a partial summerfallow substitute. As a basis for his statement he related that he first became aware of the potential of wide row spacing of grain when he was employed at the Highmore Experimental Farm in South Dakota. In the extremely dry year of 1911, the only grain to head out in that district was the grain in the breeding nursery seeded in rows spaced 18 inches apart, and kept free of weeds. Champlin related that in seasons of ample moisture the solid seeding yielded best, whereas in dry seasons the row cropped grain produced the highest yield.

The following year (1922) at the Western Canadian Society of Agronomy Meetings, Champlin (13) reported that 9 Western Canadian

Experimental Farms and 3 Prairie Agricultural Colleges had agreed to initiate experiments to determine the merits, if any, of growing grain in widely spaced rows. At this meeting he outlined the following 3 major agronomic problems that might be partially overcome by growing grain in wider spaced rows:

a. Soil drifting was becoming a serious problem because of large fields of black summerfallow;

b. Summerfallow caused rank growth of crops which resulted in the grain lodging and thus a reduction in quality;

c. With land values rising, it was becoming increasingly difficult for a crop of wheat to absorb the entire cost of summerfallowing.

Row-cropping grain as a partial summerfallow substitute would overcome these problems to a considerable extent.

In 1924, Champlin and Stevenson (14) reported on 2 year's experiments (1923-4) of row-cropping grain at several locations in Western Canada. Data from all stations showed that wheat after fallow outyielded wheat seeded after double rows of oats spaced 36 inches apart by a varying but substantial margin. However at Saskatoon, Rosthern and Scott wheat after corn spaced 42 inches, outyielded wheat after fallow. From a study of all the data accumulated, the authors concluded that future rotations in Western Canada would continue to contain a certain amount of summerfallow in most districts, but that rotations would also contain increasing percentages of intertilled crops.

In 1959, Cook et al. (16) suggested that on the basis of their experiment in which they seeded wheat and oats in 7 and 14-inch rows, a critical re-examination of row spacings in cereals would be in order. From the 7 and 14-inch rows of wheat these workers obtained average yields of 35 and 31 bushels per acre respectively, and with oats, 56 and 54 bushels respectively. The authors concluded that small grain rows could be farther apart than the conventional 7 inches. They proceeded to suggest the following advantages that might be realized from a 12-inch row spacing of small grains:

a. Seeding machinery could be simplified. Perhaps a drill equipped to side-place fertilizer could be built as cheaply as present day drills.

b. A side-placement drill with 12-inch spacings could be used as an all-crop planter on many farms. Beans, peas and sugar beets might be planted with the same drill.

c. Farmers would get better stands of legumes established by seeding companion crops at wider spacings.

Several other workers have observed that a wider row spacing of grain is preferred when the grain is sown as a companion crop during the establishment year of a forage crop (7, 8, 28). Blackman (7) conducted trials in which winter wheat and spring barley were seeded as companion crops at 7 and 14-inch spacings in combination with 6 different rates of manurial treatment. Highest grain and straw yields were obtained from the 7-inch row spacing but forage production was greater where 14-inch spacings were used. Manurial treatment had no effect.

The effect of planting a small grain nurse crop in rows 7 or 14 inches apart on the growth of legume seedlings and yield of grain has been studied by Harper (28), at the Oklahoma Agricultural Experiment Station, over a period of 16 years. The average production of grain and straw was slightly lower when drill rows were 14 inches apart and only half as much seed was planted as compared with a 7-inch spacing. For spring oats the ten year average yields in bushels per acre were 34.6 from 14-inch, and 34.3 from 7-inch spacing. This study showed very little advantage in the stand of legume seedlings from wide row spacing in the companion crop when summer rainfall was abundant and summer temperatures were below average. However, in seasons of severe summer drought, a good stand of sweet clover was obtained from plots with small grain drilled at 14-inch spacings whereas complete failure occurred on plots where the drill rows were 7 inches apart. Blackman and Snell (8) studied the effect of spacing on winter versus spring grain companion crops. In 1951 and 1952, Thorne winter wheat was sown in rows spaced 7 inches, 7 inches alternating with 14 inches and 14 inches with a sowing rate per acre of 2 bushels, 1.3 and 1 bushel, respectively. Timothy was seeded with the wheat and red clover was seeded the following March. Row spacing of the companion crop did not significantly affect the stand of the forage but somewhat taller growth was produced in the 14-inch spacing. However, grain yields from the 7, 7 and 14, and 14-inch spacings were 32.5, 34.8 and 28.4 bushels per acre respectively. Thus the authors conclude that when using winter wheat as a companion crop the alternating 7 and 14-inch spacing is preferred. When using Clinton spring oats as a companion crop, a different grain yield and forage stand pattern emerged. At the 7-inch spacing average yield of oats was 46.5 bushels and average stand of alfalfa 67.7%; at alternating 7 and 14-inch spacings, 35.2 bushels and 77.0%; at 14-inch spacing, 29.5 bushels and 83.6% stand. Thus a considerably higher yield of oats was obtained from the 7-inch spacing at a comparatively small sacrifice in alfalfa stand.

Pendleton (55) observed that as the row spacing of a companion crop of oats increased, a greater proportion of the decrease in oats yield could be attributed to competition from the clover. Oats were seeded in rows 8, 16, 24 and 32 inches apart. Compared with the yield from the 8 inch spacing, the 16, 24 and 32-inch spacings yielded 80, 66 and 54% as high. The author also reports that oats sown in 32-inch rows (undersown with red clover) produced a 190 fold seed increase compared with a 42 fold increase from the 8-inch spacing.

For the seed producer interested in maximum seed increase, the matter of rapid multiplication of scarce valuable seed is of great importance. Very few workers reporting on the effects of varying row spacings in small grain record these data. In January, 1960, the Searle Grain Co. Ltd., Winnipeg, published an account of row-cropping for maximum seed increase as experienced by R.F. Platte, a successful seed grower from Nipawin, Saskatchewan. A summary of the results of some of the crops increased by this farmer is presented in Table 1 (3).

Platte reported that the greatest seed increase he ever produced was in 1950 when he grew 90 pounds of U.M. 1020 barley in single rows spaced 3 feet apart and harvested 540 bushels clean seed. This amounted to a 360 fold increase.

A number of workers have investigated the effects on crop yield and other agronomic factors when growing cereal crops and flax under varying degrees of inter-plant competition (2, 4, 9, 15, 19, 20, 26, 30, 50).

TABLE 1.- Yield (bushels per acre) and seed increase in one wheat variety and two oat and barley varieties when seeded in various row spacings and at various seeding rates. (These findings reported by Mr. R.F. Platte, a commercial seed grower from Nipawin, Sask.).

Crop	Variety	Row Spacing	Approx. seeding rate in lbs./acre	Yield in bus./acre	Seed increase[a]
Wheat	Thatcher	normal 6 inches	30.0	45	90
Oats	Ajax	double rows 3 ft. apart	10.0	70	233
Oats	Rodney	single rows 3 ft. apart	12.5	100	266
Barley	Montcalm	single rows 3 ft. apart	12.0	59	236
Barley	U.M. 1020	single rows 3 ft. apart	12.0	77	288

[a]Bushels harvested for each bushel seeded.

In 1952, Boyd (9) summarised the literature on the effect of seeding rate on cereals. He reviewed 18 experiments dealing with winter wheat, 3 with spring wheat, 16 with spring barley and 110 dealing with spring oats. When discussing factors that would influence the rate of seeding, he stated that information on the influence of such factors as row spacing and time of sowing was scanty. A number of studies, although somewhat distantly related to each other have been reported.

Thomas and Cariss (62) compared wheat yields at 5 agricultural experiment stations in West Australia under the following row spacings and combinations of seed and superphosphate:

a. Twelve inch row spacing; 50 lbs. seed, 112 lbs. superphosphate per acre (basis 6-inch rows)

b. Six inch rows; 50 lbs. seed, 112 lbs. superphosphate

c. Six inch rows; 25 lbs. seed, 56 lbs. superphosphate

d. Six inch rows; 25 lbs. seed, 112 lbs. superphosphate

At all stations, yields from treatment (b) were higher than from (a), which had the same seed and fertilizer rate within rows. At 4 of the 5 stations, yields from treatments (b), (c) and (d) were higher than from (a). The authors concluded that seeding wheat in 12-inch rows would result in reduced yields compared with the standard 6-inch spacing. A similar trend was observed at the Norfolk Agricultural Station (2) in Great Britain. Workers at this station found that winter wheat grown in 4-inch spacings produced .7 sacks (176 lbs.) per acre more, and when grown in 12-inch spacings .9 (227 lbs.) per acre less than the standard 8-inch spacing. Experiments in India point to a similar narrow row preference for wheat. At Allahabad, Ghosh (26) state that when seeding the same number of pounds of wheat per acre, but in rows 6, 9, 12 and 15 inches apart, the yield and plant population per acre decreased with increased row width while plant erectness was favored and ripening delayed. Chiney (15) in New Delhi, reports a similar conclusion but in less detail. He studied the effects of varying seeding rates and row spacings on common wheat yields under dryland and irrigated conditions. The highest grain and straw yield per acre was obtained from a seeding rate of 100 pounds per acre in rows 6 inches apart.

After some preliminary cereal spacing studies, Van Dobben (20) of the Netherlands found that the optimum spacing for wheat and barley was 22-25 cm. (approx. 10 in.) and for rye and oats 28.6 cm. (approx. 11.5 in.) which could be increased to 33.3 cm. (13.5 in.) without impairing yield. At these somewhat wider than normal spacings less lodging of grain was observed. The author further states that should the grain crop be used as a companion crop and wider row spacings be desirable, spacing between rows could be extended to 40 cm. (16 in.), but a 10 per cent yield reduction could be expected. Heuser (30) in Germany observed that narrower row spacings were most advantageous under droughty conditions. This is contrary to the findings of Champlin (11) discussed previously. Heuser (30) studied three winter cereals, rye, barley and wheat, each seeded at a constant rate per acre, in rows 10, 15 and 20 cm. (4, 6 and 8 in.) apart. In rye the variety Carsten's was favored by narrower drill spacings whereas Petkuser was not affected by spacing, except when seeded on sandy soil or during a droughty season when the narrow spacing was favored. Two-row barley yielded higher at the narrow spacings whereas the six-row varieties did not react to drill spacing. In both the barley and rye, the fine stemmed varieties reacted favorably to narrow drill spacing. All 5 wheat varieties tested favored the narrower spacings, especially in dry years.

Moës (50) in Belgium, working with the two-row barley variety Herta, found the 10 cm. (4 in.) row spacing more productive than the 20 cm. (8 in.).

Only limited data are available as to the effects of wider row spacings on the yield of flax. Champlin (11) reported, "that flax did not respond well to row culture". Shephard (60) of England stated that in most cases 4-inch rows gave slightly higher yields than 8-inch rows, but the difference was not significant. In a 4 year study, Dillman and Brinsmade (19) grew 2 flax varieties in rows spaced 6 inches apart and plants spaced ½, 1, 2, 3, 4, 5 and 6 inches in the row. Lowest yields were obtained at the wider intra-row spacings. From the 1, 3 and 6-inch spacings, the Linota variety yielded 6.7, 8.0 and 6.8 bushels per acre respectively, and the Rio variety yielded 10.3, 10.6 and 8.7 bushels per acre.

In field crops other than cereals and flax critical row spacings for optimum yield have also been reported (4, 5, 10, 43, 61).

Geography appears to have a bearing on optimum row spacing in some crops (61, 5). Stefansson in Manitoba obtained highest soybean yields with 18-inch rows when 4 row spacings from 18 to 36 inches were compared at each of 4 rates of seeding. According to Weis (5) the optimum row spacing in soybeans increased gradually from 18 inches in Minnesota to 42 inches in the Gulf States. Apparently a longer growing season produced a greater root system which extended progressively further between rows.

Optimum spacing for Spanish and Virginia type peanuts has been found to differ considerably when grown under similar conditions (4). In Kansas, Laude (43) found that 20-inch rows of sorghum yielded considerably more than the commonly used 40-inch rows. Briggs (10) in Arizona showed that cotton yields could be increased, especially under very droughty conditions, when a "skip-row" method of planting was employed in which 4 rows of cotton alternated with 4 skipped or fallow rows.

A number of other investigators, in addition to studying the effect of varying row spacings of grain on yield per acre also studied the environmental and physiological causes responsible for yield variations due to inter or intra-row plant competition. Various aspects of stooling or tillering appear to be closely associated with row spacing (23, 25, 27, 38, 67, 70).

In 1954, Frey and Wiggans (25) seeded 100 oat varieties from the world oat collection, with plants 2 and 12 inches apart in the rows, and at 3 bushels per acre. In 1955 another 40 varieties were seeded in the same manner. They observed that the average number of tillers per plant was lower for spring than for winter varieties. They also found that the tillering capacity of a variety remained relatively consistent from year to year. Grafius (27) grew 40 varieties of oats at various stand densities and found that most varieties compensated for differences in stand density by increasing or decreasing the number of panicles per plant. Similar findings are reported by Wiggans and Frey (67). They found that the number of culms per oat plant bearing panicles decreased from 1.43 to 0.94 as the seeding rate was increased from 1 to 5 bushels per acre. Yoshida (70), of Japan, observed panicle development in spring oats when varying the date of seeding and altering the rate of seeding in rows of constant 2 foot widths. Seeding rates of 0.8, 0.5, 0.2, and 0.08 bushels per acre were seeded at 5 dates from April 27th to June 22nd in 1953. He observed that tiller numbers increased from one per plant at the highest rate to 15 at the lowest rate, irrespective of sowing date. Klaukis (38) studied tillering, yield and plant height characteristics of early and later maturing varieties of oats. Five varieties of oats were seeded in rows 7 inches apart and plant spacing of 2.5 and 5 inches in the row. Three early maturing varieties produced grain on 88 per cent of all tillers while 2 later maturing varieties bore grain on 63 and 56 per cent of tillers at the 2.5-inch spacing. The author also found that oats spaced 5 inches apart in the row yielded 75 per cent more grain than when spaced 2.5 inches apart. Data indicated that 77 per cent of the total yield increase in widely spaced plants resulted from increased tillering, 16 per cent from increased yield per tiller and 7 per cent from an interaction of both factors.

A similar space per plant by tillering relationship has been observed in other crops. Fajersson (23) tested the tillering capacity of 10 Swedish varieties of winter wheat when grown under 2 levels of plant spacing, 8 x 12.5 cm. (3.2 x 5 in.) and 25 x 25 cm. (10 x 10 in.). The Eroica variety produced 5.4 and 19.4 tillers per plant, and the Skandia variety 4.2 and 16.0 tillers from the small and large spacing respectively. The author concluded that tillering in winter wheat was strongly influenced by hereditary factors and by spacing. Krustyn (40), in the U.S.S.R., suggested that the significance of tillering in enhancing growth and development of the main stem in wheat is subject to conflicting opinions. In his study he found that wheat plants with many tillers formed more robust spikes with a greater number of kernels of higher kernel weight than did plants with few tillers. A similar finding is reported by Desni (18) in Hungary. In experiments with winter wheat he noted that the total weight of grain per ear in sparse stands was greater than in dense stands. He concluded that grain weight per spike was closely related to sowing density and crop yield. Kravcova (39), in the U.S.S.R., observed that grain weight per spike, in soft spring wheat was about 6 times as great when sown in 20 cm. (8 in.) rows at 10 seeds per metre than when sown at 150 seeds per metre. He also indicated that the light intensity was 2 to 3 times greater in the sparce stand than in the dense stand. Duncan (22) found that corn could be distinguished from soybeans, cotton, sorghum, wheat, oats, barley, potatoes, oilseed, flax and sunflowers in that the logarithm of the yield per plant in corn was linearly related to the plant population; in the other crops listed, the logarithm of the yield per plant was linearly related to the logarithm of the plant population. The author attributed this difference to a relatively inflexible leaf area in corn compared with other crops. In corn, the high plant population reduced the light intensity per unit of leaf area, whereas the other crops showed much less variation in leaf area index as plant population changed. A detailed study on the relation between leaf number and spike development in spring sown barley and oats was published by Andersen (1) in Denmark in 1955. By widening the spacing between rows from 11 cm. to 22 cm. (4.4 to 8.8 in.) no changes were observed in leaf number, spike development or in the percentage of plants with tillers. However, by increasing the rate of seeding from 50 to 800 kg. per hectare (.73 to 11.8 bu. per acre), spike development was advanced, especially in barley, leaf number per plant was slightly reduced and the percentage of plants with tillers was reduced from 59 to 0 and 67 to 0 in barley and oats respectively. In another experiment, the same author determined the effect of light intensity on the same plant characteristics. In this study barley plants were observed when (a) exposed to open air continuously, (b) open air except 10 days in shadow, (c) shadow except 10 days in open air and (d) shadow all the time. Leaf number per plant decreased with increased shadow as follows: 4.70, 4.21, 3.92, 3.30. Per cent plants with tillers, from (a) to (d) were, 81, 55, 25 and 0. The author concluded from his and other experiments that the degree of tillering depended on the relation between temperature and light intensity, because open areas of less intense sunlight presumably have lower temperatures as well.

