EFFECTS OF SEEDING RATE, ROW SPACING, RATES AND METHODS OF APPLICATION OF FERTILIZER MATERIALS AND SOIL MOISTURE ON SMALL GRAIN PERFORMANCE

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This is to certify that the

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H. D. Foth
Major professor

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Kundan Lall Kinra

AN ABSTRACT

Submitted to the School of Advanced Graduate Studies of
Michigan State University of Agriculture and Applied
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DOCTOR OF PHILOSOPHY

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ABSTRACT

Four field experiments were carried out with winter wheat, during 1957-59, to study the effects of seed rate, row spacing, fertilizer rate, placement of fertilizer and their two-factor interactions on culm count, culm height, vigor score, lodging score, yield, test weight, and protein content of grain and to study the interrelationships between several of these characteristics.

Laboratory studies were carried out, during 1958-60, to study the effects of different moisture levels and types of soil on the emergence of wheat, oat and barley seedlings when different rates and types of fertilizer were placed with the seed and to study the differential effects of two ordinary superphosphates.

Increasing seed rate gave an increase in fall culms per square foot, in height and vigor of plants, in yield and test weight, a decrease in the percent of protein in grain, and no specific trend in summer culms per square foot and in lodging.

Increasing row spacing gave an increase in percent of protein in grain, a decrease in fall and summer culms per square foot, height and vigor of plants, and no specific trend for lodging score and test weight. Seven-inch spacing gave practically the same yield as 11-inch spaving but 14-inch spacing gave about 5 bushels per acre less yield than 7-inch spacing.

Fertilizer applied at 300 pounds per acre gave more fall culms, taller and more vigorous plants, less lodging and grain with a lower percent of protein than did 600 pounds per acre. Practically no differences existed in summer culm count, yield or test weight between the two levels of fertilizer.

Side placement gave a greater number of fall and summer culms, taller, more vigorous plants, greater lodging, greater yield, higher test weight, and grain with a lower percent of protein than did contact placement.

Increasing seed rate gave an increase in number of fall culms per square foot, taller and more vigorous plants, higher yield and lower protein content in grain, regardless of row spacing, fertilizer rate or placement.

Increasing row spacing gave a decrease in number of fall and summer culms per square foot, shorter and less vigorous plants, lower yields, and higher protein content in the grain, regardless of seed rate, fertilizer rate or placement.

The higher rate of fertilizer gave a decrease in number of fall culms per square foot, shorter, less vigorous plants less subject to lodging, and grain higher in protein content, regardless of seed rate, row spacing or placement.

Side placement of fertilizer gave more fall and summer culms per square foot, taller and more vigorous plants more subject to lodging, higher yield and test weight, and lower protein content in grain than contact placement, regardless of seed rate, row spacing or fertilizer rate.

There were indications of significant (at the 1% level) positive associations between fall culm count and height of plants, between fall culm count and vigor of plants and between height and vigor of plants.

Fall culm count gave stronger relationships with yield and test weight than did summer culm count.

No consistent relationships were obtained between fall culm count and summer culm count, lodging score and yield, summer culm count and test weight, yield and test weight.

Emergence data indicated that nitrogen was more detrimental per unit than potash, and potash than phosphate.

Ammonium sulphate was more toxic than ammonium chloride, potassium sulphate more toxic than potassium chloride, and the latter more toxic than potassium nitrate.

When the same amount of fertilizer was placed in contact with the wheat seed, greater toxicity occurred in sandy (Oshtemo sand) than in soil rich in organic matter (Granby loamy sand).

Fertilizer placed in contact with wheat had a greater effect on delaying or reducing emergence as the moisture level was reduced below field capacity.

The detrimental effects of nitrogen increased at a much faster rate than the effects of potash or phosphate as the soil moisture was reduced.

As the moisture level of Plainfield sand was reduced from 8.0 to 7.6 per cent, the emergence of wheat seedlings was somewhat reduced (1 week counts) but the final emergence percentages (3 week counts) were the same for the 2 levels of soil moisture.

Oats and barley were less susceptible to injury (3 weeks count) than was wheat from contact placement of fertilizer when equal amounts were applied.

In general, the emergence of oats at the end of 1 week was much lower than that of wheat or barley. By the end of 3 weeks there

was not much difference between oats and barley in percent emergence.

The higher water soluble fluorine content of superphosphate F1, as compared to superphosphate F2, was considered the major factor in causing superphosphate F1 to be more detrimental than superphosphate F2 on the emergence of wheat seedlings.

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Dedicated to my Mother

and

In memory of my Father

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TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

TABLE		Page

I. INTRODUCTION

As early as 1733 Jethro Tull (59) noted that "too much nitre corrodes a plant." During the past 2 or 3 decades, important developments in the chemical fertilizer industry have resulted in the production of higher analysis fertilizers. Increased rates of application of these more concentrated fertilizers have made it necessary to restudy the effects of fertilizer placement for small grain crops, because all too frequently the comment of Jethro Tull seemed to apply to the conditions at hand.

Recent research investigations at Michigan State University clearly indicated the need for further studies regarding the use of these more concentrated fertilizers at greater than traditional rates of application. In addition, a need existed for studying the effects of seeding rate, row spacing, fertilizer rate, placement of fertilizer and their two-factor interactions on various characters.

The purposes of present research were:

1. To study the effects of seed rate, row spacing, fertilizer rate, placement of fertilizer and their two-factor interactions on culm count, culm height, lodging score, yield, test weight, and protein content of wheat.

2. To study the interrelationships between various characters of winter wheat.

3. To study the effects of different moisture levels and types of soil on emergence of wheat, oat, and barley seedlings when different rates and types of fertilizers are placed with the seed.

4. To study the differential effects of two ordinary superphosphates.

II. REVIEW OF LITERATURE

Effect of Cultural Practices and Fertilizer on Culm Count of Wheat

Comparatively little has been published dealing with the subject of culm count of winter wheat. The amount of tillering or stooling which gives the number of culms for each plant is affected by moisture, fertility, and physical conditions of the soil. Contradictory conclusions have been reported in the literature by the several investigators.

Buffum (10) planted spring wheat seeds 1, 2, 4, and 14 inches apart in 36 inch rows and found that the number of culms increased when planted a wide distance apart.

Grantham (18) found that early seeding of winter wheat was accompanied by a higher tillering. He used 4 and 8 pecks of seed per acre in his study and found that the thicker seeding produced fewer tillers per plant. Nitrogen and phosphate seemed to stimulate the production of tillers but potash had little or no effect.

Harris and Maughan (24) studied the effects of soil moisture during various stages of wheat growth and found that the soil moisture during the early stages in the growth of plant determined largely the number of culms sent up by each plant. In general, tillering increased with an increase in the soil moisture level until very high saturations were reached.

Luginbill and McNeal (37) found that phosphorus applied alone or in combination with nitrogen and/or potash fertilizer significantly increased the number of culms at harvest time in winter wheat.

Neither nitrogen nor potash when applied alone or in a mixture of the two showed significant differences in the numbers of culms.

Olson and Dreier (43) reported that "damage to germination under critical soil moisture is apparent at 10 pounds N per acre, increasing to the point of stand elimination with 160 pounds N per acre. Potash with the seed at 30 pounds K_2O per acre commonly reduced stand, but losses were not of the magnitude occasioned by 40 pounds N per acre."

Effect of Seed Rate on Yield and Test Weight of Winter Wheat

Percival (45) reported that "the number of straws or ears and the average weight of the ears are the factors controlling the yield per acre." Under thick sowing conditions the number of ears per acre is increased, but the weight of an individual ear is decreased. A thinly sown crop gives more tillers per plant bearing a higher average weight of ear.

Nevertheless, if the seed rate was much less, the greater tillering and weight of each ear did not compensate for the loss of plants incurred by thin sowing.

Percival further reported that in countries where the rainfall is low, a seed rate of less than 4 pecks was used. Such condition existed in Australia and many drier parts of the United States. In western Europe, with its higher rainfall, the seed rate varied between 8 and 16 pecks per acre.

Coffman (13) seeded wheat at the rate of 1, 2, 3, 4,5 and 6 pecks per acre over a period of six years, 1913-1918. The maximum average yield was obtained at 6 peck rate, having gradually risen to

23.6 bushels from 14.7 bushels for 1 peck rate. No specific trend was noted for test weight in relation to seeding rate, although maximum text weight occurred at the heaviest rate.

Coffman also reported the average yields of wheat for a period of 3 years, 1920-1922. A gradual increase of 6.9 bushels in yield was obtained as the rate of seeding was increased from 1 to 5 pecks per acre. A gradual increase in test weight was reported with increase in seeding rate. Five peck rate gave 1 pound per bushel higher test weight as compared to 1 peck rate.

Kiesselbach (29) seeded wheat at Nebraska Station at the rate of 3, 4, 5, 6 and 8 pecks per acre for a period of 5 years, 1919-1923. He found a gradual increase in yield up to 6 pecks seed rate. This was followed by a decline in yield at 8 peck rate. Test weight was not affected by seeding rate.

Brown and Down (9) reported in 1937 the results obtained from 6 rates of planting conducted by F. A. Spragg and E. E. Down at East Lansing for a period of 3 years, 1919-1921. The seed rates used were 3, 4, 5, 6, 7 and 8 pecks per acre. A gradual increase of 5.03 bushels in yield was obtained as the seed rate was increased from 3 to 7 pecks per acre. This was followed by a decrease in yield from 20.53 to 19.88 bushels per acre when seeding rate was increased from 7 to 8 pecks per acre.

Pendleton and Dungan (44) planted wheat in Illinois at 3, 6, 9, 12, 15 and 18 pecks per acre. When all 6 rates of seeding were compared on a net yield basis, the 6 pecks per acre gave the highest yield. The test weight increased from 57.2 to 57.3 as seed rate was increased from 3 to 6 pecks per acre. This was followed by a gradual decrease in test weight from 57.3 to 56.7 pounds per bushel as seeding rate was increased from 6 to 18 pecks per acre.

Effect of Row Spacing on Yield of Wheat

Salmon (53) planted wheat in Kansas in rows varying from 8 to 16 inches apart at seeding rates of 3, 4, and 6 pecks per acre. Over a period of four years there was very little tendency towards a falling off in yield with an increase in distance between rows until a distance of 14 inches was reached.

Kiesselbach et al. (30) seeded wheat in 4-, 7-, and 14-inch rows in Nebraska. Over a period of three years, the yield of grain was 4 percent lower at the 4- than at the 7-inch spacing, the yield of grain was 10.2 percent lower at the 14- than at the 7-inch spacing.

Thatcher and Lewis (57) reported that 7-inch row spacings gave a mean average yield of 34.4 bushels per acre, while 14-inch spacings yielded only 31.7 bushels per acre.

Harrington (22) studied small grains with drill rows 6-, 12-, and 18-inches apart. He found that with wheat there was a definite downward trend in yields as the distance between rows increased.

Locke and Mathews (35) reported that wheat seeded with 7-inch spacings gave only slightly better yields than when seeded with 14-inch spacings.

Blackman and Snell (5) found that an alternate spacing of 7- and 14-inches between winter wheat resulted in a 7.1 percent higher yield over a uniform spacing of 7 inches, and 22.9 percent higher yield as compared to 14 inch spacings.

Cook et al. (14) working with different fertilizer materials, rates and placement on winter wheat performance reported that 7-inch row spacings gave a mean average yield of 35 bushels per acre, while 14-inch spacings yielded only 31 bushels per acre.

Effect of Fertilizer on Yield of Wheat

Murphy (42) reported that neither nitrogen nor potash nor their combinations increased the yield of wheat. These fertilizers singly or together in various combinations yielded less than unfertilized plots. As soon as phosphate was introduced into the fertilizer, the yield was increased. Phosphate and potash combinations gave larger yields than phosphate and nitrogen or a combination of all the three elements.

Black *et al.* (4) reported that nitrogen increased the yield in 12 of 15 experiments conducted over a three-year period. The efficiency of nitrogen utilization declined with increasing rate of nitrogen application, averaging 3.7 pounds of nitrogen per bushel of wheat where the rate of nitrogen application was 20 to 40 pounds per acre and 6.5 pounds where the rate of nitrogen application exceeded 40 pounds per acre.

Smith (56) reported that application of 25 pounds each of nitrogen and phosphate per acre gave highly significant increases in yield when both of these were placed with the seed or nitrogen was utilized as spring top dressing. The use of potassium bearing fertilizer in addition to nitrogen plus phosphate did not cause an additional increase in the yield of wheat. Application of 50 pounds of nitrogen per acre with the seed did not give as good yields as did the 25 pounds of nitrogen when applied with the seed or as spring top dressing.

Bains (2) reported that application of 60 pounds of nitrogen per acre; 25 pounds of phosphate per acre; and 60 pounds of nitrogen plus 25 pounds of phosphate per acre increased wheat yields approximately 30, 49, and 40 percent, respectively, over the check plots.

Gingrich and Smith (17) established 4 wheat experiments at various locations in the eastern part of Kansas for the crop year 1950-1951. Rates of nitrogen were 0, 25, 50, and 100 pounds per acre; rates of phosphate and of potash were 0, and 25 pounds per acre. Greatest increase in yield of wheat accompanied the heaviest application of nitrogen, with single exception of one location which recently had been in alfalfa. The application of potash plus phosphorus increased the yield of wheat at this location, mostly due to phosphorus. The application of potash increased the yield appreciably where no nitrogen was added.

Williams and Smith (61) conducted experiments at 4 locations in Kansas. Rates of nitrogen used were 0, 25, 50, and 100 pounds per acre; rates of phosphate were 0, 50 and 100 pounds per acre; and rates of potash were 0, 25, and 100 pounds per acre. These materials were used alone and in combinations. Increases in yield were obtained by the application of nitrogen at all the locations. Increases in yield were noted when phosphate was included in the treatment, whereas potash had no effect.

McNeal and Davis (40) found that application of up to 100 pounds of nitrogen per acre at seeding time increased the wheat yields.

Olson and Dreier (43) reported that application of 10 pounds of nitrogen per acre with the seed occasionally caused reductions in yield. Thirty pounds of potash per acre with the seed commonly reduced yield but losses were not of the magnitude occasioned by 40 pounds nitrogen per acre. The above results were in comparison with placement of fertilizer not in contact with the seed. It was also reported that neither of these losses occurred every year, nor were they uniform across the state during the period the experiment was conducted.

Ramón and Laird (50) grew wheat on soil irrigated to 1, 40, 55, and 67 percent available moisture. Applications of 45, 90, and 135 pounds of nitrogen per acre increased grain yields at a gradually diminishing rate. The effects of applied nitrogen on grain yields were very largely dependent on soil moisture conditions. Grain yields were increased from 10.2 to 66.5 bushels per acre in the optimum soil moisture treatment and from 9.7 to 35.9 bushels per acre in the driest treatment by the application of 135 pounds of nitrogen per acre.

Carter and Foth (11) reported that an application of 20, 40, or 80 pounds of nitrogen per acre on wheat at planting time gave a significant increase in yield over the check plots in four of the six blocks.

Effect of Fertilizer on Test Weight of Wheat Grain

Murphy (42) reported that there was no effect of superphosphate (16% P_2O_5), or nitrate of soda (16.5% nitrogen), or kainite (12.4% K_2O) on test weight of wheat, when applied alone or in combination.

McNeal and Davis (40) and Carter and Foth (11) found that applications up to 100 pounds of nitrogen per acre did not affect the test weight of wheat, and Pope (49) found similar results with applications up to 150 pounds of nitrogen per acre.

Smith (56) worked with the effect of time, and method of application of 0, 25, 50, and 100 pounds of nitrogen per acre; 0, 25, and 50 pounds of phosphate per acre alone or in combination with nitrogen; and 25 pounds of phosphate in combination with 25 pounds of nitrogen plus 25 pounds of potash per acre. He reported that none of the fertilizer treatments produced a significant increase in the test weight of wheat over that of no treatment. However, test weight was significantly

reduced at 1% level in two treatments. These were the application of 25 pounds of nitrogen plus 25 pounds of phosphate per acre in plowsole, and the application of 100 pounds of nitrogen per acre with the seed. A significant decrease at 5% level was observed in another two treatments: the application of 100 pounds nitrogen per acre as spring top dressing, and the application of 50 pounds of nitrogen plus 50 pounds of phosphate per acre with the seed.

Williams and Smith (61) applied the same treatments at 4 locations in Kansas. At 2 locations (Goddard and Thayer), there was no effect due to treatment. At the Belleville location, "the 100 pound and 50 pound rates of nitrogen decreased the test weight significantly. The reduction in test weight was greatest for the 50 pound rate of nitrogen when applied alone." At Manhattan a decrease in test weight for the following treatments was observed: a) 100 pounds of nitrogen plus 50 pounds of phosphate plus 25 pounds of potash per acre; b) 25 pounds of nitrogen per acre; c) 50 pounds of nitrogen plus 50 pounds of phosphate per acre.

Effect of Fertilizer on Protein Content of Wheat Grain

The effects of fertilizers at seeding time on the protein content of wheat grain is a controversial matter.

Murphy (42) used superphosphate (16% P_2O_5), nitrate of soda, and kainite in a study in which the total fertilizer applied was 300 pounds per acre. He reported that the application of nitrogen at the rates of 12.4, 24.8, 37.2, and 49.5 pounds per acre increased the protein content over the check plots, but with the introduction of phosphate in the fertilizer, by itself or with potash, the protein content decreased.

Bains (3) reported that application of 60 pounds of nitrogen per acre increased the protein content and the application of 25 pounds of phosphate per acre decreased the protein content over check. However, the application of 60 pounds of nitrogen plus 25 pounds of phosphate per acre restored the protein content to that of the control.

Williams and Smith (61) found that protein content was increased by nitrogen fertilizer alone or in combination with phosphorus and/or potash fertilizer.

Pope (49) found that protein content was not affected by the application of 50 pounds of nitrogen per acre over check, but was affected by the larger rates of application, 100 - 150 pounds of nitrogen per acre.

Peterson (46) and Carter and Foth (11) reported that applications of 20, and 40 pounds of nitrogen per acre increased the protein content over check.

Ramón and Laird (50) found that protein content decreased with the application of 45 pounds of nitrogen per acre. With the application of 90 pounds of nitrogen per acre, the protein content was equal to that of the treatment without applied nitrogen. The application of 135 pounds of nitrogen per acre produced greatest increase in protein content.

In contrast to the previous mentioned findings, Smith (56) reported that application of 25, 50, and 100 pounds of nitrogen per acre; 50 pounds of phosphate, or phosphate and nitrogen each at the rate of 25 or 50 pounds per acre; or a combination of 25 pounds each of nitrogen, phosphate and potash per acre did not significantly influence the protein content.

Petrosini and Leone (47) reported a similar lack of effectiveness with either nitrogen or phosphate fertilization on the protein content.

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McNeal and Davis (40) and Rennie (51) found that application of up to 100 and 192 pounds of nitrogen per acre, respectively, had no effect on the protein content.

Relationships Between Wheat Plant Characteristics

Grantham (18) reported an increase in yield per head accompanied the increase in the number of tillers per plant up to 4 or 5 tillers; beyond that yield per head was more or less uniform.

