EFFECT OF SEEDING RATE ON YIELD, AND COMPONENTS OF YIELD IN THREE HARD RED WINTER WHEAT VARIETIES, CONCHO, TRIUMPH AND C.I. 12871

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Winter wheat is the principal field crop of the state of Oklahoma. If a simple cultural practice, such as seeding more or less wheat per acre, could significantly increase the yields per farm, it would materially aid the economy of the state, as well as increasing profits for the individual farmer.

There is a scarcity of technical information on the seeding rates of hard red winter wheat in this state. Only one study is known to have been conducted on rate of seeding. This experiment was conducted over a fourteen year period in Woodward County. However, results were so varied due to environmental effects that no conclusions could be drawn as to the best seeding rate.

Farmers throughout the major portion of the state generally plant hard red winter wheat at the rate of one bushel (60 lbs.) per acre. This seeding rate has been recommended for a number of years, primarily on the basis of past experience. Sixty pounds per acre usually produces a satisfactory stand, so it was adopted by many farmers as the best rate for seeding.

This problem was designed to determine if 60 pounds per acre is the best seeding rate for hard red winter wheat, or if more or less seed should be planted per acre.

The objectives of this study are as follows: (1) To determine the best seeding rate for three varieties of hard red winter wheat. (2) To

determine the effect of seeding rate on the major plant factors which influence yield in these three varieties.

REVIEW OF LITERATURE

Montgomery (26)[1/] reported, in 1912, that many experiment stations had shown that a variation of from 3 to 8 pecks per acre in seeding winter wheat had little or no effect on yield. This was borne out by the work of Hickman (14), Merrill (24, 25), Babcock (4), Stephens (35), Martin (22), Leighty and Taylor (19), Hutchinson (16), Rao et al. (29), Thatcher (38), and Farrell (6).

Stephens et al. (37) found that variations in yields showed very little relation to the variations in rate of seeding. Stephens (35) and Jardine (17) also reported that although there was little difference in yields from plots seeded at various rates, there was a distinct relationship between the rate of seeding and the time of seeding on the yield produced. The same seeding rate producing varying yields when seeded at different dates.

Farrell (6) along with Salmon (31) and Ross and Leidigh (30) reported that in semi-arid areas, if less than 3 pecks per acre were used competition from weeds would reduce yields, and if the seeding rate was too high the soil moisture would be exhausted before the crop had matured.

An unpublished experiment on date and rate of seeding was conducted at the Southern Great Plains Field Station at Woodward, Oklahoma from

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1/ The numbers in parentheses refer to the "Literature Cited", page 30.

1931 through 1945 (2). Responses were highly variable from year to year, indicating that environment is an important factor in seeding rate.

Although nearly all of the above experiments have shown that the lighter seeding rates yielded as much as the heavier rates, there have been experiments with different results. Atkinson (3) found that on the average the returns from heavy seeding were much better than from light seeding. He reported the highest yields from 14 pecks per acre but stated that the increase was so slight that it was only economically feasible to seed as high as 8 pecks per acre.

In Australia, Thomas and Carriss (39) also found that the heavier seeding rate gave the best results. However, the methods used in their experiment were such that the validity of their findings is questionable.

Montgomery (26) reported that the number of tillers decreased rapidly when the rate of planting was increased, with practically no additional tillers developing when 12 to 16 pecks per acre were used. He found that regardless of seeding rate there was a strong tendency for the thin seedings to tiller enough to bring the stand up to normal (1,700,000 plants per acre). This experiment was verified by the work of Scudder (32), Salmon (31), Georgeson et al. (8), Hutchinson (16), and Widtsoe (40). Grantham (12) found that tillering was the result of early seeding, ample plant food and a fairly thin rate of seeding. Singh and Alam (33), working in India, reported that the number of tillers in winter wheat varied from 26 per plant at 3-inch spacings to 54 at 15-inch spacings. Grantham (11) found that in the heavier seeded plots the number of tillers was decreased by 39% and the yield per plant decreased by 48%. However, the total yield for the high and low seeded plots was about the same.

Martin (23) reported that tillering, number of heads which emerge from the sheaths, length of heads, number of fertile spikelets and florets, and development and size of the kernels all depended upon suitable environmental and nutritional factors during each stage of growth. If the plants were overcrowded, the weak ones died. If the seedbed was too dry, emergence was poor and a thick stand was prevented.

Godel (9) found that the yield difference between light and heavy seeding was usually not significant, but that light seeded crops stooled better, had longer heads and stronger straw; and, heavier seeding did not give a sufficient increase in yield to pay for the extra seed.

Woodward (41) also reported no significant differences in yield from various seeding rates. However he did find that the lighter seeding rates resulted in stiffer straw, larger heads and kernels, and higher test weight per bushel than did the heavier seeding rates. He also found an interaction between rate and variety that affected the yields.