Other workers demonstrated the effects row direction and varying row spacings had on soil temperature, light intensity and moisture and thus on plant growth (37, 42, 54, 66, 69). Kersting's (37) finding that sorghum yielded higher when seeded in 20-inch rows than in 40-inch rows has already been cited. The author attributes part of the yield advantage of 20-inch rows to a lower soil and air temperature in the 20, as compared with the 40-inch rows. In 1956, the highest soil surface temperature in 40-inch rows was 143° F., compared with 107° F., in 20-inch rows. Similarly when the air temperature in 40-inch rows was 100° F., the 20-inch rows registered 80° F. These temperature differences were due to differences in shading of soil between rows. When fully grown, the shading at noon between 40 and 20-inch rows was 60 and 95 per cent respectively. This also accounted for less wind movement and a higher humidity in the 20-inch spacing. The effect of high temperatures at varying stages of growth on kernel productivity in oats was studied by Wiggans and Shaw (66). In this experiment, a range of oat varieties were grown at 70° F. in a greenhouse with a 14 hour photoperiod. At different stages of development, plants were placed in a high temperature growth chamber at 85, 90, 95 and 100°F., for 4 to 8 hours during each of 7 days. As the stage of treatment advanced from the 3 leaf to just before the boot stage, an increasing number of kernels developed on the primary tiller of each plant. However, when treated at the boot stage, a sharp drop occurred.

In 4 out of 7 years, Pendleton and Dungan (54) obtained significantly higher yields of oats when drilled in a north-south direction than when drilled in an east-west direction. The other 3 years also favored the north-south seeding, but in all years, the north-south yield advantage increased as row spacing increased. The authors attributed part of the yield increase to the effects of sunlight. They state that in the northern latitudes, the lower blades on the north side of plants in east-west rows never get full sunlight in the middle of the day. In north-south rows, all leaves on the east side of rows get adequate sunlight in the forenoon and leaves on the west side in the afternoons. Light intensity readings midway between oat rows at 11 a.m. were about 500, 400, 350, 275, 200 and 150 foot candles for the 24-inch north-south, 24-inch east-west, 16-inch north-south, 16-inch east-west, 8-inch north-south and 8-inch east-west rows respectively. They also found that moisture in the soil was slightly higher between rows of east-west seeding than in north-south seedings. Soil moisture was also found to be highest near the middle of the space between rows. Somewhat similar findings have been reported by Larson and Willis (42) from a study on the effects of planting corn in 40, 60 and 80-inch rows in east-west and north-south directions. Soil moisture was found to be lowest immediately in the row and increased progressively toward the center between rows. Moisture difference between these two locations increased with increased spacings except when under very dry or very wet conditions. Shading also had a marked effect on surface soil moisture. A considerably higher moisture level was found on the north than on the south-side of 80-inch east-west rows. The authors concluded that temperature, light and moisture conditions of plants were affected by the distance between and the direction of corn rows. Yamagata (69) demonstrated that varying light intensities influenced several characteristics of the rice plant. Under a light intensity 200 per cent normal, the number of tillers, spikes and grains per hill increased in several rice varieties. Under a weak light intensity of 40 per cent normal, and under various combinations of strong and normal light intensity, the same characteristics increased with intensity and quality of light.

A number of investigators have noted a relationship between the quality of crops produced and a number of agronomic and climatic factors that have been shown to be affected by row spacing (6, 35, 41, 44, 59, 71).

In 1932, Waldron (65) of North Dakota, studied the relationships between a number of plant characteristics of 25 varieties of hard red spring wheat. He found a highly significant negative correlation of -0.556 between yield and protein content. The regression of yield on protein content was -3.4 bushels, which is the deviation in yield in bushels for each per cent deviation in protein content. Significant positive correlations between yield and weight of grain per spike, weight per bushel, weight per 1,000 kernels and tillering were 0.742, 0.438, 0.688 and 0.454 respectively. A significant negative correlation of -0.586 and -0.527 was noted for per cent protein and grain weight per spike and 1,000-kernel weight respectively. A similar relationship of yield and protein content in wheat was reported by Neatby and McCalla (51) in 1938. They observed that in agricultural areas where relatively low wheat yields are usually obtained, protein content is generally high and where heavier yields are common, protein content is generally lower. Similar to the findings of Waldron (65), they also observed an inverse relationship between yield and protein content in wheat varieties when seeded at the same location.

Some workers have found a relationship between tillering and quality in wheat (44, 59). Romascenkov (59) of the U.S.S.R., concluded from studies with spring wheat that vigorously tillering plants produced grain of better quality than did plants with few or no tillers. He also found that vigor of tillering increased the yield of both tillers and the main ear. This observation might be partially explained by the findings of Levi and Anderson (44). In their experiment, protein contents were determined for 68 of 71 individual plants comprising a 10 feet row of Thatcher wheat.

For each plant, individual protein determinations were made on the seeds from each spike. The means for the 17 plants having 4 or more heads, and for the plants having 5 or more, indicated that the heads on the shorter tillers tended to be higher in protein content than the average for the plant.

Protein content in corn has been found to vary inversely with seeding density (6, 35, 41, 71). Zuber et al. (71) determined the effect of plant density and soil nitrogen level on the grain and stover of 2 corn hybrids. The highest protein content in grain was found in the lowest plant population per acre with the highest nitrogen rate. The lowest protein content was obtained from the highest plant population. In both years of the 2 year study the protein content in the grain and in the stover with a 50 pound per acre nitrogen application was lower than where no nitrogen was applied. Applications of 120 and 250 pounds nitrogen increased protein in all cases. Results similar to those of Zuber et al. (71) were obtained by workers at the South Carolina Agricultural Experiment Station (6). These workers found that with plant populations per acre of 4,000, 7,000, 10,000 and 13,000, the per cent crude protein declined as follows: 10.07, 9.16, 8.46 and 7.97. The quality of protein was also found to be affected by plant density. As the plant population increased from 4,000 to 13,000 plants per acre, the per cent zein fraction declined from 2.94 to 1.97 and the per cent leucine decreased from 2.27 to 2.04. There was also a tendency toward a decrease in per cent tryptophan with heavier plant stands. Ionita and Slusanschi (35) established that both protein content and per cent fat in corn grains increased as row widths increased from 30 - 40 cm. (12 to 16 in.) to 90 - 100 cm. (36 to

40 in.). However, protein content was affected more than was the fat content. A similar protein-fat relationship to plant density was observed by Lang et al. (41) when working with 9 corn hybrids.

Several attempts have been made to explain region to region and year to year differences in protein content of wheat. Most investigators have recognized that protein content in grain is influenced primarily by a complex interaction of soil moisture, nitrogen content and growing season temperatures, (24, 32, 33, 46, 53, 64, 68, 69, 71).

Fernandez and Laird (24) observed from irrigation studies in Central Mexico that the protein content of grain was lowest in the wettest treatment and highest in the driest treatment. The authors also noted a decrease in protein when applying 45 pounds nitrogen per acre and an increase in protein with higher nitrogen applications. This is in agreement with the findings of Zuber et al. (71) who also noted a protein decrease in corn when 50 pounds nitrogen was applied and an increase in protein with heavier applications. Wilson and Myers (68) make reference to a study by Sir E. John Russel of Great Britain who noted that under conditions of limited water supplies, plants make less vegetative growth and thus use less of the available nitrogen for vegetative parts. This excess of available nitrogen, he states, is then available for additional protein production in the grain.

In 1927, Mangels (46) in North Dakota confirmed the findings of other workers that environment had a major effect on the physical and chemical characteristics of wheat. He concluded that protein content and quality is finally determined by an interaction between temperature and available moisture. Waldron *et al.* (64) found that temperature influenced protein content to a greater extent than did precipitation. The authors suggested that higher air and soil temperatures made available increased quantities of soil nitrogen and thus influenced protein content. They recognized that additional soil-temperature-moisture inter-relationships existed that were too complicated to analyse by the methods employed in their study.

The finding of Hopkins (32) in 1935 is not in agreement with the temperature-nitrogen theory advanced by Waldron *et al.* (64). Hopkins was unable to show a significant correlation between mean maximum temperatures for July and August and soil nitrogen content. However, in a second study by Hopkins (33), when he used co-efficients designed to weight observed temperatures in proportion to their assumed effect on the respiration of the grain, higher temperatures during the 6 weeks preceding September 1st were shown to have a moderate positive correlation with protein content.

Paull and Anderson (53) studied the 14 year average (1927-1940) effect of rainfall on the protein content of wheat grown at 7 stations in the dry belt of southwestern Saskatchewan. Average weekly precipitation at the 7 stations for the month of June was found to be about 4 times as great as for April and twice as great as for May and July. The study also revealed that the average reduction of wheat protein from an additional inch of rainfall in April was about 4 times as great, and in May and July about twice as great as from an additional inch rainfall in June.

Varying plant densities and row spacings in barley may also influence micro-climate and thus affect quality characteristics (17, 36, 49, 51). Jahn-Deesbach and Zeitz (36) of Germany compared quality in brewing barley when seeded in 14.3 cm. (5.5 in.) and 20 cm. (8 in.) rows and found that the narrower spacing produced the better barley for brewing. Den Hartog and Lambert (17) demonstrated that protein content in barley could be used as a criterion of malting quality. He showed a highly significant positive correlation between protein content and diastatic power and a highly significant negative correlation between protein and extract, and between diastatic power and extract. Anderson, as reported by Neatby and McCalla (51) found similar relationships but suggested that because of the positive correlation between protein content and the highly desirable diastatic power, protein content was not a reliable criterion by which to assess quality in malting barley. Meredith and Olson (49) compared malting quality in barley when seeded at 1, 1 3/4 and 2 bushels per acre at 4 locations in Manitoba. In general, there were no great differences with respect to malting quality from the different seeding rates. However, it appeared that the heaviest rate of seeding was the least satisfactory for the production of malting barley. At the 2½ bushel rate of seeding, the resulting crops were highest in nitrogen content at 2 locations and contained the lowest percentage of heavy kernels at the other 2 locations. The medium rate of seeding (1 3/4 bushels per acre) appeared optimum for both yield and malting quality.

The content and quality of oil produced by plants has been found to vary when crops are grown under different densities and in rows of varying widths (19, 31, 35, 57, 58). Dillman and Brinsmade (19) found that the per cent oil in flax seed and the iodine value of flax-seed oil increased slightly with decreased plant density. When comparing corn planted in 12 and 40-inch rows, Ionita and Slusanschi (35) observed that both the protein and oil content of the seed was higher in wider row spacings. Row spacing had less effect on oil content than it had on protein content. Experiments have shown that in sunflowers closer plant spacings in the rows tend to increase oil content under certain conditions. In 1942, Putt and Unrau (58) reported that when planting Mennonite variety sunflower seed in 6, 18 and 36-inch intra-row spacings in rows 36 inches apart, the 3 year average oil content was 29.4, 26.9, and 25.0 per cent respectively. In 1948, Putt (57) demonstrated that by increasing the number of sunflower plants per hill in check row planting from 1 to 5, the per cent oil in the resulting seed increased from 27.32 to 30.64. From still another sunflower spacing experiment, Putt and Fehr (56) concluded that after a critical optimum plant density was exceeded, oil content decreased. A 3 year study indicated that when comparing 6, 12 and 18-inch plant spacings in 36-inch rows, the highest oil content was again obtained from the 6-inch plant spacing. This agreed with findings in earlier studies (57, 58). However, when similar plant spacings were compared in rows 18 inches apart, the oil content from 18-inch plant spacings was significantly higher than from 6-inch plant spacings.

Hopper and Johnson (31) attempted to establish the effects of climate on flax production in North Dakota and Minnesota by studying the relationships of temperature and moisture to flax yield, oil content and quality for the years 1919 to 1937. Their findings indicated that yield per acre was positively correlated with precipitation, both for July and for the crop year ending August 31, but was negatively correlated with the mean July temperature. Oil content was not found to be related to precipitation factors but was also negatively correlated with the mean July temperature. The iodine number was positively correlated with yield and precipitation, but negatively correlated with the mean July temperature. Of all factors related to iodine number the average mean temperature for July was the most important.

A few observations of a miscellaneous nature have been made when plant density of a crop is altered or when row spacings are varied. Luginbill and McNeal (45) noted that when sowing rate was increased and row spacing decreased, the infestation and stemcutting by wheat stem sawfly, Cephus cinctus (Norton), was considerably reduced in Rescue and Thatcher wheat.

After studying ways of reducing winter killing of fall sown oil seed crops, Torssell (63) of Sweden, discovered that this could be accomplished with winter rape and turnip rape by sowing and spacing the plants widely apart in order to restrict stem elongation and thus afford a more complete snow coverage.

Van Dobben (21) of the Netherlands found rye less susceptible to lodging, even at high nitrogen rates when seeded in rows 30 cm. (12 in.) apart as compared with 10 cm. (4 in.).

A thorough examination of row spacing by variety interaction was undertaken by Harrington (29). In a 4 year study, he compared 2 highly contrasted varieties of wheat, oats and barley when seeded in 6, 12 and 18-inch spacings. No significant variety by spacing relationships were observed with respect to earliness of maturity, bushel weight or plant height in any of the crops. In wheat and barley, significant yield interactions between varieties and row spacings occurred in only one of the 4 years. There was no significant variety by spacing interaction for yield in oats.

MATERIALS AND METHODS

Two investigations were undertaken in this study:

a. A determination of the effects of varying row spacings of wheat, oats, barley and flax on tillering, seed yield, rate of seed increase and various aspects of seed quality.

b. A study of interactions in tillering, yield, 1000-kernel weight and per cent protein of four spring wheat varieties grown at five row spacings.

A. A determination of the effects of varying row spacings of wheat, oats, barley and flax on tillering, seed yield, rate of seed increase and various aspects of seed quality.

For each of the 4 crops studied, one leading commercial variety was selected from among those recommended by the Manitoba Agronomists Conference. The varieties Selkirk, Garry, Swan and Raja were chosen to represent wheat, oats, barley and flax, respectively.

