EFFECT OF ROW-WIDTH AND RATE OF SEEDING ON PLANT CHARACTERISTICS IN WHEAT

by

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ABSTRACT

A 2-year study was conducted on the American University Farm in 1960 and in 1961 to study the effect of the rate of sowing and the row-width spacing on the yield and certain other plant characteristics in wheat.

In the drier less favorable 1960 season, the rate of seeding did not significantly affect the grain yield but there was a tendency for increased yield with increasing rate of planting. The yield of grain was closely correlated with the number of plants per unit area, the number of tillers per plant and the number of heads per plant in 1960 when conditions were not as favorable for a good stand or tillering. In 1961, conditions were more favorable for establishing a stand and for tillering and there was no significant correlation between yield of grain and number of plants per square meter or number of heads per plant. However, there was a negative correlation, in 1961, between the yield of grain and the number of tillers per plant indicating that conditions could be too favorable for tillering. Therefore, when conditions were poor for tillering, a greater amount of seed could be sown to advantage.

In both the years increasing row-width spacing significantly decreased the number of plants per unit area. In the more favorable 1961 season, the wide 45-cm. spacing tended to result in a considerably lower yield.

The rate of planting or row-width spacing did not

materially affect the yield of straw, the grain/straw ratio, the weight per 100 kernels, the plant height or the protein concentration of the grain.

Probably, the rate of planting should not be less than 10 kg. per dunum and the row-width spacing should not be over 30 cm. More definite conclusions would require the accumulation of more data over a longer period of time.

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INTRODUCTION

The use of wheat by man dates as far back as 6,700 years (21) as is evident from the archaeological excavations and explorations that have been made in several countries such as Pakistan, Turkey, and the United Arab Republic (Egyptian region). Clark (3) states that, "Civilization is in part a product of wheat, which is grown, stored, and prepared in relatively large quantities by comparatively few men, thereby releasing human energy for pursuits other than constantly hunting a food supply." This explains partly why wheat is among the world's most important grain crops. In a total of about 50 countries with nearly 400 millions of acres of land devoted to it, wheat enjoys recognition as a staple food for the majority of the world's population. In acreage, wheat exceeds all other grain crops on the world basis, while in production it ranks next only to rice with an annual production of 6 billion bushels (38). Because of this, it has attracted man's attention from very early times which has resulted in much effort to improve it's yield and quality.

Considerable improvement has been made in wheat yields by using the proper amount of seed. In general, wheat is sown broadcast at a rate ranging between 15 and 20 kilograms per dunum under the arid and semi-arid conditions prevailing in the Middle East. This rate of sowing is considered higher than that used in other areas of the world with similar rainfall conditions. The furrow method of planting, no doubt,

requires more seeds than the drill method as some of the seeds remain on top of the soil while some seeds are covered too deep. With improved methods of planting being adopted by the farmers, the proper rate of planting is important in order to improve production in the area and to minimize the amount of the crop that must be used for seed. The purpose of this study, therefore, was to determine the most desirable rate of planting and the optimum row-width for wheat when grown under the dry land conditions found in the Beka'a plain.

The experiment was conducted on the University Farm in the Beka'a plain for the two seasons, 1959-60 and 1960-61. Data involving yield, kernel weight, protein content, and other plant characteristics were studied. It is assumed that, the data obtained from this study will furnish a basis for making recommendations on the sowing rates and row-width spacings of wheat for this area.

REVIEW OF THE LITERATURE

Wheat, the mainstay of human life in many parts of the world for centuries, has naturally undergone much experimentation. One branch of such experiments relates to the rate of sowing and space between rows. Apparently the earliest record of an experiment in this line appears to be that of Merill in 1898. Merill's report cited by Woodward (42), covered an eight year experiment on rate and date of sowing wheat, oats, and barley under irrigation in Utah, USA. He obtained the highest yields of 19.5 bushels per acre for 2 pecks* and about equal yields for 8 to 10 pecks an acre.

Later experiments, at different places, have shown that thin sowing and early sowing under semi-arid conditions were beneficial. Martin (23) mentioned Breithaupt, Cotrell, Farrell, Scudder and others as having recommended sowing wheat at rates lower than 3 pecks to the acre to obtain good yields. Carleton (3) and Widtsoe (38) also share the same idea. Leighty (20) recommended 6 pecks of wheat per acre depending on the size of kernel, condition of seed-bed, soil type, soil fertility and date of seeding. He stated, "When the grains are small, the seed-bed in good condition, the soil rich, warm and well drained, and the seeding early, 5 or even 4 pecks per acre are often sufficient" for the areas in the eastern United States. For opposite conditions his recommendation ranges between 7 and 10 pecks per acre for a profitable result.

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*For wheat 1 peck = $\frac{1}{4}$ bushel = 15 pounds.

Martin (23) summarized the results of investigations conducted in the Great Plains and Great Basin of USA up to 1925 as follows: "The optimum rate of seeding for wheat is practically independent of soil type, moisture, locality, date of seeding, cultural treatments, and variety. The optimum date of seeding for winter wheat is independent of soil type, annual precipitation, variety, and rate of seeding, but is related somewhat to temperature, even though the same temperature conditions do not apply in all sections. Rates of 4 to 6 pecks per acre in general have produced the highest net yields of winter and spring wheats. Medium seeding of winter wheat usually is most favorable."

