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

by

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ABSTRACT

A two-year investigation was carried out at the American University farm in the Beqa'a plain in Lebanon to evaluate the effect of various plant populations on the grain yield and other plant characteristics of winter wheat.

Neither the rates of seeding nor the row-width spacings were found to have much effect on the grain and straw yield. Higher number of tillers and heads per square meter were obtained with the higher rates of seeding, however, these were found to decrease with the increase in row-width spacing. The various plant populations used did not influence either the plant height or the protein content in the wheat kernels.

The 1000 kernel weight and vitreousness of wheat kernels were influenced by the rates of seeding. Lighter kernels were produced with the higher rates of seeding. The wheat kernels resulting from the higher rates of seeding tended to be more starchy than those from the lower rates. The 1000 kernel weight and vitreousness of wheat kernels were not influenced by the different row-width spacings.

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INTRODUCTION

The growing of wheat goes far back into prehistoric times. Percival (37) developed the theory that the bread types of wheat resulted from the hybridizing of an emmer type with some species of the genus *Aegilops* which are wild grasses found in Western Asia and South Eastern Europe. Recent studies by Mangelsdorf (28) suggest that wheat had its origin in the Caucasus-Turkey-Iraq area and that in the evolution of our common wheat, wild einkorn evolved into einkorn, which when crossed with a wild grass gave rise to the Persian wheat. When this wheat was crossed with the grass *Aegilops Squarrosa*, our common wheat *Triticum aestivum* resulted. Mangelsdorf (28) summarized that the wheat plants growing on the earth may even outnumber those of any other seed-bearing plant species, wild or domesticated. He also mentioned this grain as one of the earlier plants cultivated by man and as the world's most widely cultivated one. The F.A.O. report (47) shows that the total area under cultivation of wheat was 204,700,000 hectares in the year 1959-60 and was the largest of the cereals. The total production of wheat was 249,900,000 metric tons as against the total production of 258,500,000 metric tons of rice in that year. Thus wheat ranks second to rice in the number of tons produced throughout the world. Wheat is the leading cash grain crop in many parts of the world and its consumption is world-wide.

Wheat has always yielded "the staff of life" to the greatest and most powerful nations since the beginning of history and has very fittingly been called "the king of cereals" (5). Wheat has furnished "the bread of life" for the great civilizations of the Mediterranean area, including Lebanon, Syria, Egypt, and Greece. The growing of wheat in this area has not changed to any degree during this long period. In general, wheat is sown broadcast at a rate of 18 to 20 kilograms per dunum. This rate of sowing is considered higher than that of the improved methods. According to Widtsoe (55) the broadcasting of seed has no place in any system of scientific agriculture, least of all in dry-farming where success depends upon the degree with which all conditions are controlled. With improved methods, higher yield may be obtained with less amount of seed. This study, therefore, was undertaken to determine the effect of different seed rates and spacings on the yield of grain and straw, protein content and other plant characteristics of winter wheat when grown under the dry farming conditions in the Beqa'a plain.

The experiment was conducted on the University Farm in the Beqa'a plain for the two seasons, 1961-62 and 1962-63. Data involving plant height, number of heads per square meter, yield of grains, average weight of 1000 kernels, protein content and other plant characteristics were collected and analyzed. The data obtained from this study may help in finding out the best rate of seeding and row-width spacing of wheat for the Beqa'a plain which is one of the main agricultural areas in Lebanon.

REVIEW OF ~~THE~~ LITERATURE

The winter wheats are most desirable for dry-farm purposes wherever they can be grown and especially in localities where a fair amount of precipitation occurs in the winter and spring. Extensive studies on rate of seeding winter wheat have been conducted in many countries. According to Pendelton and Dungan (36), Percival (37) summarized these findings and stated that the optimum seeding rate varied considerably with the climatic conditions. In countries of low rainfall, short growing season and associated low yields, the amount of seed sown often is less than one bushel per acre. Seeding rates of a bushel per acre or less were reported in Australia and in the drier areas of the United States. In England and Western Europe, under high rainfall conditions, seeding rates varied from three to four bushels per acre.