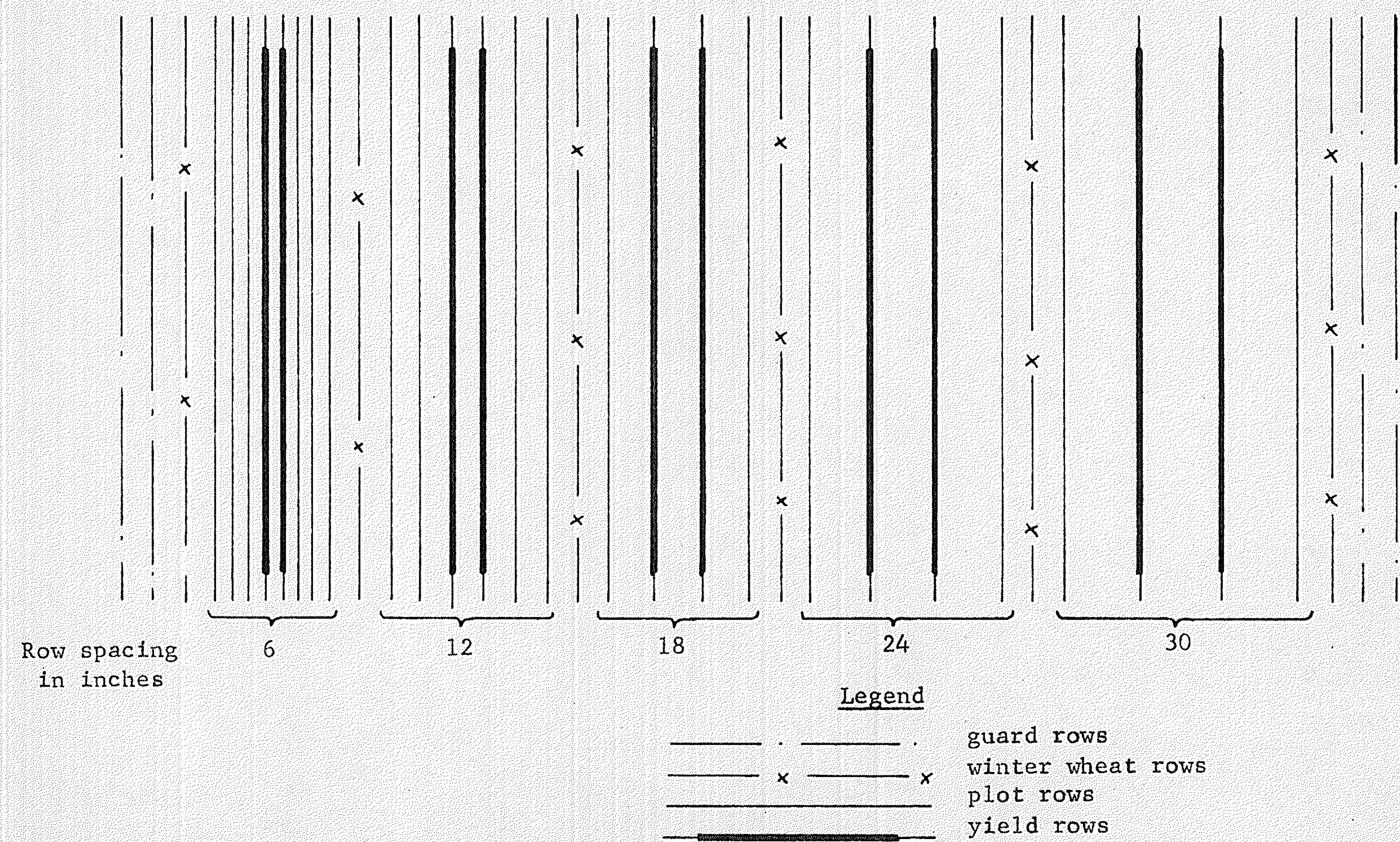
The experimental design for all crops was a randomized block with 5 replications. Treatments consisted of 5 row spacings (6, 12, 18, 24 and 30 inches) randomized within each replicate. Plots were 12 feet long. Prior to harvest, one foot of row was removed from both ends of each plot to eliminate 'border' effect and the remaining 10 feet were harvested. The number of rows constituting a plot varied with row spacing. Plots with 6-inch spacings contained 8 rows, with 12-inch spacings - 6 rows, and with 18, 24 and 30-inch spacings - 4 rows. Only the center 2 rows of each plot were harvested. Plots were separated by a row of Karkov winter wheat seeded 12 inches from both outside rows of adjoining plots as shown in Figure 1.

Rates of seeding recommended for commercial grain production were used for all crops. On the basis of 6-inch row spacings, seeding rates for wheat, oats, barley and flax were 1.25, 2.00, 1.50 and .625 bushels per acre, respectively. Seeding rate within rows was constant for all spacings of each crop. All seeding was done by means of a V-belt seeder. Plots were kept free of weeds throughout the growing season.

In the spring of 1957, the first field test of this investigation was seeded on summerfallow at the University of Manitoba. In 1958 and 1959, similar tests were seeded on summerfallow near Homewood and Portage la Prairie, Manitoba, as well as at the University of Manitoba. Two tests were abandoned in 1958; at Portage la Prairie germination was extremely poor and at the University of Manitoba high winds and drifting soil severely damaged the seedling stand about 10 days after emergence.

After harvest, stubble was pulled from a 3 foot portion of yield row in each plot to obtain material for the determination of tillering.

Figure 1. Diagram of a replicate showing the guard rows, the number and arrangement of rows within a plot at each row spacing, and the position of the winter wheat dividers between plots.



In an attempt to account for yield differences between various row spacings, per cent moisture was determined from soil samples taken half way between 6, 18 and 30-inch rows in 4 replications of the wheat and flax tests at the University of Manitoba in 1959.

Samples were obtained by means of a manually operated soil auger from depths 0-6, 6-12, 12-24, 24-36 and 36-48 inches. One sample of soil was drawn from each of the above specified plots shortly after crop emergence, at time of heading (or boll formation) and immediately after harvest.

After harvesting, the following quantitative and qualitative data were obtained:

i. The average number of tillers per plant was obtained for wheat, oats and barley by dividing the number of plants in 3 feet of yield row into the total number of spike (or panicle) bearing culms. Similarly, the extent of flax branching was determined by dividing the number of plants per 3 foot length of row into the total number of basal branches.

ii. Thousand kernel weights were obtained from the 1957 test at the University of Manitoba after grain from the 5 replications was bulked according to row spacing. For all tests in 1958 and 1959, 1000-kernel weights were determined for all crops on an individual plot basis.

iii. Bushel weights were recorded for all tests after grain from identical row spacings in the 5 replicates was bulked.

iv. Protein content of wheat was determined on the seed from each plot in all tests conducted during 1958 and 1959. Protein analyses were made by the improved Kjeldahl method for nitrate-free samples (34).

v. Oil content and protein percentage were obtained from each flax plot in the 1959 test at Hanswood. Per cent oil was determined by extraction with petroleum ether, essentially according to the method of the American Oil Chemists Society (48). Refractive index of the oil was recorded with a Bellingham and Stanley sugar and oil refractometer, 1953 model. Refractive index readings were taken for a rapid evaluation of oil quality. (Neustadt (52) reports a high correlation between refractive index and iodine number in vegetable oils and presents conversion tables by which approximate iodine numbers may be determined from refractive index readings).

vi. Per cent protein of bulked barley samples from the three 1959 tests were recorded.

B. <u>A study of interactions in tillering, yield, 1000-kernel weight and per cent protein of four spring wheat varieties grown at five row spacings.</u>

The 4 contrasting varieties of spring wheat selected for this study were Lerma, Lee, Thatcher and Selkirk. Lerma is a brown chaffed, awned variety noted for its extremely wide range of adaptation, but its quality is somewhat inferior to that of the other 3 varieties. Lee is also an awned variety but has a narrow range of adaptation. It has a high protein content and qualifies for the top Canadian wheat grades. Thatcher, also of high quality, is widely adapted in the hard red spring wheat area of North America. Thatcher is unique in that its parentage includes winter and spring type bread wheats as well as durum wheat. Selkirk was essential in this comparison because it was the variety used in Experiment (a), and because it is the dominant wheat variety grown in Manitoba.

A 5 replicate split plot design was used in this study. Each replicate consisted of 4 main plots which were randomized as to wheat varieties. Within each main plot, 5 sub-plots were randomized according to different row spacings (6, 12, 18, 24 and 30 inches). Sub-plots were the same as wheat plots in experiment (a) with respect to row length, number of rows comprising a plot, winter wheat rows between plots, seeding rate, seeding method, rows harvested and weed control.

This experiment was conducted on a block of fallow land at the University of Manitoba in 1958 and 1959. The 1958 test was abandoned because of severe seedling damage from drifting soil about 10 days after emergence.

Data were recorded for the same qualitative and quantitative characteristics reported for wheat in experiment (a), excepting that soil moisture determinations were not made in this study.

RESULTS AND DISCUSSION

A. A determination of the effect of varying row spacings of wheat, oats, barley and flax on tillering, yield, rate of seed increase and various aspects of seed quality.

Tillering and branching

The effect of row spacing on the tillering of wheat, oats and barley and on the basal branching of flax[1] is illustrated in Figure 2.

In all 5 tests of wheat, oats and barley conducted during the course of this study, the increase in tillering at the 30-inch as compared with the 6-inch spacing was significant at the one per cent level of probability. In flax, row spacings had no significant effect on basal branching except in the test at the University of Manitoba in 1957, when branching in the 24 and 30-inch rows was significantly higher than in 6-inch rows. This is in agreement with the findings of several other workers who also reported an increase in tillering in wheat and oats when seeded in rows spaced wider than the conventional 6 or 7 inches (23, 25, 27, 38). It seems reasonable to assume that part of the increase in tillering in wide row spacings can be attributed to more favorable soil moisture and nutritional conditions in the 30-inch as compared with the 6-inch rows. However, on the basis of experiments reported by other workers it appears probable that some of the increase

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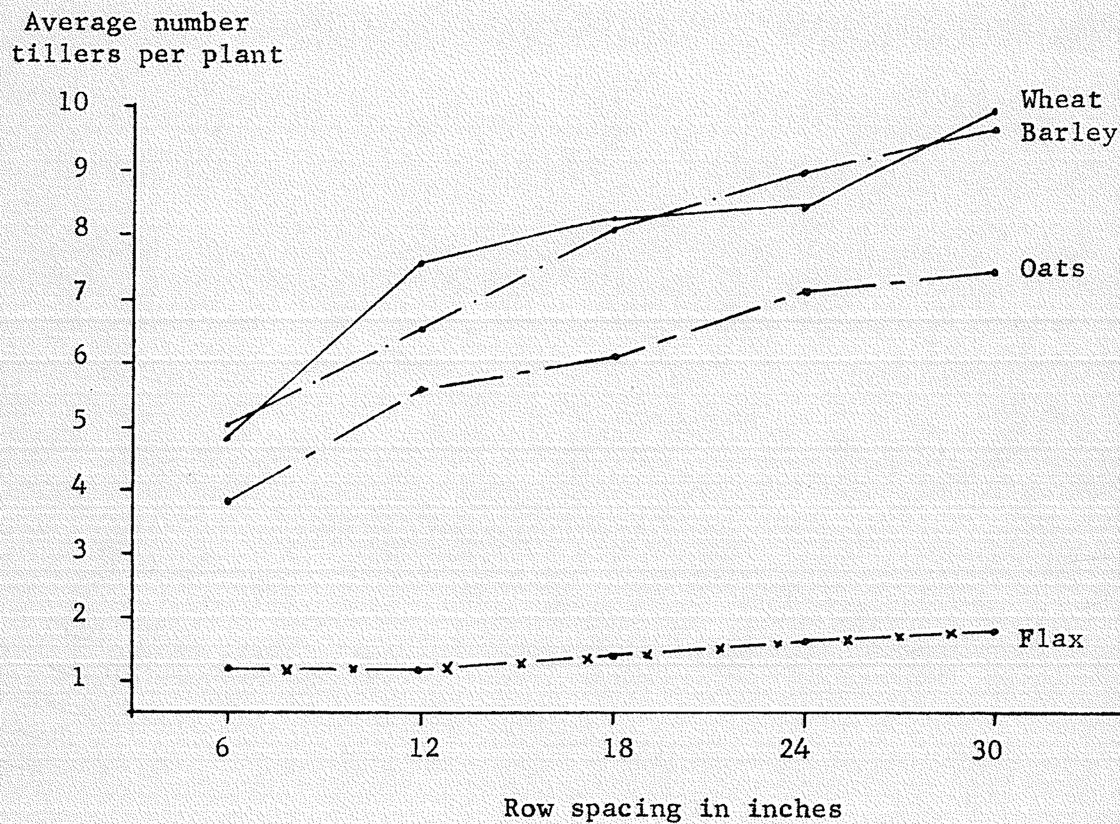
[1]For data and analysis of variance on tillering refer to Appendices 1 to 24.

Figure 2. The effect of five row spacings on the number of tillers per plant in Selkirk wheat, Garry oats, Swan barley, and on the number of basal branches in Raja flax. (Average of five tests conducted at three locations from 1957 to 1959).



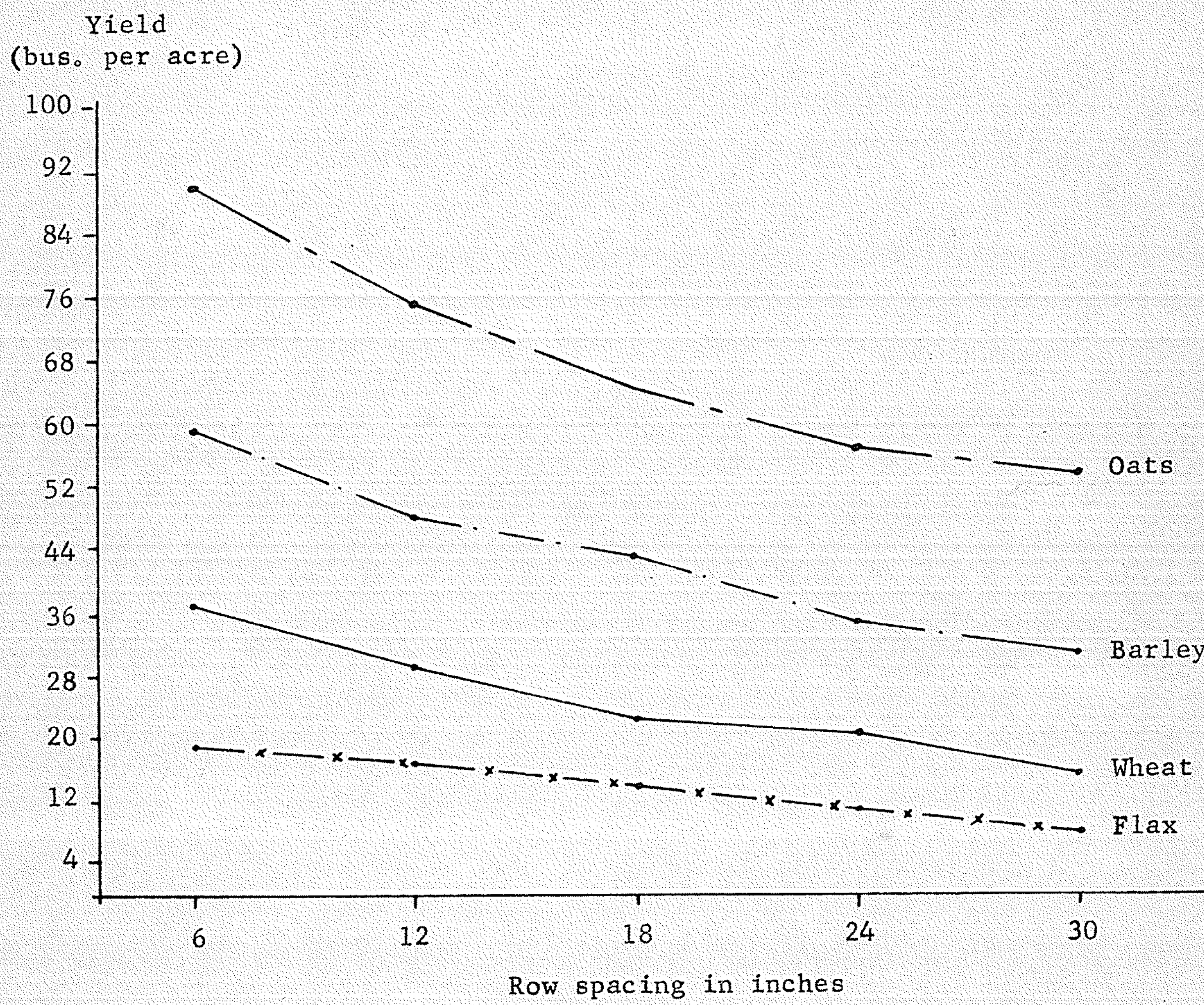
in tillering in wide row spacings may have been affected by a greater light intensity. In one study, it was found that tillering in barley was much more profuse in open sunlight than it was in a shady location (1). Other workers reported much higher light intensity readings between wide rows of grain than between narrow rows (38, 54).

Yield

The average yields of wheat, oats, barley and flax from each of the row spacings in the 5 tests of this experiment are illustrated in Figure 3 and presented in Appendices 25 to 48. The trend in all crops was for reduced yields as row spacings increased. In all tests of wheat and oats, the analysis of variance indicated a highly significant reduction in yield as distance between rows increased from 6 to 30 inches. Similarly, as row spacings increased, the decline in yields of barley and flax was highly significant in 3 of the 5 tests. The 1959 barley test at Morewood demonstrated no significant yield differences between row spacings, and at the University of Manitoba, in the same year, yield from the 3-inch spacing was significantly lower than from the 6-inch spacing at the 5 per cent level of probability. No significant yield differences were observed in the 1959 flax test at Morewood, whereas in the 1959 test at the University of Manitoba, the yield from 30-inch rows was significantly lower than from 6-inch spacings at the 5 per cent level.