Several rate-of-sowing experiments did not agree with the popular belief of thin sowing of wheat under semi-arid conditions prevailing in the western USA (24). Kiesselbach (15) in a five year experiment at the Nebraska station obtained an average of 28.6 bushels of winter wheat an acre with a sowing rate of 3 pecks per acre while with 6 pecks to the acre, the yield was 31.5 bushels. Still higher rates gave lower yields. According to Kiesselbach (16), Coffman (5) was able to get an increasingly higher yield of Kanred winter wheat when the rate of sowing was raised from 1 peck an acre to 5 pecks per acre during the 1920-22 seasons. During the 1913-1918 period the yield was likewise maximum at 6 pecks per acre, "having gradually risen to 23.6 bushels from 14.7 bushels for the 1-peck rate". With durum wheat Coffman (5) obtained the highest yield at 4 pecks per acre in an 11-year experiment

during the years 1911-22.

Harman (8) recommended a sowing rate ranging between 4 and 6-pecks an acre of wheat and a little more on poor soils. Elliot (7) advised to plant one-half to one and one-half bushels of wheat to the acre. Bracken and Stewart (1) could not find any practical difference between a sowing rate of 4 pecks to the acre and up to 8 pecks of wheat per acre under dry land conditions.

It appears from the results of many experiments that there is a rather definite optimum rate of sowing beyond which heavier rates fail to produce increased yield. Thus according to Sprague and Farris (34), Thatcher (35) reported an average yield of 27.3 bushels with 4 pecks per acre. The yields with higher rates increased negligibly up to 8 pecks. Beyond this rate, the yield decreased. Waldron (37), reported results regarding the use of heavy and light, and large and small parent seeds. He obtained a highly significant increase in yield from the heavier kernels.

Robertson et al.(29) recommended 2 pecks an acre of Kanred wheat under dry land conditions and found no justification for using a higher rate. Rather and Harrison (28) stated that, within fairly wide limits, the rate of sowing does not influence the yield very much. They recommended 4 to 6 pecks for the humid areas and 3 to 4 pecks per acre for drier areas. For late sown wheat it is better, according to them, to increase the recommended rate by 1 or 2 pecks an acre. Similar recommendations were made by Salmon and Throckmorton

(31) as mentioned by Salmon, Mathews and Leukel (33). They maintain that, "there is no rate that is outstandingly better than others", and were unable to find any real difference between the rates of 4 and 8 pecks to the acre. Their recommendation for winter wheat on clean, moist and firm seedbeds was 2 pecks or lower. For spring wheat it should not be less than 4 pecks because of possible weed competition. Lathrope and Ohlrogge's (19) recommendation stands at 6 to 8 pecks per acre of clean seed of a high yielding disease resistant variety of wheat for the southern areas in Indiana, USA.

In Woodward's experiment (42) barley, at 30 to 40 pounds to the acre, gave as high yield on irrigated soils as at higher rates up to 140 pounds an acre. For other grains, except those sown late, he found 50 to 60 pounds per acre to be adequate. Lighter rates produced stiffer straw, larger heads and kernels, and higher test weight per bushel than heavier rates. Jardine's experiment (14), as summarized by Martin and Leonard (24), has shown that thin sowing of hard red winter wheat (20 to 30 pounds per acre) was feasible in the Great Plains of USA for early sown wheat because they tiller heavily.

In the higher rainfall areas of eastern United States, sowing rates for winter wheat vary between 5 and 8 pecks per acre. In Virginia, Leighty and Taylor (21), according to Martin and Leonard (24), have shown that the highest grain yields could be secured from the 6-peck rate. Martin and Leonard (24) also mention Salmon and Taylor (32) as having

concluded that, a rate of about 6 pecks or more would give a larger yield than a lesser quantity of seeds. As summarized by Martin and Leonard (24) William's (39) extensive experiments in Ohio have suggested that the highest net yield (yield minus seeds sown) could be secured from a seeding rate of 6 to 8 pecks an acre.

Wolfe and Kipps (41) observe: "As a rule, since tillering is greater on productive soils and since the increase in number of tillers makes up for the thinner seeding, small grains are seeded at a heavier rate on thin soils than on more productive soils". According to them (41), Hutcheson and Wolfe (12) found, in Virginia, that a seeding rate of 6 pecks to the acre gave a larger yield than smaller quantities on soils capable of producing 15 to 25 bushels an acre. Soils capable of yielding 20 to 35 bushels gave a larger yield at 4 pecks per acre. Wolfe and Kipps (41) quoted Kiesselbach and Lyness (17) as having recommended for eastern Nebraska, a rate of 5 to 6 pecks of wheat per acre "with a gradual reduction westward in the state to 2 or 3 pecks per acre". Hickman (10), as mentioned by Wolfe and Kipps (41), recommended 8 to 9 pecks for the poor soils of Ohio and 5 to 6 pecks of wheat per acre for the rich soils.

To determine the relative merits of seeding implements under varying soil and climatic conditions, the effect of row-width spacing on the yield of small grains have been studied by several investigators (13).