Rate of Seeding and Yield

Widtsoe (55) suggested that the quantity of seed sown should vary with the soil conditions: the more fertile the soil is, the more seed may be sown; as the fertility or the water content diminishes, the amount of seed should likewise be diminished. He also suggested that as a general principle, light seeding should be practised under dry farming conditions, though it should be sufficient to yield a crop that will shade the ground. In the case of wheat and other grains, thin seeding gives the plant a better chance for stooling, which is nature's method of adapting the plant to the prevailing moisture and fertility conditions. When plants are crowded, stooling can not occur to any marked degree and the crop is rendered helpless in attempts to adapt itself to surrounding conditions.

Bracken (6) mentioned that the amount of grain to sow per acre is greatly influenced by the prevailing moisture and temperature conditions. He stated, "A thin stand is desirable in dry areas having a medium to long growing season while a thick stand is preferable in humid regions, particularly where the growing season is short." He further mentioned that it was hardly correct to say that thin seeding was always desirable in dry areas and thick seeding in humid areas for the reason that the condition of the soil with respect to moisture and tilth at seeding time largely determined the stand.

Hutchison (23) indicated that cereals have a remarkable ability of adaptation to their environment in occupying the land to the best advantage. Among the factors that affect yield, the rate of seeding was regarded as very important. Four years' experiment with Federation wheat sown at 33 to 129 pounds per acre resulted in more than four heads per plant from the lowest rate of seeding and a gradual decrease in heads per plant to about 1.5 from the heaviest seeding. The thinner stands produced not only more heads per plant but also more grains per head than the thicker stands.

Carleton (8) observed that more seed is needed on poorly prepared or weedy land than on rich land. He recommended the usual rate for wheat under ordinary conditions as six pecks to the acre.

Das and Varma (11) studied the individual plant characteristics in an experiment with three wheat varieties at six rates of seeding, namely 20, 30, 40, 50, 60, and 70 seers* per acre. High seed rates reduced the number of ear-bearing tillers per plant, length of ear and number of spikelets and grains per ear. The thousand-grain weight showed a decrease with increasing seed rates but straw yield was not altered by the rates of seeding. They obtained the highest grain yield per acre with the seed rate of 40 seers per acre.

Hutton (24) stated, "The proper rate to sow, depends upon the variety of grain, which involves size of the kernel and the kind and conditions of the land on which the grain is to be sown. Breaking and summer fallow well supplied with moisture will carry from one half to one bushel more seed per acre than stubble land equally well cultivated." He found it advisable to sow from two to three bushels of spring wheat per acre on well cultivated or summer fallow, reducing the amount of seed on stubble land by half a bushel to a bushel.

Hughes, Henson, Metcalfe and Johnson (22) observed that the optimum rate of seeding winter wheat depended greatly on the amount of rainfall. In western Kansas, with an average rainfall of 18.68 inches, the average rate of seeding was 3.18 pecks; in the central section with 24.8 inches of rain it was 4.38 pecks, and in the eastern section with

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* 1 seer = 2.057 pounds.

a rainfall of 35.8 inches, it was 5.25 pecks.

Wolfe and Kipps (60) summarized that within fairly wide limits, it made little difference how much seed was planted to an acre. They mentioned four to six pecks an acre as a very common rule throughout much of the more humid wheat area. When wheat was planted later than the normal date for the locality, an increase of one or two pecks an acre in rate of seeding was considered advisable. According to these workers, in Nebraska, wheat seeded at the rates of 3, 4, 5, and 6 pecks per acre over a period of 22 years produced the average grain yields of 24.9, 26.2, 26.5 and 27.1 bushels per acre, respectively.

Rao et. al. (39) explained that seeding rates ranging from 30 seers to 50 seers per acre had shown practically no difference in the yield of both grain and straw. According to them, Howard and Howard (20) and Grantham (15) had reported that provided all the conditions were the same, variations in seed rate made little difference in yield. According to Hutchison (23), Stephens, Wanser and Bracken (46), from experiments with wheat under dry land conditions, found no great difference in yields from rates of two to eight pecks per acre but concluded that five pecks was the optimum rate.

Salmon, Mathews and Leukel (42) explained that rate-of-seeding experiments for both winter and spring wheat showed little difference in net yield. Spring wheat seeded at a rate much lower than four pecks per acre was likely to suffer more from weed competition than thicker stands.