Rao et al. (29) reported that among the various interactions, the grain yield was found to be significantly affected only by the interaction between seeding rates and varieties. They found the yield contributing factors to be: total dry matter per plant, number of head-bearing tillers per plant, number of grains per head and test weight.

Locke et al. (20) presented results which showed that more than 95% of the variation in yield could be explained by the number of kernels per unit area, and that almost 60% of the variation could be explained by the number of heads alone. Number of kernels per unit area was much more important in determining yield than weight of kernel. The correlation coefficient for kernels per unit area and the number of heads was 0.927. Plants per unit area were quite unimportant because they were

compensated for by the number of heads per plant.

Quisenberry (28) substantiated a part of Locke's work. He reported that the number of heads per unit area was one of the most important factors in determining yield, closely followed by number of kernels per head or size of head. Plumpness of grain or weight of 1000 kernels was not as important a factor in determining yield as the other two factors mentioned. There was also little relationship between number of heads per area and size of heads or plumpness of grain. Grantham (10) found that different rates of seeding had no significant effect on the size of kernel. The kernels from thick seedings were as heavy as those from the thin seedings. The work of Singh and Alam (33) contradicts the results of Grantham and Quisenberry by showing that the weight of 100 grains was more at wider spacings and less at the closer spacings. Grantham (12) also reported that the yield depended to a large extent upon the weight of the kernel. The kernels of some varieties studied were much larger naturally than others, yet the number required to weigh 10 grams was largely determined by the quality or hardness of the grain. Peck (27) also found that number of heads was correlated with yield except in a few cases.

Hayes et al. (13) reported that the percentage plumpness of grain and yield were correlated to the extent of 0.623 in winter wheat.

McNeal (21) found that kernels per plant accounted for 86.7 to 89.5% of the variation in yield of grain from individual F_3 lines and F_2 plants. He believes this character includes all yield components except kernel weight.

Laude (18), working in Kansas, studied the following plant characters in relation to yield in winter wheat: number of plants per acre, number of kernels per head, and size of kernels. He found that there was a

general relationship between the number of heads and yield, and, except in one case, a decrease in yield was associated with a decrease in test weight. In 1934, a nearly constant relationship was observed between the number of heads per acre and the weight of 1000 kernels on one hand and yield on the other.

In all of the above literature, two things stand out as being the most constant: (1) There is no apparent difference in yield among various seeding rates if moisture is not limiting, and weeds are controlled. The upper rate is determined by the amount of moisture available and the lower rate is determined by the ability of the wheat to overshadow competing weeds. (2) The three primary plant factors which affect yield in hard red winter wheat are number of seeds per unit area, the number of heads per unit area and the weight per seed.

MATERIALS AND METHODS

The three varieties of hard red winter wheat used in this study were Triumph C.I.[2]/12132, Concho C.I. 12517, and C.I. 12871.

Concho, C.I. 12517, is a selection from the cross Comanche x Blackhull-Hard Federation. It is a bronzed-chaff and red-seeded variety of winter habit. The spikes are bearded, fusiform and mid-dense. Concho is medium in height and maturity. It is resistant to the important races of bunt and has some leaf rust resistance. It is susceptible to the Hessian fly.

The parentage of Triumph is reported by the late Mr. Joseph Danne[3]/ to be a selection from the cross (Kanred-Blackhull F_1 x Burbank Quality[4]/) F_1 x (Kanred x Blackhull F_1). Triumph is a white-glumed, red-seeded variety of winter habit. The spikes are bearded, fusiform and dense. It is an early maturing, short, stiff-strawed variety. It is extremely susceptible to leaf rust and susceptible to bunt and stem rust, but has good resistance to loose smut. Because of its earliness, it frequently escapes heavy rust infections.

C.I. 12871 is a selection from the cross Early Blackhull-Tenmarq x

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2/ Refers to accession number assigned by the Crops Research Division, U.S.D.A.

3/ From personal records of the late Mr. Joseph Danne, private wheat breeder, El Reno, Oklahoma.

4/ Probably Florence Quality.

Oro-Mediterranean-Hope. It is an early maturing, white-glumed, red-seeded variety of winter habit. The spikes are bearded, fusiform and moderately-lax. It is moderately resistant to leaf rust and bunt. It is susceptible to soil borne mosaic, stem rust and Hessian fly.

Each of these varieties was planted at the rate of 20.79, 38.55, 60.81 and 76.82 pounds per acre in a randomized block design with four replications. Each plot consisted of 6, 10-foot rows spaced one foot apart. A Columbia hand drill was calibrated to sow as close as possible to 20, 40, 60 and 80 pounds per acre. The number of seed in ten grams of each variety was counted and the number of grams for each seeding rate was measured prior to seeding. Knowing these two factors, a very close approximation could be made of the total number of seed sown in each 10-foot row.