According to Harper (9), Kiesselbach, Anderson and Lyness (18) obtained lower yields of wheat in 14-inch rows as compared with 7-inch rows, over a 3-year period when the same quantity of seed was used. Harper (9) also mentioned that Thatcher and Lewis had reported similar results. Salmon, as cited by Harper (9), planted wheat at the rate of 3, 4, and 6 pecks per acre, in rows varying from 8 to 16 inches apart. He obtained very little variation in yield due to different spacings or rates of planting over a 4-year period.

Harper (9) reported the result of a study of the effect of planting a small grain crop, in rows 7 or 14 inches apart, on the growth of legume seedlings and yield of grain. It was found that the effects of row spacings on the yield were quite variable. At 14-inch row spacing, the average production of grain and straw was slightly lower and it required half the amount of seed needed for 7-inch spacings. At Stillwater, Oklahoma, a 10-year experiment showed no difference in yield between row widths of 14 and 7 inches. The average yields were 34.6 and 34.3 bushels per acre, respectively. A barley variety planted at 1 bushel per acre in 14-inch rows suffered a greater reduction in yield (about 3 bushel net loss) than winter wheat, rye or spring oats. Elliot's (7) recommendation stands at 6-8 inches between rows.

McClelland (25,26) studied the effect of border rows on the yield of spring oats. Border rows, 16 inches apart, produced 25.8 percent more grain than the inside rows 8 inches apart. When the alley was 24 inches wide, border rows pro-

duced a 43.7 percent increase in yield above the inside rows. A larger growth of red clover occurred in the alleys because the border rows did not make full use of the alley space.

Reports of Sprague and Farris (34) showed that the rate of planting could vary as much as 40 percent without reducing the yield of barley when rows were 8 inches apart. The tendency of barley roots is to grow downward with a limited lateral spread. Wheat, oats, and rye were found to have a more extensive root system than barley, and a wider fluctuation in the rate of planting can occur without affecting the yield.

Dungan and Burlison (6) reported results of spacing experiments on oats but they were not able to reach a decisive conclusion. The results were in favor of the 4-inch row-width in some seasons, while in the other season higher yields were obtained in 8-inch rows. Varietal trials in the Sudan (30) showed that wider spacing, 30 cm., was significantly better for most of the varieties of wheat tried than narrow spacing, 20 cm., for higher yield.

MATERIALS AND METHODS

The experiment was conducted for two seasons on the University Farm, located about 50 miles east of Beirut, under dry farming conditions. The soil was a clay type with a pH value of about 8.0. The variety of wheat used in this trial was a late durum wheat named Senator Capelli. The 1959-60 crop year was a very dry one for Lebanon. The total rainfall for the year, from September 1959 to August 1960, was at a record low of 219 mm. as compared to a total of 316.4 mm. during the previous season. This necessitated the application of two irrigations (overhead sprinkler), on April 14th and on May 4th, 1960, to save the crop from complete failure. The total rainfall for 1960-61 was 283 mm. or only a little better than the previous year. One irrigation was made on May 10, 1961, to save the crop grown the second year of the experiment.

Three different rates of sowing were made each at different row-width spacings. The rates were 6, 10 and 14 kg. per dunum, and the spacings between rows were 15, 30 and 45 centimeters, respectively. The soil was fertilized at the rate of 4 kg. per dunum of N in the form of ammonium nitrate and 4 kg. per dunum of P_2O_5 in the form of superphosphate. The fertilizers were broadcast and then disked into the soil before planting time.

The experiment was laid out on a split-plot design involving nine treatment combinations of rates and spacings with each replicated three times. The size of each plot was 2 by

18 meters. The sowing was accomplished with a regular 6 foot small grain drill except for the heaviest rates and highest spacings (14 kg. and 45 cm.) which was done with a Planet Junior hand drill. Planting was done on November 12, 1959, and on November 16, 1960. Emergence of wheat seedlings was recorded on December 7, 1960 and on January 1, 1961. Table 1 shows the rates of planting at the various row-width spacings.

Table 1. Rates of planting wheat at various row-width spacings.

Rates of seeding, kg./dunum	Row-width, centimeters	Drill setting
6	15	11
6	30	22
6	45	33
10	15	18
10	30	36
10	45	54
14	15	25
14	30	50
14	45	-

Care was taken to reduce the population of weeds and thereby reduce the competition between the wheat plants and the weeds. Weeding was done with the regular nursery equipment. Hand weeding was used in the plots having 15 cm. spacing since no mechanical device could be used between the narrow rows in these plots. Some weed competition resulted in the 15 cm. plots during the early stages of growth as hand weeding required more time than mechanical weeding.

Date of emergence, plant height, date of heading, number of plants per square meter, number of tillers and heads per plant, weight of straw, grain yield and average weight of

100 kernels were obtained and recorded. Three samples, each representing an area equivalent to 0.8361 square meter, were harvested from each plot, placed in a cloth sack and dried in the sun for two weeks. Threshing, cleaning and sieving were all done with the usual nursery equipment.