Sprague and Farris, (44) observed in four years of testing spring barley in Ontario to give the following yields: for 6 pecks of seed, 47.8 bushels; for 8 pecks, 50.3 bushels and for 10 pecks, 48.5 bushels. They concluded that there was no advantage in increasing the average number of plants per unit area beyond a certain definite limit. The limit itself was determined by the conditions of soil, climate and characteristics of the crop.

Hudson and Stafford (21) also observed that where rates exceeded the optimum, no appreciable differences occurred in yield, weight of grain, bushel weight and commercial value of grain. According to Woodward (61), Merill (30) reported from eight years' experiment on rates of seeding, that wheat, oat and barley produced yields of 19.5 bushels per acre for two pecks and about equal yields for eight to ten pecks per acre.

Martin (29) summarized studies from rate-of-seeding experiments with winter wheat from 10 stations in the Great Plains and 4 stations in the Great Basin area, and concluded that when all conditions were favourable, two to three pecks of seed per acre were sufficient. He suggested four pecks of seed per acre for seed bed in poorer condition and an additional peck or two as cheap insurance against thin stands especially when it was realized that the thicker seeding would do no harm and might be very helpful if dry fall weather, winter killing, seed injury or insect damage occurred.

Wilson and Swanson (59) observed that under conditions of high moisture and late seeding, higher seeding rates were favourable while the reverse was true with low moisture and early seeding.

Pendelton and Dungan (36) made plantings at rates of 3, 6, 9, 12, 15 and 18 pecks per acre and compared all six rates of seeding on the net yield. They found that six peck per acre rate returned the highest grain yield.

Carleton (8) found that the best rate of seeding spring wheat was five and one-half pecks to the acre. The seeding of winter wheat above four pecks to the acre increased the winter killing. According to him Atkinson and Nelson (2) found, in five years' experiment with rates of seeding with winter wheat, that three to four pecks gave the best yield. Similar results were also obtained at the Archer, Wyoming substation (8).

Small differences in yields were obtained at the Kansas station by seeding wheat at rates from three to four pecks per acre, except in seeding later than October 15, when the four-peck rate gave the best returns (25).

Donaldson (12) also obtained results of experiments in favour of sowing winter wheat at the rate of three pecks per acre. The period from August 10 to September 10 was reported as the best time for sowing. He recommended the quantity of seed for spring wheat and small kerneled, early varieties of oats as four pecks to the acre.

Swanson (48) suggested the seeding of winter wheat with an acre rate of not less than four pecks when sown from September 20 to October 1.

Coffman (9) advised from three to five pecks per acre for winter and spring wheat for early seeding.

Nelson (32) reported that at the Wyoming station, winter wheat seeded in the stubbles of a spring cereal produced the highest average yields. He suggested that seeding should be made about September 1 at rates of three to four pecks per acre on fallow and up to five pecks on stubbles.

Robertson, Coleman and others (41) suggested that winter wheat should be planted between September 1 and September 15 for the best yields on summer fallow or corn land and at the rate of two pecks of seed per acre.

Hickman (18) found that under normal conditions seeding at the rate of eight to ten pecks per acre gave superior quality with higher yields as compared with thinner seeding. He recommended eight to nine pecks of seed per acre for the thinner and less fertile soils of the state and five to six pecks for the rich, alluvial or very strong upland soils.

Woodward (61) recommended that seeding rates for small grains on irrigated land in the inter-mountain states should range from 90 to 120 pounds per acre.

Reports of Thatcher (49) showed that at the Ohio station, wheat seeded at the rate of eight pecks per acre gave the largest average net yield, 29.8 bushels. Based on the reports from 246 different farms, he suggested the average rate for the state as 7.2 pecks per acre. Williams (58) also suggested the same rate of seeding wheat in the same area.

From rate and date of seeding winter wheat experiments Stephens and Hill (45) summarized that 44 to 55 pounds of seed per acre sown between October 10 and October 25 would give the best results. They found that eight pecks rate of seeding gave the highest average yield, 20.3 bushels for early sowing, while the three pecks rate gave the highest yield, 13.6 bushels for late sowing.