Plants were counted 16 days after emergence on 8-foot sections of rows 2 and 5 of each plot. The percent emergence was computed after the seed sown figure was adjusted to account for the germination percentage (a standard 100 seed, 5-replication germination test was made in the laboratory).

The number of head producing tillers per 2-foot sections of rows 2 and 5 of each plot was counted prior to harvest. The 2-foot sections were chosen at random from each row by picking numbered beans from a box.

For yield component studies, 50 heads were harvested from rows 2 and 5 of each plot after discarding one foot from each end of the rows. The sample was obtained by harvesting the first 25 heads in each row which came after the randomly selected foot mark. These heads were threshed in a Vogel Head Thresher. The seeds from each 50-head sample

were counted and the average number of seeds per head, the average weight of seeds per head and the average weight per seed were determined.

Yield per acre and weight per bushel were determined from material harvested from eight feet of the center two rows (3 and 4). The two border rows (1 and 6) of each plot were discarded.

All data were analyzed statistically on the IBM type 650 Magnetic Drum Data Processing Machine. The coefficients of correlation and analyses of variance were determined by the method described by Snedecor (34). The multiple range tests used were those proposed by Duncan (5).

This study was conducted on the Agronomy Farm at Stillwater, Oklahoma during the 1958-1959 crop year.

EXPERIMENTAL RESULTS

Table 1 shows a summary of the actual seeding rate, the number of seeds planted per square foot, the number of plants emerged per sqaure foot, the weight in grams of the number of seeds actually producing plants and the emerged seeding rate. The seeding rates of 20.8, 38.6, 60.8 and 76.8 pounds per acre actually emerged at the rates of 18.0, 25.2, 41.6 and 48.9 pounds per acre, respectively (an average of the 3 varieties).

Table 1.--Summary data showing averages of seeding rate, number of seeds planted per square foot, number of plants emerged per square foot, weight of seeds that produced plants and the emerged seeding rate for 3 varieties of hard red winter wheat.

Variety*	Seeding Rate lbs/Ac.	No. Seeds Planted	No. Plants Emerged	Grams of Seed Producing Plants**	Emerged Seeding Rate
		Per Square Foot			Lbs/Ac.
Concho	20.8	7.15	5.97	0.173	17.3
C.I. 12871	20.8	6.97	6.42	0.192	19.2
Triumph	20.8	6.72	5.66	0.175	17.5
Concho	38.6	14.31	8.55	0.249	23.1
C.I. 12871	38.6	13.94	9.72	0.290	26.9
Triumph	38.6	13.44	8.89	0.275	25.5
Concho	60.8	21.55	13.70	0.398	38.7
C.I. 12871	60.8	20.94	15.55	0.464	45.2
Triumph	60.8	20.19	13.59	0.421	41.0
Concho	76.8	28.60	17.03	0.495	45.7
C.I. 12871	76.8	27.91	19.73	0.589	54.3
Triumph	76.8	26.91	16.38	0.507	46.8

* Concho = 34.4 seeds/gm., C.I. 12871 = 33.5 seeds/gm., Triumph = 32.3 seeds/gm.

** $\frac{\text{Number of plants emerged per square foot}}{\text{Number of seed per gram}}$ = Grams of seed producing plants.

Table 2 presents data on the number of seeds planted, number of plants emerged, percent emergence and number of plants per square foot for each replicate of each variety and rate. The statistical analysis of the number of plants per square foot is also included. These data show that the percent of plants emerged was greater at the 18.0 pound seeding rate than at the higher seeding rates. The percent emergence for the 25.2, 41.6 and 48.9 pound seeding rates was very similar within varieties. The three higher rates of seeding resulted in an average decrease in emergence of 16.1% for C.I. 12871, 17.4% for Triumph and 18.9% for Concho.

These data also show that the differences among varieties and among rates for plants per square foot were significant at the 1% level. There was also a significant interaction (not shown) between rates and varieties. The number of plants emerged was about equal at the lower seeding rate. However, at the three higher rates, C.I. 12871 had a slightly higher emergence than did Concho or Triumph.

Data showing the number of head producing tillers per square foot and the statistical analysis for the number of heads per square foot are presented in Table 3. Differences among rates and interaction between rates and varieties were not significant. At all of the three higher rates, C.I. 12871 had the largest number of heads per square foot, followed by Concho and Triumph.

Data showing the number of seeds per head with the statistical analysis for this factor are presented in Table 4. The difference among varieties and among rates for the number of seeds per head was significant at the 1% level. The number of seeds per head was nearly the same for C.I. 12871 and Triumph, averaging 19.7 and 19.8, respectively. Concho had the largest number of seeds per head averaging 22.2. The largest

Table 2.--The emerged seeding rate, average number of seeds planted, number of plants emerged, percent emergence, number of plants per square foot and the statistical analysis for plants per square foot for three varieties of hard red winter wheat.