After threshing and cleaning, the whole kernels in each sample were separated from the broken ones and the 100 kernel weight determined. For protein determination a representative sample of each lot was dried for 90 hours at a constant temperature of 70°C. and ground in a micro Wiley mill using a 20 mesh screen. Analyses for nitrogen content were then made according to the modified Kjeldahl method (10) to determine the percentage of protein. The nitrogen values obtained were multiplied by the factor 5.7 and the data reported as percent protein. All results were reported on a 12.5 percent moisture basis. Results of duplicates differing from the sample mean by 6 percent or over were rejected and the analysis repeated. The following formula was used to calculate the range of variation:

$$\frac{X-Xm}{Xm} \times 100 \leq 6\%$$

where, X = the percent total of N in the sample.

Xm = mean percentage of total N in the sample.

All data were tabulated and standard statistical methods, namely, analysis of variance, the 't' test and the correlation coefficient were used to calculate the difference between the treatment combinations (26).

RESULTS AND DISCUSSION

A 2-year experiment was conducted to study the effect of rate of sowing and row-width spacing on the grain yield and certain other plant characteristics in wheat. The grain yield obtained in 1961 was about three times higher than that obtained in the previous year. This increased yield was probably due to the fact that 66 mm. more rain was received in 1961 than in 1960.

Yield of grain.

In the two years, grain yield showed no significant difference due to rate of sowing. However, the highest grain yield was recorded, in both the seasons, from the heaviest rate of sowing (14 kg./dunum). There was a definite trend towards increasing yield of grain with increasing rates of sowing in 1960 and in 1961 except that with the 45-cm. row-width spacing, there was a tendency for a decrease in yield, though not statistically significant, with increasing rates of sowing in 1961. In 1960, the medium spacing, 30 cm., was significantly lower in grain yield than the narrower or the wider spacings (Table 2). No reason was discovered for this unexpected result. In the more favorable 1961 season, the 45-cm. spacing tended to result in a decreased yield although the differences were not statistically significant at the 5 percent level. There were no definite differences between the 15-cm. and 30-cm. row-width spacings in 1961.

The trend towards increasing yield with increasing

Table 2. The effect of rate of seeding and row-width spacing on the grain yield of wheat, kg./dunum.

Row-width spacing, cm.	Rate of seeding, kg./dunum. 6 Kg., r_1 1960	1961	10 Kg., r_2 1960	1961	14 Kg., r_3 1960	1961
15, s_1	72.3	265.7	64.0	196.6	113.8	272.4
30, s_2	39.7	234.9	52.3	240.7	53.3	272.4
45, s_3	63.0	216.7	92.3	204.1	125.4	179.0

	1960 LSD at 5%	LSD at 1%	1961 LSD at 5%	LSD at 1%
Rate	67.01	111.14	49.64	82.33
Spacing	34.05	47.73	50.88	71.33

Rate	r_1	r_2	r_3	r_2	r_1	r_3#
	58.3	69.5	97.5	213.8	239.1	241.3
Spacing	s_2	s_1	s_3	s_3	s_1	s_2#
	48.4	83.1	93.6	199.9	244.9	249.3

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	8930.23	985.28
Rates	2	3667.45	2104.86
Error(a)	4	2622.58	1439.93
Spacing	2	5045.59*	6724.82
Rate X Spacing	4	785.86	256.08
Error(b)	12	1098.66	2453.03

#_____. Treatments underlined do not differ significantly at the 5 percent level.

*Statistically significant at the 5 percent level.

rate of sowing was also observed by other workers (1, 4, 14, 15). They found that this tendency was maintained up to a certain limit whereafter the yield decreased with an increase in the sowing rate (1, 32). Harper (8) found very little difference in yield due to different rates of sowing or row-width spacings over a period of four years. This finding was in agreement with the results obtained in 1961 and partially so in 1960 when the medium row-width spacing, 30 cm., resulted in a significant decrease in yield of grain.

Thus, other factors remaining equal, it appeared that, no one rate of sowing can be classed as outstandingly better than others. Probably the rate of seeding should not be less than 10 kg. per dunum and the row-width spacing should not be over 30 cm. More data over a longer period of time would be needed in order to make more definite recommendations.

Yield of straw.

The rate of seeding did not have any significant effect on the straw yield response in either year (Table 3). There was a definite tendency towards an increase in yield of straw with increasing rates of sowing in 1960; but in 1961 no definite trend was apparent. The lowest rate of sowing, 6 kg. per dunum, gave the highest amount of straw in the second year while it yielded the lowest amount in the first year.

None of the spacings had any significant effect on the yield of straw in the two seasons except the widest spacing, 45 cm., which, in the drier 1960 season, was significantly higher in straw yield than the other two spacings. In the

Table 3. The effect of rate of seeding and row-width spacing on the yield of wheat straw, kg./dunum.

Row-width spacing, cm.	Rate of seeding, kg./dunum. 6 Kg., r_1 1960	1961	10 Kg., r_2 1960	1961	14 Kg., r_3 1960	1961
15, s_1	332.6	765.9	319.2	518.8	423.6	675.4
30, s_2	348.8	660.3	365.9	650.0	398.6	753.1
45, s_3	419.1	647.0	435.3	577.7	449.2	569.2

	1960 LSD at 5%	1960 LSD at 1%	1961 LSD at 5%	1961 LSD at 1%
Rate	126.67	210.08	228.71	379.32
Spacing	62.52	87.65	109.39	153.36

	r_1	r_2	r_3	r_2	r_3	r_1 #
	366.8	373.4	423.8	582.2	665.9	691.0

	s_1	s_2	s_3	s_3	s_1	s_2
Spacing	358.5	371.1	434.5	598.0	653.4	687.8

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	11716.39	182607.30
Rates	2	8736.89	29253.25
Error(a)	4	9369.00	30548.63
Spacing	2	14964.03*	18487.25
Rate X Spacing	4	1776.84	16390.88
Error(b)	12	3704.04	11339.94

#_____. Treatments underlined do not differ significantly at the 5 percent level.