Buffum (10) reported that the late-formed secondary stems were barren or produced lower yields of grain per head or were later in maturity than the primary stems in the case of excessive tillering.

Laude (31) at Kansas State College found a close correlation between yield and number of heads per unit area during 1932, 1934, 1935, and 1937 for winter wheat seeded at different dates. "The best three ecological conditions in 1933 when yields were about 45 bushels indicate an inverse relation for both number of heads and test weight when compared with yield." Relationship between test weight and yield was studied during 1932 and 1933. In 1932, yield was positively associated with test weight five out of six cases and negatively associated in sixth case. In 1933, yield was positively correlated with test weight in four cases and negatively correlated in three cases. Correlation coefficients were not reported in the paper.

Locke et al. (34) reported the results of studies made at the Southern Great Plains Field Station, Woodward, Oklahoma, from 1929 to 1934. He concluded that neither the number of plants per unit area nor the number of heads per plant greatly explained the differences in yield, as these characters tended to compensate for each other.

Welton and Morris (60) reported that early lodging reduced grain yields more than late lodging.

Eldredge (16) reported that straws broken over as the heads were beginning to emerge resulted in reduction of yields about 50 percent. A gradual decrease in injury at succeeding weekly intervals occurred until just before ripening time when there was reduction of approximately 10 percent. Protein content was higher in lodged than in the non-lodged grain. Test weight was affected less by lodging in the 5-day period just before heading than later or earlier.

Laude and Pauli (32) reported a yield reduction equal to about one third due to lodging 1 - 2 weeks before heading and 1 - 2 weeks after heading. When lodging took place 2 - 3 weeks after heading, reduction in yield was about one fourth. The damage continued to decrease as lodging occurred later until the binder ripe stage, after which lodging caused no decrease in yield of grain.

Effect of Fertilizer Placement on Seedling Emergence

Truog (58) compiled about 200 references dealing with the method of applying fertilizer and made available in a condensed form most of the work done on the subject up to 1928. He pointed out that serious injury to germination, when fertilizer was placed with the seed, was less to small grains than to corn, owing to a much lower concentration of fertilizer per linear foot.

During the past 20 - 30 years, important developments in the chemical fertilizer industries have resulted in the production of higher analysis fertilizers. Increased rates of application of these more concentrated fertilizers have made it necessary to restudy the effects of fertilizer placement for small grain crops.

Harris (23) reported the toxicity of 13 salts on wheat germination in three soils. The most toxic is given first and the least last in any series. The order of toxicity in Greenville loam was: NaCl, $CaCl_2$, KNO_3, $(NH_4)_2CO_3$, $NaNO_3$, KCl, $Mg(NO_3)_2$, $MgCl_2$, Na_2CO_3, $MgSO_4$, K_2SO_4, Na_2SO_4, K_2CO_3, The order of toxicity in College loam was: NaCl, $CaCl_2$, $NaNO_3$, KCl, $MgCl_2$, KNO_3, $Mg(NO_3)_2$, $(NH_4)_2CO_3$, $MgSO_4$, Na_2CO_3, K_2SO_4, K_2CO_3. The order of toxicity in sand was: $(NH_4)_2CO_3$, NaCl, K_2CO_3, $NaNO_3$=KCl, $CaCl_2$, $MgCl_2$, Na_2CO_3, KNO_3, $Mg(NO_3)_2$, K_2SO_4, Na_2SO_4, $MgSO_4$. In general the order of detrimental effects of anions were in the following order: chloride, nitrate, carbonate and sulphate.

Allison (1) reported that concentration of salt, irrespective of kind, is the primary cause of injury to germination and seedling growth. He obtained similar effects from ammonium nitrate, sulphate and phosphate.

Salter (54) reported the anions commonly found in fertilizers in the following decreasing order of toxicity: nitrate, chloride, sulphate, and phosphate. He also reported a greater degree of toxicity in sandy soils than in clay or muck soils.

Olson and Dreier (43) in 1954 reviewed 24 articles related to the subject of fertilizer placement. He found that, in both field and laboratory, it was at a low moisture level at which the most serious damage of fertilizer salts to germination occurred, but full germination was not assured at any soil moisture level without a surface increment of moisture sufficient to leach fertilizer away from the seed. Emergence loss from nitrogen adjacent to the seed at low moisture level was in direct proportion to the time interval before rain or irrigation raised the level. In general, nitrogen materials were more

detrimental per unit than potash, and potash more than phosphate. Damage to germination was apparent at the rate of 10 pounds of nitrogen per acre, increasing to the point of stand elimination with 160 pounds of nitrogen per acre. "Straight carriers of phosphate cause little damage, but ammonium phosphates of 1:1:0 ratio are harmful when placed with the seed under conditions of limited moisture."

Guttay (19) found 100 pounds or more of nutrients per acre in contact with wheat seed seriously reduced germination and emergence. Phosphate was as injurious as nitrogen and potash. Fertilizer placed in contact with wheat had greater effect in delaying and reducing emergence under dry than under moist conditions. Oats were less susceptible to injury from contact placement of fertilizer than wheat.

Chapin (12) in 1959 found 20 to 100 pounds of nitrogen and 20 to 100 pounds of potash per acre in contact with wheat at planting time in soil at or near field capacity had little effect upon final germination. Delay in seedling emergence was observed with the heavier rate causing the greater delay. Fertilizers placed with the wheat, at or near the permanent wilting point, greatly reduced germination and even prevented germination with the higher rates of fertilizer application. Nitrogen at rates comparable to amounts of potash, caused greater delay in germination and greater final reductions than did potash.

Lawton and Davis (33) reported on the influence of application of 500 pounds per acre of 2 fertilizers, 5-20-0 and 5-20-20 in the greenhouse on emergence of wheat seedlings, under optimum moisture conditions. The fertilizer was applied by five different methods: liquid spray on the soil surface; contact with the seed; 1 1/2 inches directly below the seed; 1 1/2 inches below and to the side of the seed; and 1 1/2 inches below and 3 1/2 inches to the side of the seed.

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No significant differences were reported in the rate of emergence for any fertilizer placement except that of in contact with the seed. In the case of 5-20-0 applied in contact with the seed, the emergence was delayed for about 3 days and total emergence was 99% at the end of 8 days after planting. In the case of 5-20-20 in contact with the seed, seedlings started to emerge on the 7th day and at the end of 2 weeks after planting, only 62% emergence was observed.

Brage *et al.* (8), investigating applications of equal pounds of nutrients per acre with winter wheat, reported higher stand reduction by application of ammonium nitrate than superphosphate. He also observed higher emergence of wheat by application of ammonium nitrate than ammonium sulphate when equal amounts of nitrogen from both sources were applied with the seed. The decreasing order of toxicity reported for various anions were sulphate, nitrate and phosphate. Barley gave better stand count than wheat when equal amounts of ammonium nitrate applied in both the cases.

Effect of Fluorine on Seedling Emergence

Hendricks *et al.* (25) and Jacob *et al.* (27) have shown that fluorine is, generally, a part of the raw mineral phosphate in all deposits.

Marshall *et al.* (39) Jacob *et al.* (28) and Hill *et al.* (26) reported that rock phosphate contains more than 3 but usually less than 4 percent fluorine. Moreover, the second mentioned of the investigators reported that in the production of ordinary superphosphate about 11 to 42 percent of fluorine in phosphate rock is volatilized during the mixing and denning process.

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Jacob et al. (28) reported that small quantities are also lost during the subsequent handling of fresh superphosphate. He reported that the values of total fluorine of den superphosphate from Florida pebble varies between 1.49 and 2.01 percent; and of granulated superphosphate varies between 1.63 and 1.66. The values of total fluorine in superphosphate varies from manufacturing plant to plant and the source of rock phosphate used in its production.

Blanck (6) reported an average value of 1.64 percent fluorine for normal superphosphate and 1.56 percent fluorine for concentrated superphosphate.

No data have been published as to what amount of fluorine in superphosphate is water soluble.

Sigmund (55) working with peas, corn, and rape seeds found that a 0.5% solution of KF entirely prevented germination.

Bokorny (7) found that a 0.1% solution of NaF was very injurious to cress seedlings and that a 0.1% solution of HF completely prevented the germination of cress, barley, peas, flax, and bean seeds.
He attributed the toxicity to the passage of fluorine into the seed where it is united with the calcium present to form calcium fluoride.

Allison (1) found that heavy application of 18% superphosphate greatly reduced the germination of wheat grown in tumblers.

Rost (52) in greenhouse and field trials found that both 16 and 46% superphosphate were injurious to corn at heavy rates of application. The 46% superphosphate was more toxic in equivalent amount than the 16% superphosphate. Contact with the soil for one month before planting largely overcame the toxicity of both fertilizers.

Morse (41) placed corn seeds for 24 hours in pastes made by moistening with distilled water superphosphates with 20% and 44% P_2O_5 and monocalcium phosphate. Seeds were also placed in 0.1 M phosphoric acid, rock phosphate plus water (5 gm./100 cc.), 0.143N sulfuric acid, and rock phosphate plus 0.143N sulfuric acid (5 gm/100cc.) for 24 hours. After 24 hours, the seeds were recovered and washed with distilled water and tested for germination by "rag doll" method. No germination occurred in the seeds subjected to either of the superphosphates or rock phosphate plus sulfuric acid treatment. The pH of sulfuric acid, phosphoric acid and monocalcium phosphate were much lower than the treatments which showed complete toxicity. He concluded that acidity was not responsible for the toxicity.

Morse, in another experiment, found the major reason for toxicity in superphosphate was the amount of water soluble fluorine present, but toxicity was modified by higher osmotic concentration and higher acidity. It was also reported that superphosphate with a high amount of soluble fluorine was more toxic than the one having a lower amount of soluble fluorine. Hydrogen fluoride was more toxic than NaF. The addition of soil to the superphosphate solution caused a marked reduction in the soluble fluorine content and in the acidity. More than 12 times as much superphosphate with soil added was required to produce the same degree of toxicity obtained when superphosphate was used without soil.

III. METHODS AND MATERIALS

Field Experiments

a) Kleis Farm, Ingham County, 1957-58

Genesee wheat was planted from September 18 through 20, 1957, in plots 6 feet wide and 68 feet long on Conover silt loam soil. The soil is an imperfectly drained Gray-Brown Podzolic developed in calcareous, non-stratified, medium-textured, glacial till. No drainage problem was observed during the period the experiment was conducted.

A total of 48 treatments was used consisting of: 3 seed rates -- 2, 4, and 6 pecks per acre; 4 row spacings -- 7, 9, 11, and 14 inches; 2 fertilizer rates -- 300 and 600 pounds of 8-20-20 per acre; 2 placements -- contact and 2-inch below and 1-inch to the side of the seed. The 8-20-20 fertilizer was obtained by mixing at rate of 114.3 pounds diammonium phosphate (21-53-0) to 100 pounds of muriate of potash (0-0-60). The mixture was prepared shortly before planting.

The field experiment was a complete randomized block design, replicated 5 times. All 5 replications were used for yield and test weight determinations. The first four replications were used for fall culm count, vigor, and height readings. Replications 2, 3, and 4 were used for summer culm count (near-harvest time). Replication 1 was not included for the summer culm count as it showed greater lodging than the other replications.

Fall culm counts were made on 3-foot sections of row from the second, middle, and next to the last row. They were taken from 192 plots on October 5, 1957. The sample from the second row was taken

from a distance of about 3 feet from the northern end of the plot; the sample from the middle row was taken from near the middle of the plot; and the sample from the next to the last row was taken from a distance of about 3 feet from southern end of that plot.

Height of the plants was also actually measured at 5 randomly chosen locations in each plot on October 5, 1957. Height was measured, to the nearest inch, from the base of the plant to the tip of the leaf when stretched upward.

Growth, fall stand, and height of the plants were considered as the main factors affecting vigor, which was estimated on October 5, 1957. The best plots were rated as 10, the poorest as 2 and the others in between.

Summer culm count was made on July 11, 1958 from the second row and next to the last row in each plot at approximately the same location as that of the fall culm counts. All tillers were counted provided they were taller than about 8 inches and regardless of presence or absence of head.

Lodging score observations were taken on July 22, 1958. Plots showing no lodging were graded as zero, a little as one, flat ones as 9, and other in between.

Grain was harvested with a self-propelled combine. The grain was weighed to the nearest half-pound and then converted to bushels per acre. Plots 1 - 20 regardless of treatment, in each of first four replications were harvested on July 26, 1958. Rains caused a delay in the harvesting of the remaining plots until August 4 and 5. The test weight of grain was determined by the number of grams per quart and converting to pounds per bushel.

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b) Ferden Farm, Saginaw County, 1957-58

Dual wheat was planted in plots 6 feet wide and 68 feet long on Sims clay loam soil on September 24 and 25, 1957. The Sims is a poorly drained Humic Gley developed in moderately fine-textured, calcareous, lacustrine deposits. The field had both tile and open ditch drains, but the slowly permeable subsoil impeded the rate of water removal.

The experiment consisted of the same 48 treatments as in the case of the Kleis farm experiment and the order of planting was also kept the same. The field experiment was a complete randomized block design with 4 replications. All replications were used for yield and test weight determinations. Replications 1 and 2 were used for fall and summer culm count.

For fall culm count, samples from 3-foot sections from second and next to the last rows were taken on November 12, 1957. The samples from these rows were taken in a manner similar to the previous experiment. Summer culm count was made on July 18, 1958, in each plot at approximately the same locations as of the fall culm count.

The plots were harvested on July 23, 1958. Test weight was determined by standard procedure.

Samples from each plot were saved for total nitrogen determination. The 4 replications of a treatment were composited to give one sample per treatment for chemical analysis. Though the analyses were run in duplicate, only the averages were used in the analysis of variance. Total nitrogen determinations were made by the Kjeldahl method with certain modifications as described by Pierce and Haenisch (48). The percentage protein was calculated by multiplying the total nitrogen content by the factor 6.25.

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c) Fick Farm, Calhoun County, 1958-59

Genesee wheat was planted on September 26, 1958, in plots 6 feet wide and 50 feet long on Kalamazoo sandy loam soil. This soil is a well drained Gray-Brown Podzolic developed on coarse textured outwash material. The soil is naturally low in organic matter and is one of the more droughty agricultural soils in the vicinity. A total of 16 treatments were used consisting of: 2 seed rates, 4 and 6 pecks per acre; 2 row spacings--7 and 11 inches; 2 fertilizer rates--300 and 600 pounds of 8-20-20 per acre; 2 placements--contact and 2 inch below and 1 inch to the side of the seed. The field experiment was a complete randomized block design, replicated 4 times. All of the replications were used for culm count, yield, and test weight determinations.

For fall culm count four 50-inch sections from each plot were taken at random on October 16, 1958.

The crop was harvested on July 10-11, 1959. Yield in bushels per acre and test weight in pounds per bushel were determined by standard procedures.

d) Ferden farm, Saginaw County, 1958-59

Dual wheat was planted on September 25, 1958 in plots 6 feet wide and 50 feet long on Sims clay loam soil. The characteristics of this soil type have already been described in connection with field experiment b, Ferden Farm, 1957-58 wheat crop. The experiment consisted of the same 16 treatments as that of the Fick Farm experiment. The order of planting was also kept the same as that of the Fick Farm experiment. The experiment was a complete randomized block design replicated 4 times. All replications were used for culm count, yield, and test weight determinations.

For fall culm count two 50-inch sections from each plot were taken at random on October 28, 1958.

The crop was harvested on July 12, 1959. Yield in bushels per acre and test weight in pounds per bushels were determined by standard procedures.

Planting Machine

An experimental grain drill designed by the AERD, ARS, USDA was used in these field experiments. Special features of this drill as reported by Hansen *et al*. (21) are:

(i) Top delivery fertilizer hoppers for precision calibration of fertilizer rate.

(ii) Micrometer adjustment facilities for seed boxes.

(iii) Fertilizer placement components which operate independently of seed placement mechanism.

(iv) Fertilizer placement mechanism which is adjustable in both vertical and horizontal directions.

(v) Seed placement mechanism with both vertical and horizontal adjustments.

(vi) Row spacing variations from 7 to 60 inches.

(vii) Presswheels following single disc openers for seed.

Laboratory Experiments

a) Emergence Study

Three soils used in this study were the Oshtemo sand and Plainfield sand from the Rose Lake Conservation Area, Clinton County and the Granby loamy sand from the University Farm, Ingham County. Soil was collected down to a depth of about 7 inches. The soil was then air dried and passed through a quarter inch mesh screen. The screening served the purpose of removing trash and other coarse materials.

The three soils were brought to field capacity moisture level. As determined by the tension table procedure, they were weighed daily for one week and distilled water was added to maintain the condition.

Plainfield sand was also brought to 5.6, 6.7, 7.6, and 8.0 percent moisture levels. The soil was kept in air-tight containers for a period of one week for the soil-moisture to come to equilibrium.

Plastic boxes, having an inside area 3 1/2 inches x 7 1/2 inches and a depth of 3 inches, were filled to a depth of 1 inch with soil. The soil was levelled and packed lightly with a plastic plate slightly narrower than the box. Twenty-four seeds were placed at equal distances in a continuous line approximately 5/8 inch in from the sides of the box, giving a length of row of 17 inches. Fertilizer was placed in a narrow band on top of the seeds. Another 1 inch of soil was then added and packed lightly. The containers were covered and kept at room temperature for a period of 21 days for emergence study. Each treatment was replicated 3 times.

The emergence of wheat (Seneca), oats (Gary), and barley (Hudson) was counted after removing the cover every second or third day until the count became constant. The cover was put back immediately after counting. Laboratory treatments and materials used are shown in Tables 2.1 to 2.10.

Calculation of the amount of fertilizer to apply was based upon an area equal to the linear length (17 inches) times 7 inches (the usual distance between grain rows in the field).

An acre, on basis of rows 7 inches apart, would give an effective linear length of $\frac{43560 \times 12}{7}$ or 74674 feet.

For example, at the rate of 100 pounds per acre the material required for 17 inches linear length would be $\frac{17 \times 100 \times 453.6}{12 \times 74674}$ or .86 gms.

b) Differential Effects of Two Ordinary Superphosphates

Three methods of approach were used in this study:

a) Hydrogen ion concentration--Dilutions of superphosphate with distilled water, varying in ratio from 1:2 to 1:35 were used in measuring pH with a glass electrode assembly.

b) Total acidity--A standard procedure was used.

c) Fluorine content

i) Qualitative test--A standard method of testing was used.

ii) Total and water soluble fluorine content--The method of analysis. used for total and water soluble fluorine was a combination of the following two methods with certain modifications:

Method 1. Method of determination of fluorine in soils as is given by the Association of Official Agricultural Chemists (1955) page 39.

Method 2. Method of determination of fluorine in insecticides containing no organic matter as is given by the Association of Official Agricultural Chemists (1955) page 54-55.

The procedure used is given below:

I. Preparation of Standard Curve

(a) Dilute portions of the standard NaF solution, containing from 0-200 mmg. in 20 mmg increments, respectively, to 100 ml. in 250 ml. beaker.