Variety	Emerged Seeding Rate lbs/Ac.	Rep.	Per 16 feet of row: No. seed planted	No. plants emerged	% Emergence*	No. plants Per sq.ft.
Concho	17.3	1	119.2	106	90.5	6.6
		2	119.2	91	77.7	5.7
		3	119.2	83	70.9	5.2
		4	119.2	102	87.1	6.4
		Av	119.2	95.5	81.5	6.0
Concho	23.1	1	222.6	144	65.9	9.0
		2	222.6	140	64.0	8.8
		3	222.6	156	71.4	9.8
		4	222.6	107	48.9	6.7
		Av	222.6	136.8	62.6	8.6
Concho	38.7	1	348.5	207	60.5	12.9
		2	348.5	227	66.3	14.2
		3	348.5	217	63.4	13.6
		4	348.5	226	66.0	14.1
		Av	348.5	219.2	64.1	13.7
Concho	45.7	1	440.3	261	60.4	16.3
		2	440.3	280	64.8	17.5
		3	440.3	277	64.1	17.3
		4	440.3	272	62.9	17.0
		Av	440.3	272.5	63.0	17.0
C.I. 12871	19.2	1	116.0	109	96.3	6.8
		2	116.0	99	87.5	6.2
		3	116.0	95	83.9	5.9
		4	116.0	108	95.4	6.8
		Av	116.0	102.8	90.8	6.4
C.I. 12871	26.9	1	215.2	152	72.4	9.5
		2	215.2	157	74.8	9.8
		3	215.2	159	75.7	9.9
		4	215.2	154	73.3	9.6
		Av	215.2	155.5	74.1	9.7
C.I. 12871	45.2	1	339.4	252	76.1	15.8
		2	339.4	244	73.7	15.3
		3	339.4	251	75.8	15.7
		4	339.4	248	74.9	15.5
		Av	339.4	248.8	75.1	15.6

Table 2.--(Continued)

Variety	Emerged Seeding Rate lbs/Ac.	Rep.	Per 16 feet of row: No. seed planted	No. plants emerged	% Emergence*	No. plants Per sq.ft.
C.I. 12871	54.3	1	428.8	320	76.5	20.0
		2	428.8	297	71.0	18.6
		3	428.8	319	76.2	19.9
		4	428.8	327	78.1	20.4
		Av	428.8	315.7	75.4	19.7
Triumph	17.5	1	110.4	92	86.3	5.8
		2	110.4	88	82.5	5.5
		3	110.4	85	77.0	5.3
		4	110.4	97	91.0	6.1
		Av	110.4	90.5	84.9	5.7
Triumph	25.5	1	207.5	147	73.4	9.2
		2	207.5	151	75.3	9.4
		3	207.5	147	73.4	9.2
		4	207.5	124	61.9	7.7
		Av	207.5	142.3	71.0	8.9
Triumph	41.0	1	327.2	230	72.8	14.4
		2	327.2	201	63.6	12.6
		3	327.2	228	72.1	14.3
		4	327.2	211	66.8	13.2
		Av	327.2	217.5	68.8	13.6
Triumph	46.8	1	413.4	275	68.9	17.2
		2	413.4	259	64.9	16.2
		3	413.4	262	65.6	16.4
		4	413.4	252	63.1	15.8
		Av	413.4	262	65.6	16.4

* Corrected to account for germination percentage of grain seeded.

Standard error of a difference between any two variety-rate means = .486; S.E.M. = .344; C.V. = 5.82%.

1% Multiple range on variety means (plants/sq. ft.)			1% Multiple range on seeding rate means			
Triumph	Concho	C.I. 12871	18.0	25.2	41.6	48.9
11.1	11.3	12.9	6.0	9.1	14.3	17.7

Any 2 means not underlined by the same line are significantly different.

Table 3.--Number of head-producing tillers per square foot and statistical analysis for three winter wheat varieties at four seeding rates.

Varieties	Concho				C.I. 12871				Triumph			
Emerged Seeding Rates	17.3	23.1	38.7	45.7	19.2	26.9	45.2	54.3	17.5	25.5	41.0	46.8
Replication												
1	53.0	52.8	45.0	51.0	42.8	60.5	57.3	60.0	55.8	55.8	48.0	47.0
2	54.5	54.3	47.0	47.5	43.8	54.8	53.5	52.0	46.3	44.5	47.3	42.0
3	47.0	55.5	53.0	57.8	57.5	59.3	52.8	52.8	51.0	49.8	45.3	49.0
4	52.8	57.8	55.8	50.8	48.5	52.5	56.8	54.3	50.8	58.3	57.3	49.5
Av	51.8	55.1	50.2	51.8	48.1	56.8	55.1	54.8	51.0	52.1	49.4	46.9
Variety average all rates	52.2				53.7				49.9			

Standard error of a difference between any two variety-rate means = 2.86; S.E.M. = 2.02; C.V. = 7.77%

5% Multiple range on variety means

Triumph	Concho	C.I. 12871
49.9	52.2	53.7

Any 2 means not underlined by the same line are significantly different

Table 4.--Number of seeds per head for three winter wheat varieties at four seeding rates and the statistical analysis.