* Statistically significant at the 5 percent level.

first season, the straw yield response due to spacings followed a definite trend - the straw yield increasing with wider spacings. This was not true for the second season, in which the highest yield tended to result from the 30-cm. spacing.

Grain/straw ratio.

The grain/straw ratio was almost three times higher in 1961 than it was in 1960 indicating more favorable moisture conditions for grain yield in 1961. The analysis of variance for the grain/straw ratio (Table 4), did not show any significant differences in either year which could be attributed to differences in the rate of planting. In 1960, there was a definite trend towards an increase in the ratio with an increase in the rate of planting; but no definite trend was observed in the 1961 season. In the second season, there was a significant difference in the ratio due to the blocks which might be due to soil variability.

The effect of row-width spacing on the grain/straw ratio was significant at the 5 percent level in both the years. In the first season, the medium spacing between the rows, 30 cm., gave a significantly lower ratio while the other two spacings did not differ significantly between themselves. In the 1961 season, the wide 45-cm. spacing gave a significantly lower grain/straw ratio than the 15 cm. spacing. The lowest spacing, 15 cm., usually gave the highest ratio.

A high grain/straw ratio is a desirable characteristic for high grain yield and it appeared that a high rate of

Table 4. The effect of rate of seeding and row-width spacing on the grain/straw ratio in wheat.

Row-width spacing, cm.	Rate of seeding, kg./dunum					
	6 Kg., r_1		10 Kg., r_2		14 Kg., r_3	
	1960	1961	1960	1961	1960	1961
15, s_1	0.222	0.370	0.197	0.388	0.242	0.410
30, s_2	0.114	0.384	0.144	0.379	0.134	0.362
45, s_3	0.151	0.348	0.134	0.354	0.267	0.335

	1960		1961	
	LSD at 5%	LSD at 1%	LSD at 5%	LSD at 1%
Rate	0.0999	0.1657	0.0763	1.2659
Spacing	0.0575	0.0806	0.0419	0.0587

	1960			1961		
Rate	r_1	r_2	r_3	r_1	r_3	r_2#
	0.163	0.182	0.214	0.367	0.369	0.374
Spacing	s_2	s_3	s_1	s_3	s_2	s_1#
	0.131	0.207	0.221	0.346	0.375	0.389

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	0.02810	0.03620*
Rates	2	0.00620	0.00005
Error(a)	4	0.00583	0.00340
Spacings	2	0.02130*	0.00440
Rate X Spacing	4	0.00300	0.00313
Error(b)	12	0.00313	0.00166

#_____. Treatments underlined do not differ at the 5 percent level.

*Statistically significant at the 5 percent level.

sowing with a narrow row-width spacing would give a higher grain/straw ratio and probably a higher yield.

Number of plants per square meter.

The rate of sowing and the row-width spacing had a significant effect on the stand of wheat plants in both the years (Table 5). There was a definite increase in stand thickness with an increase in the rate of sowing or a decrease in the row-width spacing.

In the first year, the heaviest rate of sowing, 14 kg. per dunum, with 45 cm. between rows produced only 86.8 plants per square meter which was inconsistent with the rest of the data. This unexpectedly low population resulted in an interaction between rate of planting and row-width spacing that was significant at the 1 percent level. The interaction was insignificant in 1961, however.

A comparison, to determine the increase in the field stand with increase in the rate of planting showed, in the drier 1960 season, that a rise in the rate of planting by 4 kg. over the 6-kg. rate gave a 25 percent actual increase in the stand thickness as compared to the theoretical 67 percent increase. An additional increase of 4 kg. over the 10 kg. rate increased the population by only 15 percent as against the calculated expectation of 40 percent. In the more favorable 1961 season, a 4 kg. increase in the rate of planting over the 6 kg. rate increased the population by 57 percent which was only slightly less than the theoretical population

Table 5. The effect of rate of seeding and row-width spacing on the number of wheat plants per square meter.

Row-width spacing, cm.	Rate of seeding, kg./dunum					
	6 Kg., r_1		10 Kg., r_2		14 Kg., r_3	
	1960	1961	1960	1961	1960	1961
15, s_1	121.0	103.6	153.0	157.9	207.2	208.5
30, s_2	95.9	90.4	119.5	144.5	141.6	184.7
45, s_3	76.1	85.7	94.7	135.6	86.8	144.9

	1960		1961	
	LSD at 5%	LSD at 1%	LSD at 5%	LSD at 1%
Rate	29.95	49.68	19.96	33.1
Spacing	11.46	16.07	17.61	24.68
Rate X Spacing	19.86	27.84		

Rate	r_1	r_2	r_3	r_1	r_2	r_3#
	97.7	122.2	145.2	93.2	146.0	179.4

Spacing	s_3	s_2	s_1	s_3	s_2	s_1#
	85.9	119.0	160.4	122.0	139.9	156.7

Rate X Spacing, 1960

r_1s_3	r_3s_3	r_2s_3	r_1s_2	r_2s_2	r_1s_1	r_3s_2	r_2s_1	r_3s_1#
76.1	86.8	94.7	95.9	119.5	121.0	141.6	153.0	207.2

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	266.48	613.94
Rates	2	5095.82*	16988.23**
Error(a)	4	524.09	232.60
Spacing	2	12543.05**	2697.85**
Rate X Spacing	4	1220.13**	521.65
Error(b)	12	124.60	293.56

#_____. Treatments underlined do not differ significantly at the 5 percent level.