Kiesselbach (26) mentioned that winter wheat grown at the Nebraska station during the five years 1919-23, at the five planting rates of 3, 4, 5, 6 and 8 pecks per acre, ranged in yield from 28.6 bushels for the thinnest to 31.5 bushels for the six peck rate.

Thatcher (50) suggested a rate of from six to eight pecks of wheat per acre. In a combined rate and date of seeding test, he observed that ten pecks produced a greater six-year average yield than six to eight pecks seeded on September 15, but smaller average yields when seeded 10, 20, 30 and 40 days later.

From the rate of seeding tests with winter wheat and winter rye at the Grand Rapids, Minn. substation, Bergh (3) observed that six pecks was the minimum amount that could be recommended for both of the crops. This amount gave maximum yields when sown between August 20 and September 1.

As observed by Bracken and Stewart (4), the rate of seeding wheat on clay loam was regularly five to six pecks per acre with less on lighter soils. According to them the rate and date of seeding test at Nephi with two to eight pecks per acre indicated regular increases in yield of wheat with the increased rates of seeding up to and including four pecks per acre. From four to eight pecks the differences in yield were so small as to be negligible.

Williams (57) summarized that in tests with wheat using a 6.5 and 4.5 peck rate of seeding, the respective yields for the eight inch and 4 inch drills, were 28.71 and 28.37 bushels of grain and 3,247 and 3,487 pounds of straw.

Kiesselbach (26) described that during the six year period 1913-18, at the Akron station, winter wheat was seeded at the rates of 1, 2, 3, 4, 5 and 6 pecks per acre and the maximum yield per acre was obtained at the six-peck rate, having gradually risen to 23.6 bushels for the one-peck rate.

Faizullah (13) did not find any significant difference in grain yield using different seed rates of 6 kg., 10 kg., and 14 kg. per dunum in the Beqa'a plain.

Row-width and Yield

Several investigators have studied the effect of row width spacing on the yield of small grains under varying soil and climatic conditions. Harper (17) conducted several experiments to compare the effect of drilling small grains in wide rows, 14 to 16 inches apart with standard methods of planting. He concluded that the data on yield did not vary for more than one or two bushels than those of seven or eight inches spacings.

According to Wiggans and Fray (56), Buffum found that wheat plants produced more head bearing culms per plant as the space between plants was increased from one to twelve inches.

Trials at the Sprawston, Norfolk Agricultural Station from 1953-56 with Atle spring wheat, showed that narrow row spacing (4 inches) combined with heavy seed rates (upto 3.5 bushels/acre) and heavy nitrogen manuring, produced no increase in grain yield compared with the normal practice (33).

In an experiment covering a 7-year period with rows 7, 14, 21 and 28 inches apart, Bracken and Stewart (4) observed that the bushel yields showed only slight variation for the widths greater than seven inches, which was normal.

Faizullah (13) did not find any significant difference in grain yield by using 3 row-width spacings of 15 cm., 30 cm., and 45 cm. in the Beqa'a plain.

Gill (14) reported from West Pakistan that an experiment with wheat sown in furrows at a distance of $4\frac{1}{2}$", 9", and $13\frac{1}{2}$" with seed rates of 17 1/3 seers, 26 seers and 52 seers per acre showed that furrows 9" apart with 26 seers of seed rate per acre gave the best results.

Rate of Seeding and other Characteristics

According to Wilson and Swanson (59), Percival (37), working with Swan winter wheat, found that increasing the area for a single plant from 6 to 18, 36, 72 and 144 square inches gave progressively lower plot yields and weight of seed per head. The head number per plant increased with decreased plant population.

Olson (34) reported that increasing the distance between the rows seemed to increase the nitrogen content of wheat grown in the nursery under non-irrigated conditions at Pullman. He also observed that increasing the distance between the rows did not affect the nitrogen content of wheat under irrigated condition at Grandview.

Kiesselbach (26) reported that winter wheat grown at the Nebraska station during five years, 1919-23, at the five planting rates of 3, 4, 5, 6 and 8 pecks per acre yielded the protein percentage in grain as 13.1, 13.1, 13.1, 13.2 and 13.4 respectively.

Faizullah (13) observed that in the Beqa'a plain, the rate of planting and row width spacing had only slight effects on the protein content in winter wheat. There was a trend towards higher protein content with increased rate of seeding. With an increase in row-width spacing the protein content tended to be slightly decreased.