(b) Add 2 ml. of the alizarin indicator.

(c) Neutralize to faint pink with 0.05 N and 0.01 N NaOH.

(d) Adjust to pH 3.0 with buffer solution.

(e) Titrate to faint pink end point by addition of 0.01 N $Th(NO_3)_4$ solution from the microburet graduated in 0.01 ml.

(f) Plot the curve using F as the abscissa and ml. $Th(NO_3)_4$ as the ordinate. In plotting curve, correct for titration blank.

II. Determination of Total Fluorine

(a) Weigh 1 gm. of fertilizer and with aid of little water transfer to 250 ml. claisen distilling flask containing 12 glass beads and adjust to 30 ml. with distilled H_2O.

(b) Connect to condenser.

(c) Close flask with a 2-hole rubber stopper, through which pass thermometer and steam in-let tube, both of which extend into solution.

(d) Bring water in steam generating flask to boiling point.

(e) Add 25 ml. of conc. H_2SO_4 through the side arm of claisen flask. Close the side arm with a rubber stopper.

(f) Connect steam inlet tube with the steam generator.

(g) Light burner under claisen flask.

(h) Regulate flow of steam by adjusting burner flames so that volume of solution is held constant and temperature of 145-150^{o} C. is maintained in distilling flask.

(i) Continue distillation until about 400 ml. distillate is collected in 500 volumetric flask.

(j) Dilute to 500 ml. with distilled water.

(k) Transfer 2.5 ml. aliquot to 250 ml. beaker and dilute to 100 ml.

(l) Proceed as in I, b-e.

(m) Read the value from the standard curve.

(n) Calculate the per cent of fluorine from the following equation:

$$\%F = \frac{\text{mmg as read from curve} \times 500 \times 100}{2.5 \times 10^6}$$

III. Determination of Water Soluble Fluorine

(a) Weigh 2 gm. of sample and transfer to a 250 ml. erlenmeyer flask.

(b) Add 100 ml. of H_2O and close with a rubber stopper.

(c) Shake for 4 hours on a gyrotory shaker.

(d) Filter through double filter paper (#41).

(e) Transfer 50 ml. of solution to 250 ml. claisen flask containing 12 glass beads.

(f) Proceed as II, b-j.

(g) Transfer 10 ml. aliquot to 250 ml. beaker and dilute to 100 ml.

(h) Proceed as II, 1-m.

(i) Calculate the per cent of fluorine from the following equation:

$$\%F = \frac{\text{mmg read from curve} \times 500 \times 100}{10 \times 10^6}$$

IV. Notes

1. In step I-c--Use .05 N NaOH till the color becomes orange and then add .01 N NaOH to get faint pink end-point. If one uses .05 NaOH all the way, the change of color is so sudden that one might miss the desired point. If one uses only .01 N NaOH, the quantity needed would be greater than is convenient.
2. In step I-d--Add buffer drop by drop to adjust to pH 3.0. If pH goes below 3.0, one can raise it by addition of NaOH solution, but it has usually given lower values.
3. In step III-c--Shaking for a period of 2 hours, 4 hours or 6 hours does not make any difference in results.
4. In step III-d--Use double filter paper #41 as single filter paper does not give clear solution.

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5. In step III-e--It is necessary to distill the solution obtained in III-d, in order to eliminate the interference of phosphorus as that interferes with the titration.
6. It is desirable to use a white background to compare the end-point with blank.

Computation

Statistical significance was determined by analysis of variance and use of Duncan's Significant Studentized Range Test (15). Any difference greater than the corresponding R. E. value was considered significant at that level. The R. E. (20) value is the range of equality which is obtained when using the maximum number of means being compared.

To determine whether two coefficients of correlation differ significantly from one another, the Love (36) procedure was followed.

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IV. RESULTS AND DISCUSSION

I. Field Experiments

Due to the fact that the 2 bushel seed rate and 9- and 14-inch row spacings were omitted in 1958, not all of the comparisons made on the 1957 crop can be made on the 1958 data.

A. Fall Culm Count

Average values, with respective ranges of equality (R. E.), and analysis of variance of fall culm count of wheat per square foot are presented in Table 1. 1.

Single Factors

(i) Seed rate: On the average, the plots seeded at 6 pecks per acre gave the greatest number of culms per square foot. This was true at all 4 locations. The increase was highly significant over plots seeded at the rate of 4 pecks per acre and the 4 peck rate gave a highly significantly greater number of culms than 2 peck rate at both locations.

One would expect the number of culms to increase with increase in seeding rate, but at a diminishing rate. The expected trend was true in all 4 cases. Similar findings have been reported by earlier investigators (8, 16).

(ii) Row spacing: Seven- and 9-inch row spacing did not behave in the same manner in 1957. Seven-inch row spacing gave a highly significantly greater number of culms over 11-inch row spacing at 3 out of the 4 locations. In the 4th location, Fick farm, the findings were just the reverse.

Table 1.1 Fall culm count of wheat, per square foot basis, obtained on Kleis and Ferden farms, 1957-58, and on Fick and Ferden farms, 1958-59.

Location	Kleis	Ferden	Fick	Ferden
Date	Oct. 5, 57	Nov. 12, 57	Oct. 16, 58	Oct. 28, 58
A. Average values with respective ranges of equality (R.E.)				
General	12.5	24.6	5.1	31.6
Seed rate, 2 pks/A	6.8	13.8	-	-
4 pks/A	11.5	25.5	4.3	27.2
6 pks/A	19.2	34.6	5.9	35.9
R.E. 5% level	1.0	1.6	0.5	2.3
1% level	1.4	2.1	0.6	3.1
Row spacing, 7 inches	13.3	28.2	4.2	35.7
9 inches	14.0	25.3	-	-
11 inches	11.9	20.6	6.0	27.4
14 inches	10.7	24.6	-	-
R. E. 5% level	1.2	1.9	0.5	2.3
1% level	1.6	2.4	0.6	3.1
Rate of fert. 300 lbs/A	13.4	26.7	5.3	33.1
600 lbs/A	11.5	22.6	4.9	30.1
R.E. 5% level	0.8	1.2	N.s.	2.3
1% level	1.1	1.6		3.1
Placement contact	11.0	19.9	1.3	27.9
side	13.9	29.3	8.8	35.2
R.E. 5% level	0.8	1.2	0.5	2.3
1% level	1.1	1.6	0.6	3.1

B. Analyses of variance

	Kleis Df.	Kleis M.Sq.	Ferden Df.	Ferden M.Sq.	Fick Df.	Fick M.Sq.	Ferden Df.	Ferden M.Sq.
C. V. %	20.2		12.2		18.6		14.7	
Source	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.
Error	117	6.4	70	9.1	50	0.92	50	21.5
Replicates	2		1		3		3	
		F		F		F		F
Seed rate (S)	2	298.5**	2	283.9**	1	43.6**	1	56.0**
Row spacing (R)	3	11.9**	3	25.9**	1	53.3**	1	50.7**
Rate of fert. (F)	1	19.2**	1	44.6**	1	3.0	1	6.9*
Placement (P)	1	46.0**	1	234.1**	1	980.5**	1	39.6**
SxR	6	1.7	6	14.8**	1	14.6**	1	4.0
SxF	2	1.2	2	6.4**	1	<1	1	<1
SxP	2	23.8**	2	13.1**	1	22.4**	1	2.5
RxF	3	1.9	3	1.6	1	5.7*	1	1.7
RxP	3	10.1**	3	11.9**	1	31.9**	1	1.8
FxP	1	9.7**	1	16.3**	1	14.1**	1	39.7**

*Significant at 5% level
**Significant at 1% level

At Fick farm, the soil was acid (pH 5.5) in nature. In acid soils, the fixation of added phosphate is great. Fertilizer rate on an acre basis was kept constant. Hence, in the wider spaced rows, more fertilizer down the row was used, so that, if the same amount of fixation took place, there would be more phosphate available in the wider spaced rows. This might result in having more culms per square foot in plots with 11-inch row spacings than in plots with 7-inch row spacings.

It was expected that there would be more culms in close rows than wide rows because all had been seeded at the same rate per square foot and not linear foot. Grantham (16) and Buffum (8) reported thicker seeding produced fewer tillers per plant. The results given in Table 1.1 are not completely in accordance with these expectations. This is seen in the 1957 Ferden farm 11- and 14-inch row spacings and in the 1958 Fick farm 7- and 11-inch row spacing. The reason for reverse results at Fick farm have been given in the previous paragraph.

(iii) Rate of fertilizer: Fertilizer applied at 300 pounds per acre gave more culms than did 600 pounds at all the 4 locations.

With higher fertilizer rate, there would be more detrimental effect of soluble salt on emergence as compared to lower rate. The retarding and the inhibiting actions of excess soluble salts on seed germination have long been known and reported by many investigators (12, 19, 33, 43, 58).

(iv) Placement of fertilizer: Placing the fertilizer 2 inches below and 1 inch to the side of the seeds gave greater number of culms per square foot than did contact placement at all the 4 locations. This was what was expected from the work of previous investigators (12, 19, 33, 43, 58).

Where fertilizer is placed with the seed, the salt concentration and the osmotic pressure of the area immediately surrounding the seed is increased. Seeds cannot get adequate amounts of moisture due to this raised osmotic pressure. The toxicity of certain ions and the inhibiting action of soluble excess salts on seed germination have been reported by many investigators (7, 12, 19, 41, 52, 55, 58).

Interactions

The discussion thus far has been concerned with the average reaction which may be attributed to each of the factors--rate of seeding, row spacing, rate of fertilizer, and placement of fertilizer--by itself. But these averages involve many effects due to the interactions of the above four factors with each other and with other factors which could not be evaluated.

Some of these interaction effects may be considered as due to two factors, some due to three factors, and some due to the four factors operating simultaneously. By the analysis of variance method these several types of interaction effects may be isolated statistically. The evaluation of the meaning of a three-factor interaction, which interaction is similar to a fourth dimensional figure, is rather difficult to explain. For this reason, the discussion on interaction effects is limited to two-factor (three dimensional) interactions. The third dimension is the magnitude of the character being measured.

In discussing interactions it must be borne in mind that an interaction mean-square tends to measure the failure of similar increase, or decrease, in the numerical magnitude of the successive levels of one factor, say S, as one progresses from one level to the successive level of the other factor, say R. For there to be no interaction in the analysis of variance table, the arithmetic change from R_1 to R_2 will be exactly the same in both S_1 and S_2. If it is not exactly the same, then the

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the interaction mean square is not zero. The greater the failure of these differences to be the same, the greater the mean square. Whether the interaction mean square is due primarily to a true organic interaction between the two factors concerned or whether it is due to other causes cannot be determined by mere inspection of either the interaction mean square or its F-value.

In Table 1.1 are shown the fall culm count F-values for each of the six two-factor interactions in each of the four experiments. The two-way tables for all the interactions are presented in Tables 1.1.a to 1.1.f.

(a) Seed rate x row spacing, Table 1.1.a. With an increase in row spacing and a constant rate of seeding in bushels per acre, the number of seeds per linear foot would increase. Likewise increasing the seed rate for a constant width of row would also cause an increase in number of seeds per linear foot. This over-crowding of seeds might be expected to have detrimental effects upon the number of culms present after emergence. The two-way tables tend to indicate that the detrimental effect of increasing the number of seeds per linear foot of row did enter into at least 3 of the experiments. In 4th experiment, Fick farm, the findings were just the reverse. Possible reasons could be the same as already stated under seed rate, namely, the acid nature of the soil.

It is interesting to note that where this interaction was not significant, some rainfall occurred within a week after seeding. The rains might have lowered the osmotic pressure and salt concentration, and, hence, might have provided better emergence conditions.

(b) Seed rate x fertilizer rate, Table 1.1.b. We would expect an interaction between these two factors, if no rainfall occurred for a considerable period after seeding. Under dry conditions the higher [illegible] culm count of wheat, per square foot basis, at four locations as affected by seed rate and row spacing.

Table 1.1.a Fall culm count of wheat, per square foot basis, at four locations as affected by seed rate and row spacing.

Seed Rate pks/A	1957								1958			
	Kleis farm Row spacing in inches				Ferden farm Row spacing in inches				Fick farm Row spacing in inches		Ferden farm Row spacing in inches	
	7	9	11	14	7	9	11	14	7	11	7	11
2	6.9	7.7	7.5	4.9	17.0	15.6	12.0	10.6	-	-	-	-
4	11.9	13.6	10.6	9.8	31.0	22.0	18.0	31.1	3.0	5.6	30.2	24.3
6	21.0	20.6	17.5	17.4	36.4	38.2	31.6	32.0	5.5	6.3	41.2	30.6

Table 1.1.b Fall culm count of wheat, per square foot basis, at four locations as affected by seed rate and fertilizer rate.

Seed Rate pks/A	1957				1958			
	Kleis farm fertilizer rate		Ferden farm fertilizer rate		Fick farm fertilizer rate		Ferden farm fertilizer rate	
	300 lbs/A	600 lbs/A	300 lbs/A	600 lbs/A	300 lbs/A	600 lbs/A	300 lbs/A	600 lbs/A
2	7.2	6.3	14.5	13.1	-	-	-	-
4	12.6	10.4	28.9	22.1	4.6	4.1	28.9	25.6
6	20.4	17.9	36.7	32.5	6.1	5.7	37.3	34.5

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fertilizer rate and higher seeding rate would be more detrimental than lower rate of fertilizer and higher seeding rate. The two-way tables indicate the detrimental effect of increased seed rate and fertilizer rate. In general, 300 pounds of fertilizer was less detrimental than 600 pounds. Increase in seed rate did not give increase in number of culms to the same proportion.

The interaction was highly significant in only 1 (Ferden farm, 57) of 4 cases reported. Table 3.5 indicates that no rainfall occurred at Ferden farm for a period of about 3 weeks after seeding, whereas, such a long dry period did not occur in 2 other cases, see Table 3.4 and 3.6. In the 4th case, Fick farm, no rainfall data were recorded.

(c) Seed rate x placement, Table 1.1.c. As seeding rate was increased, the number of seeds per linear foot was increased which would lead to a crowding condition. Contact placement would be more detrimental at higher seeding rate than side placement because of increased detrimental effects of close contact of seeds with the fertilizer and crowding condition. This would lead to an interaction. The interaction was highly significant in 3 out of 4 cases. In the 4th case, Ferden farm, (58), the trend was in the same direction as evident from Table 1.1.c. The lack of significance is due to big error line (Table 1.1).

(d) Row spacing x fertilizer rate, Table 1.1.d. As the fertilizer rate was increased, the amount of fertilizer per linear foot was increased which would lead to a higher salt concentration and hence greater detrimental effects on germination. With increase in row spacing, it would be expected that detrimental effects of higher rate would increase at a much faster rate than with the lower rate of fertilizer. The two-way tables indicate the expected trend in 3 out of 4 cases. In the 4th case, Fick farm, the interaction was due to inconsistent results.

Table 1.1.c Fall culm count of wheat, per square foot basis, at four locations as affected by seed rate and placement.

Seed rate pks/A	1957 Kleis farm placement contact	1957 Kleis farm placement side	1957 Ferden farm placement contact	1957 Ferden farm placement side	1958 Fick farm placement contact	1958 Fick farm placement side	1958 Ferden farm placement contact	1958 Ferden farm placement side
2	5.4	8.1	10.6	16.9	--	--	--	--
4	11.8	11.2	21.4	29.6	1.1	7.5	24.5	30.0
6	15.9	22.4	27.7	41.4	1.6	10.2	31.3	40.4

Table 1.1.d Fall culm count of wheat, per square foot basis, at four locations as affected by row spacing and fertilizer rate.

Row spacing in inches	1957 Kleis farm fertilizer rate 300 lbs/A	1957 Kleis farm fertilizer rate 600 lbs/A	1957 Ferden farm fertilizer rate 300 lbs/A	1957 Ferden farm fertilizer rate 600 lbs/A	1958 Fick farm fertilizer rate 300 lbs/A	1958 Fick farm fertilizer rate 600 lbs/A	1958 Ferden farm fertilizer rate 300 lbs/A	1958 Ferden farm fertilizer rate 600 lbs/A
7	13.8	12.8	30.2	26.1	4.1	4.3	36.4	29.7
9	14.3	13.6	26.5	24.0	--	--	--	--
11	13.4	10.4	22.4	18.7	6.5	5.5	34.9	25.2
14	12.0	9.4	27.7	21.4	--	--	--	--

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(e) Row spacing x placement, Table 1.1.e. With an increase in row spacing, the number of seeds, as well as amount of fertilizer, per linear foot of row, was increased, because seed rate and fertilizer rate, on an acre basis,were kept constant. In general, the differences between contact and side placement became much greater with increased row spacing. This differential action and lack of consistency in data caused the interactions. The interaction was considerable in 3 out of 4 cases. In the 4th case, Ferden farm, 58, the trend was in the same direction.

(f) Fertilizer rate x placement, Table 1.1.f. The detrimental effects of increased fertilizer rate and contact placement have been discussed separately. Table 1.1.f shows the differential action on fall culm count which occurs when fertilizer and placement are considered together. This differential response was great enough to cause the interactions to be highly significant in all 4 cases.

B. Summer Culm Count

Average values, with respective ranges of equality (R.E.), and analyses of variance for summer culm count of wheat per square foot area are presented in Table 1.2.

Single Factors

(i) Seed rate: The 2 cases studied show inconsistent results. No significant differences occurred as to culm count at Kleis farm location. At Ferden Farm location 4 pecks seed rate gave the highest culm count followed by 2 peck and then 6 pecks seed rate. No reasonable explanation can be attributed for such inconsistent behavior.

(ii) Row spacing: Both cases studied show a consistent decrease in number of culms per square foot with increase in row spacings.

Table [illegible] Fall culm count of wheat, per square foot basis, at four locations as affected by row spacing and placement.

Table 1.1.e Fall culm count of wheat, per square foot basis, at four locations as affected by row spacing and placement.

Row spacing in inches	1957				1958			
	Kleis farm placement		Ferden farm placement		Fick farm placement		Ferden farm placement	
	contact	side	contact	side	contact	side	contact	side
7	13.5	13.1	25.6	30.8	1.1	7.3	32.8	38.6
9	12.0	16.0	22.1	28.4	--	--	--	--
11	9.0	14.8	14.3	26.9	1.5	10.4	23.0	31.9
14	9.8	11.7	17.8	31.5	--	--	--	--

Table 1.1.f Fall culm count of wheat, per square foot basis, at four locations as affected by fertilizer rate and placement.

Fertilizer rate	Kleis farm placement		Ferden farm placement		Fick farm placement		Ferden farm placement	
	contact	side	contact	side	contact	side	contact	side
300 lbs/A	12.6	14.2	23.2	30.1	2.0	8.6	33.1	33.1
600 lbs/A	9.5	13.6	16.6	28.5	0.7	9.1	22.7	37.3

The results are similar to that found by Buffum (8). The trend is similar to that reported for fall culm count.