**Statistically significant at the 1 percent level.

*Statistically significant at the 5 percent level.

increase. Likewise, an increase in the rate of sowing by 4 kg. over the 10 kg. rate increased the size of the plant population by 22 percent as against the possible 40 percent increase. This indicated a higher field survival of plants in the more favorable year.

It was apparent from the results that the percentage increase in the stand of plants for each unit increase in the rate of seeding was not uniform and fell below the possible size of population. This suggested that the field survival of the plants was below the stand expectation as indicated by the actual field counts.

The yield of grain was found to be highly correlated with the plant population (Table 11) in 1960 while in 1961 the correlation was slight but positive. The 'r' value obtained in 1960 was 0.9393 which was statistically significant at the one percent level.

Number of tillers per plant.

The amount of tillering was almost twice as great in the second season than it was in the first season. Both in 1960 and in 1961, the analysis of variance indicated no significant difference for rate of sowing on the number of tillers per plant (Table 6). However, there was a definite tendency, in both the seasons, towards a decrease in the number of tillers with increasing rate of sowing. Thayer and Rather (36) obtained similar results with barley.

The amount of tillering was significantly higher with

Table 6. The effect of rate of seeding and row-width spacing on the number of tillers per plant in wheat.

Row-width spacing, cm.	Rate of seeding, kg./dunum: 6 Kg., r_1 1960	6 Kg., r_1 1961	10 Kg., r_2 1960	10 Kg., r_2 1961	14 Kg., r_3 1960	14 Kg., r_3 1961
15, s_1	3.91	6.52	3.24	5.40	3.03	5.04
30, s_2	3.50	5.84	3.13	5.39	2.95	4.92
45, s_3	3.86	6.45	3.79	6.32	4.27	7.13

	1960 LSD at 5%	1960 LSD at 1%	1961 LSD at 5%	1961 LSD at 1%
Rate	0.598	0.992	1.296	2.150
Spacing	0.338	0.474	0.540	0.757
Rate X Spacing			0.935	1.311

Rate	r_2	r_3	r_1	r_3	r_2	r_1#
	3.39	3.42	3.76	5.70	5.71	6.27

Spacing	s_2	s_1	s_3	s_2	s_1	s_3#
	3.19	3.39	3.97	5.39	5.65	6.63

Rate X Spacing, 1961

r_3s_2	r_3s_1	r_2s_2	r_2s_1	r_1s_2	r_2s_3	r_1s_3	r_1s_1	r_3s_3#
4.92	5.04	5.39	5.40	5.84	6.32	6.45	6.52	7.13

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	1.2962	3.2178
Rates	2	0.3838	0.9806
Error(a)	4	0.2087	0.6643
Spacing	2	1.4694**	3.8786**
Rate X Spacing	4	0.3462	1.0030*
Error(b)	12	0.1074	0.2761

#_____. Treatments underlined do not differ significantly at the 5 percent level.

**Statistically significant at the 1 percent level.

*Statistically significant at the 5 percent level.

the 45 cm. spacing in both 1960 and 1961. No significant differences existed between the low and medium row-width spacing in either year although there was a tendency for less tillering at the 30-cm. spacing than at the 15-cm. spacing. The combination of the 14-kg. rate of seeding and the 45-cm. spacing resulted in a high rate of tillering and this was not consistent with the trend of the rest of the data. This inconsistency resulted in a significant interaction between the rate of planting and row-width spacing in 1961. The same combination gave a high rate of tillering in 1960 but the interaction was not statistically significant.

A significantly positive correlation existed between the grain yield and the number of tillers per plant in 1960 (Table 11). In the following year, the correlation was significant but negative indicating that too many tillers might decrease the yield. The number of plants per square meter was found to have a slight and positive correlation ($r = 0.2053$) with the number of tillers per plant in the first season while in the second season the correlation was negative ($r = 0.5003$) and highly significant. This indicated that the amount of tillering might depend on the size of the population. The higher the number of plants per unit area, the greater would be the amount of competition and the lesser would be the number of tillers produced per plant.

Number of heads per plant.

In the two years the number of heads per plant was not

significantly influenced by the rate of sowing (Table 7). The medium rate of sowing, 10 kg. per dunum, tended to give the lowest amount of heads per plant while the 6-kg. rate produced the highest. The effect of the heavy rate of sowing, 14 kg. per dunum, was variable. In the drier crop year of 1960, the amount of tillering was only about half that obtained in the 1961 cropping season with more favorable growing conditions.