Varieties	Concho				C.I. 12871				Triumph			
Emerged Seeding Rates	17.3	23.1	38.7	45.7	19.2	26.9	45.2	54.3	17.5	25.5	41.0	46.8
Replication												
1	25.8	23.1	22.1	20.0	21.1	21.1	18.5	16.7	21.2	18.8	19.2	18.9
2	22.3	22.9	20.2	20.3	21.2	21.2	17.6	17.1	22.6	20.9	19.9	20.7
3	22.6	23.4	21.7	20.1	22.0	23.8	18.8	17.1	21.2	21.7	18.8	17.8
4	23.3	23.8	23.0	21.2	21.0	20.6	19.3	18.6	18.5	21.2	16.0	18.7
Av	23.5	23.3	21.8	20.4	21.3	21.7	18.5	17.4	20.9	20.7	18.5	19.0
Variety average all rates	22.2				19.7				19.8			

Standard error of a difference between any two variety-rate means = 0.87; S.E.M. = 0.615; C.V.= 5.97%

1% Multiple range on variety means

C.I. 12871 Triumph Concho
19.7 19.8 22.2

1% Multiple range on seeding rate means

48.9 41.6 25.2 18.0
18.9 19.6 21.9 21.9

Any 2 means not underlined by the same line are significantly different

number of seeds per head, 21.9, was found at the 18.0 and 25.2 pound per acre seeding rates. The 41.6 pound per acre seeding rate was intermediate with 19.6 seeds per head and the 48.9 pound per acre rate had the least number of seeds per head averaging 18.9. The variety x rate interaction was not significant.

Data showing the weight per seed and the statistical analysis of this factor are given in Table 5. Varietal seed weight differences were significant at the 1% level. There was no significant difference among rates and no significant variety x rate interaction. Triumph was the heaviest variety with an average weight per seed of 29.0 milligrams followed by C.I. 12871 and Concho with weights of 27.9 milligrams and 23.6 milligrams, respectively.

Data showing yield and the statistical analysis of yield are presented in Table 6. The difference among varieties was significant at the 1% level while differences among rates and variety x rate interaction were not significant. Concho had the highest yield followed by C.I. 12871 and Triumph with yields of 47.4, 42.9 and 39.2[5/] bushels per acre, respectively. This difference in yield is shown graphically in Figure 1. This figure also shows the wide variations in yield between Triumph and C.I. 12871 at the different seeding rates as compared with the minor variations in Concho at the various rates. However, there was no significant variety x rate interaction.

Table 7 presents data showing the height of plants and the statistical analysis for three varieties of hard red winter wheat at four seeding

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5/ The yields from 2 plots of Triumph were not included in this figure. These plots had suffered severe nematode damage. The yield was 37.5 bu. per acre when these plots were included.

Table 5.--Weight per seed in milligrams for three winter wheat varieties at four seeding rates and the statistical analysis.

Varieties	Concho				C.I. 12871				Triumph			
Emerged Seeding Rates	17.3	23.1	38.7	45.7	19.2	26.9	45.2	54.3	17.5	25.5	41.0	46.8
Replication												
1	24.4	22.4	22.4	22.2	28.5	28.9	28.9	25.5	29.4	28.2	26.9	30.6
2	23.3	25.4	23.1	24.0	28.3	27.1	27.1	29.8	30.9	29.7	29.5	30.9
3	22.4	24.4	25.8	22.9	28.2	28.5	27.8	26.3	27.6	31.8	27.3	28.7
4	23.7	24.4	23.2	23.1	27.2	27.7	28.8	27.5	26.4	30.8	26.8	28.5
Av	23.5	24.2	23.6	23.1	28.0	28.1	28.1	27.3	28.6	30.1	27.6	29.7
Variety average all rates	23.6				27.9				29.0			

Standard error of a difference between any two variety-rate means = 0.89; S.E.M. = 0.632; C.V. = 4.71%

1% Multiple range on variety means

Concho	C.I. 12871	Triumph
23.6	27.9	29.0

Any 2 means not underlined by the same line are significantly different

Table 6.--Grain yield in bushels per acre for three varieties of winter wheat at four seeding rates and the statistical analysis.