(iii) Rate of fertilizer: Fall culm count results indicated that fertilizer applied at 300 pounds per acre gave more culms than did 600. No such differences existed in summer culm counts. Probably it could be said that more late tillers are formed where higher rate of fertilizer was applied. Luginbill et al. (37) reported an increase in summer culms where phosphorus was applied alone or in combination with nitrogen and/or potash.

(iv) Placement of fertilizer: Side placement gave greater number of culms than did contact placement, although significant differences existed at only 1 of the 2 locations.

Fall data (Table 1.1) indicate damage by contact placement was much greater at Ferden farm as compared to Kleis farm. The greater amount of injury due to contact placement at Ferden farm might have been compensated for by subsequent stooling.

Interactions

Although the interactions were not statistically significant, the two-way tables indicated the following trends:

(a) Seed rate x row spacing, Table 1.2.a. At both locations the number of culms per square foot decreased with increase of row spacing regardless of seed rate. Similar results were observed by Buffum (8). The trend within seed rate was similar to that reported for fall culm count. Although fall culm count also indicated an increase in number of culms with an increase in seed rate, there was no similar trend present in summer culm count.

(b) Seed rate x fertilizer rate, Table 1.2.a. No trend was present.

(c) Seed rate x placement, Table 1.2.b. In 5 of the 6 comparisons, side placement of fertilizer gave the greater culm count.

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Table 1.2 Summer culm count of wheat, per square foot basis, obtained on Kleis and Ferden farms, 1957-58.

Location	Kleis	Ferden
Date	July 11, 58	July 18, 58
A. Average values with respective ranges of equality (R.E.)		
General	41.9	39.1
Seed rate, 2 pks/A	41.8	36.3
4 pks/A	41.6	41.0
6 pks/A	42.1	33.9
R.E. 5% level	N.S.	3.0
1% level		3.9
Row spacing 7 inches	50.1	45.3
9 inches	44.8	39.0
11 inches	38.7	38.2
14 inches	33.8	34.1
R.E. 5% level	3.8	3.6
1% level	5.0	4.7
Rate of fert. 300 lbs/A	42.2	38.9
600 lbs/A	41.6	39.3
R.E. 5% level	N.S.	N.S.
Placement contact	41.6	37.4
side	42.1	40.8
R.E. 5% level	N.S.	2.3
1% level		3.1

B. Analysis of variance				
C.V.%		17.8		14.7
Source				
	Df.	M.Sq.	Df.	M.Sq.
Error	117	55.7	70	33.1
Replicates	2	2	2	
		F		F
Seed rate (S)	2	< 1	2	6.1**
Row spacing (R)	3	32.5**	3	15.4**
Rate of Fert. (F)	1	< 1	1	< 1
Placement (P)	1	< 1	1	8.4**
SxR	6	< 1	6	1.7
SxF	2	< 1	2	< 1
SxP	2	1.3	2	2.2
RxF	3	1.7	3	< 1
RxP	3	< 1	3	< 1
FxP	1	< 1	1	< 1

* Significant at 5% level

** Significant at 1% level

... of wheat, per square foot basis, at two locations as affected by seed rate

Table 1.2.a Summer culm count of wheat, per square foot basis, at two locations as affected by seed rate and row spacing, seed rate and fertilizer rate, 1958.

Seed rate pks/A	Kleis farm Row spacing in inches 7	9	11	14	Ferden farm Row spacing in inches 7	9	11	14	Kleis farm Fertilizer rate 300 lbs/A	600 lbs/A	Ferden farm Fertilizer rate 300 lbs/A	600 lbs/A
2	48.4	45.5	39.3	34.2	42.4	37.6	37.5	27.7	41.4	42.3	36.0	36.5
4	52.6	45.0	36.4	33.6	49.2	39.3	37.6	37.9	42.6	40.7	40.4	41.5
6	49.2	44.0	40.5	33.6	44.4	40.0	39.4	36.7	42.4	41.8	40.3	40.0

Table 1.2.b Summer culm count of wheat, per square foot basis, at two locations as affected by seed rate and placement, row spacing and fertilizer rate, 1958.

Seed rate pks/A	Kleis farm Placement contact	side	Ferden farm Placement contact	side	Row spacing in inches	Kleis farm Fertilizer rate 300 lbs/A	600 lbs/A	Ferden farm Fertilizer rate 300 lbs/A	600 lbs/A
2	40.8	42.8	32.8	39.7	7	51.6	48.5	45.4	45.2
4	42.8	40.5	40.3	41.6	9	42.8	46.9	38.7	39.2
6	41.2	43.0	39.1	41.2	11	39.2	38.3	37.7	38.7
					14	34.9	32.7	33.9	34.3

Table [illegible] Summer culm count of wheat, per square foot basis, at two locations as affected by row spacing and placement, fertilizer rate and placement, 1958.

Table 1.2.c Summer culm count of wheat, per square foot basis, at two locations as affected by row spacing and placement, fertilizer rate and placement, 1958.

Row spacing in inches	Kleis farm placement contact	Kleis farm placement side	Ferden farm placement contact	Ferden farm placement side	Fertilizer rate	Kleis farm placement contact	Kleis farm placement side	Ferden farm placement contact	Ferden farm placement side
7	49.1	51.1	44.4	46.2	300 lbs/A	41.8	42.4	36.9	40.9
9	44.7	45.0	37.2	40.7					
11	38.5	39.0	35.9	40.4	600 lbs/A	41.4	41.8	37.9	40.7
14	34.2	33.4	32.1	36.1					

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(d) Row spacing x fertilizer rate, Table 1.2.b. The number of culms per square foot decreased with increase of row spacing, regardless of fertilizer rate. This was true at both locations. Although fall culm count (Table 1.1.d) indicated greater number of culms at lower fertilizer rate, at both locations there was no such definite trend present in summer culm counts.

(e) Row spacing x placement, Table 1.2.c. The number of culms per square foot decreased with increase in row spacing, regardless of placement. This was true at both locations. In general, a similar trend was observed for fall culm count. Contact placement gave lower number of culms as compared to side placement in 7 out of 8 comparisons. Similar trends were observed for fall culm count (Table 1.1.e).

(f) Fertilizer rate x placement, Table 1.2.c. At both locations, side placement gave greater number of culms than contact placement regardless of the rate of fertilizer. Similar observations were true for fall culm count (Table 1.1.f). The differences were of much greater magnitude in fall than in summer. Although the fall culm counts at the Kleis and Ferden farms had a reduced number of culms for the higher rate of fertilizer (Table 1.1.f), no such definite trend was present in summer count.

C. Height of Plants

Average values, with respective ranges of equality (R.E.), and analysis of variance of height of plants are presented in Table 1.3.

Single plants may have no competition for light, moisture and nutrients. However, plants close together do exert competitive influences on one another for light and other factors. Hence, if there are more plants per unit area, the plants would be taller.

Table 1.3 Height of plants in inches, vigor estimation and lodging score of wheat obtained on Kleis farm, 1957-58.

Character studied		Height	Vigor	Lodging
Date		Oct.5, 57	Oct.5, 57	July 22, 58
A. Average values with respective ranges of equality (R.E.)				
General		4.5	6.6	2.8
Seed rate, 2 pks/A		4.3	5.4	2.8
4 pks/A		4.6	6.5	2.6
6 pks/A		4.7	7.7	3.0
R.E. 5% level		0.1	0.2	0.4
1% level		0.2	0.3	0.5
Row spacing 7 inches		4.7	6.8	2.9
9 inches		4.6	6.8	2.6
11 inches		4.2	6.4	2.9
14 inches		4.6	6.2	2.7
R.E. 5% level		0.1	0.2	N.S.
1% level		0.2	0.3	
Rate of fert. 300 lbs/A		4.6	7.2	2.7
600 lbs/A		4.4	5.9	2.9
R.E. 1% level		0.1	0.2	N.S.
Placement contact		4.3	5.2	2.6
side		4.8	7.9	3.0
R.E. 1% level		0.1	0.2	0.3
B. Analysis of variance				
C.V.%		7.4	8.8	30.6
Source				
	Df.	M.Sq.	M.Sq.	M.Sq.
Error	164	0.11	0.34	0.73
Replicates	3			
		F	F	F
Seed rate (S)	2	22.0**	266.2**	4.2*
Row spacing (R)	3	26.2**	13.9**	1.5
Rate of fert. (F)	1	15.6**	220.2**	2.6
Placement (P)	1	86.4**	1,059.1**	7.8**
SxR	6	2.5*	6.7**	< 1
SxF	2	2.2	3.0	< 1
SxP	2	2.7	27.4**	< 1
RxF	3	1.4	3.3**	1.8
RxP	3	2.2	23.3**	1.6
FxP	1	11.7**	198.3**	6.0*

* Significant at 5% level
** Significant at 1% level

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Single Factors

(i) Seed rate: On the average, the plots seeded at 6 pecks per acre gave the tallest plants. This increase was nearly significant over plots seeded at 4 pecks per acre. The 4 peck rate gave highly significantly taller plants than the 2 peck rate.

(ii) Row spacing: In Table 1.1 it was observed that the number of culms decreased with wider row spacing. Since that was the case, one would expect fall height to behave in the same manner, Table 1.3. The expected trend was there except for 14-inch rows.

(iii) Rate of fertilizer: Fertilizer applied at 300 pounds per acre gave taller plants than did 600 pounds. This was what was expected from the fall culm count information (Table 1.1).

(iv) Placement of fertilizer: The side placement of fertilizer gave taller plants than did contact placement of fertilizer. This was what was expected from the culm count information (Table 1.1).

Interactions

In Table 1.3 are shown the height of plant F-values for each of the six two-factor interactions. The two-way tables for all the interactions are presented in Table 1.3.a.

Although only two out of six two-factor interactions were statistically significant, the two-way tables indicated the following trends:

(a) Seed rate x row spacing, Table 1.3.a. The height of plants increased with increase of seeding rate regardless of row spacing. Similar behavior was noted for fall culm count, Table 1.1.a. With increase in row spacing from 7 to 9 to 11 inches, there was a tendency for reduction in height regardless of seed rate. Such a trend was expected on account of fall culm count information, Table 1.1.a.

(b) Seed rate x fertilizer rate: The increase in seed rate from 2 to 4 pecks per acre resulted in an increase in height regardless of

Table 1.3.a Height of wheat plants in inches on Kleis farm as affected by seed rate and row spacing, seed rate and fertilizer rate, seed rate and placement, row spacing and fertilizer rate, row spacing

Table 1.3.a Height of wheat plants in inches on Kleis farm as affected by seed rate and row spacing, seed rate and fertilizer rate, seed rate and placement, row spacing and fertilizer rate, row spacing and placement, fertilizer rate and placement, 1957.

Seed rate pks/A	Row spacing in inches 7	9	11	14	Fertilizer rate 300 lbs/A	600 lbs/A	Placement contact	side	Row spacing in inches	Fertilizer rate 300 lbs/A	600 lbs/A
2	4.3	4.4	4.0	4.5	4.4	4.3	4.0	4.6	7	4.8	4.7
4	4.9	4.5	4.3	4.6	4.6	4.5	4.3	4.8	9	4.6	4.5
6	5.0	4.7	4.3	4.8	4.9	4.5	4.6	4.8	11	4.3	4.0
									14	4.8	4.5

Row spacing in inches	Placement contact	side	Fertilizer rate	Placement contact	side
7	4.5	4.9			
9	4.4	4.7	300 lbs/A	4.5	4.8
11	4.0	4.4	600 lbs/A	4.1	4.7
14	4.3	5.0			

fertilizer rate. Further increase in seeding rate from 4 to 6 peck resulted in an increase in height only at lower rate of fertilizer. No further increase in height was observed at higher rate of fertilizer. Increase in fertilizer rate gave reduction in height regardless of seed rate. The above tendencies were expected, in general, on account of fall culm count information Table 1.1.b.

(c) Seed rate x placement: Increase in seed rate from 2 to 4 pecks per acre resulted in an increase in height regardless of placement. Further increase in seed rate from 4 to 6 peck, resulted in an increase in height only with placement of fertilizer with the seed. No further increase in height was obtained with side placement.

(d) Row spacing x fertilizer rate: Higher fertilizer rate gave shorter plants regardless of row spacing. This would be expected due to delay in emergence at higher fertilizer rate.

(e) Row spacing x placement: Side placement gave taller plants regardless of row spacing. In general, the difference between contact and side placement became much greater with increased row spacing. With increase in row spacing from 7 to 9 to 11 inches there was a reduction in height regardless of placement.

(f) Fertilizer rate x placement. The trend was similar as already reported for fall culm count, Table 1.1.f.

D. Vigor of Plants

Average values, with respective ranges of equality (R.E.), and analysis of variance of vigor of plants are presented in Table 1.3.

Single Factors

(i) Seed rate: On the average, the plots seeded at 6 pecks per acre gave the most vigorous plants. This difference in vigor of plants was highly significant over plots seeded at 4 pecks per acre, and 4 peck rate gave highly significantly more vigorous plants than the 2 peck rate.

(ii) Row spacing: In Table 1.1 it was observed that the 7-inch and 9-inch row spacings gave statistically the same number of plants per square foot. Table 1.3 indicates that 7-inch spacings barely gave significantly taller plants than 9-inch row spacings. From such trends in number of plants and height of plants, one would expect the plants of same vigor in both row spacings. The expected trend was there. In general, the number of fall culms per square foot and height of plants decreased with wider row spacings as shown in Table 1.1 and Table 1.3 respectively. Since that was the case, one would expect vigor of the plants to behave in the same manner, Table 1.3. This was true.

(iii) Rate of fertilizer: Fertilizer [redacted] applied at 300 pounds per acre gave more culms and taller plants than did the 600 pounds, as indicated in Table 1.1 and Table 1.3, respectively. Since that was the case, one would expect more vigorous plants where fertilizer was applied at the lower rate than at the higher rate. The expected differences were there.

(iv) Placement of fertilizer: The side placement of fertilizer gave more vigorous plants over contact placement of fertilizer. This was similar to what was expected from the fall culm count, Table 1.1 and height of the plants Table 1.3.

Interactions

In Table 1.3 are shown the vigor of plants F-values for each of the six two-factor interactions. The two-way tables for all the interactions are presented in Table 1.3.b.

Table 1.3.b Vigor score of wheat plants on Kleis farm as affected by seed rate and row spacing, seed rate and fertilizer rate, seed rate and placement, row spacing and fertilizer rate, row spacing and placement, fertilizer rate and placement, 1957.

Seed rate pks/A	Row spacing in inches 7	9	11	14	Fertilizer rate 300 lbs/A	600 lbs/A	Placement contact	side	Row spacing in inches	Fertilizer rate 300 lbs/A	600 lbs/A
2	5.2	5.8	5.7	5.1	5.9	5.0	4.0	6.9	7	7.2	6.4
4	6.9	6.8	6.2	6.0	7.2	5.7	5.5	7.4	9	7.4	6.1
6	8.4	7.7	7.2	7.4	8.3	7.1	6.0	9.4	11	7.2	5.6
									14	6.7	5.5

Row spacing in inches	Placement contact	side	Fertilizer rate	Placement contact	side
7	6.0	7.8	300 lbs/A	6.4	7.9
9	5.3	8.2			
11	4.7	8.1	600 lbs/A	4.0	7.9
14	4.6	7.7			

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There were five out of six interactions statistically significant, the two-way tables (Table 1.3.b) indicated in general similar trends as reported for fall culm count Tables 1.1.a to 1.1.f.

E. Lodging Score

Average values, with respective ranges of equality (R.E.), and analysis of variance of lodging score of plants are presented in Table 1.3.

Single Factors

(i) Seed rate: Although there was a significant difference in lodging score between plots planted at 4 pecks per acre and those planted at 6 pecks per acre, the results were not consistent.

(ii) Row spacing: The four row spacings used apparently had little effect on lodging score. No specific trend was present.

(iii) Rate of fertilizer: No significant difference in lodging score occurred between 300 and 600 pounds per acre of fertilizer. The heavier rate, on the average, was associated with the higher lodging score.

(iv) Placement of fertilizer: Placing the fertilizer 2 inches below and 1 inch to the side of the seeds was associated with the higher lodging score. The difference in score between the two placements was highly significant.

Interactions

In Table 1.3 are shown the lodging score F-values for each of the six two-factor interactions. The two-way tables for all the interactions are presented in Table 1.3.c.

(a) Seed rate x row spacing. No specific trend was present, although within a row spacing the 6 peck seed rate was associated with heavier lodging in 3 out of 4 comparisons.

... as affected by seed rate and row spacing, seed rate and

Table 1.3.c Lodging score of wheat on Kleis farm as affected by seed rate and row spacing, seed rate and fertilizer rate, seed rate and placement, row spacing and fertilizer rate, row spacing and placement, fertilizer rate and placement, 1958.

Seed rate	Row spacing in inches				Fertilizer rate		Placement		Row spacing	Fertilizer rate	
pks/A	7	9	11	14	300 lbs/A	600 lbs/A	contact	side	in inches	300 lbs/A	600 lbs/A
2	2.7	2.6	2.9	3.0	2.7	2.8	2.7	2.9	7	2.7	3.1
4	2.9	2.3	2.7	2.3	2.4	2.7	2.4	2.7	9	2.3	2.9
									11	2.8	2.9
6	3.2	2.9	3.0	2.9	2.9	3.1	2.7	3.3	14	2.8	2.6

Row spacing	Placement		Fertilizer	Placement	
in inches	contact	side	rate	contact	side
7	3.0	2.9	300 lbs/A	2.6	2.7
9	2.3	2.9			
11	2.6	3.1	600 lbs/A	2.6	3.2
14	2.5	3.0			

(b) Seed rate x fertilizer rate: The heavier fertilizer rate gave the greater score regardless of seed rate.

(c) Seed rate x placement. Side placement gave the greater score regardless of seed rate.

(d) Row spacing x fertilizer rate. In 3 of the 4 comparisons heavier rate was associated with greater lodging.

(e) Row spacing x placement. For the three wider row spacings side placement gave the greater score and the differences in these widths were practically the same.

(f) Fertilizer x placement. Side placement gave the greater score regardless of fertilizer rate. This was especially true in the heavier rate of application and sufficient to make the interaction significant.

F. Yield in Bushels Per Acre

Average values, with respective ranges of equality (R.E.), and analysis of variance of yield of wheat are presented in Table 1.4.

Single Factors

(i) Seed rate: On the average, the plots seeded at 6 pecks per acre gave the greatest yield in 2 of 4 cases. The increase was highly significant over plots seeded at the rate of 4 pecks per acre. In the 3rd case, Kleis farm, the plots seeded at 4 pecks per acre gave highly significantly higher yields over plots seeded at 6 peck rate. In the 4th case, Ferden farm, 59, the plots either seeded at 6 peck or 4 peck rate gave the same yield.

Percival (45) reported that a higher seed rate could be used more profitably at places receiving higher rainfall. It was probable that lower rainfall in June (Table 3.4) was a factor reducing yields after 4 peck rate at Kleis farm.

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Table 1.4 Yield in bushels per acre of wheat obtained on Kleis and Ferden farms, 1958, and on Fick and Ferden farms, 1959.