Growing 61 hard red spring wheat strains in rod-row trials at the Morris Branch Station in Minnesota, Bridgford and Hays (7) obtained positive correlation between yield and weight of 1,000 kernels. Waldron (53) and Faizullah (13) also reported similar results.

MATERIALS AND METHODS

The experiment was conducted for two seasons 1961-62 and 1962-63 on the American University Farm located in the Beqa'a plain 80 km. east of Beirut. Florence aurore, a winter variety of wheat was used for the experiment. The land used had a calcarious clay type of soil with a pH value of 8.0. The land was under fallow for one year before the experiment was started. The soil was fertilized with nitrogen at the rate of eight kg. per dunum in the form of ammonium sulfonitrate (26.5 percent N) and eight kg. per dunum of P_2O_5 in the form of super phosphate (18 percent P_2O_5). The fertilizers were spread and disced into the soil before planting time.

The experiment was conducted under dry farming conditions. The total rainfall for the season 1961-62 beginning from September 1, 1961 to August 31, 1962 was 469.7 mm. and that of the season 1962-63 was 524.9 mm. as shown in table I.

The experiment was laid out on a split-plot design involving three rates of seeding and three row-width spacings with three replications. The rates of seeding were 6 kg., 10 kg., and 14 kg. per dunum and the three row-width spacings were 15 cm, 30 cm, and 45 cm. The size of each plot was 2 x 18 meters and that of each block 21 x 18 meters.

Table I. Rainfall and average temperature at the American University Farm in the Beqa'a.*

Month	Rainfall (mm.)		Temperature (C) Mean	
	1961-62	1962-63	1961-62	1962-63
September	3.0	0.0	18.7	21.6
October	5.9	19.3	16.9	17.1
November	41.1	0.0	11.1	14.1
December	138.5	164.1	8.0	7.7
January	93.1	124.1	6.3	7.1
February	130.6	70.0	5.1	7.4
March	10.5	82.4	10.9	7.0
April	43.3	53.3	11.3	11.9
May	3.7	11.7	17.1	14.0
June	0.0	0.0	21.4	
July	0.0	0.0	22.9	
August	0.0	0.0	24.6	
	469.7	524.9	—	—

* Information obtained from American University Farm Meteorological Data, Beqa'a Valley, Lebanon by H.G. Nasr and F.M. Malouf.

The seeds were sown on the 14th of November in 1961 and the seventh of November in 1962. The sowing was done with a six foot small grain press drill, except for plots with the heaviest seeding rate (14 kg./dunum) and widest spacing 45 cm. In these particular plots the sowing was done with a Planet Junior hand drill.

Table 2 shows the different rates of seeding with the respective row-width spacing and drill setting of the grain drill.

Weeding was regularly done with the nursery equipments and also by hand to reduce the population of weeds and their competition with the wheat plants. In 1963, 2, 4-D was used to control the broad-leaf weeds.

Table 2. Rates of seeding and row-width spacing with drill setting.

Rates of seeding (kg./dunum)	Row-width (cm)	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	32 (Pl.Jr.)

Data were collected for plant height, date of heading, number of plants per square meter, number of heads per square meter, weight of grain and straw and average weight of 1000 kernels.

When the crop was mature, five samples of one square meter each were harvested from each plot. Harvesting was done with the hand sickle cutting the wheat plants at the ground level. After harvesting, the samples were kept in separate cloth sacks for each plot and dried in the sun for about two weeks.

After drying, the samples from each plot were weighed separately, and the weight of straw and grain was obtained. Threshing and cleaning was done with the regular nursery equipments. The clean seeds were then weighed to get the grain weight. The difference of the grain weight from the weight of straw and grains gave the total weight of straw from the representative samples from each plot. The whole kernels from each sample were separated from the broken ones and 1000 kernel weight was determined.