Varieties	Concho				C.I. 12871				Triumph			
Emerged Seeding Rates	17.3	23.1	38.7	45.7	19.2	26.9	45.2	54.3	17.5	25.5	41.0	46.8
Replication												
1	47.6	49.8	49.2	51.2	48.9	48.8	49.0	35.7	42.4	38.6	43.4	40.7
2	46.9	44.7	48.9	45.7	45.5	37.5	43.7	44.5	45.2	33.5	33.4	40.8
3	49.9	48.4	46.8	42.8	48.9	41.4	45.4	33.5	32.5	41.0	36.2	42.9
4	51.2	43.3	43.6	48.3	34.6	39.0	46.4	43.4	24.6	42.5	32.7	29.4
Av	48.9	46.6	47.1	47.0	44.5	41.7	46.1	39.3	36.2	38.9	36.4	38.5
Variety average all rates	47.4				42.9				37.5 (39.2)*			

* The 39.2 figure excludes yields from 2 plots which had sustained severe nematode damage.

Standard error of a difference between any two variety-rate means = 33.30; S.E.M. = 23.54; C.V. = 11.06%

1% Multiple range on variety means

Triumph	C.I. 12871	Concho
39.2	42.9	47.4

Any 2 means not underlined by the same line are significantly different

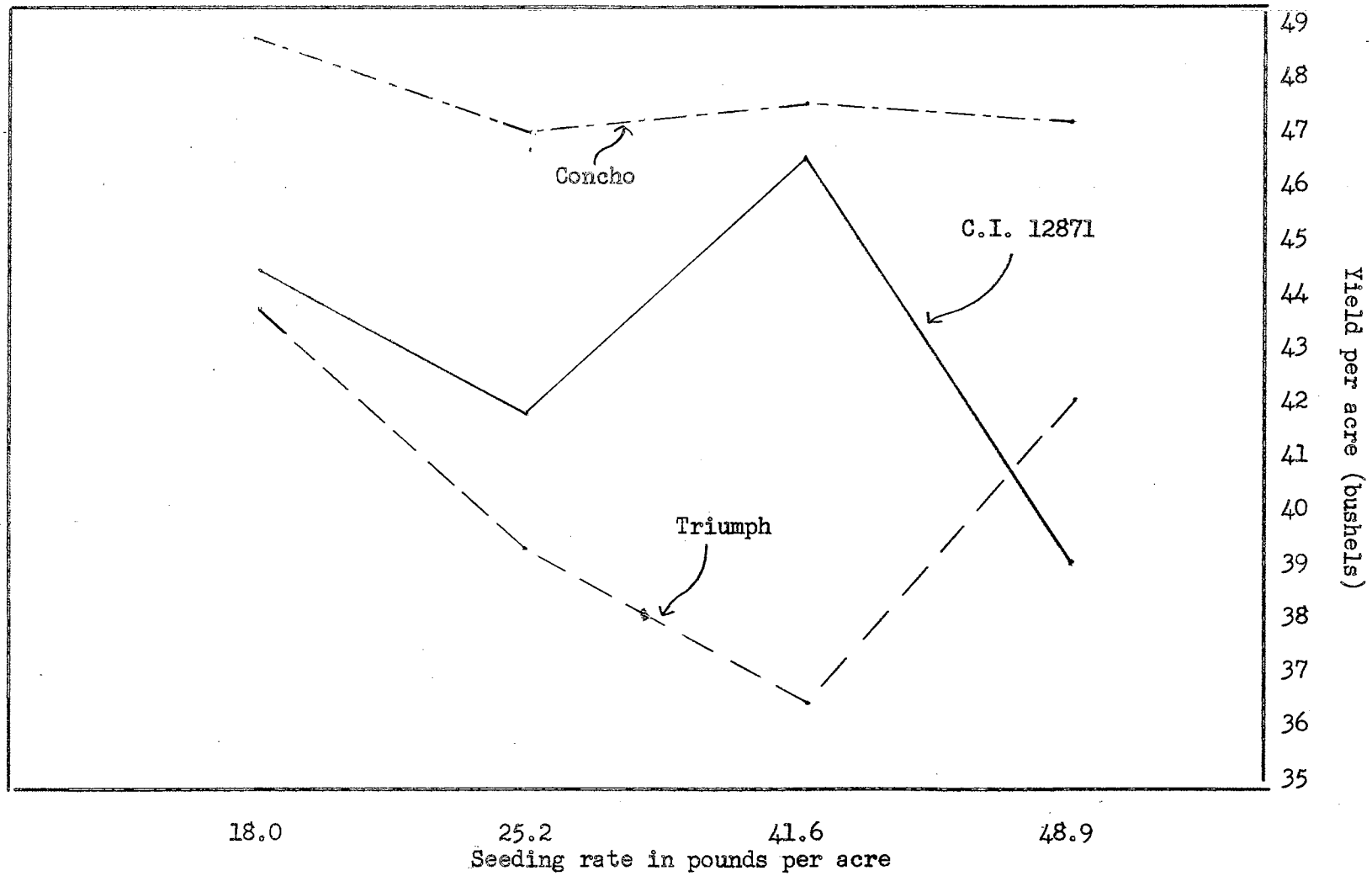

Figure 1.--Yield of three varieties of hard red winter wheat at four seeding rates.