The effect of row-width spacing was more pronounced in both the seasons than the effect of rate of sowing on the number of heads per plant. The narrow and medium spacings, 15- and 30-cm., did not differ significantly in their influence on the number of heads per plant. The wider spacing, 45 cm., in both the years gave a significantly higher number of heads per plant. There was a definite tendency towards higher number of heads per plant with increasing row-width spacing.

Correlation of the grain yield in 1960 with number of heads per plant gave an 'r' value of 0.6060 which indicated a fairly close positive relationship (Table 11). In 1961, the relationship was negative and slight ($r = -0.2666$). Bridgford and Hayes (2) could not find any significant relationship between grain yield and number of heads per row in wheat. The number of heads, in both the years, was negatively correlated with the number of plants per unit area. The number of heads per plant was highly associated with the number of tillers per plant in both years. The positive relationship between number

Table 7. The effect of rate of seeding and row-width spacing on the number of heads per plant in wheat.

Row-width spacing, cm.	Rate of seeding, kg./dunum					
	6 Kg., r_1		10 Kg., r_2		14 Kg., r_3	
	1960	1961	1960	1961	1960	1961
15, s_1	2.05	3.43	1.65	2.76	1.58	2.65
30, s_2	1.96	3.33	1.80	3.00	1.67	2.80
45, s_3	2.19	3.65	2.26	3.76	2.55	4.26

	1960		1961	
	LSD at 5%	LSD at 1%	LSD at 5%	LSD at 1%
Rate	0.344	0.571	0.713	1.183
Spacing	0.281	0.393	0.468	0.657

Rate	r_2	r_3	r_1	r_2	r_3	r_1#
	1.90	1.93	2.07	3.17	3.23	3.47

Spacing	s_1	s_2	s_3	s_1	s_2	s_3#
	1.76	1.81	2.33	2.95	3.04	3.89

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	0.4166	1.1456
Rates	2	0.6970	0.2179
Error(a)	4	0.1068	0.2980
Spacing	2	0.9082**	2.4291**
Rate X Spacing	4	0.1492	0.4287
Error(b)	12	0.0745	0.2075

#_____. Treatments underlined do not differ significantly at the 5 percent level.

**Statistically significant at the 1 percent level.

of heads and yield of straw was highly significant in the first year while it was slight and negative for the second year.

Weight of 100 kernels.

The weight of 100 kernels was not significantly influenced by the rate of sowing in either year (Table 8). The kernel weight was lower in the first year than it was in the more favorable second year. The kernel weight did not fluctuate in a definite order in the first season while in the following season the tendency was towards an increase in the weight of 100 kernels as the rate of sowing decreased.

The weight of kernels was significantly higher at the 15-cm. spacing than at the 30-cm. spacing in 1960. In the later season, the row-width spacing did not make any significant difference in the weight of the kernels and no definite trend was observed.

The weight of 100 kernels was positively correlated with the yield of grain in the first season while in the latter year the correlation was very low. Bridgford and Hayes (2) obtained a positive correlation between the yield and the 1000 kernel weight in wheat.

Protein content.

Under the semi-arid conditions, prevailing in the Beka'a plain, the rate of planting and row-width spacing had only slight effects, in either year, on the protein content in wheat. The results obtained (Table 9) indicated a definite

Table 8. The effect of rate of seeding and row-width spacing on the weight of 100 kernels, gm.

Row-width spacing, cm.	Rate of seeding, kg./dunum					
	6 Kg., r_1		10 Kg., r_2		14 Kg., r_3	
	1960	1961	1960	1961	1960	1961
15, s_1	3.81	4.62	4.05	4.40	3.94	4.18
30, s_2	3.35	4.64	3.83	4.33	3.65	4.44
45, s_3	3.43	4.36	3.97	4.44	3.90	4.27

	1960		1960	
	LSD at 5%	LSD at 1%	LSD at 5%	LSD at 1%
Rate	0.698	1.157	0.638	1.059
Spacing	0.3188	0.4469	0.200	0.280

Rate	r_1	r_3	r_2	r_3	r_2	r_1#
	3.53	3.83	3.95	4.30	4.39	4.56
Spacing	s_2	s_3	s_1	s_3	s_1	s_2
	3.61	3.77	3.93	4.38	4.40	4.47

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	1.1943	0.4169
Rates	2	0.4218	0.1624
Error(a)	4	0.2844	0.2391
Spacing	2	0.0453	0.0184
Rate X spacing	4	0.1218	0.0410
Error(b)	12	0.0963	0.0379

#_____. Treatments underlines do not differ significantly at the 5 percent level.

Table 9. The effect of rate of seeding and row-width spacing on the protein content in wheat (percent).