For protein determination, a representative sample of each plot was ground in a Wiley mill using 20 mesh seive and the ground material was collected and stored in screw top bottles. Analysis for protein were made according to the modified Kjeldahl method as specified in the Official Method of Analysis by the Association of Official Agricultural Chemists (19) to determine the percentage of nitrogen. The nitrogen values obtained from each sample was multiplied by the factor 5.7 to obtain the percent protein in that sample. Results of duplicate samples that were differing from the sample means by six percent or over were rejected and the analysis repeated. To calculate the range of variation the following formula was used:

$$\frac{x - xm}{xm} \times 100 \geqq \% \text{ nitrogen}$$

Where x = the percent total of N in the sample

xm = mean percentage of total N in the sample.

The data were tabulated and statistical methods appropriate to the split-plot design were used to analyze the data. Analysis of variance, t test and correlation coefficients were used to calculate the difference between the different treatment combinations (35, 38).

RESULTS AND DISCUSSION

A two-year study was undertaken to find the effect of various plant populations on the grain yield and other plant characteristics of winter wheat. The results are summarized and reported in Tables 3 to 12. Analysis of variance tables are reported in the appendix (Tables 13 to 21). The L.S.D. figures at the five per cent and one per cent levels are given in the tables for rates, spacings and only for the interactions that were statistically significant as found in the analysis of variance tables.

Grain Yield

The grain yield showed no significant difference due to rates of sowing in the two years as shown in Table 3. The grain yield was higher in 1962 than in 1963 which was due primarily to the more fertile soil conditions present during the first year. In 1962, there was a trend of higher yields at the lower rate of planting while in 1963 the trend was towards increased grain yield with the increased rate of sowing. Similar results were obtained by Faizullah (13) at the University Farm during the two years 1960 and 1961 and other workers in the United States (4 and 26).

There was no significant effect on the grain yield due to the three different spacings used in this trial. In 1963, there was a trend towards a decrease in yield due to the increased row-width spacing though

TABLE 3. Effect of rate of seeding and row-width spacing on the grain yield in kg/dunum of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg.(r1)		10 kg.(r2)		14 kg.(r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	188.7	101.3	197.9	109.2	174.1	121.4
30 (s2)	198.9	93.1	193.5	117.0	167.7	110.8
45 (s3)	196.5	102.4	190.5	102.7	203.2	115.3

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	14.05	23.29	33.95	56.31
Spacing	16.94	23.75	15.41	21.59

Rate:

1962			1963		
(r1)	(r2)	(r3) #	(r3)	(r2)	(r1)
194.7	193.9	181.6	115.8	109.6	98.9

Spacing:

1962			1963		
(s3)	(s1)	(s2) #	(s1)	(s2)	(s3)
196.7	186.9	186.7	110.6	107.0	106.8

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

not statistically significant. Siemens (43), Faizullah (13) and Cook et al. (10) also observed a decrease in grain yield due to the increase in row-width spacing.

Under the condition of this experiment it seems that the rate of seeding and row-width spacing have little influence on the resulting grain yield. Thus, by the use of machinery the present rate of seeding can be appreciably reduced in the Beqa'a plain and a large amount of seeds can be saved without affecting the yields.

Yield of Straw

The rates of sowing did not have much effect on the yield of straw as is apparent from the data in Table 4. With the increase in rates of sowing a tendency towards increased straw yield was observed though the results were not consistent in the two years. Similar effects of rate of sowing were observed by Faizullah (13) at the University Farm.

The row-width spacings also had no significant effect on the yield of straw in either year. The results were consistent during the two years of the study.

Grain/Straw Ratio

The data presented in Table 5 show that the rates of sowing and row-width spacing had no significant effect on the grain/straw ratio in the two years. The grain/straw ratio was higher in 1963 than in 1962. The higher moisture obtained during the later part of the season in 1963 (Table 1) was more favorable for grain yield, resulting in an increase in grain/straw ratio. The best ratio of .568 was obtained in 1963 when

TABLE 4. Effect of rate of seeding and row-width spacing on the yield of straw in kg./dunum of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg.(r1)		10 kg.(r2)		14 kg.(r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	465.9	176.8	527.3	191.4	475.5	240.4
30 (s2)	501.5	189.5	535.9	219.8	532.6	237.9
45 (s3)	477.1	181.1	547.5	196.3	508.5	235.6

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	74.57	123.68	48.88	80.89
Spacing	52.71	73.90	17.28	24.23

Rate:

1962			1963		
(r2)	(r3)	(r1) #	(r3)	(r2)	(r1)
536.9	505.6	481.5	237.9	202.5	182.5

Spacing:

1962			1963		
(s2)	(s3)	(s1) #	(s2)	(s3)	(s1)
523.3	511.0	489.6	212.4	204.3	202.8

#_______. Means of treatments underlined do not differ significantly at the 5 % level.