Location	Kleis	Ferden	Fick	Ferden
Date	July, 58	July, 58	July, 59	July, 59
A. Average values with respective ranges of equality (R.E.)				
General	58.0	52.9	30.6	60.1
Seed rate, 2 pks/A	57.4	46.6	-	-
4 pks/A	59.6	53.8	26.5	60.1
6 pks/A	57.0	58.3	34.7	60.1
R.E. 5% level	1.5	1.6	3.2	N.S.
1% level	1.9	2.1	4.2	
Row spacing, 7 inches	58.9	55.0	30.2	62.5
9 inches	59.2	54.9	-	-
11 inches	58.5	53.4	31.0	57.7
14 inches	55.6	48.4	-	-
R.E. 5% level	1.7	1.9	N.S.	1.4
1% level	2.3	2.4		1.9
Rate of fert. 300 lbs/A	58.3	52.9	31.7	57.8
600 lbs/A	57.7	52.9	29.5	62.4
R.E. 5% level	N.S.	N.S.	N.S.	1.4
1% level				1.9
Placement contact	57.3	50.7	19.0	59.7
side	58.7	55.1	42.2	60.5
R.E. 5% level	1.1	1.2	3.2	N.S.
1% level	1.5	1.6	4.2	

B. Analysis of variance								
C.V. %		7.7		8.2		20.5		4.7
Source								
	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.
Error	211	19.8	164	18.7	50	39.4	50	7.96
Replicates	4		3		3		3	
		F		F		F		F
Seed rate (S)	2	8.0**	2	120.8**	1	27.6**	1	< 1
Row spacing (R)	3	8.2**	3	24.6**	1	<1	1	47.0**
Rate of fert.(F)	1	1.0	1	< 1	1	1.8	1	43.0**
Placement (P)	1	6.1*	1	50.7**	1	218.2**	1	1.2
SxR	6	< 1	6	1.2	1	8.6**	1	13.2**
SxF	2	< 1	2	2.3	1	2.0	1	< 1
SxP	2	2.0	2	< 1	1	< 1	1	< 1
RxF	3	< 1	3	1.5	1	< 1	1	< 1
RxP	3	1.0	3	2.3	1	6.3*	1	< 1
FxP	1	< 1	1	5.3*	1	13.4**	1	< 1

*Significant at 5% level

**Significant at 1% level

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Coffman (13) reported maximum average yields from seed rates of 6 pecks and 5 pecks per acre for the studies conducted from 1913-18, and from 1920-22, respectively. Kiesselbach (29) and Pendleton and Dungan (44) reported a gradual increase in yield up to 6 peck rate followed by a decrease in yield when seed rate was increased any further. Brown and Down (9) reported increase in yields up to 7 peck seed rate followed by a decrease when seed rate was increased beyond 7 peck rate.

The present data indicate that 2 peck rate is too low a seed rate. Averaging all the 4 experiments, the 6 peck rate gave the maximum yield, 2.5 bushels higher than 4 peck rate. These results are in agreement with workers cited in the previous paragraph.

(ii) Row spacing. Seven-, 9- and 11-inch row spacings gave practically the same yield per acre during 1957-58 crop year. The yields of 7-, 9-, and 11-inch row spacings were significantly (at 1 percent level) greater than 14-inch row spacings. During 1958-59 crop: at one location, Fick farm, 7- and 11-inch spacings gave practically the same yield; at the other locations, Ferden farm, 7-inch spacings gave highly significantly greater yield than the 11-inch spacings.

Previous investigations (5, 14, 30, 35, 53 and 58) have reported that 7-inch spacings gave a higher yield than 14-inch spacings. Also Harrington (22) found a definite downward trend in yields as the distance between rows increased from 6 to 12 to 18 inches. Fourteen-inch spacings seems to be too wide a distance apart between the rows for wheat. On the average of 1957-58 crop year, the 14-inch spacings gave 5 bushels per acre less yield than 7-inch spacings.

(iii) Rate of fertilizer: No significant differences in yield occurred between 300 pounds and 600 pounds of fertilizer in 3 out of

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4 experiments. In the 4th case, Ferden farm 59, the higher rate gave higher yields. Average of all the 4 experiments gave a yield of 50.2 bushels per acre in case of lower rate of fertilizer and 50.6 bushels in case of higher fertilizer rate. This indicates that on the average, the application of 600 pounds of 8-20-20 per acre fertilizer did not give any better yields than 300 pounds.

(iv) Placement of fertilizer: Placing the fertilizer 2-inches below and 1-inch to the side gave higher yields in all the 4 experiments, but significant differences occurred in only 3 of the 4 cases. On the average of all the 4 experiments side placement gave 7.4 bushels per acre greater yield than placement with the seed. Olson (43) reported similar findings.

Interactions

In Table 1.4 are shown the yield F-values for each of the 4 experiments. The two-way tables for all the interactions are presented in Tables 1.4.a to 1.4.f.

(a) Seed rate x row spacing, Table 1.4.a. The data were not consistent. However, in general a tendency for the yields to decrease was observed as distance between rows increased, regardless of seed rate. The greatest fall off in yield was observed as the distance between rows became 14-inches.

Previous investigations (5, 14, 22, 30, 35, 53 and 58) have reported similar findings. In 2 of 4 cases studied increase in seeding rate resulted in increased yields regardless of row spacing. In the 3rd case, Kleis farm 58, increase in yield was obtained up to 4 pecks seed rate regardless of row spacing. This was followed by a decrease in yield when seeding rate was increased from 4 to 6 pecks per acre. In the 4th case, Ferden 59, increase in seeding rate resulted in increased yield at 7-inch spacing and decreased yield at 11-inch spacing.

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(b) Seed rate x fertilizer rate, Table 1.4.b. In 3 of 4 cases a definite increase in yield was obtained as the seed rate increased regardless of fertilizer rate. In the 4th case, Kleis farm 58, increase in yield was obtained up to 4 pecks seed rate. This was followed by a decrease in yield when seeding rate was increased from 4 to 6 pecks per acre.

(c) Seed rate x placement, Table 1.4.c. In 8 of the 10 comparisons side placement of fertilizer gave higher yields regardless of seeding rate. In 1 of the other 2 cases, yields were equal and in the other the yield for contact was slightly higher.

(d) Row spacing x fertilizer rate, Table 1.4.d. The data were not consistent. In general, with a few exceptions, there was a downward trend in yields as distance between rows increased, regardless of fertilizer rate. The greatest fall off in yield was noted as the distance between rows became 14 inches apart.

(e) Row spacing x placement, Table 1.4.e. In 11 of 12 comparisons side placement gave higher yields, regardless of row spacing. In general, with a few exceptions, there was a downward trend in yields as the distance between rows increased, regardless of placement.

(f) Fertilizer rate x placement, Table 1.4.f. In all of the 8 comparisons side placement gave higher yields, regardless of fertilizer rate. Under side placement, the higher rate of fertilizer increased yields in 3 of 4 cases, but under contact placement, the higher rate of fertilizer reduced yields in 3 of 4 cases. This differential action between fertilizer rates and placement effects on yields were great enough in 2 of 4 cases to cause the interaction to be significant.

G. Test Weight of Wheat Grain

Average values, with respective ranges of equality (R.E.), and analysis of variance of test weight in pounds per bushel are presented in Table 1.5.

Table 1.4.a Yield in bushels per acre of wheat at four locations as affected by seed rate and row spacing.

Seed rate pks/A	1958 Kleis farm Row spacing in inches 7	9	11	14	1958 Ferden farm Row spacing in inches 7	9	1	14	1959 Fick farm Row spacing in inches 7	11	1959 Ferden farm Row spacing in inches 7	11
2	57.4	59.7	58.5	54.0	47.8	49.0	47.6	41.7	--	--	--	--
4	60.8	60.2	58.9	57.8	57.8	54.7	58.6	49.1	23.8	29.2	60.1	59.0
6	58.4	57.6	57.1	55.1	59.2	60.9	58.8	54.3	36.7	32.8	63.8	56.4

Table 1.4.b Yield in bushels per acre of wheat at four locations as affected by seed rate and fertilizer rate.

Seed rate pks/A	1958 Kleis farm fertilizer rate 300 lbs/A	600 lbs/A	1958 Ferden farm fertilizer rate 300 lbs/A	600 lbs/A	1959 Fick farm fertilizer rate 300 lbs/A	600 lbs/A	1959 Ferden farm fertilizer rate 300 lbs/A	600 lbs/A
2	57.9	56.8	47.4	45.6	--	--	--	--
4	59.9	59.4	53.3	54.3	26.5	26.6	57.7	57.9
6	57.1	57.0	57.8	58.8	36.9	32.6	62.6	62.3

Table I.4.c Yield in bushels per acre of wheat at four locations as affected by seed rate and placement.

Table 1.4.c Yield in bushels per acre of wheat at four locations as affected by seed rate and placement.

Seed rate pks/A	1958 Kleis farm placement contact	1958 Kleis farm placement side	1958 Ferden farm placement contact	1958 Ferden farm placement side	1959 Fick farm placement contact	1959 Fick farm placement side	1959 Ferden farm placement contact	1959 Ferden farm placement side
2	55.9	58.1	44.7	48.4	--	--	--	--
4	59.1	60.1	51.2	56.4	14.3	38.7	59.4	60.8
6	56.9	56.2	56.1	60.5	23.8	45.7	60.1	60.1

Table 1.4.d Yield in bushels per acre of wheat at four locations as affected by row spacing and fertilizer rate.

Row spacing in inches	1958 Kleis farm fertilizer rate 300 lbs/A	1958 Kleis farm fertilizer rate 600 lbs/A	1958 Ferden farm fertilizer rate 300 lbs/A	1958 Ferden farm fertilizer rate 600 lbs/A	1959 Fick farm fertilizer rate 300 lbs/A	1959 Fick farm fertilizer rate 600 lbs/A	1959 Ferden farm fertilizer rate 300 lbs/A	1959 Ferden farm fertilizer rate 600 lbs/A
7	59.6	58.1	54.0	55.9	31.0	29.5	59.9	65.2
9	59.0	59.3	54.6	55.1	--	--	--	--
11	59.3	57.7	53.5	53.2	32.4	29.6	55.7	59.7
14	55.4	55.8	49.3	47.5	--	--	--	--

Table 1.4.e Yield in bushels per acre of wheat at four locations as affected by row spacing and placement.

Row spacing in inches	1958 Kleis farm placement contact	side	1958 Ferden farm placement contact	side	1959 Fick farm placement contact	side	1959 Ferden farm placement contact	side
7	58.0	59.7	53.1	56.8	20.6	39.9	61.8	63.2
9	58.2	60.1	53.5	56.2	--	--	--	--
11	58.6	58.4	51.2	55.5	17.4	44.6	57.6	57.8
14	54.4	56.7	44.8	51.9	--	--	--	--

Table 1.4.f Yield in bushels per acre of wheat at four locations as affected by fertilizer rate and placement.

Fertilizer rate	1958 Kleis farm placement contact	side	1958 Ferden farm placement contact	side	1959 Fick farm placement contact	side	1959 Ferden farm placement contact	side
300 lbs/A	57.5	59.2	51.3	54.4	23.0	40.4	57.2	58.4
600 lbs/A	57.2	58.3	50.0	55.9	15.1	44.0	62.3	62.6

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Table 1.5 Test weight in pounds per bushel of wheat obtained on Kleis and Ferden farms, 1958, and on Fick and Ferden farms, 1959.

Location	Kleis	Ferden	Fick	Ferden
Date	July, 58	July, 58	July, 59	July, 59
A. Average values with respective ranges of equality (R.E.)				
General	58.1	60.4	55.9	59.7
Seed rate 2 pks/A	58.0	59.9	-	-
4 pks/A	58.2	60.6	55.5	59.6
6 pks/A	58.0	60.7	56.2	59.7
R.E. 5% level	N.S.	0.2	0.4	N.S.
1% level		0.3	0.5	
Row spacing 7 inches	58.2	60.5	55.7	59.6
9 inches	58.1	60.5	-	-
11 inches	58.0	60.3	56.0	59.7
14 inches	58.1	60.3	-	-
R.E. 5% level	N.S.	N.S.	N.S.	N.S.
Rate of fert. 300 lbs/A	58.0	60.4	56.0	59.6
600 lbs/A	58.1	60.4	55.8	59.8
R.E. 5% level	N.S.	N.S.	N.S.	N.S.
Placement contact	58.1	60.3	55.3	59.7
side	58.1	60.5	56.4	59.6
R.E. 5% level	N.S.	0.2	0.4	N.S.
1% level		0.3	0.5	

B. Analysis of variance

	Kleis		Ferden		Fick		Ferden	
C.V. %		1.24		0.91		1.24		0.80
Source	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.	Df.	M.Sq.
Error	211	0.52	164	0.29	50	0.48	50	0.23
Replicates	4		3		3		3	
		F		F		F		F
Seed Rate (S)	2	1.7	2	40.9**	1	17.5**	1	1.4
Row spacing (R)	3	<1	3	1.9	1	2.6	1	1.4
Rate of fert (F)	1	2.4	1	<1	1	2.3	1	1.7
Placement (P)	1	<1	1	4.4*	1	39.9	1	<1
SxR	6	<1	6	4.0**	1	1.7	1	2.8
SxF	2	<1	2	3.3*	1	<1	1	3.0
SxP	2	<1	2	<1	1	<1	1	1.7
RxF	3	<1	3	1.7	1	6.0*	1	<1
RxP	3	<1	3	2.9*	1	<1	1	<1
FxP	1	1.5	1	<1	1	<1	1	<1

*Significant at 5% level
**Significant at 1% level

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Single Factors

(i) Seed rate: On the average, in 3 of 4 experiments the test weight increased as the seed rate increased. In the 4th case, Kleis farm, the test weight increased from 58.0 to 58.2 as seed rate was increased from 2 to 4 pecks per acre. This was followed by a decrease in test weight as seeding rate was increased from 4 to 6 pecks per acre.

Kiesselbach (29) reported that test weight was not affected by seeding rate. Coffman (13) on the basis of 6-year results, 1913-1918, reported no specific trend in relation to seeding rate. He further reported on the basis of 3-year results, 1920-1922 a gradual increase in test weight with increase in seeding rate. Pendleton and Dungan (44) reported an increase in test weight as seed rate was increased from 3 to 6 pecks per acre. This was followed by a gradual decrease as seeding rate was increased from 6 to 18 pecks per acre.

(ii) Row spacing: The row widths resulted in essentially the same test weight of grain.

(iii) Fertilizer rate: On the average, no differences in test weight occurred with 300 pounds and 600 pounds of 8-20-20 fertilizer per acre. Previous investigators (11, 40, 42, 49, 56 and 61) have reported similar results.

(iv) Placement of fertilizer: On the average, in 2 of 4 cases contact placement of fertilizer gave grains with heavier test weight. In other 2 cases there was no difference in test weight due to placement. Similar lack of consistent findings have been reported by other workers (56 and 62).

Interactions

In Table 1.5 are shown the test weight F-values for each of the six two-factor interactions in each of the four experiments. The two-way

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tables for all the interactions are presented in Table 1.5.a to 1.5.f.

(a) Seed rate x row spacing, Table 1.5.a. No specific trend was present.

(b) Seed rate x fertilizer rate, Table 1.5.b. No specific trend was present.

(c) Seed rate x placement, Table 1.5.c. In general, test weight increased with increase in seed rate regardless of the placement of fertilizer.

(d) Row spacing x fertilizer rate, Table 1.5.d. In 8 of 12 comparisons, higher fertilizer rate gave grains higher in test weight regardless of row spacing.

(e) Row spacing x placement, Table 1.5.e. In 6 of 12 comparisons side placement gave grain of higher test weight regardless of row width. In 2 comparisons both placements gave grains of same test weight.

(f) Fertilizer rate x placement, Table 1.5.f. In 6 of 8 comparisons side placement gave grains of higher test weight regardless of fertilizer rate.

H. Protein Content of Wheat Grain

Average values, with respective ranges of equality (R.E.) and analysis of variance, of wheat grain are presented in Table 1.6.

Single Factors

(i) Seed rate: With increase in seed rate fall culm count increased at a diminishing rate (Table 1.1). With more culms, there would be less availability of nutrients per culm at higher seeding rate. This probably would result in reduction of protein content in grain with increase in seeding rate. The present data represent this trend.

Table 1.5.a Test weight in pounds per bushel of wheat at four locations as affected by seed rate and row spacing

Table 1.5.a Test weight in pounds per bushel of wheat at four locations as affected by seed rate and row spacing.

Seed rate pks/A	1958 Kleis farm Row spacing in inches 7	9	11	14	1958 Ferden farm Row spacing in inches 7	9	11	14	1959 Fick farm Row spacing in inches 7	11	1959 Ferden farm Row spacing in inches 7	11
2	58.1	58.1	57.8	57.9	60.2	60.7	60.0	59.4	--	--	--	--
4	58.3	58.3	58.0	58.2	60.0	60.6	60.3	60.7	55.3	55.8	59.0	59.8
6	58.0	57.9	58.1	58.1	60.7	60.7	60.7	60.7	56.2	56.3	59.8	59.7

Table 1.5.b Test weight in pounds per bushel of wheat at four locations as affected by seed rate and fertilizer rate.

Seed rate pks/A	1958 Kleis farm fertilizer rate 300 lbs/A	600 lbs/A	1958 Ferden farm fertilizer rate 300 lbs/A	600 lbs/A	1959 Fick farm fertilizer rate 300 lbs/A	600 lbs/A	1959 Ferden farm fertilizer rate 300 lbs/A	600 lbs/A
2	57.9	58.0	60.0	59.8	--	--	--	--
4	58.1	58.2	60.7	60.5	55.6	55.5	59.4	59.8
6	57.9	58.2	60.6	60.8	56.5	56.0	59.8	59.7

Table 1.5.c Test weight in pounds per bushel of wheat at four locations as affected by seed

Table 1.5.c Test weight in pounds per bushel of wheat at four locations as affected by seed rate and placement.

Seed rate pks/A	1958 Kleis farm placement contact	1958 Kleis farm placement side	1958 Ferden farm placement contact	1958 Ferden farm placement side	1959 Fick farm placement contact	1959 Fick farm placement side	1959 Ferden farm placement contact	1959 Ferden farm placement side
2	58.0	58.0	60.0	60.0	--	--	--	--
4	58.2	58.1	60.4	60.7	54.9	56.1	59.6	59.6
6	58.0	58.1	60.7	60.7	55.8	56.7	59.9	59.6

Table 1.5.d Test weight in pounds per bushel of wheat at four locations as affected by row spacing and fertilizer rate.

Row spacing in inches	1958 Kleis farm fertilizer rate 300 lbs/A	1958 Kleis farm fertilizer rate 600 lbs/A	1958 Ferden farm fertilizer rate 300 lbs/A	1958 Ferden farm fertilizer rate 600 lbs/A	1959 Fick farm fertilizer rate 300 lbs/A	1959 Fick farm fertilizer rate 600 lbs/A	1959 Ferden farm fertilizer rate 300 lbs/A	1959 Ferden farm fertilizer rate 600 lbs/A
7	58.1	58.2	60.5	60.5	55.7	55.8	59.6	59.7
9	58.0	58.2	60.6	60.3	--	--	--	--
11	57.9	58.1	60.2	60.4	56.4	55.7	59.6	59.8
14	58.0	58.2	60.4	60.2	--	--	--	--

Table I.5.8 Test weight in pounds per bushel of wheat at four locations as affected by

Table 1.5.e Test weight in pounds per bushel of wheat at four locations as affected by row spacing and placement.