Row-width spacing, cm.	Rate of seeding, kg./dunum. 6 Kg., r_1 1960	1961	10 Kg., r_2 1960	1961	14 Kg., r_3 1960	1961
15, s_1	16.43	15.92	16.24	15.73	17.35	17.02
30, s_2	16.46	15.95	16.69	16.17	16.69	16.38
45, s_3	16.45	15.93	16.49	15.98	16.82	16.53

	1960 LSD at 5%	1960 LSD at 1%	1961 LSD at 5%	1961 LSD at 1%
Rate	2.176	3.610	2.304	3.821
Spacing	0.885	1.240	0.856	1.201

Rate	r_1	r_2	r_3	r_1	r_2	r_3#
	16.45	16.47	16.96	15.93	15.96	16.64
Spacing	s_3	s_2	s_1	s_3	s_2	s_1#
	16.59	16.61	16.67	16.15	16.17	16.22

Analysis of variance

Source	D.F.	M.S. 1960	M.S. 1961
Blocks	2	5.6748	4.0473
Rates	2	0.7402	1.4419
Error(a)	4	2.7659	3.0991
Spacing	2	0.0156	0.0134
Rate X Spacing	4	0.2514	0.2360
Error(b)	12	0.7415	0.6940

#_____. Treatments underlined do not differ significantly at the 5 percent level.

trend towards higher protein content with higher rate of seeding in both the seasons. With an increase in the row-width spacing, the protein content, both in 1960 and in 1961, tended to be slightly decreased. In the first year, the protein content was slightly higher than it was in the second year. The lower amount of rainfall received in 1960, when the grain yield was materially less than the more favorable 1961 season, might account for the higher amount of protein in the kernels. Kiesselbach (14, 15) found protein content to increase with reduction in yield of grain and test weight.

Plant height.

Data obtained for the 1961 season (Table 10) revealed no statistically significant influence on the plant height due to either rate of planting or row-width spacing. The effect of rate of sowing did not follow any definite trend. The effect of row-width spacing had a definite tendency towards increased plant height with increasing space between rows. The height of plants had no statistically significant correlation with the yield of grain (Table 11).

Table 10. The effect of rate of seeding and row-width spacing on the height of wheat plants, cm.

Row-width spacing, cm.	Rate of seeding, kg./dunum		
	6 Kg., r_1 1961	10 Kg., r_2 1961	14 Kg., r_3 1961
15, s_1	100.3	96.3	102.5
30, s_2	101.2	94.9	104.8
45, s_3	103.5	102.1	108.9

1961

	LSD at 5%	LSD at 1%
Rate	13.30	22.05
Spacing	5.61	7.86

Rate	r_2	r_1	r_3#
	97.9	101.6	105.4

Spacing	s_1	s_2	s_3#
	99.7	100.3	104.8

Analysis of variance

Source	D.F.	M.S. 1961
Blocks	2	130.73
Rate	2	130.72
Error(a)	4	103.25
Spacing	2	71.54
Rate X Spacing	4	6.53
Error(b)	12	29.78

#_____. Treatments underlined do not differ significantly at the 5 percent level.

Table 11. Correlation between certain plant characteristics in wheat.

Characteristics compared	r values	
	1960	1961
1. Grain yield and number of plants per square meter.	0.9393**	0.2581
2. Grain yield and number of tillers per plant	0.4140*	-0.3830*
3. Grain yield and number of heads per plant	0.6060**	-0.2666
4. Grain yield and plant height, cm.	—	0.2299
5. Grain yield and 100 kernel weight	0.7599**	0.0079
6. Number of plants per square meter and number of tillers per plant	0.4271*	-0.5003**
7. Number of plants per square meter and number of heads per plant	-0.6036**	-0.4450*
8. Number of tillers per plant and number of heads per plant	0.8592**	0.8727**
9. Number of heads per plant and yield of straw	0.6599**	-0.2979

* Statistically significant at the 5 percent level

** Statistically significant at the 1 percent level

SUMMARY AND CONCLUSIONS

The purpose of this 2-year study was to evaluate the effect of the rate of sowing and the row-width spacing on the yield and certain other plant characteristics in wheat. Because 1960 was a drier, less favorable year for plant growth than 1961, there was considerable difference in the results for the two years.

In 1960 which was less favorable than 1961 for plant growth the yield of grain was not significantly affected by the rate of sowing but there was a definite tendency for increased yield with increasing planting rates. The conditions were not as good in 1960 as in 1961 for obtaining a stand of plants or for tillering of plants. Consequently, the grain yield of wheat in 1960 was positively and significantly correlated with the number of plants per square meter, the number of tillers per plant and the number of heads per plant. In 1961 the rate of tillering was about double that of 1960 and the grain yield was not significantly correlated with the rate of sowing, the number of plants per square meter, or the number of heads per plant. There was a significant negative correlation between the yield of grain and the number of tillers per plant indicating that conditions can be too favorable for tillering. Therefore, it could be concluded that when conditions were poor for tillering of plants it was advantageous to sow greater amounts of seed per unit area.

In the less favorable year of 1960, the row-width spac-

ing showed no definite trend but in the more favorable 1961 season, the wide 45-cm. spacing tended to result in a lower yield although the differences were not significant. In both years, increasing the row-width spacing significantly decreased the number of plants per unit area.

Neither rate of sowing nor row-width spacing materially affected the yield of straw, the grain/straw ratio, the weight per 100 kernels, the plant height or the protein content of the grain in wheat.

Under the varying conditions of the two seasons in the study, it appeared that, no one rate of planting or row-width spacing could be classed as outstandingly better than others. Probably, the rate of seeding should not be less than 10 kg. per dunum and the row-width spacing should not be over 30 cm. In view of the nature of the data obtained in the two years of study, no definite conclusions could be drawn until more data over a longer period of time were collected.

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