From the graph in Figure 3, it appears that yields of oats drop more rapidly than the yields of flax when row spacings are increased.

Figure 3. The effect of five row spacings on the yield (in bushels per acre) of Selkirk wheat, Garry oats, Swan barley and Raja flax. (Average of five tests conducted at three locations from 1957 to 1959).



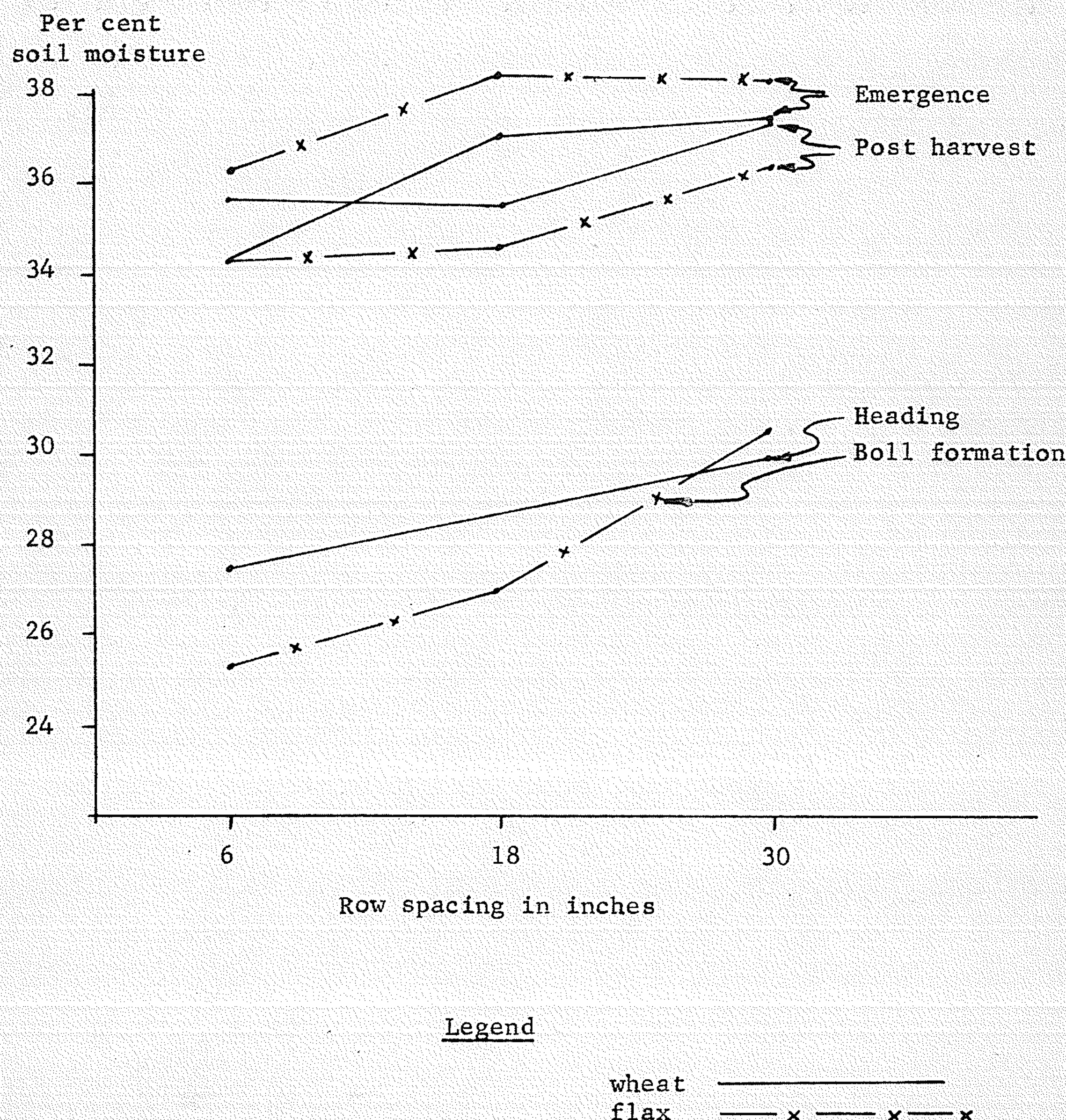
This, however, is not the case in terms of percentage decrease. The average per cent yield reductions in the 30-inch spacings as compared with the 6-inch spacings for wheat, flax, barley and oats was 59.2, 53.8, 40.9 and 40.8, respectively.

Yield decreases from wide row spacings, similar to those found in this study, have also been reported by other workers in wheat (2, 7, 9, 11, 13, 15. 16, 20, 26, 30), oats (16, 20, 55), barley (7, 20, 50) and flax (4, 60). Although several observations of lower yields from wide than narrow row spacings of grain have been reported, none of the authors reporting these observations attempt to explain the causes for these yield differences. Most workers appear to assume that in row spacings wider than 6 or 7 inches, either the seeding rate per acre was too light or the space between rows too wide for maximum utilization of available soil moisture and nitrogen.

In the wheat tests under study, the seeding rate was reduced from 75 to 15 pounds per acre when distance between rows increased from 6 to 30 inches. Comparative grain yields would suggest that 15 pounds of seed per acre, distributed in rows 30 inches apart does not utilise available soil moisture and nutrients as efficiently as 75 pounds of seed in 6-inch rows.

The soil moisture study conducted in the wheat and flax tests at the University of Manitoba in 1959, and illustrated in Figure 4, suggests that available soil moisture may not have been fully utilised by grain seeded in 30-inch rows. The data indicate that the average soil moisture content to a depth of 48 inches, midway between 30-inch

Figure 4. Soil moisture content (per cent oven dry weight) as affected by three row spacings of Selkirk wheat and Raja flax at three crop stages. (University of Manitoba, 1959).



rows of flax was higher at the time of boll formation than between the 18 and 6-inch rows. Analysis of variance[1] indicated that this difference was significant at the 5 per cent level of probability. In wheat, soil moisture content also appeared to increase gradually from the 6-inch to the 30-inch spacing, although this increase was slightly less than required for significance at the 5 per cent level.

During the time of heading in wheat and boll formation in flax, the average soil moisture content was significantly lower (at the one per cent level) than at the time of crop emergence or after harvest. Thus, under conditions existing at the University of Manitoba in 1959, soil moisture supplies were at their lowest when crops were heading out and required a heavy supply of moisture. Since Table 4 shows that available soil moisture in flax was more fully utilized at the 6-inch than at the 30-inch spacing, it seems reasonable to assume that this may be at least one factor contributing to lower yields at the widest row spacing. Similarly, Figure 8 appears to indicate a greater supply of available soil nitrogen for protein production at the 30-inch spacing of wheat, relative to the amount of crop growth, than at the 6-inch spacing. If this assumption is accepted, it would appear probable that the 30-inch rows of grain were also too far apart to efficiently utilize available soil nitrogen for maximum grain yield production.

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[1]For data and variance analysis of soil moisture see Appendices 49 to 52.

Seed Increase

Although yield per acre in all crops decreased with an increase in row spacing, Figure 5 indicates that the seed return per bushel seeded increased as row spacings became wider.

According to Figure 5, seed return in oats continued to increase at a uniform rate as row spacing widened from 6 to 30 inches. It appears that the optimum row spacing for maximum seed return in oats may be more than 30 inches. In barley the rate of seed increase began to fall off at the 18-inch spacing and in flax a leveling off occurred beyond the 18-inch rows. At row spacings wider than 6 inches, wheat appeared to increase at a slower rate than other crops. However, the increase in seed return of wheat was fairly uniform up to the 24-inch spacing, beyond which a leveling off or slight decline was noted.[1]

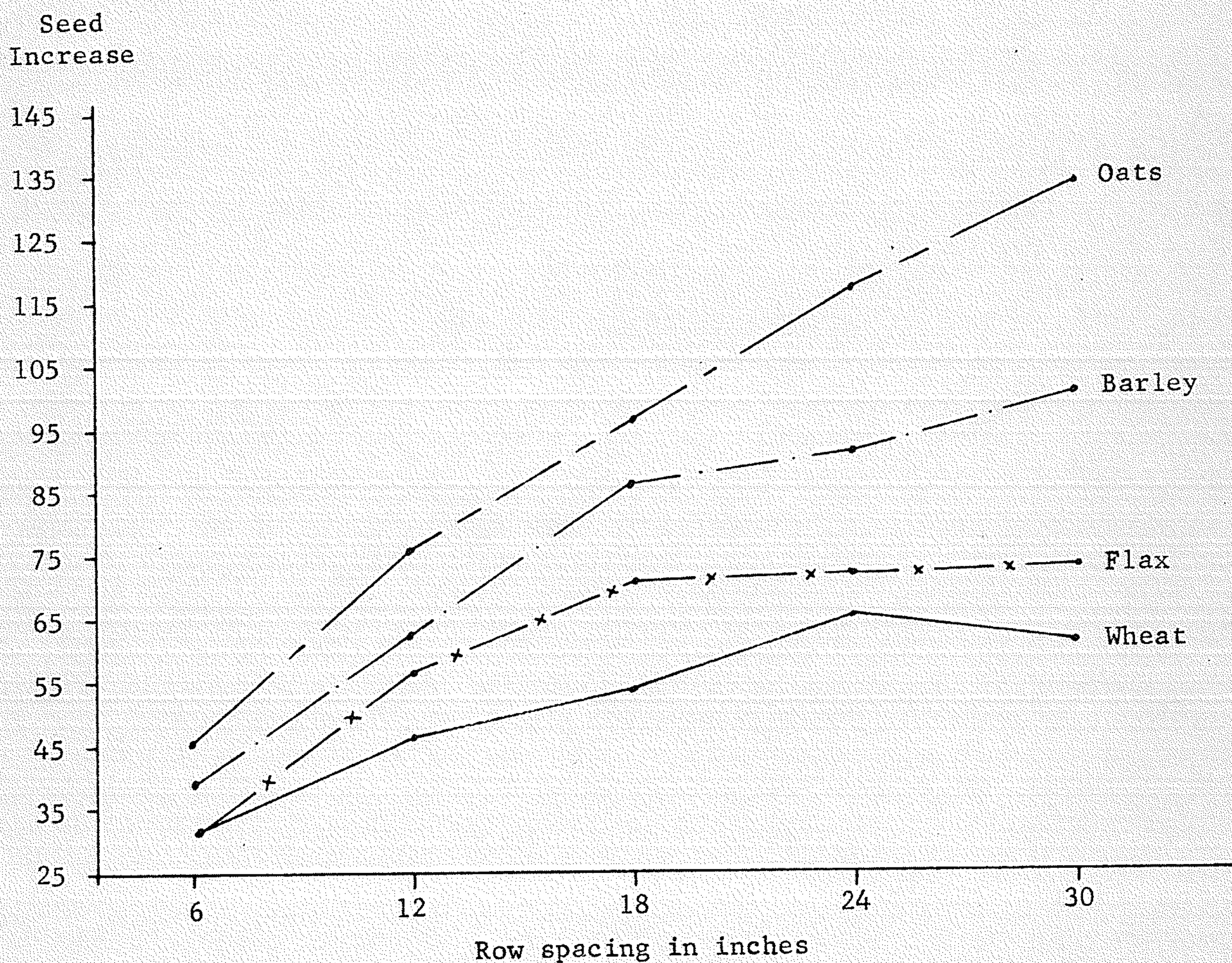
Figure 5 does not necessarily indicate the maximum seed increase possible at the respective row spacings. In this study, the seeding rate within rows was the same for all spacings of each crop. Another experiment is required to determine whether seed return could be materially increased by either decreasing or increasing the seeding rates within rows from the constant rates used in this study.

Bushel Weight and 1000-Kernel Weight

From Figure 6 it appears that row spacing had relatively little effect on the bushel weight of wheat, oats, barley and flax. However, in wheat and barley bushel weight may have been slightly reduced by wider spacings, but width of row appeared to have even less effect on

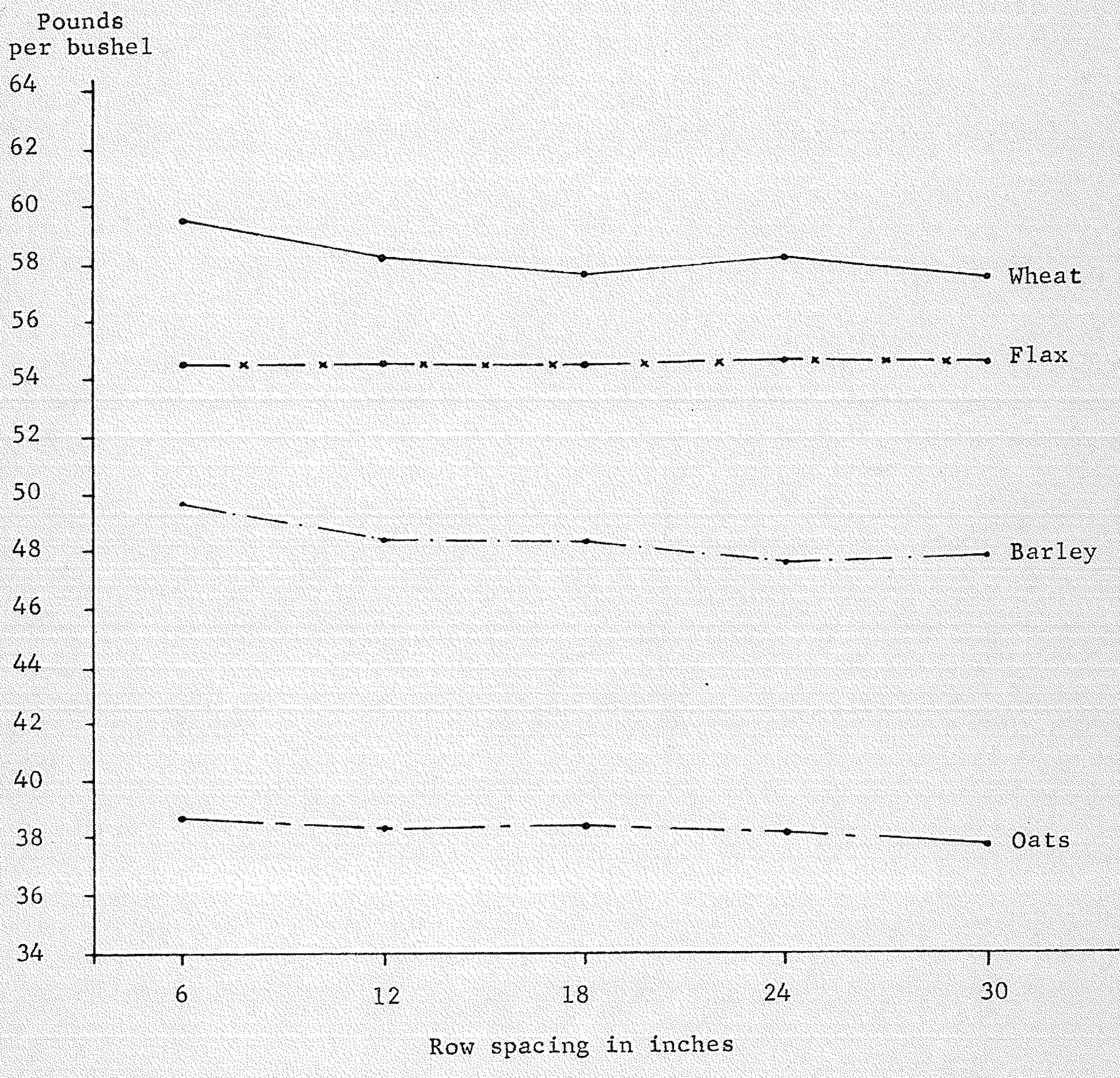
[1]For data on seed increase refer to Appendices 53 to 56.

Figure 5. The effect of five row spacings on seed increase in Selkirk wheat, Garry oats, Swan barley and Raja flax*. (Average of five tests conducted at three locations from 1957 to 1959).