Row spacing in inches	1958				1959			
	Kleis farm placement		Ferden farm placement		Fick farm placement		Ferden farm placement	
	contact	side	contact	side	contact	side	contact	side
7	58.2	58.1	60.4	60.6	55.2	56.2	59.7	59.6
9	58.0	58.1	60.4	60.5	--	--	--	--
11	58.0	58.0	60.4	60.3	55.4	56.6	59.8	59.7
14	58.1	58.1	60.0	60.5	--	--	--	--

Table 1.5.f Test weight in pounds per bushel of wheat at four locations as affected by fertilizer rate and placement.

Fertilizer rate	1958				1959			
	Kleis farm placement		Ferden farm placement		Fick farm placement		Ferden farm placement	
	contact	side	contact	side	contact	side	contact	side
300 lbs/A	57.9	58.1	60.4	60.5	55.5	56.5	59.7	59.5
600 lbs/A	58.2	58.1	60.3	60.4	55.2	56.3	59.7	59.8

Table 1.6 Percent of protein content of wheat grain obtained on Ferden farm, 1958.

A. Average values with respective ranges of equality (R.E.)	
General	12.3
Seed rate, 2 pks/A	13.0
4 pks/A	12.1
6 pks/A	12.0
R.E. 5% level	0.2
1% level	0.3
Row spacing 7 inches	12.1
9 inches	12.3
11 inches	12.4
14 inches	12.5
R.E. 5% level	0.3
1% level	0.4
Rate of fert. 300 lbs/A	12.2
600 lbs/A	12.5
R.E. 1 level	0.2
Placement contact	12.5
side	12.2
R.E. 1% level	0.2

B. Analysis of Variance			
C.V. %		2.3	
Source	Df.		M.Sq.
Error	23		0.08
Replicates	2		
			F
Seed rate (S)	2		58.5**
Row spacing (R)	3		4.5**
Rate of fert.(F)	1		11.3**
Placement (P)	1		8.7**
SxR	6		2.1
SxF	2		<1
SxP	2		2.0
RxF	3		1.4
RxP	3		<1
FxP	1		0.0

*Significant at 5% level
**Significant at 1% level

(ii) Row spacing: Fall culm count per unit area decreased with increase in row spacing. Because of this protein content of grain would be expected to increase with row spacing. The expected trend was there.

(iii) Rate of fertilizer: With higher fertilizer rate the plants had a greater amount of fertilizer available and hence produced grain with higher protein content.

It has been pointed out in review of literature that the effect of fertilizers at seeding time on the protein content is a controversial matter. Several investigators (40, 47, 51 and 56) have reported that fertilization at seeding time did not significantly influence the protein content. While others (3, 11, 46, 49, 50 and 61) reported that fertilizer did increase the protein content of wheat.

(iv) Placement: Contact placement reduced number of fall culms per unit area and hence more fertilizer per culm was available. This resulted in the production of grains with higher protein content where fertilizer was placed with the seed.

Interactions

In Table 1.6 are shown the protein content of grain F-values for each of the six two-factor interactions. The two-way tables for all the interactions are presented in Table 1.6.a.

(a) Seed rate x row spacing. In general a tendency for the protein to decrease was observed as seed rate increased regardless of row spacing. Protein content of the grain showed a tendency to increase as distance between rows increased regardless of seed rate. The difference between protein content of grain became much greater between 7-inch and 14-inch spacings as seed rate increased.

(b) Seed rate x fertilizer rate. Protein content decreased as the seed rate increased at a diminishing rate regardless of fertilizer rate.

Table 1.6.a Percent of protein content of wheat grain as affected by seed rate and row spacing, seed rate and fertilizer rate, seed rate and placement, row spacing and fertilizer rate, row spacing and placement, fertilizer rate and placement, at Ferden farm, 1958.

Seed rate	Row spacing in inches				Fertilizer rate		Placement		Row spacing	Fertilizer rate	
pks/A	7	9	11	14	300 lbs/A	600 lbs/A	contact	side	in inches	300 lbs/A	600 lbs/A
2	13.0	13.0	12.8	13.1	12.8	13.2	13.0	12.9	7	12.1	12.2
4	11.8	12.0	12.2	12.2	11.9	12.2	12.3	11.8	9	12.2	12.4
6	11.5	11.9	12.1	12.4	11.9	12.0	12.1	11.8	11	12.3	12.5
									14	12.3	12.8

Row spacing in inches	Placement contact	side	Fertilizer rate	Placement contact	side
7	12.2	12.1	300 lbs/A	12.3	12.1
9	12.4	12.2			
11	12.6	12.1	600 lbs/A	12.6	12.4
14	12.7	12.4			

Protein content increased as the fertilizer rate increased regardless of seed rate.

(c) Seed rate x placement. Protein content decreased as the seed rate increased at a diminishing rate, regardless of placement. Protein content decreased with side placement of fertilizer irrespective of seed rate.

(d) Row spacing x fertilizer rate. Protein content increased as the row spacing increased, regardless of fertilizer rate, The higher fertilizer rate resulted in the production of grain with higher protein content regardless of row spacing.

(e) Row spacing x placement. Side placement gave grain low in protein content regardless of row spacing. Increase in row spacing resulted in production of grain high in protein content irrespective of placement.

(f) Fertilizer rate x placement. Application of higher fertilizer rate resulted in the production of grain with higher protein content irrespective of placement. Side placement gave grain low in protein content irrespective of fertilizer rate.

I. Interrelationships Between Various Characters of Winter Wheat

Simple correlation coefficients are presented in Table 1.7.

Many of the correlation coefficients are relatively low in value despite the fact that they are statistically significant. Such a situation would suggest a relationship between the two characters considered but that the relationship was affected also by factors other than those indicated.

a. Fall Culm Count and Height of the Plants

A coefficient of correlation of 0.491** was obtained for fall culm count and height of plants. Such a relationship was expected because with more plants, the plants are expected to be taller due to greater competition for light.

Table 1.7 Simple correlation coefficients showing relationships between various variables of winter wheat using treatment average values (Table 3.1-3.3).

Location: Variables	Crop year: No. pairs	1957-1958 Kleis farm	Ferden farm	1958-1959 Fick farm	Ferden farm
(a) Fall culm count: height of plants	48	0.491**			
(b) Fall culm count: vigor of plants	48	0.735**			
(c) Height of plants: vigor of plants	48	0.720**			
(d) Fall culm count: summer culm count:	48	0.202	0.464**		
(e) Fall culm Count: yield	48	0.365*	0.716**		
	16	-0.073†	0.570*†	0.935**	0.262
(f) Summer culm count: yield	48	0.248	0.282*		
(g) Lodging score: yield	48	0.124			
(h) Fall culm count: test weight	48	0.315*	0.703**		
	16	0.303†	0.510*†	0.852*	0.067
(i) Summer culm count: test weight	48	0.090	0.418**		
(j) Yield: test weight	48	0.195	0.674**		
	16	-0.173†	0.460†	0.560*	0.127

*Significant at 5% level.

**Significant at 1% level.

†Based on the same treatments as 1958-1959.

b. Fall Culm Count and Vigor of Plants

A correlation coefficient of 0.735** was obtained. It might be pointed out that culm count indicated a better association with vigor than with height of plants.

c. Height and Vigor of Plants

The coefficient of correlation between these two characters was 0.720**, a fair degree of positive association. Vigor of the plants was an estimation, whereas height of the plants was an actual measurement to the nearest inch.

Vigor estimation is much less time consuming than taking height measurements. The relationship suggests that one could estimate vigor, which is a quicker process, rather than actually measuring the height of the plants.

d. Fall Culm Count and Summer Culm Count

Among the two cases studied, the respective correlation coefficients were 0.202 and 0.464**. These two coefficients of correlation did not differ significantly from one another, even though one is highly significant while the other is non-significant. Differences in summer culm count due to treatments were not as wide as the fall culm count differences because of the ability of wheat to compensate for stand by tillering.

e. Fall Culm Count and Yield

1957-58 data (n = 48) indicated that correlations of 0.365* and 0.716** were present at Kleis farm and Ferden farm, respectively. It may be recalled from methods and materials that the that the experiment was reduced for the crop year 1958-59. Correlation studies were also made for treatments (n = 16) which appeared in the 1958-59 crop. The relationship became much weaker with the smaller number of items as shown by the correlation coefficients, -0.073 and 0.570*, respectively. This suggests the omitted treatments caused the relationship to be greater when they were included. However, statistically the r values obtained by using n = 48 were not different from the r values obtained by using n = 16.

1958-59 data indicated that a correlation of 0.935** existed at Fick farm and that a correlation of 0.262 existed at the Ferden farm.

In general, there was a positive association between the fall culm count and yield.

f. Summer Culm Count and Yield

A positive association was observed at both the locations. Correlations of 0.248 and 0.282* were found at Kleis farm and the Ferden Farm, respectively. These two coefficients of correlation did not differ significantly from one another.

Comparing with the correlation coefficients obtained between fall culm count and yield, one could point out that better relationship existed between fall culm count and yield than between summer culm count and yield.

g. Lodging score and Yield

Statistically, lodging score had no effect on yield. Such a relation was expected because lodging occurred late after head formation. Further, there was no difficulty in harvesting and combining in the lodged plots. Similar results have been reported by other workers (13, 27, 52).

h. Fall Culm Count and Test Weight

1957-58 data (n = 48) gave correlations of 0.315* and 0.703** at Kleis farm and Ferden Farm, respectively. When correlations were run between those treatments which appeared during 1958-59 crop, the relationship became much weaker 0.303 and 0.510*, respectively.

Statistically, the correlation values obtained by using n = 48 were not different from those obtained by using n = 16.

1958-59 data gave correlations of 0.852** and 0.067 at the Fick farm and Ferden farm, respectively.

In general, there was a positive association between fall culm count and test weight.

i. Summer Culm Count and Test Weight

Correlation values of 0.090 and 0.418** at Kleis farm and Ferden farm, respectively, were found. These two coefficients of correlation did not differ significantly from one another. The relationship for fall culm count and test weight was comparatively stronger, 0.315* and 0.703**, respectively. Statistically, correlation coefficient 0.090 was not different from 0.315 nor was 0.418 different from 0.703.

j. Yield and Test Weight

The correlation coefficients between yield and test weight for 1957-58 data (n = 48) were 0.195 and 0.674** at Kleis farm and Ferden farm, respectively. Correlation studies were also made for treatments (n = 16) which appeared in the 1958-59 crop. The relationship became much weaker as shown by the correlation coefficients, -0.173 and 0.460, respectively. Statistically, the r values obtained by using n = 48 were not different from the r values obtained by using n = 16. The correlation coefficients for 1957-58 data (n = 16) were 0.560* and 0.127 at the Fick farm and Ferden farm, respectively. Laude (31) reported positive as well as negative relationships between test weight and yield. Laude reported a negative correlation under 3 best ecological conditions during 1933. The present data also showed lower relationships where yields were greater.

2. Laboratory Experiments

A. Emergence study

Data on the emergence of wheat seedlings using Oshtemo sand at field capacity moisture level are given in Table 2.1. Various rates of 7 commercial fertilizers, 8 chemically pure salts and 3 mixtures of commercial fertilizers with chemically pure salts were used.

Nitrogen was more detrimental per unit than potash, and potash more than phosphate. Delay in emergence was increased while final emergence was reduced greatly at higher rates. Some investigators (8, 12, 19, and 43) have reported similar results.

The nature of the fertilizer material is not without importance, as it may produce excessive local acidity or alkalinity, or it may be such as to produce excessive toxic action on germination and emergence (8, 23, and 54).

As noted in the literature references, there is some disagreement among investigators as to the damage caused by various fertilizer components.

The data in Table 2.1 indicated that ammonium sulphate was more toxic than ammonium chloride, potassium sulphate more toxic than potassium chloride, and the latter more toxic than potassium nitrate. Brage (8) reported that sulphate anions are more toxic than nitrate which is in agreement with what has been said above that potassium sulphate was more damaging than potassium nitrate. Comparing the effects of potassium chloride, potassium sulphate and potassium nitrate on emergence, the toxic effects of anions agree to the following extent with Harris (23) that chloride anions are more toxic than nitrate anions.

Table 2.1 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers, using Oshtemo sand at field capacity.[1]

Pounds per acre N-P_2O_5-K_2O	Percent emergence 1 wk.	2 wks.	3 wks.	Materials used
0-0-0	89	92	93	
21-0-0	31	50	53	Ammonium sulphate[2]
31.5-0-0	0	11	22	
42-0-0	0	3	3	
26-0-0	51	82	83	Ammonium chloride[2]
52-0-0	0	13	18	
78-0-0	0	0	0	
0-45-0	81	83	83	Con. superphosphate[3]
0-90-0	81	83	83	
0-135-0	24	74	74	
0-180-0	17	54	57	
0-270-0	4	18	24	
0-315-0	4	17	19	
0-45-0	82	87	87	Ordinary superphosphate[3]
0-80-0	66	81	81	
0-90-0	56	72	72	
0-180-0	18	62	64	
0-270-0	0	24	31	
0-38-0	90	90	90	Dicalcium phosphate dihydrate[2]
0-190-0	90	90	90	
0-570-0	90	90	90	
0-48-0	88	88	88	Dicalcium phosphate[2]
0-192-0	93	93	93	
0-720-0	88	88	88	
0-62-0	89	89	89	Calcium metaphosphate conditioned with limestone[2]
0-186-0	92	92	92	
0-930-0	89	89	89	

[1]Oshtemo sand contains 10% moisture at field capacity.
[2]Chemically pure salt.
[3]Commercial fertilizer.

Continued

Table 2.1 - Continued

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 wk.	2 wks.	3 wks.	Materials used
0-0-27	14	58	81	Potassium sulphate[2]
0-0-40.5	0	37	61	
0-0-54	0	28	81	
0-0-67.5	0	0	0	
0-0-60	8	58	69	Potassium chloride[2]
0-0-90	0	14	36	
0-0-120	0	6	14	
11-48-0	69	71	71	11-48-0[3]
22-96-0	19	28	28	
33-144-0	8	14	14	
44-192-0	0	0	0	
21-53-0	4	68	68	Diammonium phosphate[3]
42-106-0	0	0	21	
63-159-0	0	0	0	
84-212-0	0	0	0	
7-0-23.2	81	83	83	Potassium nitrate[2]
14-0-46.5	64	75	75	
21-0-69.7	11	75	75	
28-0-93	8	38	58	
35-0-116.2	0	20	42	
42-0-139.5	0	19	33	
49-0-162.7	0	0	8	
0-25-25	81	86	86	0-25-25[3]
0-50-50	56	82	85	
0-75-75	21	76	78	
0-100-100	3	47	56	
0-125-125	0	10	28	
11-28-28	81	92	92	11-28-28[4]
22-56-56	0	56	78	
27.5-70-70	0	31	47	
33-84-84	0	17	19	

[2]Chemically pure salt.
[3]Commercial fertilizer.
[4]Prepared by mixing muriate of potash (60 percent K_2O) and dicalcium phosphate (21-53-0) fertilizer.

Table 2.1 - Continued

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 wk.	2 wks.	3 wks.	Materials used
5-20-20	83	90	90	5-20-20[3]
7.5-30-30	57	77	79	
10-40-40	30	68	75	
15-60-60	10	28	33	
20-80-80	0	8	14	
12-12-12	87	90	90	12-12-12[3]
24-24-24	48	90	90	
36-36-36	0	40	68	
48-48-48	0	7	17	
12-24-24	47	68	68	6-12-12[5]
18-36-36	19	58	60	
24-48-48	0	29	32	
30-60-60	0	6	10	
12-24-24	47	69	69	6-12-12[6]
18-36-36	21	51	58	
24-48-48	0	36	58	
30-60-60	0	11	18	

[3]Commercial fertilizer

[5]Prepared by mixing ammonium chloride (26 percent N), superphosphate (45 percent P_2O_5), muriate of potash (60 percent K_2O).

[6]Prepared by mixing ammonium sulphate (21 percent N), superphosphate (45 percent P_2O_5), muriate of potash (60 percent K_2O).

Harris (23) reported that potassium carbonate was least toxic out of the 13 treatments used in Greenville and College loam, but it was the third most toxic treatment in sand. The disagreement in results from other investigators could be due to soil differences.

Concentrated superphosphate was slightly more toxic to emergence of seedlings than ordinary superphosphate when equal amounts of phosphates were applied. Rost (52) reported similar results.

Dicalcium phosphate dihydrate, dicalcium phosphate and calcium metaphosphate conditioned with limestone were not at all injurious to emergence even when applied at high rates.

One hundred pounds of diammonium phosphate (21-53-0) was more detrimental than 150 pounds of potassium nitrate (21-0-69.7). Earlier it was pointed out that potash was more detrimental per unit than phosphate. The present discrepancy might be due to different sources of nitrogen used. However, these materials need a further study.

A fertilizer having the analysis of 6-12-12 was prepared by mixing ammonium chloride with superphosphate and muriate of potash and was found to be more detrimental than a 6-12-12 prepared by mixing ammonium sulphate with superphosphate and muriate of potash to the emergence of wheat seedlings. Earlier it was noted that ammonium sulphate was more toxic than ammonium chloride. This change of situation might be attributed to the combination effects. This suggested that ammonium chloride was more detrimental in the mixture than ammonium sulphate. At lower rates both were equally toxic and this agrees with findings reported by Allison (1).

In general, as the fertilizer rate was increased, the detrimental effects increased at a much faster rate.

Data on the emergence of wheat seedlings using Granby loamy sand at field moisture level are given in Table 2.2. Three rates of

Table 2.2 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with two ordinary superphosphate fertilizers, F1 and F2, using Granby loamy sand at field capacity.[1]

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence					
	Fertilizer F1			Fertilizer F2		
	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.
0-80-0	54	64	64	78	83	83
0-180-0	20	36	37	51	71	71
0-270-0	8	17	17	23	54	54

[1]Granby loamy sand contains 22.0% moisture at field capacity.

2 superphosphates, labelled as 20% phosphates, collected from two different sources. Fertilizer F1 was more toxic than F2 when equal amounts of fertilizer from both sources were applied. The reasons for such differential action will be discussed later under "Differential effects of two ordinary superphosphates."

Data on the emergence of wheat seedlings in Oshtemo sand at field capacity using 3 fertilizers at various rates are given in Table 2.3. The most toxic was 6-12-12 the least toxic was 6-12-0. The 6-0-12 was more toxic to emergence than the 6-12-0, indicating the greater degree of toxicity due to potash than phosphate.

As the fertilizer rate was increased, the detrimental effects increased at a much faster rate.