TABLE 5. Effect of rate of seeding and row-width spacing on the grain/straw ratio of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg. (r1)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	.434	.575	.380	.568	.367	.498
30 (s2)	.405	.483	.364	.537	.322	.473
45 (s3)	.426	.566	.359	.522	.410	.495

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	.0677	.1123	.1943	.3223
Spacing	.4942	.8331	.1504	.2108

Rate:

1962			1963		
(r1)	(r2)	(r3) #	(r2)	(r1)	(r3)
.4216	.3680	.3665	.542	.541	.488

Spacing:

1962			1963		
(s3)	(s1)	(s2)	(s1)	(s3)	(s2)
.3982	.3939	.3641	.547	.527	.453

#_______. Treatment means underlined by the same line do not differ significantly at the 5 % level.

the wheat was sown at 10 kg. per dunum in rows 15 cm. apart, however in 1962 the 6 kg. rate was the highest.

Number of Tillers per Square Meter

The number of tillers per square meter were significantly influenced by the different rates of sowing and row-width spacing studied (Table 6). Wheat planted at the rate of 10 and 14 kg. per dunum produced a larger number of tillers per square meter than whem planted at six kg. per dunum. For example in 1963, 351 and 313 tillers were produced at the 14 and 10 kg. rates, respectively, while only 237 tillers were produced when six kg. of seed per dunum were sown.

Row-width spacings significantly influenced the number of tillers per square meter. Wheat plantings made in the rows 15 centimeter apart produced the largest number of tillers per square meter, while the planting made in 45 cm. rows produced the least number of tillers per square meter.

Number of Heads Per Square Meter

The number of heads per square meter was significantly affected by the rates of sowing and row-width spacing in 1962 and 1963 as shown in Table 7. With the increase in rate of seeding the number of heads per square meter also increased and there was a consistency in the results in the two years.

The number of heads significantly decreased with the increase in row-width spacing and the results were consistent during the two-year study.

TABLE 6. Effect of rate of seeding and row-width spacing on the number of tillers/square meter of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum*					
	6 kg. (r1)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	628.3	269.9	825.6	377.2	711.1	429.6
30 (s2)	535.4	226.6	613.4	289.9	624.8	321.8
45 (s3)	459.9	214.0	485.9	271.7	505.6	302.4

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	77.86	129.27	56.55	93.78
Spacing	81.36	114.06	35.84	50.22

Rate:

1962			1963		
(r2)	(r3)	(r1) #	(r3)	(r2)	(r1)
641.6	613.8	541.2	351.24	312.94	236.87

Spacing:

(s1)	(s2)	(s3)	(s1)	(s2)	(s3)
721.7	591.2	493.8	358.89	279.46	262.70

* Average number of seeds planted per square meter is as follows: 6 kg = 162.3, 10 kg = 270.5 and 14 kg = 378.7.

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

TABLE 7. Effect of rate of seeding and row-width spacing on the number of heads/square meter of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum*					
	6 kg. (r1)		10 kg.(r2)		14 kg.(r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	350.5	168.3	437.1	219.5	469.1	263.9
30 (s2)	280.1	129.4	395.8	219.3	463.1	297.0
45 (s3)	314.5	136.8	346.0	204.4	372.7	216.7

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	60.77	100.78	15.99	26.52
Spacing	38.28	53.68	16.80	23.55
Rate x spacing	N.S.	N.S.	29.35	41.15

Rate:

1962			1963		
(r3)	(r2)	(r1) #	(r3)	(r2)	(r1)
434.9	392.9	315.0	259.2	214.4	144.8

Spacing:

(s1)	(s2)	(s3)	(s1)	(s2)	(s3)
418.9	379.7	344.4	217.3	215.3	185.9

Rate x Spacing, 1963

(r3)(s2)	(r3)(s1)	(r2)(s1)	(r2)(s2)	(r3)(s3)	(r2)(s3)	(r1)(s1)	(r1)(s3)	(r1)(s2)
297.0	263.9	219.5	219.3	216.7	204.4	168.3	136.8	129.4

* Average number of seeds planted per square meter is as follows: 6 kg = 162.3, 10 kg = 270.5 and 14 kg = 378.7.