* Seed increase represents bushels harvested for each bushel seeded.

Figure 6. The effect of five row spacings on the bushel weight (in pounds) of Selkirk wheat, Garry oats, Swan barley and Raja flax. (Average of five tests conducted at three locations from 1957 to 1959).



bushel weight of oats and no effect on flax. Since bushel weight determinations were made after seed from similar treatments in a test was bulked, a statistical analysis of the data was not undertaken.[1]

The effect of row spacing on the weight per 1000-kernels was different for each of the crops. Figure 7 shows that the average 1000-kernel weight of barley was about 4 grams more at the 30-inch than at the 6-inch spacing whereas the 1000-kernel weight of wheat and flax appears to decrease slightly as row spacings become wider. In oats, a slight decline in 1000-kernel weight occurred when the row spacing increased from 6 to 12 inches. However, from the 12 to 30-inch spacings, a small but gradual increase followed. In 3 of the 4 barley tests in which the data were statistically analyzed, the increase in 1000-kernel weights at the 30-inch compared with the 6-inch spacings was significant at the one per cent level of probability. In the fourth test, the increase was significant at the 5 per cent level. In oats, the increase in 1000-kernel weight at the widest spacing was significant at the one per cent level of probability in only one of the tests, and in only one additional test was the increase significant at the 5 per cent level.

The 1000-kernel weight of wheat responded inconsistently to wider row spacings although Figure 7 indicates a gradual trend downward as rows were spaced further apart. In 1959, at the University of Manitoba, the 1000-kernel weight of wheat from 30-inch rows was 28.61 grams compared with 32.90 grams from wheat sown in 6-inch rows. This

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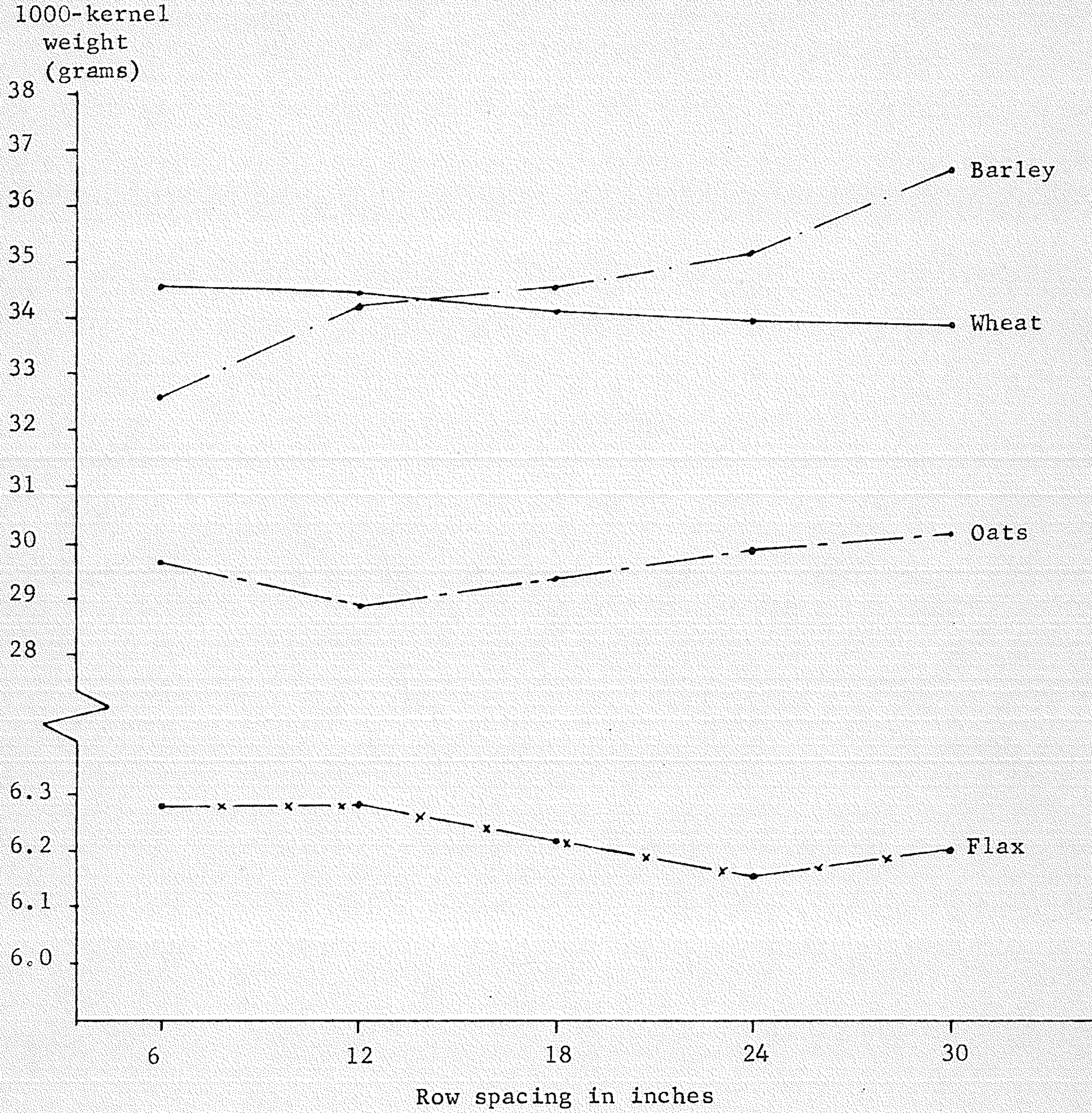
[1]For data on bushel weights refer to Appendices 57 to 60.

Figure 7. The effect of five row spacings on the 1000-kernel weight (in grams) of Selkirk wheat, Garry oats, Swan barley and Raja flax. (Average of five tests conducted at three locations from 1957 to 1959).



difference was significant at the one per cent level. No significant differences were observed in any of the other tests. As row spacings increased, a slight downward trend in 1000-kernel weights was noted in one test and an upward trend in two other tests.

Similarly, as row spacings of flax became wider, the 1000-kernel weights were affected differently in different tests. In both of the tests conducted at Morewood the 1000-kernel weight increased as row spacing increased up to 24 inches. In 1958 the increase was significant at the 5 per cent and in 1959 at the 1 per cent level of probability. However, in the 1959 test at the University of Manitoba, the 1000-kernel weight at the 30-inch spacing was significantly lower at the 5 per cent level, than at the narrow spacing.[1]

Figure 7 depicts an interesting difference between the manner in which wider row spacings affect wheat and barley. Although substantiating data are not available, this difference might be partially explained by the determinate and indeterminate number of florets per spikelet in barley and wheat respectively. It is known that after fertilization wheat responds to favorable environment by increasing the number of fertile florets per spikelet. Martin and Leonard (47), state that within a spikelet of wheat the second grain from the base is usually the largest and the first grain is next in size, but when present, the third, fourth and fifth grains are progressively smaller. Thus, wheat might respond to favorable environment by producing a larger number of kernels, but with a progressively smaller average size. Barley, however,

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[1]For data and variance analyses on 1000-kernel weights refer to Appendices 61 to 80.

is limited to one grain per spikelet regardless of environmental conditions after fertilization. It is therefore reasonable to assume that barley would respond to particularly favorable moisture and nutrition conditions by increasing the size of individual kernels.

It appears, therefore, that more favorable growing conditions in the 30-inch as compared with the 6-inch spacings may have been responsible for the 1000-kernel weight increase in barley and decrease in wheat at the wider spacings.

Protein Content

Figure 8 shows that as distance between rows of wheat became greater, the protein content of the seed steadily increased. At the 6-inch spacing, the average per cent protein (of four tests) was 15.1 compared with 18.3 at the 30-inch spacing. In all tests, the protein increase at the wider spacings was significantly higher than at the narrowest spacing at the one per cent level of probability.[1] In 1959, protein differences between replicates were significant at the 5 per cent level of probability at the University of Manitoba and at Portage la Prairie and at the one per cent level at Homewood.

Protein determinations of barley were made on bulked seed samples from all tests conducted in 1959. Table 2 indicates that as row spacing increased, the protein content of barley also tended to increase but at a slower rate than in wheat.

On the basis of the 1959 test at Homewood, protein content in

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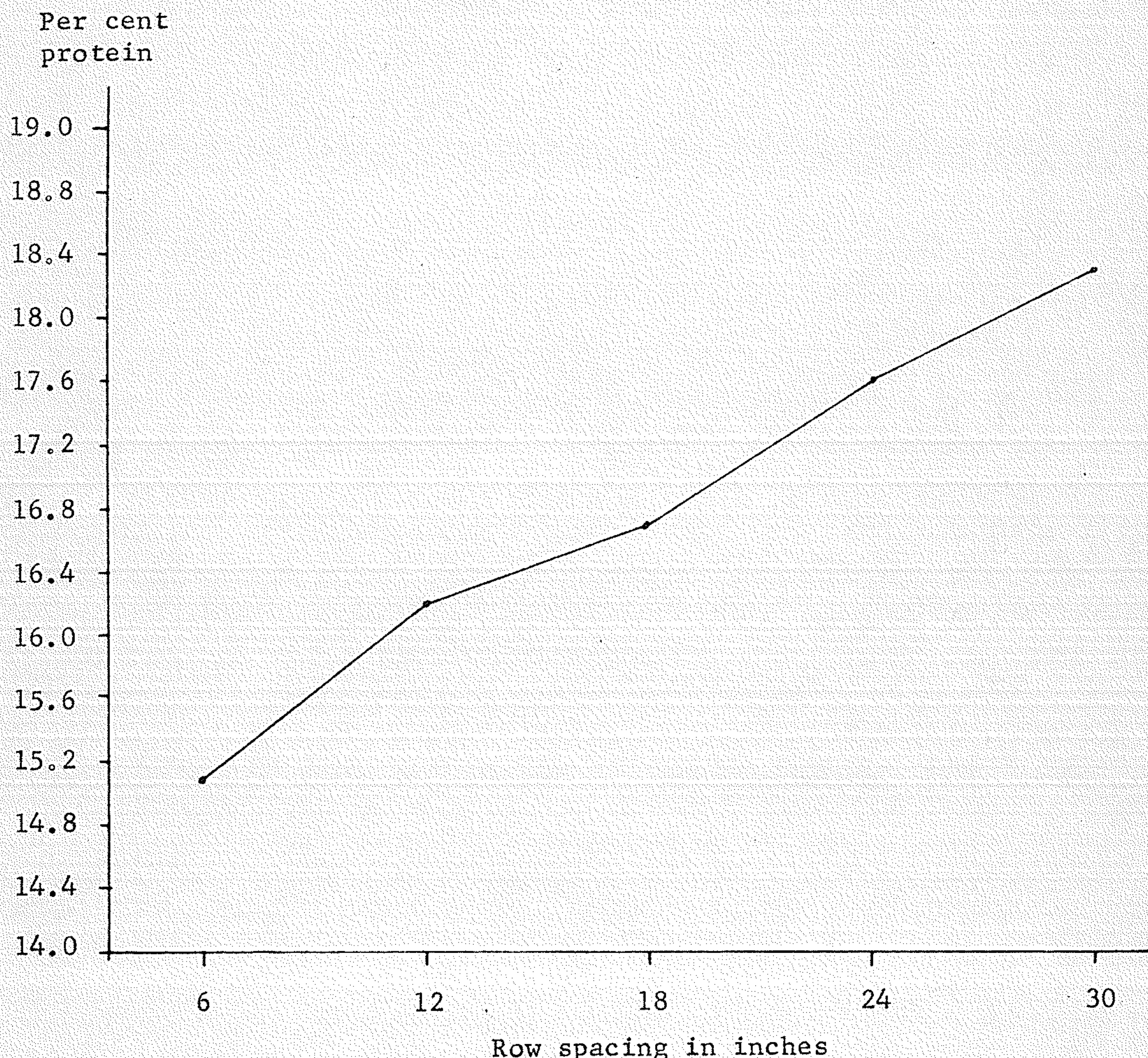
[1] For data and variance analyses on protein content of wheat and flax refer to Appendices 81 to 86.

Figure 8. The effect of five row spacings on the per cent protein of Selkirk wheat. (Average of four tests conducted at three locations during 1958 and 1959).



flax followed a trend similar to that established in wheat and barley. Protein increases at the wider row spacing closely approached significance at the 5 per cent level of probability. D_ata on protein content of flax are presented in Table 3 and Appendix 85.

The higher protein content in grain harvested from the wider row spacings appears to be related to a greater supply of soil nitrogen in relation to the amount of plant growth than in the narrow spacings. This explanation is in agreement with the findings of a number of other workers who suggested that defferences in grain protein content attributed to changes in climate could usually be traced to an increase or decrease in available soil nitrogen for crop development (32, 46, 53, 64). It is possible, that higher soil temperatures in the wider spacings may have resulted in more rapid nitrification and therefore to a greater amount of available soil nitrogen, which in turn would lead to a higher protein content in the crop. A close relationship between mean July temperature and wheat protein content has been reported (46, 64). In another study, soil and air temperatures were found to be considerably higher between wide row spacings of grain than between narrow spacings (37).

Table 2.- Per cent protein in Swan barley when seeded at 5 row spacings and at three locations in 1959.

Row Spacing in inches	University of Manitoba	Homewood	Portage la Prairie
6	15.5	13.2	14.3
12	15.5	12.6	13.9
18	15.5	13.5	14.9
24	16.1	15.1	15.4
30	16.3	15.1	15.8

Table 3.- The per cent oil and protein in flax seed and the refractive index of flax seed oil when Raja flax was grown at five row spacings at Homewood in 1959.

Row spacing in inches	Per cent protein	Per cent Oil	Refractive index
6	23.9	36.9	73.9
12	25.2	37.6	73.8
18	25.4	37.5	73.8
24	26.3	36.6	73.7
30	25.9	37.4	73.5

Differences were not significant at the 5 per cent level of probability.

According to Figures 4 and 8, the results of this study do not conform to the observations of a number of workers who reported a decrease in per cent wheat protein as more moisture became available to the growing crop (24, 46, 53, 68). However, the inverse relationship between seed yield and protein content, as seen from Figures 3 and 8, is consistent with the findings of a number of other workers (6, 35, 41, 51, 65, 71).

Oil Content and Refractive Index in Flax

Data presented in Table 3 suggests that in the 1959 flax test at Homewood, row spacing did not appear to influence the percentage oil or the refractive index of the oil.[1] Thus, according to the positive correlation between refractive index and iodine number in vegetable oils as reported by Neustadt (52), row spacing in flax appears to have no effect on the iodine number of flax-seed oil. It is recognized, however,

[1]For analysis of variance of per cent oil and refractive index of flax-seed oil refer to Appendices 87 and 88.

that firm conclusions should not be drawn on the basis of results obtained from a single experiment.

B. <u>A study of interactions in tillering, yield, 1000-kernel weight and per cent protein of four spring wheat varieties grown at five row spacings.</u>

The data and analysis of variance (Appendices 89 to 93) indicate that in yield and 1000-kernel weights, interaction of wheat variety by row spacing was significant at the one per cent level of probability. No significant interactions were found in tillering and per cent protein.

A study of the data suggests that the highly significant interaction in yield does not present a serious problem because the varieties yielded in the same order in all except the 24 and 30-inch spacings. At these wider spacings the second and third highest yielding varieties, Selkirk and Lee, merely exchanged positions. When row spacing increased from 6 to 30 inches, the rust resistant variety Selkirk seemed to maintain its yielding ability better than the highly rust susceptible variety Thatcher. Although the degree of rust infections at various spacings was not recorded, it is conceivable that there may have been a greater yield reduction due to rust at the wide than at the narrow spacings. If this supposition is accepted a portion of the variety by spacing interaction in yield could be attributed to the rust infections of susceptible varieties.

The absence of a variety by spacing interaction in per cent protein is also noteworthy. This implies that per cent protein in wheat can be expected to increase with wider row spacings irrespective of variety.

The results of this one year experiment indicate that caution should be exercised when making general row spacing recommendations on the basis of a study in which o ly one variety was used.

SUMMARY

The following two aspects of row spacing in cereal crops and flax were studied.

a. A determination of the effects of varying row spacings of wheat, oats, barley and flax on tillering, seed yield, rate of seed increase and various aspects of seed quality.

b. A study of interactions in tillering, yield, 1000-kernel weight and per cent protein of four spring wheat varieties grown at five row spacings.