Data on the emergence of wheat seedlings using Granby loamy sand at field capacity moisture level, and 4 materials at various rates are given in Table 2.4. The materials tested were found in the following order of decreasing toxicity: 6-12-12, 6-0-12, 0-12-12 and 6-12-0. As the fertilizer rate increased the injury increased at a much faster rate. Comparing the results reported in Table 2.3, it may be noted that the order of toxicity remained the same in both the soils and the treatments were less damaging in Granby loamy sand than Oshtemo sand. This was due to the presence of greater amounts of organic matter in the Granby loamy sand. Salter (54) reported the greater degree of toxicity in sandy soils than in clay or muck soils. The injury increased at a much faster rate with increase of fertilizer rate.

Data on the emergence of wheat seedlings using Plainfield sand at 8.0 percent moisture level with 5 fertilizer materials are given in Table 2.5.

Table 2.3 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers* at several rates, using Oshtemo sand at field capacity.

Fertilizer rate	Fertilizer treatments								
	6-0-12			6-12-12			6-12-0		
Pounds per acre	Percent emergence			Percent emergence			Percent emergence		
	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.
0	93	93	93	93	93	93	93	93	93
300	68	81	81	-	-	-	63	84	84
400	42	74	74	8	60	61	44	78	80
500	14	72	78	0	36	38	28	78	80
600	0	36	43	0	15	24	6	60	60
800	0	11	14	0	0	0	0	35	39

*Fertilizer made up of ammonium nitrate (33.5 percent N), superphosphate (45 percent P_2O_5), muriate of potash (60 percent K_2O).

Table 2.4 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers,* at several rates, using Granby loamy sand at field capacity.

Fertilizer rate	Fertilizer treatment											
	6-0-12			6-12-0			6-12-12			0-12-12		
Pounds per acre	Percent emergence			Percent emergence			Percent emergence			Percent emergence		
	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.	1 wk.	2 wks.	3 wks.
0	90	92	93	90	92	93	92	93	93	90	92	93
200	90	92	93	93	93	93	92	93	93	-	-	-
300	79	81	81	88	88	88	86	93	93	90	90	90
400	-	-	-	-	-	-	76	86	86	68	76	76
500	67	82	82	69	81	81	57	68	68	-	-	-
600	54	76	76	56	89	89	40	63	69	51	74	74
700	51	75	76	-	-	-	32	54	57	38	72	72
800	43	69	69	47	69	69	14	44	50	-	-	-
1000	0	31	43	26	68	68	3	25	31	19	43	45
1200	0	10	19	19	58	63	-	-	-	8	31	31
1500	0	0	0	1	29	46	-	-	-	3	11	15

*Fertilizer made up of ammonium nitrate (33.5 percent N), superphosphate (45 percent P_2O_5), muriate of potash (60 percent K_2O).

Table 2.5 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers, using Plainfield sand at 8.0 percent moisture level.[1]

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 wk.	2 wks.	3 wks.	Material used
0-0-0	88	88	88	
26-0-0	0	0	15	Ammonium chloride[2]
0-0-60	24	64	67	Muriate of potash[3]
21-53-0	0	46	53	Diammonium phosphate[3]
14-0-46.5	46	67	67	Potassium nitrate[2]
5-20-20	65	76	76	5-20-20[3]
7.5-30-30	29	64	64	

[1]The soil contains 10% moisture at field capacity.

[2]Chemically pure salt.

[3]Commercial fertilizer.

Plainfield sand and Oshtemo sand are soils very alike in nature, hence one could compare the results obtained with the results presented in Table 2.1. A glance at both tables would indicate the greater reduction at lower moisture level. Twenty-six pounds per acre of nitrogen reduced the emergence at the end of 3 weeks, from 83 to 15 percent as the moisture was reduced from 10 to 8 percent level. Reduction with other materials were also noted, but not to the same degree indicating that the detrimental effects of nitrogen increases at a much faster rate than potash or phosphate as soil moisture was reduced.

Data on the emergence of wheat seedlings using Plainfield sand at 6.7 moisture level, using 8 materials at various rates are given in Table 2.6. Comparisons common to Tables 2.5 and 2.6, namely 0-0-60, 14-0-46.5 and 7.5-30-30, indicated greatly reduced numbers of seedlings at the end of one week as moisture level was reduced from 8 to 6.7 percent. At the end of 3 weeks there was not much difference in number of seedlings obtained at these two moisture levels. The reduction in moisture level from 8.0 to 6.7 percent delayed emergence, but not the final emergence percentage.

Data on the emergence of wheat seedlings using Plainfield sand at 5.6 percent moisture level with 2 fertilizers at various rates are given in Table 2.7. Under no fertilizer treatment, the emergence at the end of 1 week or 3 weeks were not much different from the results obtained at higher moisture levels, Tables 2.1, 2.5 and 2.6. Twenty-one pounds of nitrogen reduced the emergence at the end of 3 weeks from 53 to 17 percent as moisture was reduced from 10.0 to 5.6 percent. The 100 pounds of diammonium phosphate (21-53-0) reduced the emergence from 68 to 53 to 31 percent as moisture level was reduced from 10.0 to 8.0 to 5.6 percent, respectively. The 200 pounds of

Table 2.6 Precent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers, using Plainfield sand at 6.7 percent moisture level.[1]

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 wk.	2 wks.	3 wks.	Material used
0-0-0	90	92	92	
0-20-0	78	79	79	0-20-0 (F2)[3]
0-30-0	81	82	82	
0-40-0	79	81	81	
0-80-0	23	29	39	
0-20-0	86	86	86	0-20-0 (F1)[3]
0-30-0	83	85	85	
0-40-0	58	63	63	
0-80-0	20	32	32	
0-0-27	43	57	58	Potassium sulphate[2]
0-0-40.5	37	45	46	
0-0-63	3	42	50	Potassium chloride[2]
0-0-94.5	0	3	3	
0-0-60	6	52	62	Muriate of potash[3]
14-0-46.5	14	60	61	Potassium nitrate[2]
28-0-93.0	0	4	7	
5-20-20	66	77	78	5-20-20[3]
7.5-30-30	36	61	64	
10-40-40	8	16	25	
15-60-60	0	0	0	
11-28-28	32	52	53	11-28-28[4]

[1]The soil contains 10 percent moisture at field capacity.
[2]Chemically pure salt.
[3]Commercial fertilizer.
[4]Prepared by mixing muriate of potash (60 percent K_2O), and dicalcium phosphate (21-53-0) fertilizer.

Table 2.7 Percent emergence of wheat 1, 2 and 3 weeks after planting in contact with various fertilizers, using Plainfield sand at 5.6 percent moisture level.[1]

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 w,	2 wks.	3 wks.	Material used
0-0-0	83	86	86	
21-0-0	0	12	17	Ammonium sulphate[2]
33-0-0	0	0	0	
21-53-0	3	20	31	Diammonium phosphate[3]
31.5-79.5-0	0	4	6	
42-106-0	0	0	0	

[1]The soil contains 10 percent moisture at field capacity.
[2]Chemically pure salt.
[3]Commercial fertilizer.

diammonium phosphate (42-103-0) reduced the final emergence from 21 to 0 as moisture was reduced from 10.0 to 5.6 percent level.

Data on the emergence of oats seedlings using Plainfield sand at 7.6 percent moisture level with 7 materials at various rates are given in Table 2.8. The decreasing order of harmfulness of 3 potassium materials used were: potassium sulphate, potassium nitrate and potassium chloride. Comparing with the emergence values with wheat study at 8.0 percent moisture level (Table 2.5), it may be noted that oats are less susceptible to injury than wheat from contact placement of fertilizer. Guttay (19) reported similar findings.

Data on the emergence of barley seedlings using Plainfield sand at 8.0 percent moisture level are given in Table 2.9. The treatments were the same as tested for wheat in Table 2.5. In all cases studied, wheat gave much lower emergence as compared to barley. The data indicated that barley was less susceptible than wheat to injury from contact placement of fertilizer, when equal amounts of fertilizer were applied in both cases. Brage (8) found similar results.

Data on the percent emergence, as a percent of check, of wheat, oats and barley using Plainfield sand at field capacity are given in Table 2.10. The data indicate that wheat is more injured by contact placement of fertilizer than oats or barley. In the case of oats in general, emergence at the end of 1 week much slower than that of wheat or barley. By the end of 2 or 3 weeks there was not much difference between oats and barley in percent emergence.

Table 2.8 Percent emergence of oats 1, 2 and 3 weeks after planting in contact with various fertilizers, using Plainfield sand at 7.6 percent moisture level.[1]

Pounds per acre N-P_2O_5-K_2O	Percent emergence 1 w,.	2 wks.	3 wks.	Material used
0-0-0	100	100	100	
0-40-0	90	97	97	0-20-0 (F2)[3]
0-60-0	69	93	93	
0-80-0	33	92	92	
0-40-0	82	92	92	0-20-0 (F1)[3]
0-60-0	43	94	94	
0-80-0	17	93	93	
0-0-27	17	53	56	Potassium sulphate[2]
0-0-40.5	3	18	22	
0-0-54	0	4	4	
0-0-60	0	60	81	Muriate of potash[3]
0-0-120	0	0	0	
28-0-93	0	7	24	Potassium nitrate[2]
5-20-20	24	97	97	5-20-20[3]
7.5-30-30	0	85	92	
10-40-40	0	42	81	
11-28-28	3	96	96	11-28-28[4]
22-56-56	0	15	47	

[1]The soil contains 10 percent moisture at field capacity.
[2]Chemically pure salt.
[3]Commercial fertilizer.
[4]Made up of muriate of potash (60 percent K_2O), and diammonium phosphate (21-53-0) fertilizer.

Table 2.9 Percent emergence of barley 1, 2 and 3 weeks after planting in contact with various fertilizers, using Plainfield sand at 8.0 percent moisture level.

Pounds per acre $N-P_2O_5-K_2O$	Percent emergence 1 wk.	2 wks.	3 wks.	Material used
0-0-0	96	99	99	
26-0-0	6	39	49	Ammonium chloride[1]
0-0-60	17	81	82	Muriate of potash[2]
21-53-0	0	49	68	Diammonium phosphate[2]
14-0-46.5	68	93	94	Potassium nitrate[1]
5-20-20	81	90	90	5-20-20[2]
7.5-30-30	36	85	85	

[1]Chemically pure salt.
[2]Commercial fertilizer.

Table 2.10 Percent emergence as a percent of check of wheat, oats and barley 1, 2 and 3 weeks after planting in contact with 7 fertilizers, using Plainfield sand at field capacity moisture level.

Pounds per acre	Percent emergence of check									Material used
	Wheat			Oats			Barley			
$N-P_2O_5-K_2O$	1 wk.	2 wks	3 wks.	1 wk.	2 wks.	3 wks	1 wk.	2 wks.	3 wks	
18-0-0	45	79	79	61	96	96	87	94	94	Ammonium chloride [1]
30-0-0	2	48	57	6	79	82	9	88	91	Ammonium chloride [1]
0-100-0	53	65	65	25	99	99	35	94	94	Conc. superphosphate [2]
15-90-0	25	54	54	21	83	83	32	81	81	[3]
0-0-40	93	97	97	89	100	100	99	100	100	Muriate of potash [2]
0-0-100	12	65	65	0	74	89	23	78	85	Muriate of potash [2]
0-45-20	93	97	97	89	100	100	99	100	100	[4]

[1] Chemically pure salt

[2] Commercial fertilizer

[3] Prepared by mixing ammonium chloride and superphosphate

[4] Prepared by mixing superphosphate and muriate of potash

Differential Effects of Two Ordinary Superphosphates

Differential effects of two superphosphate fertilizers, F1 and F2, on delaying and/or reducing the final emergence of wheat at field capacity moisture level, of wheat at 6.7 percent moisture level, and oats at 7.6 percent moisture level are presented in Tables 2.2, 2.6 and 2.8, respectively. A glance at these tables is sufficient to conclude that superphosphate F1 was more toxic than F2.

A study was made of three of the possible causes for this difference in response, namely a) total acidity, b) hydrogen ion concentration, and c) fluorine content.

a) Total acidity

It was found that total acidity of superphosphate F1 was 24.07 me/100 gms. and F2 was 19.16 me/100 gms. No work has been published pertaining to total acidity of superphosphate and its toxic effect on germination. While total acidity could be a factor for a superphosphate to be toxic, it is more important to know the active acidity, i. e. hydrogen ion concentration.

b) Hydrogen ion concentration, Table 2.11.

It was observed that the hydrogen ion concentration of superphosphate F1 was approximately twice that of F2. Morse (41) reported that acidity was not the main reason for toxicity of superphosphate, but that toxicity was modified by higher acidity. Morse also reported that free acid present would increase fluorine solubility and also the amount of hydrogen fluoride. Bokorny (7) and Morse (41) reported that hydrogen fluoride exerted toxic effects on germination of seeds.

c) Fluorine content

1) Qualitative test. Glass etchings were observed for both fertilizers, a positive proof of fluorine, although the test did not reveal which one had the greater amount.

Table 2.11 Hydrogen ion concentration of two ordinary superphosphate fertilizers, F1 and F2, at various dilutions with distilled water.

Fert.:H_2O	[H] concentration of F1	[H] concentration of F2	[H] conc. of F1 / [H] conc. of F2
1:2	25.1×10^{-4}M	12.60×10^{-4}M	1.99
1:4	15.8 x "	7.95 x "	1.99
1:5	15.8 x "	7.95 x "	1.99
1:6	15.8 x "	7.95 x "	1.99
1:7	12.6 x "	6.31 x "	1.99
1:8	12.6 x "	6.31 x "	1.99
1:9	12.6 x "	6.31 x "	1.99
1:10	12.6 x "	6.31 x "	1.99
1:15	10.0 x "	5.02 x "	1.99
1:20	7.95 x "	3.99 x "	1.99
1:25	6.31 x "	3.16 x "	1.99
1:30	6.31 x "	3.16 x "	1.99
1:35	6.31 x "	3.16 x "	1.99

2) Quantitative test. Total fluorine, Table 2.12. The values found were very close to what have been reported by Blanck (6) and Jacob *et al*. (27). Analysis of variance indicated that superphosphate F1 contained a significantly greater percent of total fluorine than F2. Investigators (22, 24, and 32) have reported that rock phosphate contains more than 3 but usually less than 4 percent fluorine. Morse (41) reported that rock phosphate was not toxic to germination of corn. So toxicity might not be completely attributed to the total fluorine content.

Water soluble fluorine, Table 2.13. Many investigators (7, 41, 52 and 55) have reported the injurious effect of water soluble fluorine in reducing and even preventing germination. The more toxic superphosphate, F1, contained about 3 times the amount of water soluble fluorine contained by the less toxic superphosphate, F2.

Superphosphate F1 had 1.25 times greater total acidity, 1.99 times greater H-ion concentration, 1.14 times greater total fluorine and 2.93 times greater water soluble fluorine content than superphosphate F2. Water soluble fluorine content was considered the most important in being the cause for the greater harmful effects of superphosphate F1.

Table 2.12 Total fluorine in superphosphates, F1 and F2.

Fertilizer	Distillation number	% Fluorine quadruplicate results				Average
Superphosphate F1	1	1.67	1.67	1.47	1.53	1.58
	2	1.53	1.53	1.53	1.53	1.53
	3	1.60	1.63	1.63	1.81	1.68
	4	1.88	1.88	1.75	1.65	1.79
	5	1.55	1.75	1.53	1.72	1.64
	6	1.63	1.70	1.75	1.72	1.70
	Grand average					1.65
Superphosphate F2	1	1.37	1.50	1.47	1.42	1.44
	2	1.53	1.50	1.38	1.37	1.44
	3	1.38	1.42	1.53	1.38	1.43
	4	1.50	1.50	1.38	1.53	1.48
	5	1.48	1.33	1.48	1.43	1.43
	6	1.37	1.42	1.42	1.50	1.43
	Grand average					1.44
	L. S. D. 1%					0.14

Table 2.13 Water soluble fluorine in superphosphates F1 and F2.

Fertilizer	Distillation number	% Fluorine quadruplicate results				Average
Superphosphate F1	1	.48	.48	.45	.48	.47
	2	.40	.41	.42	.44	.42
	3	.48	.46	.42	.44	.45
	4	.46	.42	.42	.46	.44
	5	.46	.43	.40	.47	.44
	6	.44	.46	.40	.42	.43
	Grand average					.44
Superphosphate F2	1	.15	.16	.15	.17	.16
	2	.15	.12	.16	.16	.15
	3	.14	.16	.15	.16	.15
	4	.14	.16	.14	.14	.14
	5	.15	.16	.14	.15	.15
	6	.15	.15	.16	.14	.15
	Grand average					.15
	L. S. D. 1%					.02

V. SUMMARY

Field Experiments

Effect of seed rate

The number of fall culms per square foot in winter wheat increased in all 4 experiments with an increase in seeding rate.

No specific trend was noted for summer culms in relation to seeding rate.

Gradual increases in height and in vigor of plants were noted with an increase in seeding rate.

No specific trend was noted for the lodging score in relation to seeding rate, although maximum lodging occurred at the heaviest rate. The present data indicated that the 2 peck rate is too low a seed rate for top yields. Averaging all the experiments, the 6 peck rate gave the maximum yield, 2.5 bushels higher than the 4 peck rate.

In 3 out of the 4 experiments test weight increased as seed rate increased. The percentage of protein in the grain decreased with an increase in seeding rate.

Effect of row spacing

Seven-inch row spacing gave a highly significantly greater number of fall culms per square foot than did the 11-inch row spacing at 3 of the 4 locations. The reverse results obtained at the 4th location were probably due to the acidic nature of the soil.

A gradual decrease in the summer culm count per square foot was obtained with an increase in row spacing.

Height of plants decreased with an increase in row spacing up to 11 inches.

Vigor of plants gradually decreased with an increase in row spacing.

All row spacings gave practically the same amount of lodging.

In 3 of the 4 experiments, 7-inch spacing gave statistically the same yield as 11-inch spacing. On the average of the 1957-58 crop year, the 14-inch spacing gave about 5 bushels per acre less yield than the 7-inch spacing. The 14-inch spacing proved to be too far apart for top yields.

All row spacings resulted in the production of grain having practically the same test weight.

The percentage of protein in the grain increased with an increase in row spacing.

Effect of the rate of the fertilizer

Fertilizer applied at 300 pounds per acre gave more fall culms than 600 pounds at all 4 locations, although significant differences existed at only 3 locations.

No such differences existed in the number of summer culms.

The lower rate of fertilizer gave the taller and more vigorous plants.

The heavier rate of fertilizer was associated with more lodging.

On the average, no differences in yield and test weight occurred between 300 pounds and 600 pounds of 8-20-20 fertilizer per acre.

The higher rate of fertilizer resulted in the production of grain with a greater percent of protein.

Effect of fertilizer placement

Side placement of fertilizer gave a significantly (at the 1% level) greater number of fall culms per square foot than did contact placement at all 4 locations.

Side placement was associated with a greater summer culm count at both locations, although significant differences existed in only one case.