Table 7.--Height of plants and the statistical analysis for three varieties of winter wheat at four seeding rates.

Emerged Seeding Rates	18.0			25.2			41.6			48.9		
Varieties	Cch	12871	Tmp	Cch	12871	Tmp	Cch	12871	Tmp	Cch	12871	Tmp
Replication												
1	37	38	38	33	39	36	35	38	35	35	37	37
2	38	38	39	38	39	39	37	37	36	37	35	36
3	39	39	37	39	39	38	38	37	37	37	37	38
4	39	37	33	37	39	38	36	36	37	34	36	36
Av	38.2	38.0	36.8	36.7	39.0	37.7	36.5	37.0	36.3	35.8	36.3	36.8

Rate average all varieties	37.6	37.8	36.6	36.3

Standard error of a difference between any two variety-rate means = 0.913; S.E.M. = 0.645; C.V. = 3.48%

1% Multiple range on rate means

48.9	41.6	18.0	25.2
36.3	36.6	37.6	37.8

Any 2 means not underlined by the same line are significantly different

rates. Only among rates was there a significant difference. The height decreased from the lowest seeding rate to the highest with approximately a 1.5 inch total decrease in height.

Correlation coefficients for five factors which influence yield are found in Table 8. The number of seedling plants per square foot was negatively correlated with number of seed per head and height. Both were significant at the 1% level. The number of heads per square foot was not significantly correlated with any of the other factors. The number of seed per head was negatively correlated at the 5% level with weight per seed as well as with the number of plants per square foot mentioned above and positively correlated with yield at the 1% level. The weight per seed was also negatively correlated with yield at the 5% level. Yield was not significantly correlated with height.

Table 8.--Correlation coefficients for 5 yield components of the 3 hard red winter wheat varieties, Concho, C.I. 12871 and Triumph.

	No. seedling plants per square foot	No. heads per square foot	No. seed per head	Weight per seed	Yield	Height
No. seedling plants per square foot						
No. heads per square foot	0.0196					
No. seed per head	-0.6540**	0.0076				
Weight per seed	-0.0333	-0.1089	-0.2976*			
Yield	-0.0568	0.0628	0.4531**	-0.3659*		
Height	-0.3741**	0.1472	0.2866	0.2684	0.1596	

* Significant at the 5% level.
** Significant at the 1% level.

DISCUSSION

The yields of three commercial varieties of hard red winter wheat seeded at four rates are considered in the following section. The effect of seeding rate upon the primary factors which influence yield, plants per square foot, number of heads per square foot, number of seeds per head and weight per seed are also discussed. Data for height are also considered.

The actual seeding rates, as based on percent emergence, were much lower than had been planned. The lower percent emergence of the three higher seeding rates as compared with the lowest rate is difficult to explain. Normally, moisture as a limiting factor could be considered. However, during the 1958-59 crop year, there was ample moisture at planting time (2.90 inches during the week following planting) and during the period of emergence. Ahlgren et al. (1) recognized that the oxygen level of the soil surrounding the seeds also influenced the germination of seeds. They reported that adequate supplies of oxygen in the soil are essential for seed germination. Hutchins (15) has shown that wheat seed will germinate well when the oxygen supplying power of the soil is 3.0 milligrams or more per square meter per hour; and they will fail to germinate at all below 1.5 milligrams per square meter per hour. He found that when wheat seeds were planted in a thick layer the seeds which were closest to the surface germinated normally while those closer to the bottom of the layer were slower and more deficient in germination. When a large number of

germinating seeds were confined to a small area, the oxygen in that area was rapidly depleted. If the oxygen fell below the minimum requirements needed for germination, the deeper seeds or the later germinating seeds were not able to obtain sufficient oxygen to emerge.

The above work could possibly explain the lower percent emergence at the higher seeding rates in this experiment. Possibly only those seeds nearest the surface or which had germinated early had sufficient oxygen available to emerge. Since neither temperature nor moisture were limiting in this experiment, no other explanation seems plausible. Further investigation of this problem should be considered.

A significant difference at the 1% level among the yields of the three varieties was obtained. The differences in number of seedling plants per square foot were significant among varieties as were all of the other factors except height. The greater the number of seeds per head, the lower the weight per seed, and, the lower the weight per seed the higher the yield. Triumph was the lowest yielding variety and had the highest weight per seed. C.I. 12871 was intermediate, both for yield and weight per seed, and Concho had the lightest seed and the highest yield.