A. Five row spacings (6, 12, 18, 24 and 30 inches) were used to study the effects of row spacing of wheat, oats, barley and flax on tillering (or basal branching), seed yield, rate of seed increase and various aspects of seed quality. Data were obtained from experiments conducted at the University of Manitoba in 1957 and 1958, at Morewood in 1958 and 1959 and at Portage la Prairie in 1958.

Tillering of wheat, oats and barley increased significantly as row spacing increased from 6 to 30 inches whereas basal branching in flax was significantly increased in only one of the five tests. However, increased tillering at the wider spacings was not sufficient to offset reductions in seed yield. Yields of all crops consistently declined as row spacings increased. In part, these yield reductions at the wider spacings may have been caused by the inability of the crop grown at the wider spacings to use as much of the soil moisture and available nitrogen as when grown at narrow spacings. At the time

of boll formation in flax, soil moisture content mid-way between the 30-inch rows was significantly higher than between the 6-inch rows. In wheat, a small soil moisture increase in the 30-inch as compared with the 6-inch spacings (at the time of crop heading), approached the 5 per cent level of significance. Chemical analysis of the seed from all wheat tests grown in 1938 and 1939 clearly indicated that wheat grown in 30-inch rows contained a higher nitrogen content than when grown in 6-inch spacings. This suggests that available soil nitrogen was more efficiently utilized at the narrower row spacings.

Seed return (bushels harvested from each bushel seeded), increased with wider row spacings. Seed return in oats continued to increase at a fairly uniform rate as row spacings changed from 6 to 30 inches. However, in barley the rate of seed increase began to fall off at the 18-inch spacing and in flax a leveling off occurred beyond the 18-inch rows. At row spacings wider than 6 inches, wheat appeared to increase at a slower rate than did other crops. However, the increase in seed return was fairly uniform up to the 24-inch spacing, beyond which a leveling off or slight decline was noted.

According to the results of this experiment, row spacing appeared to have no consistent effect on the bushel weights of oats and flax. With wheat and barley, a slight downward trend in bushel weight was observed as row spacings became wider. The 1000-kernel weights of crops responded quite differently to wider row spacings. Whereas increases in 1000-kernel weights of barley were significant at the wider spacings, a slight decrease appeared in wheat and flax as row spacings increased. In oats, a slight decline in 1000-kernel weight occurred when the row spacing increased from 6 to 12 inches. However, from the 12 to 30-inch spacings a small but gradual increase followed.

Perhaps the most significant finding of this study was that protein content of wheat increased consistently with wider row spacings. Based on an average of four tests, percentage protein in wheat increased from 15.1 to 18.3 as row spacings changed from 6 to 30 inches. A similar, although less pronounced row spacing - protein relationship was observed in all barley tests in 1959 and in the flax test at Hanwood in 1959. From the one test on which analyses were made it appeared that oil content of flax seed and the refractive index of flax seed oil were not affected by row spacing. Because of the close relationship between refractive index and iodine number, it is reasonable to assume that row spacing also had no effect on the iodine number of flax seed oil.

B. When four distantly related wheat varieties were also grown in 6, 12, 18, 24 and 30-inch row spacings in 1959, no significant variety by row spacing interactions were noted in tillering and per cent protein. However, highly significant variety by spacing interactions were found in seed yields and 1000-kernel weights.

CONCLUSIONS

1. Protein content in wheat is increased by increasing row spacing beyond the conventional 6 inches. The average per cent protein of 4 tests increased from 15.1 at 6-inch spacings to 18.3 at 30-inch spacings.
2. Seed yields of wheat, oats, barley and flax are decreased by cropping in rows wider than 6 inches.
3. Seed return (bushels harvested from each bushel seeded) is substantially increased in wheat, oats, barley and flax by increasing the row spacing. In all crops except oats the rate of increase in seed return began to decline at spacings less than 30 inches.
4. Tillering in wheat, oats and barley increases as row spacings are increased from 6 to 30 inches.
5. Until further information becomes available on the yield interactions between crop varieties and row spacings, caution should be exercised when making general row spacing recommendations.

LITERATURE CITED

1. Andersen, S., Relation between leaf number and ear development in spring sown barley and oats. Physiologia Plantarum 8: 404 - 417, 1955.

2. Anonymous, Norfolk Agricultural Station, Great Britain. 48th Annual Report, 1955-56, p. 22 (Field Crop Abstracts; 10:783).

3. Anonymous, Two hundredfold and more. A professional seed grower at work. Grain Market Features, 30:2, p. 2, Searle Grain Co. Ltd., 1960.

4. Anonymous, Georgia Experiment Station, Sixty First Annual Report, 1948-49, p. 79, (Field Crop Abstracts; 4:778).

5. Anonymous, Row width, growing season govern yields of soybeans, Soils and Crops, 5:3, p. 24, 1952.

6. Anonymous, Effects of nitrogen, fertilization, plant spacing and variety on the protein composition of corn, Dept. of Agron., So. C. Agric. Exp. Sta. Tech. Cont. No. 219; Agron. J., 46:4, 185-6.

7. Blackman, C.R., Spacing and fertilization of winter versus spring grain companion crops. Diss. Abstr. 15:12, 2374-5, 1955. (Field Crop Abstracts; 9:796).

8. Blackman, R.C. and Snell, R.S., Effect of spacing in winter versus spring grain companion crops and its relation to nitrogen fertilization of the spring type. Agron. J. 46:11, 489-91, 1954.

9. Boyd, D.A., The effect os seed rate on yield of cereals, Emp. J. Exp. Agric. Rothamsted Exp. Sta. 20:78, 115-22, 1952. (Field Crop Abstracts; 6:123).

10. Briggs, R.E., Profitable skip-row planting needs higher cotton yields. Soils and Crops, 10:9, p. 24, 1958.

11. Champlin, M., Growing grain in rows, Proceedings of the Second Annual Meeting of the West. Can. Soc. of Agron., p. 7-11, Man. Dept. of Agric. and Imm., Winnipeg, 1921.

12. Champlin, M., Summerfallow substitutes for Saskatchewan. Bul. No. 16, College of Agric., Univ. of Sask., 1924.

13. Champlin, M., Report of committee on summerfallow substitutes, Proc. of the 3rd Annual Mtg. of the West. Can. Soc. of Agron., p. 104-6, Sask. Dept. of Agric., 1922.

14. Champlin, M. and Stevenson, Results of experiments in the use of intertilled crops vs. fallow as preparation for wheat production in Saskatchewan and Western Manitoba. J. Amer. Soc. Agron., 17:12, 807-12, 1925.

15. Chinoy, J.J., Effect of spraying on yield of wheat, Curr. Sci. 16:121. Indian Agric. Res. Inst., New Delhi, 1947. (Field Crop Abstracts 1:86).

16. Cook, R.L., Cuttay, J.R., Robertson, L.S., and Wolcott, A.R., Small grain planting and fertilization, Soils and Crops, 11:7, p. 10-11, 1959.

17. Den Hartog, G.T. and Lambert, J.W., The relationship between certain agronomic and malting characteristics of barley, Agron. J. 45:5, 202-13, 1953.

18. Dezmi, L., Effect of spacing in winter wheat crops, (Hungarian) Növénytermelés 6:1, 45-52, 1957, (Field Crop Abstracts 11:2).

19. Dillman, A.C. and Brinsmade, J.C. Jr., Effect of spacing on the development of the flax plant, J. Am. Soc. Agron. 30:4, 267-86, 1938.

20. Dobben, W.H. Van, Preliminary cereal spacing trials, Rep. Exp. Fm. "Die Bouwing". Randwijk 62-7, (Field Crop Abstracts 11: 1523).

21. Dobben, W.H. Van., Interprovincial field trials of winter cereals under different doses of nitrogen and different planting distances, Versl. Cent. Inst. Landbouwk, Onerzoek, 1948: 49-53, 1949. (Field Crop Abstracts 3:350).

22. Duncan, W.G., Effects of plant population and of fertilizer placement on plant growth and development. Diss. Abstr. 19:17, 1500-1, 1959. (Field Crop Abstracts 12:1403).

23. Fajersson, F., Tillering capacity of some winter wheat varieties in relation to spacing between plants. Agric. Lort. Genet. Landskrona 15:1-2, 88-103, 1957, (Field Crop Abstracts 10:1257).

24. Fernandez, O.N. and Laird, R.J., Yield and protein content of wheat in central Mexico as affected by available soil moisture and nitrogen fertilization. Agron. J. 51:1, 33-7, 1959.

25. Frey, K.J. and Wiggans, S.C., 1. Tillering studies in oats, Agron. J. 49:1, 48-50, 1957.

26. Ghosh, A.K., Report of the Agronomy Dept. for 1954-55, Agricultural Institute Allahabad, India. Allahabad Far. 29:3, 115-41, 1955, (Field Crop Abstracts 9:653).

27. Grafius, J.E., The relationship of stand to panicles per plant and per unit area in oats, Agron. J. 48:10, 460-2, 1956.

28. Harper, H.J., Wide row planting of small grains to establish sweet clover and lespedeza, Okl. Agric. Exp. Sta. Bul. B-298, 1946.

29. Harrington, J.B., The effect of having rows different distances apart in rod row plot tests of wheat, oats and barley, Sci. Agric. 21:10, 589-607, 1941.

30. Houser, W., An examination of the effect of distance between drills on the level and nature of the yield of winter cereals, being at the same time, a contribution to the question of small and large-spaced types. (German), Z. Acker-u. Pfl. bau, 98:1, 25-52, 1954. (Field Crop Abstracts 8:114).

31. Hopper, T.H. and Johnson, M., Flax production and climate of North Dakota and Minnesota, 1919-1937, Bul. No. 298, Agric. Exp. Sta. N.D. Agric. College, 1941.

32. Hopkins, J.W., Influence of weather conditions on the nitrogen content of wheat, Can. J. Res. 12:2, 228-37, 1935.

33. Hopkins, J.W., Weather and wheat yield in Western Canada. 1. Influence of rainfall and temperature during the growing season on plot yields, Can. J. Res. 12:2, 306-34.

34. Horwitz, W. (Editor), Official methods of analysis of the Association of Official Agricultural Chemists. Assoc. of Official Agric. Chemists, Washington, D.C., 1955.

35. Ionita, M. and Slusanschi, H., Influence of sowing distance on the protein and fat content of maize, (French), Anal. Fac. Agron. cluj. 12: 121-6, 1949, (Field Crop Abstracts 2: 1286).

36. John-Dassbach and Zeitz, E., Results of brewing barley experiments, The effect of row spacing sowing rate and nitrogen manuring on yield and quality, and their interactions (Germany), Z. Acker-u, Pfl. Bau, 103:2, 157-80, 1955, (Field Crop Abstracts 11:61).

37. Kersting, J., Kansas farmers like narrow row sorghum, Soils and Crops 10:6, p. 12, 1958.

38. Klaukis, K., Tillering and yield of oat plants grown under different spacings, Note; Agron. J. 47:3, 147, 1955.

39. Kravcova, B.E., The intensity of translocation of assimilates to spring wheat grain when the crop is grown under different sowing densities. (Russian). Proc. Acad. Sci. U.S.S.R., 113:5, 1163-4, 1957, (Field Crop Abstracts 11:41).

40. Krustyn, A.O., Productivity of winter wheat plants with different tillering capacity, (Russian), J. Agric. Sci. U.S.S.R., 3:12, 53-6, 1959, (Field Crop Abstracts 12:1119).

41. Lang, A.L., Pendleton, J.W. and Dungan, G.H., Influence of population and nitrogen levels on yield and protein and oil contents of nine corn hybrids, Agron. J. 48:7, 284-9, 1956.

42. Larson, W.E. and Willis, W.O., Light, soil temperature, soil moisture and alfalfa-red clover distribution between corn rows of various spacings and row direction, Agron. J. 49:8, 422-6, 1957.

43. Laude, H.H., Biggest sorghum yield comes in 21-inch rows. Soils and Crops 5:5, p. 22, 1953.

44. Levi, I. and Anderson, J.A., Variations in protein content of plants, heads, spikelets and individual kernels of wheat, Can. J. Res. 28: 71-81, 1950.

45. Luginbill, P. Jr. and McNeal, F.H., Influence of seeding density and row spacings on the resistance of spring wheats to the wheat stem sawfly, J. Econ. Ent. 51:6, 804-6, 1958.

46. Mangels, C.E., Pre-harvest factors which affect wheat quality, Cereal Chemistry, 4:5, 376-88, 1927.

47. Martin, J.H. and Leonard, W.H., Principles of Field Crop Production, p. 463, The MacMillan Co., New York, 1949.

48. Mehlenbacher, V.C. (Editor), Official and tentative methods of the American Oil Chemists Society, 2nd Ed., American Oil Chemists Society, Chicago, 1946.

49. Meredith, W.O.S. and Olson, P.J., Cultural studies with barley, IV. Summary of results for yield and malting quality, Sci. Agric. 23: 237, 46, 1942.

50. Möes, A. , Productivity in spring barley in a clay zone. Rev. Agric. Brux. 7:11, 1302-5, 1954, (Field Crop Abstracts 8:413).

51. Neatby, K.W. and McCalla, A.G., The productivity of quality cereal crops in the park and wooded areas of Alberta, Bul. No. 30, The Dept. of Ext., Univ. of Alta, 1938.

52. Neustadt, M.H., Rapid testing of oil seeds for oil quality and iodine number of oil, Tech. Bul. No. 1171, U.S.D.A., 1957.

53. Paull, A.E. and Anderson, J.A., The effects of amount and distribution of rainfall on the protein content of Western Canadian wheat, Can. J. R.s. 20: 212-27, 1942.

54. Pendleton, J.W. and Dungan, G.H., Effect of row direction on spring oat yield, Agron. J., 50:341-3, 1958.

55. Pendleton, J.W., Effect of clover, row spacing and rate of planting on spring oats yields, Agron. J. 49:10, 555-8, 1957.

56. Putt, E.D. and Fehr, J.A., Effect of plant spacing, row spacings and number of plants per hill on Advance hybrid sunflower, Sci. Agric. 31:11, 489-92, 1951.

57. Putt, E.D., Sunflower Seed Production, Manitoba's newest agricultural industry, Co-op Vegetable Oils Ltd., Altona, Man. p. 9, 1948.

58. Putt, E.D. and Unrau, J., The influence of various cultural practices on seed and plant characteristics in the sunflower. Sci. Agric. 23:7, 384-99, 1943.

59. Romašenkov, D.D., Influence of tillering of spring wheat on yield and quality of grain, (Russian), Selek. Semenovod, 2: 30-35, 1950, (Field Crop Abstracts 3:801).

60. Shepherd, R.W., Linseed cultivation trials in East Anglia, 1948-50, Agriculture, London, 59:8, 381-5, 1952, (Field Crop Abstracts 6: 726).

61. Stefansson, B.R., Division of Plant Science, University of Manitoba, Unpublished data.

62. Thomas, I. and Cariss, H.G., Drill spacing and rate of seeding. Results of research station experiments, J. Dept. Agric. W. Aust. 1. (3rd Ser.), No. 2, 239-41, (Field Crop Abstracts 6:2).

63. Torssell, B., Methods and possibilities for improving the over-wintering of autumn sown oil seed crops. (Swedish) Svensk Frötidn 27:4, 43-7, 1958, (Field Crop Abstracts 12: 1459).

64. Waldron, L.R., Harris, R.H., Stoa, T.E., and Sibbitt, Protein and quality in hard red spring wheat with respect to temperature and rainfall, Bul. 311, Agric. Exp. Sta. N.D. Agric. College, 1942.

65. Waldron, L.R., Yield and protein content of hard red spring wheat under conditions of high temperature and low moisture, J. Agric. Res. 47:3, 129-47, 1933.

66. Wiggans, S.C. and Shaw, R.H., The effects of high temperatures at varying stages of growth on kernel productivity in oats, Proc. Iowa Acad. Sci. 65: 201-5, 1958, (Field Crop Abstracts 12: 1694).

67. Wiggans, S.C. and Frey, K.J., Tillering studies in oats, III, Effect of rate of planting and test weight, Agron. J. 49:10, 549-51, 1957.