Side placement of fertilizer was associated with taller, more vigorous plants and with greater lodging. The differences in these three types of scores due to the two placements were highly significant.

On the average of all 4 experiments, side placement gave 7.4 bushels per acre more yield and 0.3 pounds per bushel higher test weight than did the contact placement.

Side placement gave grain with significantly (at the 1% level) lower percent protein content than contact placement of fertilizer.

The two-factor interactions

An increase in seeding rate gave an increase in the number of fall culms per square foot, taller and more vigorous plants, a higher yield and lower protein content in the grain, regardless of the row spacing, fertilizer rate or placement.

An increase in row spacing gave a decrease in the number of fall and summer culms per square foot, shorter and less vigorous plants, lower yields, and a higher protein content in the grain, regardless of seed rates, fertilizer rates or placement.

The higher rate of fertilizer gave a decrease in the number of fall culms per square foot, shorter, less vigorous plants less subject to lodging, and grains higher in protein content, regardless of the seed rate, row spacing or placement.

Side placement of fertilizer gave an increase in the number of fall and summer culms per square foot, taller and more vigorous plants more subject to lodging, a higher yield and test weight, and a lower protein content in the grain, regardless of the seed rate, row spacing or fertilizer rate when compared with contact placement.

Interrelationships between various characteristics

There were indications of significant (at the 1% level) positive associations between fall culm count and the height of plants, between fall culm count and vigor of plants and between height and vigor of plants.

The fall culm count gave stronger relationships with yield and test weight than did the summer culm count.

No consistent relationships were obtained between fall culm count and summer culm count, lodging score and yield, summer culm count and test weight, yield and test weight.

Laboratory Experiments

Emergence data indicated that nitrogen was more detrimental per unit than potash, and potash more than phosphate.

Ammonium sulphate was more toxic than ammonium chloride, potassium sulphate more toxic than potassium chloride, and the latter more toxic than potassium nitrate.

A fertilizer having the analysis of 6-12-12 prepared by mixing ammonium chloride with superphosphate and muriate of potash was more detrimental to the emergence of wheat seedlings than a 6-12-12 prepared by mixing ammonium sulphate with the same superphosphate and muriate of potash.

The decreasing order of toxicity of 6-12-12, 6-0-12 and 6-12-0 at various rates was noted in Oshtemo sand as well as in Granby loamysand at field capacity moisture levels.

When the same amount of fertilizer was placed in contact with the wheat seed, greater toxicity occurred in sandy (Oshtemo sand) than in soil rich in organic matter (Granby loamy sand).

In general, as the fertilizer rate was increased, the detrimental effects increased at a much faster rate.

Fertilizer placed in contact with wheat had a greater effect on delaying or reducing emergence as the moisture level was reduced below field capacity.

The detrimental effects of nitrogen increased at a much faster rate than the effects of potash or phosphate as the soil moisture was reduced.

As the moisture level of Plainfield sand was reduced from 8.0 to 7.6 per cent, the emergence of wheat seedlings was somewhat reduced (1 week counts) but the final emergence percentages (3 week counts) were the same for the 2 levels of soil moisture.

Oats and barley were less susceptible to injury (3 weeks count) than was wheat from contact placement of fertilizer when equal amounts were applied.

In general, the emergence of oats at the end of 1 week was much lower than that of wheat or barley. By the end of 3 weeks there was not much difference between oats and barley in the percent emergence.

Superphosphate F1 had 1.25 times greater total acidity, 1.99 times greater H-ion concentration, 1.14 times greater total fluorine and 2.93 times greater water soluble fluorine content than superphosphate F2. Water soluble fluorine content was considered the most important in being the cause for the greater harmful effects of superphosphate F1.

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APPENDIX

Table 3.1 Average values of the various characters as affected by different treatments, wheat 1957-58, Kleis farm.

Treat. No.	Row spacing (inches)	Seed rate (pecks)	Fert. rate 8-20-20 (lbs/a)	Place-ment[1]	Fall[2] culm count/ sq. ft.	Fall[3] culm count/ sq. ft.	Height[2] of plants (inches)	Vigor[2] of plants	Summer[3] culm count/ sq. ft.	Lodging[3] score	Yield[3] (bu/a)	Test[3] weight (lbs/bu)
1	7	2	300	C	6.2	6.4	4.3	5.0	46.4	2.0	52.2	57.8
2	7	2	300	S	7.7	7.8	4.5	6.3	50.1	1.0	57.3	58.4
3	7	2	600	C	6.0	6.0	3.7	3.5	51.5	2.3	59.3	58.0
4	7	2	600	S	7.1	7.4	4.8	6.0	45.5	1.3	54.1	58.5
5	9	2	300	C	7.0	7.2	4.3	5.7	42.3	1.7	56.2	57.8
6	9	2	300	S	8.6	9.1	4.6	7.3	43.6	1.7	59.2	58.5
7	9	2	600	C	6.7	6.0	4.1	3.3	46.0	1.3	55.2	58.5
8	9	2	600	S	7.8	8.5	4.9	7.0	50.1	1.3	59.0	58.1
9	11	2	300	C	6.9	6.8	4.0	4.7	41.5	1.3	54.1	57.8
10	11	2	300	S	10.0	9.9	4.0	7.7	37.1	1.7	60.1	58.0
11	11	2	600	C	4.7	4.2	3.5	3.0	34.0	1.7	56.0	58.0
12	11	2	600	S	9.3	9.3	4.3	7.5	44.4	3.0	57.3	57.6
13	14	2	300	C	4.7	4.2	4.5	4.5	34.3	1.7	53.7	57.6
14	14	2	300	S	5.8	6.4	4.9	6.3	35.9	2.7	53.7	57.9
15	14	2	600	C	3.1	2.8	3.9	2.5	30.7	2.0	53.1	58.2
16	14	2	600	S	6.0	6.3	5.0	7.0	36.1	2.3	53.5	57.6
17	7	4	300	C	14.1	13.9	4.8	7.5	50.7	2.3	56.0	58.5
18	7	4	300	S	10.3	10.5	5.0	7.3	56.0	2.0	59.4	57.8
19	7	4	600	C	12.9	12.6	4.7	5.5	51.9	1.7	55.2	58.2
20	7	4	600	S	10.9	10.7	4.9	7.3	51.8	3.0	60.3	58.6
21	9	4	300	C	13.3	13.6	4.5	6.7	43.2	0.7	59.2	58.3
22	9	4	300	S	14.7	14.8	4.7	8.5	47.9	0.3	59.7	58.6
23	9	4	600	C	9.7	9.2	4.2	4.0	50.1	1.7	58.6	58.6
24	9	4	600	S	15.6	16.8	4.7	8.0	38.7	3.0	58.8	58.5
25	11	4	300	C	10.1	10.3	4.1	6.3	42.3	2.0	57.3	57.5
26	11	4	300	S	13.2	13.6	4.6	8.0	32.2	1.7	58.2	58.0
27	11	4	600	C	8.1	8.5	3.8	3.5	34.2	1.7	57.7	57.7
28	11	4	600	S	12.8	9.8	4.5	7.3	37.0	2.3	58.6	58.0
29	14	4	300	C	16.9	17.5	4.4	7.3	35.8	2.3	56.1	58.6
30	14	4	300	S	6.0	6.3	4.9	6.3	32.8	1.7	59.2	58.2
31	14	4	600	C	9.9	8.5	4.0	3.5	34.2	1.3	56.5	59.3
32	14	4	600	S	6.6	6.8	4.9	7.0	27.5	1.7	58.6	58.1
33	7	6	300	C	22.7	22.5	4.9	8.0	48.4	1.7	60.1	58.6
34	7	6	300	S	22.2	21.7	5.3	9.5	58.4	1.7	61.1	58.0
35	7	6	600	C	20.2	19.4	4.8	6.7	45.5	2.7	57.5	58.7
36	7	6	600	S	21.7	20.5	4.9	9.3	44.7	2.7	57.9	58.5
37	9	6	300	C	19.4	18.5	4.8	7.3	40.4	1.3	51.6	58.3
38	9	6	300	S	22.1	22.5	4.7	9.3	39.4	1.3	59.9	57.8
39	9	6	600	C	17.8	17.3	4.6	5.0	46.3	1.3	56.0	58.3
40	9	6	600	S	24.0	24.1	4.8	9.5	50.1	2.7	61.4	58.7
41	11	6	300	C	16.1	16.4	4.4	7.3	38.5	2.0	60.9	58.4
42	11	6	300	S	24.6	25.1	4.9	9.3	43.6	2.0	56.6	58.0
43	11	6	600	C	9.7	9.3	3.8	3.7	40.2	2.0	58.2	59.0
44	11	6	600	S	20.7	21.1	4.1	8.7	39.7	2.0	54.1	59.1
45	14	6	300	C	17.1	15.8	4.9	6.5	38.4	2.0	55.8	57.7
46	14	6	300	S	22.0	22.1	5.1	9.7	32.4	2.3	54.8	58.3
47	14	6	600	C	10.8	9.8	4.3	3.5	31.8	1.3	54.1	58.4
48	14	6	600	S	21.8	22.1	5.0	10.0	35.9	3.0	61.8	58.6

[1] C (contact) placement refers to the placing of seed and fertilizer together. S (side) placement refers to placing of fertilizer 2-inch below and 1-inch to the side of the seed.

[2] Refers to average values of replications 1 to 4.

[3] Refers to average values of replications 2 to 4.

Table 3.2 Average values,[1] of various characters as affected by different treatments, wheat 1957-58, Ferden farm.

Treat. No.	Row spacing (inches)	Seed rate (pecks)	Fert. rate 8-20-20 (lbs/a)	Place-[2] ment	Fall culm count/ sq. ft.	Summer culm count/ sq. ft.	Yield (bu/a)	Test Weight (lbs/bu)
1	7	2	300	C	18.4	40.0	45.1	60.2
2	7	2	300	S	18.6	46.6	46.0	60.2
3	7	2	600	C	9.4	38.4	48.0	59.8
4	7	2	600	S	21.6	43.8	45.6	59.8
5	9	2	300	C	14.9	32.3	46.7	60.0
6	9	2	300	S	16.0	39.6	49.2	60.2
7	9	2	600	C	11.9	35.4	49.6	59.8
8	9	2	600	S	19.4	43.3	49.4	59.8
9	11	2	300	C	10.8	37.8	45.1	60.0
10	11	2	300	S	14.4	39.6	48.4	59.5
11	11	2	600	C	8.4	29.8	42.6	60.2
12	11	2	600	S	14.6	42.8	49.2	59.2
13	14	2	300	C	6.7	23.6	40.8	58.5
14	14	2	300	S	16.2	29.0	43.0	59.5
15	14	2	600	C	4.6	25.3	36.6	58.8
16	14	2	600	S	14.9	33.0	46.4	59.3
17	7	4	300	C	33.9	49.1	53.8	60.2
18	7	4	300	S	36.1	48.6	56.2	60.8
19	7	4	600	C	24.4	52.2	55.9	60.2
20	7	4	600	S	29.8	46.7	61.3	60.2
21	9	4	300	C	20.6	39.2	54.4	60.8
22	9	4	300	S	26.0	40.8	55.4	61.0
23	9	4	600	C	17.0	37.0	52.8	59.8
24	9	4	600	S	24.4	40.1	56.4	60.0
25	11	4	300	C	12.8	33.0	50.9	60.2
26	11	4	300	S	27.3	38.9	51.7	60.2
27	11	4	600	C	11.3	41.4	53.4	60.2
28	11	4	600	S	20.8	37.0	52.0	60.2
29	14	4	300	C	32.8	34.8	41.2	60.0
30	14	4	300	S	41.9	38.7	51.1	61.0
31	14	4	600	C	18.5	36.0	45.0	60.0
32	14	4	600	S	31.0	42.0	53.0	60.5
33	7	6	300	C	37.8	38.8	57.2	60.8
34	7	6	300	S	36.2	49.0	55.0	60.2
35	7	6	600	C	29.3	47.7	58.0	60.2
36	7	6	600	S	42.4	42.2	61.3	61.0
37	9	6	300	C	39.9	41.0	53.2	60.8
38	9	6	300	S	41.7	39.2	60.1	60.5
39	9	6	600	C	28.4	38.6	59.1	60.5
40	9	6	600	S	43.1	41.0	65.4	60.5
41	11	6	300	C	23.8	36.6	58.9	60.0
42	11	6	300	S	45.5	40.0	61.2	60.8
43	11	6	600	C	18.4	37.1	57.7	61.0
44	11	6	600	S	38.9	43.9	58.6	60.8
45	14	6	300	C	26.2	36.6	52.7	61.0
46	14	6	300	S	42.2	40.9	57.0	60.8
47	14	6	600	C	18.1	36.4	49.0	60.2
48	14	6	600	S	41.6	33.0	57.0	60.8

[1]Refers to average values of replications 1 and 2.

[2]C (contact) placement refers to the placing of seed and fertilizer together.
S (side) placement refers to placing of fertilizer 2-inch below and 1-inch to the side of the seed.

Table 3.3 Average values,[1] of fall culm count, yield and test weight of wheat 1958-1959, as affected by various treatments, as obtained on Fick and Ferden farms.

Treat. No.	Row spacing (inches)	Seed rate (pecks)	Fert. rate 8-20-20 (lbs/a)	Place-[2] ment	Fick farm: Culms/ sq.ft.	Fick farm: Yield (bu/a)	Fick farm: Test weight (lbs/a)	Ferden farm: Culms/ sq.ft.	Ferden farm: Yield (bu/a)	Ferden farm: Test weight (lbs/a)
1	7	4	300	C	1.2	17.8	54.7	32.6	55.5	59.2
2	7	4	300	S	4.6	30.0	55.7	30.9	60.7	59.6
3	7	4	600	C	0.5	11.5	54.6	23.4	65.0	59.5
4	7	4	600	S	5.5	36.0	56.3	33.9	63.8	59.5
5	11	4	300	C	2.0	15.8	55.4	26.9	56.8	59.6
6	11	4	300	S	10.2	42.2	56.8	25.2	57.6	59.4
7	11	4	600	C	0.7	12.1	55.0	15.1	60.3	60.0
8	11	4	600	S	9.6	46.7	56.0	29.9	61.3	60.1
9	7	6	300	C	2.0	29.0	55.9	41.7	62.4	60.0
10	7	6	300	S	8.7	47.2	56.6	40.7	60.9	59.6
11	7	6	600	C	0.8	24.1	55.8	33.6	64.4	60.0
12	7	6	600	S	10.4	46.4	56.6	48.8	67.5	59.6
13	11	6	300	C	2.7	29.3	56.1	31.2	54.0	60.0
14	11	6	300	S	10.9	42.2	57.2	35.6	54.4	59.6
15	11	6	600	C	0.7	12.7	55.2	18.9	59.4	59.4
16	11	6	600	S	10.9	47.1	56.5	36.9	57.7	59.8

[1]Refers to average values of replication 1 to 4.

[2]C (contact) placement refers to the placing of seed and fertilizer together.
S (side) placement refers to placing of fertilizer 2-inch below and 1-inch to the side of the seed.

Table 3.4 Inches of recorded rainfall at East Lansing for the crop year 1957-58.

Year:	1957				1958						
Month: Date	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1					.05		T				
2	.12				.09	T	.02				.12
3	T					T	.08		T		1.61
4	.16						T	.07			.48
5				T		T	.12	.64			.10
6				.21	.04		.05	.01			.69
7				.50	.01						
8			.54			T			.07	.23	
9	.12		T							.52	
10	.12			.08							.04
11				.07		T		.20			
12	.21					T		.03		.29	
13			.30			T				.22	
14			1.07			.04	T				.06
15	.16		.01	.02		.31	T			T	.23
16		1.31				.25	T				
17		.19		.02	T		T		.02		T
18		T	.21	.34			T		.03		
19		T	.09	.03	T	T				T	
20	.01		.02	.59	.03	T	T	.21		T	
21	.31		.05	.08	.57		T				
22	T	.19	T		.05			.13	.10		
23	.02	1.76						.03			
24		.24			.35			.22	T	.08	
25			.01	.35	.21					.34	.03
26						T					
27		.07			T	.05		T	.05		
28			.13	.14		.13		.02			.95
29		.05		T	.07						
30		.02	T	.07	.10						T
31				.36	T						
Total	1.23	3.83	2.43	2.86	1.57	0.78	0.27	1.56	1.07	2.32	4.31

T = Trace

Date planted - Sept. 18-20, 1957.

Date harvested - July 26, August 4, 5, 1958.

Table 3.5 Inches of recorded rainfall at Ferden farm for the crop year 1957-58.

Year:	1957				1958						
Month: Date	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1	.01				.28		.06			1.88	
2	.11						.08				
3	.08						.04		.07		.30
4	.08										.27
5											.28
6				.12			.12	.57			
7				.09				.59			
8			.45						.05	.04	
9			.01							.06	
10	.55					T				.05	T
11	.02							.21			
12	.45							.10			
13	.11		.19			T				.24	
14			.75								
15	.44		.31	.03		.06	.01				
16		.81		T		.08	T				
17		.24					T		.03		
18		.05	.22	.12			T		.03		
19			.16	.17				.02		.15	
20	.32		.04	.45	.20		T	.57		.26	
21	.71			.01	.19		T				
22	T	.04			.25	T		.35	.55		
23	.07	1.06									
24		.97			.01			.37		.80	
25			T	.21	.21				T	.38	
26			.05	.13		T					
27		.02			.03	.14					
28			.10	.18		.31					
29			.01		T						
30		.26	.02	.05	.01						
31		.06		.34					.26		
Total	2.95	3.51	2.32	1.88	1.18	.59	.31	2.77	.99	3.86	.85

T = Trace

Date planted - Sept. 24, 25, 1957.

Date harvested - July 23, 1958.

Table 3.6 Inches of recorded rainfall at Ferden farm for the crop year 1958-59.

Year:	1958				1959						
Month: Date	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
1			.07		.37						.37
2	.02				T			1.26			
3	T				.01	.11	T	.55			
4					.04	.01		.02			.07
5				T							.01
6	.11						.50				
7				.02				.08			
8	.25	.12	.11	.07	T		.13	T			
9	.08	.62	.12			.10	.20	.08			T
10	.10		.07			.69		.02	.02		
11		.06				T			.26	.45	.01
12				.01			T				
13			.20								
14			.14		T	.33	T				
15			.50		.06	T	.49		.02		
16	.06				.06	T					
17	1.18			T			.26	.06			T
18	.21					.02					.52
19				T	.08				.18		
20				T							.49
21	.04			T	.60				.55		
22					.10						.17
23		.24			.02	.36			1.15		1.02
24	.25	.01	.01	.01	.09			.20		.18	.07
25		.35	.15	.04	.26					.44	
26			.02			.11	T	.09	.53	.14	
27			.15	.07			.23	.23			
28								.74			
29								.15	.07		.04
30	.32			T	.16		.03			.13	1.23
31							.01		.65		.06
Total	2.72	1.40	1.80	.22	1.85	1.73	2.35	3.48	3.43	2.64	4.06

T = Trace

Date planted - Sept. 25, 1958

Date harvested - July 13, 1959