There was a significant difference among varieties for plants per square foot. A possible explanation for this difference could be that these varieties have different individual oxygen requirements with C.I. 12871 requiring less oxygen to germinate than was required by Concho or Triumph. Work by Ahlgren et al. (1) and Hutchins (15) has shown that different species have different oxygen level requirements for germination. It is possible that different varieties within a species also have different oxygen requirements. This could also account for the

significant interaction that was found between varieties and rates. As was expected the difference in number of plants per square foot was highly significant among the seeding rates. Woodward (41) also found a significant interaction between rate and variety in one out of the three years covered by his experiment. However, he could offer no explanation for its cause.

Differences in the number of heads per square foot was significant only among varieties, and then only at the 5% level. At the lowest seeding rate, Concho exhibited a slightly better tillering ability than did the other two varieties. However, at the three higher rates, it was surpassed by C.I. 12871. Montgomery (26) found that the number of heads per unit area was highly significant among seeding rates. This work was verified by Salmon (31), Scudder (32) and several others (8, 16, 40, 12, 33, 11, 9). Many investigators have found significant differences among varieties (32, 12, 22, 11, 23, 10). The failure of this experiment to agree with all of the above work could be explained by the low actual seeding rates (due to poor emergence). All of the seeding rates were so low, the highest only slightly above 2 1/2 pecks, that a true test of tillering ability under competitive conditions may not have been obtained.

There were no significant differences among the various seeding rates for weight per seed. These results were in accordance with the findings of Grantham (10, 12), Locke (20) and Quisenberry (28), all of whom reported that the weight per seed was relatively unimportant in determining yield. This factor being equal caused the yield differences among seeding rates to be determined by the only other two factors which were significant for rates, i.e., number of plants per square foot and number of seeds per head. This agreed with the findings of Locke (20)

who reported that 95% of the variation in yield could be explained by the number of kernels per unit area, and that nearly 60% of the variation could be explained by the number of heads alone. Further, these findings agreed with those of Rao et al. (29), Quisenberry (28) and Peck (27). Due to the negative correlation between these two factors in this study, the yields were nearly equal. The greater number of plants per square foot was compensated for, in the yield analysis, by a smaller number of seeds per head. This may explain why the various seeding rates failed to produce significantly different yields. These findings are in accord with those of Locke (20), Quisenberry (28), Rao et al. (29) and others (10, 21).

The height of the plants was highly significant among rates. The higher the seeding rate the shorter the plants. Apparently a greater competition for moisture, nutrients, sunlight, etc., was caused by additional plants per unit area. Seeding rate was the only factor which was significantly correlated with height.

It is evident from the results of this study, that this problem should be continued. Not, however, to determine the best seeding rate for all varieties of hard red winter wheat, but to determine which is the best seeding rate for specific varieties. Further work should also be done to determine if the weight per seed is as highly correlated with yield as this one year's data indicate. If this correlation proves to be correct, this factor could be used in a breeding program to aid in the selection of high yielding varieties.

SUMMARY

A study of the effect of seeding rate upon the yield and some plant characters affecting yield of three varieties of hard red winter wheat was carried out during the 1958-1959 crop year.

The main objectives of this research were: (1) to determine if 60 pounds per acre is the best seeding rate for hard red winter wheat; and, (2) to determine the effect of seeding rate upon some of the primary plant factors which influence yield including: (1) number of plants per square foot; (2) number of heads per square foot; (3) number of seeds per head; (4) weight per seed; (5) yield; (6) height.

Three varieties of hard red winter wheat were planted at four seeding rates, in four replications, in a random block design. The actual seeding rates (counting only the plants which emerged) were 18.0, 25.2, 41.6 and 48.9 pounds per acre instead of 20.8, 38.6, 60.8 and 76.8 pounds per acre as planned. Plants were counted after emergence. Head bearing tillers were counted and samples were taken to determine the number of seed per head and weight per seed. Yield and height data were also taken.

There was no significant difference in yield among the various seeding rates. However, there was a significant difference in yield among varieties. Concho was the highest yielding variety followed by C.I. 12871 and Triumph. A negative correlation was found between the number of plants per square foot and the number of seed per head over all rates and varieties. Each of these factors compensated for the other causing

the yields to remain approximately the same.

There was a significant difference among varieties for all of the factors except height.

Significant correlation coefficients showed that the greater the number of seeds per head, the lower the weight per seed, and, the lower the weight per seed the higher the yield.

An analysis of the number of plants which emerged per square foot revealed a decrease in emergence between the lowest seeding rate and the three higher seeding rates of 16.1% for C.I. 12871, 17.4% for Triumph and 18.9% for Concho.

The statistical analysis showed that the difference in plants emerged among rates was significant at the 1% level. It is thought that there was insufficient oxygen available in the soil at the higher seeding rates to allow many of the seeds to germinate.

The only significant difference for number of head producing tillers per square foot was among varieties at the 5% level, which indicated that these varieties may have different individual oxygen requirements. These results conflict with those of several previous experiments and it is believed that the number of plants per square foot was too low to give a good test of tillering ability under competitive conditions.

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