68. Wilson and Myers, Field Crop Production, J.B. Lippincott Co., New York, p. 91, 1954.

69. Yamagata, H., Studies on the limit of possibility of the increase in number of leaves and grains of the main stem of rice varieties, 4. Influence of sunlight intensity, (Japanese) Bul. Fac. Agric. Yamaguti, 9: 1001-10, 1958, (Field Crop Abstracts 12: 1259.

70. Yoshida, H., Results of varying the dates of seeding and altering the spacing of stands on the growth of ears in spring oats, (Japanese), Proc. Crop Sci. Soc. of Japan, 24:3, 191-2, 1956, (Field Crop Abstracts 10:48).

71. Zuber, M.S., Smith, G.E., and Gehrke, C.W., Crude protein of grain, corn and stover as influenced by different hybrids, plant populations and nitrogen levels, Agron. J. 46:6, 257-6, 1954.

APPENDICES

Appendix 1. The effect of five row spacings on the number of tillers per plant in Selkirk wheat grown at three locations from 1957 to 1959.

		Row spacing in inches					L.S.D.*	
Location	Year	6	12	18	24	30	P.05	P.01
		Number of tillers per plant						
Univ.of Man.	1957	3.89	5.77	7.01	7.05	7.94	.85	1.17
	1959	5.29	6.68	8.30	8.84	10.42	1.63	2.25
Homewood	1958	4.19	6.90	7.69	9.04	9.59	2.27	3.18
	1959	6.30	8.92	11.37	12.60	11.59	2.10	2.86
Portage la Prairie	1959	4.37	9.66	7.32	7.22	10.17	1.55	2.13

* Least significant difference.

Appendix 2. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Selkirk wheat. (University of Manitoba, 1957)

Source of variance	D.F.	M.S.
Replicates	4	.50
Spacings	4	12.34 **
Error	16	.41
Total	24	

** Significant at 1% level of probability.

Appendix 3. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Selkirk wheat. (Homewood, 1958)

Source of variance	D.F.	M.S.
Replicates	3	.49
Spacings	4	18.06 **
Error	12	2.17
Total	19	

** Significant at 1% level of probability.

Appendix 4. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Selkirk wheat. (University of Manitoba, 1959)

Sources of Variation	D.F.	M.S.
Replicates	4	2,2560
Spacings	4	19,5992 **
Error	16	1,4742
Total	24	

** Significant at 1% level of probability.

Appendix 5. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Selkirk wheat. (Homewood, 1959)

Sources of Variation	D.F.	M.S.
Replicates	4	2,8955
Spacings	4	32,3664 **
Error	16	2,3804
Total	24	

** Significant at 1% level of probability.

Appendix 6. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Selkirk wheat. (Portage la Prairie, 1959)

Sources of Variation	D.F.	M.S.
Replicates	4	1,5924
Spacings	4	26,7292 **
Error	16	1,3235
Total	24	

** Significant at 1% level of probability.

Appendix 7. The effect of five row spacings on the number of tillers per plant in Garry oats grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches: 6	12	18	24	30	L.S.D.*: P.05	P.01
		Number of tillers per plant						
Univ. of Man.	1957	2.61	3.65	4.53	5.17	6.22	.64	.85
	1959	3.40	5.36	5.94	5.63	7.32	1.38	1.90
Homewood	1958	3.85	4.98	6.10	6.07	7.76	1.06	1.46
	1959	4.66	6.56	7.09	9.65	7.92	2.06	2.83
Portage la Prairie	1959	4.27	7.37	6.65	9.69	8.15	1.40	1.93
Average		3.76	5.58	6.06	7.24	7.47		

* Least significant difference.

Appendix 8. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Garry oats. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	.35
Spacings	4	9.58 **
Error	16	.21
Total	24	

** Significant at 1% level of probability.

Appendix 9. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Garry oats. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	4	
Spacings	4	10.56 **
Error	16	.63
Total	24	

** Significant at 1% level of probability.

Appendix 10. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Garry oats. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1,4471
Spacings	4	10,8919 **
Error	16	1,0503
Total	24	

** Significant at 1% level of probability.

Appendix 11. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Garry oats. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1,5562
Spacings	4	23,0308 **
Error	16	2,3345
Total	24	

** Significant at 1% level of probability.

Appendix 12. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Garry oats. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.1500
Spacings	4	20.0162 **
Error	16	1.0950
Total	24	

** Significant at 1% level of probability.

Appendix 13. The effect of five row spacings on the number of tillers per plant in Swan barley grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches					L.S.D.*	
		6	12	18	24	30	P.05	P.01
		Number of tillers per plant						
Univ. of Man.	1957	3.59	6.39	7.45	8.19	9.03	.85	11.08
	1959	4.93	6.92	8.10	9.92	10.41	2.40	3.30
Homewood	1958	4.04	4.73	5.95	6.62	8.87	1.44	1.98
	1959	7.06	7.58	9.08	10.91	11.02	1.78	2.45
Portage la Prairie	1959	5.37	8.12	10.13	9.45	9.44	2.16	3.03
Average		5.00	6.55	8.14	9.02	9.75		

* Least significant difference.

Appendix 14. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Swan barley. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	.34
Spacings	4	24.42 **
Error	16	.35
Total	24	

** Significant at 1% level of probability.

Appendix 15. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Swan barley. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	4	1.57
Spacings	4	17.62 **
Error	16	1.14
Total	24	

** Significant at 1% level of probability.

Appendix 16. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Swan barley. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	6.5412
Spacings	4	25.1580 **
Error	16	3.1806
Total	24	

** Significant at 1% level of probability.

Appendix 17. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Swan barley. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1.9677
Spacings	4	16.7968 **
Error	16	1.7415
Total	24	

** Significant at 1% level of probability.

Appendix 18. Analysis of variance. The effect of five row spacings on the number of tillers per plant in Swan barley. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	3.0620
Spacings	4	16.4121 **
Error	12	1.9491
Total	19	

** Significant at 1% level of probability.

Appendix 19. The effect of five row spacings on the number of basal branches per plant in Raja flax grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30	L.S.D.* P.05	P.01
		Number of basal branches per plant						
Univ. of Man.	1957	1.44	1.33	1.74	2.04	2.46	.43	.62
	1959	1.23	1.46	1.39	1.66	1.71	N.S.**	
Homewood	1958	1.26	1.30	1.61	1.56	1.75	N.S.	
	1959	1.06	1.18	1.34	1.51	1.29	N.S.	
Portage la Prairie	1959	1.00	1.05	1.10	1.24	1.14	N.S.	
Average		1.20	1.26	1.44	1.60	1.67		

* Least significant difference.
** No significance.

Appendix 20. Analysis of variance. The effect of five row spacings on the number of basal branches per plant in Raja flax. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	.09
Spacings	4	1.06 **
Error	15	.11
Total	23	

** Significant at the 1% level of probability.

Appendix 21. Analysis of variance. The effect of five row spacings on the number of basal branches per plant in Raja flax. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	.0855
Spacings	4	.1776
Error	12	.0719
Total	19	

Differences not significant.

Appendix 22. Analysis of variance. The effect of five row spacings on the number of basal branches per plant in Raja flax. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.0584
Spacings	4	.1967
Error	16	.0909
Total	23	

Differences not significant.

Appendix 23. Analysis of variance. The effect of five row spacings on the number of basal branches per plant in Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.1211
Spacings	4	.1425
Error	16	.0620
Total	24	

Differences not significant.

Appendix 24. Analysis of variance. The effect of five row spacings on the number of basal branches per plant in Raja flax. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	.0272
Spacings	4	.0397
Error	12	.0188
Total	19	

Differences not significant.

Appendix 25. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30	L.S.D.* P.05	P.01
		Bushels per acre						
Univ. of Man.	1957	14.2	33.8	33.7	27.2	21.0	3.4	4.8
	1959	32.5	23.3	9.2	9.5	5.4	5.7	7.8
Homewood	1958	51.6	44.7	37.1	34.8	27.3	5.6	7.8
	1959	30.1	27.4	20.0	19.4	15.2	2.6	3.5
Portage la Prairie	1959	30.1	17.5	13.6	11.4	8.4	7.2	10.0
Average		37.7	29.3	22.7	20.5	15.4		

* Least significant difference.

Appendix 26. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	59.18 **
Spacings	4	372.66 **
Error	16	6.67
Total	24	

** Significant at the 1% level of probability.

Appendix 27. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	6.94
Spacings	4	349.24 **
Error	12	13.06
Total	19	

** Significant at 1% level of probability.

Appendix 28. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	71.78 *
Spacings	4	656.66 **
Error	16	18.04
Total	24	

* Significant at 5% level of probability.

** Significant at 1% level of probability.

Appendix 29. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1.25
Spacings	4	18.82 **
Error	16	3.66
Total	24	

** Significant at 1% level of probability.

Appendix 30. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Selkirk wheat. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	76.55
Spacings	4	360.87 **
Error	16	29.30
Total	24	

** Significant at 1% level of probability.

Appendix 31. The effect of five row spacings on the yield (bushels per acre) of Garry oats grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches: 6	12	18	24	30	L.S.D.* P.05	P.01
		Bushels per acre						
Univ. of Man.	1957	115.4	106.1	98.2	81.6	71.1	12.1	16.6
	1957	104.4	86.7	69.2	61.6	61.1	13.1	18.0
Homewood	1958	101.2	85.0	78.4	70.8	70.3	8.4	11.8
	1959	56.4	54.2	42.2	39.0	34.3	12.6	17.3
Portage la Prairie	1959	65.8	45.5	34.0	29.7	31.0	6.7	9.2
Average		90.6	75.5	64.5	56.5	53.6		

* Least significant difference.

Appendix 32. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Garry oats. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	58.33
Row spacings	4	1622.58 **
Error	16	81.40
Total	24	

** Significant at 1% level of probability.

Appendix 33. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Garry oats. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	85.80
Row spacing	4	649.19 **
Error	12	29.52
Total	19	

** Significant at 1% level of probability.

Appendix 34. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Garry oats. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	138.22
Row spacings	4	1745.76 **
Error	16	95.10
Total	24	

**Significant at 1% level of probability.

Appendix 35. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Garry oats. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	35.10
Spacings	4	841.88 **
Error	16	88.34
Total	24	

** Significant at 1% level of probability.

Appendix 36. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Garry oats. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	56.86
Row spacings	4	1139.43 **
Error	16	24.97
Total	24	

** Significant at 1% level of probability.

Appendix 37. The effect of five row spacings on the yield (bushels per acre) of Swan barley at three locations from 1957 to 1959.

		Row spacing in inches					L.S.D.*	
Location	Year	6	12	18	24	30	P.05	P.01
		Bushels per acre						
Univ. of Man.	1957	66.5	57.2	46.3	37.6	28.8	9.0	12.5
	1959	68.4	64.8	62.3	44.9	42.0	10.3	14.2
Homewood	1958	72.0	46.0	43.8	34.9	30.0	13.5	18.5
	1959	47.0	39.9	34.0	26.5	27.0	N.S.**	
Portage la Prairie	1959	41.2	32.0	29.5	29.0	22.0	9.9	
Average		59.0	47.9	43.2	34.6	30.1		

* Least significant difference.
** No significance.

Appendix 38. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Swan barley. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	24.45
Row spacings	4	1,128.08 **
Error	16	45.47
Total	24	

** Significant at 1% level of probability.

Appendix 39. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Swan barley. (Homewood, 1958.)

Sources of variation	D.F.	M.S.
Replicates	4	189.12
Row spacings	4	1,324.92 **
Error	16	100.71
Total	24	

** Significant at 1% level of probability.

Appendix 40. Analysis of variance. The effect of five row spacings on the yield of (bushels per acre) Swan barley. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	160.55
Row spacings	4	735.60 **
Error	16	59.56
Total	24	

** Significant at 1% level of probability.

Appendix 41. Analysis of variance. The effect of five row spacings on the yield of (bushels per acre) Swan barley. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	106.31
Row spacing	4	304.61
Error	11	123.31
Total	18	

Differences not significant.

Appendix 42. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Swan barley. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	129.60
Row spacings	4	183.04 *
Error	12	41.28
Total	19	

* Significant at 5% level of probability.

Appendix 43. The effect of five row spacings on the yield (bushels per acre) of Raja flax grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30	L.S.D.* P.05	P.01
		Bushels per acre						
Univ. of Man.	1957	15.3	13.6	9.1	7.9	6.1	2.1	2.9
	1959	26.5	23.8	24.2	16.6	12.5	2.9	
Homewood	1958	20.4	23.4	19.7	16.2	15.2	N.S.**	
	1959	13.4	12.7	10.8	8.6	5.0	4.2	5.9
Portage la Prairie	1959	20.1	16.0	8.9	6.8	5.4	2.6	3.7
Average		19.1	17.9	14.5	11.2	8.8		

* Least significant difference.
** No significance.

Appendix 44. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Raja flax. (University of Manitoba, 1957)

Sources of variation	D.F.	M.S.
Replicates	4	6.89
Row spacings	4	75.80 **
Error	16	2.56
Total	24	

** Significant at 1% level of probability.

Appendix 45. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Raja flax. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	24.45
Row spacings	4	44.39
Error	12	19.28
Total	19	

Differences not significant.

Appendix 46. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Raja flax. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	12.13
Row spacings	4	173.95 *
Error	16	4.62
Total	24	

* Significant at 5% level of probability.

Appendix 47. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	6.03
Row spacings	4	45.82 **
Error	12	7.36
Total	19	

** Significant at 1% level of probability.

Appendix 48. Analysis of variance. The effect of five row spacings on the yield (bushels per acre) of Raja flax. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	29.44 **
Row spacings	4	160.03 **
Error	11	2.90
Total	18	

** Significant at 1% level of probability.

Appendix 49. Soil moisture content (percent of oven dry weights), as affected by three row spacings of Selkirk wheat at three crop stages. (University of Manitoba, 1959)

Sampling depth in inches	Stages: Emergence, Row spacing in inches: 6	18	30	Heading, Row spacing in inches: 6	18	30	Post Harvest, Row spacing in inches: 6	18	30
0-6	27.7%	41.1%	44.8%	29.9%	32.0%	32.0%	40.9%	39.7%	43.7%
6-12	38.6	38.5	38.9	26.8	29.1	32.2	39.2	37.7	38.7
12-24	37.1	37.0	36.0	26.9	28.2	28.7	32.4	35.0	36.3
24-36	34.6	34.2	32.5	26.3	27.1	29.5	30.6	31.6	33.3
36-48	33.8	33.6	34.7	27.9	26.9	27.5	35.3	33.1	34.5

Differences not significant.

Appendix 50. Analysis of variance. Soil moisture content (percent oven dry weight) as affected by three row spacings of Selkirk wheat at three crop stages. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	2	10.0
Stages	2	830.0 **
Error (a)	4	5.7
Main plots		
Row spacings	2	62.0
Row spacing x stages	4	7.8
Error (b)	12	32.3
Sub-plots		
Depths	4	158.8 **
Depths x stages	8	19.0
Depths x row spacings	8	20.9
Depths x row spacings x stages	16	20.1
Error (c)	72	11.8
Total	134	

** Significant at 1% level of probability.

Appendix 51. Soil moisture content (percent oven dry weight), as affected by three row spacings of Raja flax at three crop stages. (University of Manitoba, 1959)

Sampling depth in inches	Stages: Emergence — Row spacing in inches			Heading — Row spacing in inches			Post Harvest — Row spacing in inches		
	6	18	30	6	18	30	6	18	30
0-6	37.4%	44.6%	44.2%	24.2%	26.4%	33.4%	40.8%	36.8%	37.6%
6-12	38.7	40.4	41.0	23.4	25.8	32.6	38.1	37.0	36.8
12-24	35.0	38.9	38.5	24.6	27.2	30.0	32.3	34.5	40.0
24-36	36.2	34.4	34.7	28.3	27.6	29.0	29.0	32.0	33.0
36-42	34.2	35.2	33.4	25.6	27.8	28.6	30.6	32.9	34.0

Least significant difference at 5 percent level: 8.1
at 1 percent level:10.8

Appendix 52. Analysis of variance. Soil moisture content (per cent oven dry weight) as affected by three row spacings of Raja flax at three crop stages. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	21.7
Stages	2	1666.5 **
Error (a)	6	13.7
Main plot		
Row spacings	2	151.0
Row spacings x stages	4	29.2 *
Error (b)	18	9.9
Sub-plot		
Depths	4	154.0 **
Depths x stages	8	44.2
Depths x spacings	8	10.5
Depths x spacings x stages	16	21.4
Error (c)	108	8.5
Total	179	

* Significant at 5% level of probability.
** Significant at 1% level of probability.

Appendix 53. Seed increase of Selkirk wheat when grown under five different row spacings at three locations from 1957 to 1959. *

Location	Year	Row spacing in inches				
		6	12	18	24	30
		Bushels harvested for each bushel seeded				
Univ. of Man.	1957	35.4	54.1	81.0	87.2	84.0
	1959	26.0	37.3	22.1	30.4	21.6
Homewood	1958	41.3	71.5	89.2	111.5	109.2
	1959	24.1	43.8	48.1	62.2	60.8
Portage la Prairie	1959	24.1	28.0	32.8	36.5	33.6
Average		30.2	46.9	54.6	65.5	61.8

* Seed increase refers to bushels harvested for each bushel seeded.

Appendix 54. Seed increase of Garry oats when grown under five different row spacings at three locations from 1957 to 1959. ¥

Location	Year	Row spacing in inches 6	12	18	24	30
		Bushels harvested for each bushel seeded				
Univ. of Man.	1957	57.0	106.1	147.4	163.2	177.7
	1959	52.2	86.7	103.9	123.2	152.7
Homewood	1958	50.6	85.0	117.7	141.6	175.7
	1959	33.2	54.2	63.4	78.0	85.7
Portage la Prairie	1959	32.9	45.5	51.0	59.4	77.5
Average		45.2	75.5	96.7	117.7	133.9

¥ Seed increase refers to bushels harvested for each bushel seeded.

Appendix 55. Seed increase of Swan barley when grown under five different row spacings at three locations from 1957 to 1959. *

Location	Year	Row spacing in inches				
		6	12	18	24	30
		Bushels harvested for each bushel seeded				
Univ. of Man.	1957	44.3	76.3	92.6	100.3	96.0
	1959	45.6	86.4	124.6	119.7	140.0
Homewood	1958	48.0	61.3	87.6	93.1	100.0
	1959	31.3	53.2	68.0	70.7	90.0
Portage la Prairie	1959	27.5	42.7	59.0	77.3	75.3
Average		39.3	63.4	86.4	92.2	100.2

* Seed increase refers to bushels harvested for each bushel seeded.

Appendix 56. Seed increase of Raja flax when grown under five different row spacings at three locations from 1957 to 1959.

Location	Year	6	12	18	24	30
		Row spacing in inches				
		Bushels harvested for each bushel seeded				
Univ. of Man.	1957	24.5	43.6	44.0	49.7	48.8
	1959	42.4	76.3	116.9	107.1	100.0
Homewood	1958	32.6	75.0	95.2	104.5	121.6
	1959	21.4	40.7	52.2	55.5	40.0
Portage la Prairie	1959	32.2	51.3	43.0	43.9	51.4
Average		30.6	57.3	70.3	72.1	72.9

* Seed increase refers to bushels harvested for each bushel seeded.

Appendix 57. The bushel weight (in pounds) of Selkirk wheat when grown under five different row spacings at three locations from 1957 to 1959.

Location	Year	Row spacing in inches: 6	12	18	24	30
		Bushel weight in pounds				
Univ.of Man.	1957	60.0	59.2	59.0	59.0	59.0
	1959	59.8	56.1	54.5	57.1	54.2
Homewood	1958	64.0	64.0	64.0	63.7	63.7
	1959	57.0	56.7	56.1	56.1	56.0
Portage la Prairie	1959	56.7	55.0	54.9	55.5	55.1
Average		59.50	58.20	57.70	58.28	57.60

Appendix 58. The bushel weight (in pounds) of Garry oats when grown under five different row spacings at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30
		Bushel weight in pounds				
Univ.of Man.	1957	38.5	38.5	38.5	37.2	36.7
	1959	37.2	35.9	36.8	36.3	37.5
Homewood	1958	42.3	42.5	42.2	41.7	41.5
	1959	38.1	37.1	37.6	37.8	36.5
Portage la Prairie	1959	38.2	37.3	36.9	38.1	37.0
Average		38.86	38.26	38.40	38.22	37.84

Appendix 59. The bushel weight (in pounds) of Swan barley when grown under five different row spacings at three locations from 1957 to 1959.

		Row spacing in inches				
Location	Year	6	12	18	24	30
		Bushel Weight in pounds				
Univ.of Man.	1957	49.5	47.0	45.7	45.5	45.0
	1959	50.5	49.2	48.9	48.3	48.2
Homewood	1958	51.7	52.3	52.5	52.2	52.0
	1959	48.2	48.3	47.7	47.3	47.3
Portage la Prairie	1959	49.1	45.9	46.8	46.0	47.2
Average		49.80	48.54	48.32	47.86	47.94

Appendix 60. The bushel weight (in pounds) of Raja flax when grown under five different row spacings at three locations from 1957 to 1959.

		Row spacing in inches				
Location	Year	6	12	18	24	30
		Bushel weight in pounds				
Univ. of Man.	1957	55.0	54.7	54.7	54.5	54.0
	1959	54.8	55.4	55.2	55.7	55.9
Homewood	1958	54.0	54.0	54.0	54.0	54.5
	1959	54.5	54.6	54.4	54.6	54.1
Portage la Prairie	1959	54.5	54.4	54.2	55.1	54.8
Average		54.56	54.62	54.50	54.78	54.66

Appendix 61. The effect of five row spacings on the 1,000-kernel weight (in grams) of Selkirk wheat grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30	L.S.D.** P.05	P.01
		1,000-kernel weight in grams						
Univ.of Man.	1957*	35.00	37.85	37.00	37.10	36.00		
	1959	32.50	31.09	29.34	28.24	28.61	1.48	2.04
Homewood	1958	38.78	38.70	40.30	39.85	40.67	N.S.	
	1959	34.05	33.23	32.33	33.14	33.28	N.S.	
Portage la Prairie	1959	32.49	31.39	31.86	31.42	30.85	N.S.	
Average		34.56	34.45	34.17	33.95	33.88		

* Taken from bulked samples. Data not analyzed.
** Least significant difference.

Appendix 62. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Selkirk wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	4.88 *
Row spacings	4	16.12 **
Error	16	1.21
Total	24	

* Significant at 5% level of probability.
** Significant at 1% level of probability.

Appendix 63. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Selkirk wheat. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	4.3
Row spacings	4	4.3
Error	12	1.4
Total	19	

Differences not significant.

Appendix 64. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Selkirk wheat. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.08
Row spacings	4	1.86
Error	16	1.42
Total	24	

Differences not significant.

Appendix 65. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Selkirk wheat. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	5.63
Row spacings	4	1.87
Error	16	2.10
Total	24	

Differences not significant.

Appendix 66. The effect of five row spacings on the 1,000-kernel weight (in grams) of Garry oats grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches 6	12	18	24	30	L.S.D.** P.05	P.01
		1,000-kernel weight in grams						
Univ.of Man.	1957*	28.75	26.25	27.25	27.50	30.00		
	1959	27.47	28.08	28.17	28.36	28.74	N.S.	
Homewood	1958	33.00	33.04	33.02	34.08	34.20	.95	
	1959	27.66	27.93	29.12	29.71	29.02	1.00	1.37
Portage la Prairie	1959	28.45	28.66	29.16	29.95	29.28	N.S.	
Average		29.07	28.79	29.34	29.92	30.25		

* Taken from bulked samples. Data not analyzed.

** Least significant difference.

Appendix 67. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Garry oats. (University of Man., 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.44
Row spacing	4	1.07
Error	16	.42
Total	24	

Differences not significant.

Appendix 68. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Garry oats. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	4	.25
Row spacings	4	1.75 *
Error	16	.50
Total	24	

* Significant at 5% level of probability.

Appendix 69. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Garry oats. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.16
Row spacing	4	3.72 **
Error	16	.55
Total	24	

** Significant at 1% level of probability.

Appendix 70. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Garry oats. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.89
Row spacings	4	1.72
Error	16	.61
Total	24	

Differences not significant.

Appendix 71. The effect of five row spacings on the 1,000-kernel weight (in grams) of Swan barley grown at three locations from 1957 to 1959.

		Row spacings in inches					L.S.D.**	
Location	Year	6	12	18	24	30	P.05	P.01
		1,000-kernel weight in grams						
Univ. of Man.	1957*	34.00	36.00	34.25	35.10	37.00		
	1959	33.06	36.08	35.42	35.77	36.15	.91	1.25
Homewood	1958	33.10	35.25	35.40	37.45	38.18	1.78	2.52
	1959	32.34	32.38	34.81	35.00	35.70	1.85	
Portage la Prairie	1959	30.51	31.41	32.72	32.77	36.58	1.98	2.78
Average		32.62	34.22	34.52	35.22	36.72		

* Taken from bulked samples. Data not analyzed.

** Least significant difference.

Appendix 72. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Swan barley. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1.24
Row spacings	4	8.23 **
Error	11	.46
Total	24	

** Significant at 1% level of probability.

Appendix 73. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Swan barley. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	1.0
Row spacings	4	16.2 **
Error	11	1.3
Total	18	

** Significant at 1% level of probability.

Appendix 74. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Swan barley. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	6.53 *
Row spacings	4	8.09 *
Error	11	1.44
Total	18	

* Significant at 5% level of probability.

Appendix 75. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Swan barley. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	1.06
Row spacings	4	22.40 **
Error	12	1.68
Total	19	

** Significant at 1% level of probability.

Appendix 76. The effect of five row spacings on the 1,000-kernel weight (in grams) of Raja flax grown at three locations from 1957 to 1959.

Location	Year	Row spacing in inches					L.S.D.**	
		6	12	18	24	30	P.05	P.01
		1,000-kernel weight in grams						
Univ. of Man.	1957*	5.40	5.50	4.90	4.60	5.30		
	1959	6.61	6.50	6.64	6.59	6.46	.13	
Homewood	1958	6.27	6.29	6.43	6.44	6.45	.13	
	1959	6.20	6.53	6.52	6.54	6.17	.20	.28
Portage la Prairie	1959	6.92	6.60	6.62	6.56	6.60	N.S.	
Average		6.28	6.28	6.22	6.15	6.20		

* Taken from bulked samples. Data not analyzed.
** Least significant difference.

Appendix 77. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Raja flax. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.0075
Row spacings	4	.0300 *
Error	16	.0094
Total	24	

* Significant at 5% level of probability.

Appendix 78. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Raja flax. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	.040
Row spacings	4	.030 *
Error	11	.008
Total	18	

* Significant at 5% level of probability.

Appendix 79. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	.0033
Row spacings	4	.1500 **
Error	12	.0167
Total	19	

** Significant at 1% level of probability.

Appendix 80. Analysis of variance. The effect of five row spacings on the 1,000-kernel weight (in grams) of Raja flax. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	.0133
Row spacings	4	.0250
Error	12	.0125
Total	19	

Differences not significant.

Appendix 81. The effect of five row spacings on the percent protein of Selkirk wheat grown at three locations in 1958 and 1959.

		Row spacing in inches					L.S.D.*	
Location	Year	6	12	18	24	30	P.05	P.01
		Percent protein						
Univ. of Man.	1959	17.4	18.4	19.6	19.7	20.1	.6	.8
Homewood	1958	12.5	13.1	13.9	14.9	17.0	.9	1.3
	1959	13.8	15.1	16.3	16.6	17.2	.8	1.1
Portage la Prairie	1959	16.6	18.2	18.9	19.2	18.9	.8	1.1
Average		15.1	16.2	16.7	17.6	18.3		

* Least significant difference.

Appendix 82. Analysis of variance. The effect of five row spacings on the percent protein of Selkirk wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.82*
Row spacings	4	6.08**
Error	15	.20
Total	23	

* Significant at 5% level of probability.

** Significant at 1% level of probability.

Appendix 83. Analysis of variance. The effect of five row spacings on the percent protein of Selkirk wheat. (Homewood, 1958)

Sources of variation	D.F.	M.S.
Replicates	3	.13
Row spacings	4	12.48 **
Error	12	.36
Total	19	

** Significant at 1% level of probability.

Appendix 84. Analysis of variance. The effect of five row spacings on the percent protein of Selkirk wheat. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	2.98 **
Row spacings	4	9.02 **
Error	16	.39
Total	24	

** Significant at 1% level of probability.

Appendix 85. Analysis of variance. The effect of five row spacings on the percent protein of Selkirk wheat. (Portage la Prairie, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1.21 *
Row spacings	4	5.70 **
Error	16	.37
Total	24	

* Significant at 5% level of probability.
** Significant at 1% level of probability.

Appendix 86. Analysis of variance. The effect of five row spacings on the percent protein of Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	1.06
Row spacings	4	3.25
Error	12	1.41
Total	19	

Differences not significant.

Appendix 87. Analysis of variance. The effect of five row spacings on the oil content (in percent) of Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	2.06
Row spacings	4	.78
Error	12	1.53
Total	19	

Differences not significant.

Appendix 88. Analysis of variance. The effect of five row spacings on the refractive index of oil extracted from the seeds of Raja flax. (Homewood, 1959)

Sources of variation	D.F.	M.S.
Replicates	3	.04
Row spacings	4	.09
Error	12	.11
Total	19	

Differences not significant.

Appendix 89. Tillering, yield, 1000-kernel weight and protein content of four spring wheat varieties grown at five row spacings. (University of Manitoba, 1959)

	Row spacing in inches				
Variety	6	12	18	24	30
			Tillers per plant		
Lerma	5.24	5.17	7.79	7.63	9.24
Lee	3.78	5.45	6.28	8.22	7.22
Thatcher	4.87	6.55	7.60	8.13	7.46
Selkirk	5.09	8.47	8.08	10.25	9.37
			Yield (bushels per acre)		
Lerma	29.1	16.0	12.4	11.4	8.5
Lee	45.1	25.7	20.7	17.2	13.1
Thatcher	22.2	12.4	8.4	6.9	5.5
Selkirk	29.9	21.3	14.1	10.4	8.2
			1000-kernel weight (grams)		
Lerma	29.58	26.85	26.44	26.09	26.04
Lee	32.40	32.11	32.02	31.84	30.88
Thatcher	22.20	21.64	21.59	21.04	20.45
Selkirk	32.22	30.28	29.02	26.95	28.89
			Protein content (per cent)		
Lerma	14.9	16.3	17.0	17.2	17.7
Lee	17.0	17.4	18.0	18.1	18.2
Thatcher	15.4	16.1	16.7	17.2	17.4
Selkirk	17.4	18.4	19.0	19.4	19.4

Appendix 90. Analysis of variance. The effect of five row spacings on the number of tillers per plant in four varieties of spring wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	1.7084
Varieties	3	18.2791 *
Error (a)	12	4.4382
Main plot	19	
Row spacings	4	48.8108 **
Varieties x row spacings	12	2.8795
Error (b)	64	2.9958
Total	99	

* Significant at 5% level of probability.
** Significant at 1% level of probability.

Appendix 91. Analysis of variance. The effect of five row spacings on the yield (in bushels per acre) of four varieties of spring wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	15.76
Varieties	3	761.65 **
Error (a)	12	23.16
Main plots	19	
Row spacings	4	1,615.48 **
Varieties x row spacings	12	36.54 **
Error (b)	64	9.58
Total	99	

** Significant at 1% level of probability.

Appendix 92. Analysis of variance. The effect of five row spacings on the 1,000-kernel weights (in grams) of four va rieties of spring wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	3.18
Varieties	3	505.63 **
Error (a)	12	2.25
Main plot	19	
Row spacings	4	23.30 **
Varieties x row spacings	12	3.53 **
Error (b)	64	1.17
Total	99	

** Significant at 1% level of probability.

Appendix 93. Analysis of variance. The effect of five row spacings on the percent protein of four varieties of spring wheat. (University of Manitoba, 1959)

Sources of variation	D.F.	M.S.
Replicates	4	.91
Varieties	3	26.90 **
Error (a)	12	.36
Main plot	19	
Row spacings	4	13.17 **
Varieties x row spacings	12	.35
Error (b)	64	.19
Total	99	

** Significant at 1% level of probability.