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

The interaction between rates and spacings was significant only in 1963. In this year, the heaviest rate of seeding (14 kg./dunum) with 15 cm. and 30 cm. row-width spacings produced a significantly higher number of heads per square meter than the other combination. The same combinations gave a higher number of heads in 1962 but the interaction was not statistically significant. In both years, planting wheat at six kg. per dunum resulted in the fewest heads per square meter at all of the three spacings used.

Plant Height

Neither the rates of sowing nor row-width spacings had any significant effect on the height of wheat plants in either year (Table 8). However, there appears a trend towards increased plant height with increase in spacing between the rows, but the differences are not statistically significant. The results of row-width spacing and plant height were quite consistent in 1962 and 1963 and these are in agreement with the data of Faizullah (13).

Weight of 1000 Kernels

The weight of 1000 kernels was affected by the rates of sowing as shown in Table 9. With the increase in the rate of sowing the weight of 1000 kernels tended to decrease. On the basis of the 2-year average, wheat planted at six kg. per dunum produced grain weighing 40.1 grams while that sown at 14 kg. per dunum weighed 37.1 grams per 1000 kernels. Das and Varma (11) observed similar effects of rate of sowing on the 1000 kernel weight of wheat.

The different row-width spacings did not show any significant

TABLE 8. Effect of rate of seeding and row-width spacing on the height of plants in centimeters of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg. (r1)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	55.4	59.5	65.6	55.4	61.8	54.9
30 (s2)	60.5	59.9	70.1	59.2	63.2	58.2
45 (s3)	59.7	59.3	69.6	58.8	65.8	64.6

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	19.84	32.91	8.74	14.50
Spacing	6.67	9.35	4.38	6.14

Rate:

1962			1963		
(r2)	(r3)	(r1) #	(r1)	(r3)	(r2)
68.5	63.6	58.6	59.55	59.23	57.80

Spacing:

1962			1963		
(s3)	(s2)	(s1) #	(s3)	(s2)	(s1)
65.1	64.6	60.9	60.90	59.08	56.60

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

TABLE 9. Effect of rate of seeding and row-width spacing on 1000 kernel weight in grams of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg. (rl)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (sl)	37.5	42.0	37.7	40.2	36.0	38.9
30 (s2)	37.7	42.3	37.4	39.9	34.2	37.4
45 (s3)	38.4	42.6	37.2	39.8	36.6	39.5

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	2.19	3.64	1.89	3.13
Spacing	2.00	2.81	1.74	2.44

Rate:

1962			1963		
(rl)	(r2)	(r3) #	(rl)	(r2)	(r3)
37.9	37.4	35.6	42.31	39.95	38.62

Spacing:

1962			1963		
(s3)	(sl)	(s2) #	(s3)	(sl)	(s2)
37.4	37.1	36.4	40.64	40.38	39.85

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

TABLE 10. Effect of rate of seeding and row-width spacing on the protein content of winter wheat during 1962 and 1963 at the University farm.

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg. (r1)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	12.94	11.44	13.00	10.82	12.58	10.81
30 (s2)	13.09	11.35	12.71	10.85	12.72	11.42
45 (s3)	12.94	11.41	12.89	11.21	12.49	10.73

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	.94	1.57	1.33	2.21
Spacing	.54	.76	2.07	2.90

Rate:

1962			1963		
(r1)	(r2)	(r3) #	(r1)	(r3)	(r2)
12.99	12.87	12.59	11.40	10.99	10.96

Spacing:

1962			1963		
(s2)	(s1)	(s3) #	(s2)	(s3)	(s1)
12.84	12.83	12.78	11.21	11.12	11.02

#________. Treatment means underlined by the same line do not differ significantly at the 5 % level.

effect on the weight of 1000 kernels and the results were quite consistent in the two years.

Protein Content.

The protein content of wheat was not significantly influenced by the rate of sowing or row-width spacing in either year (Table 10). The protein content in the wheat kernels was higher in the first year than in the second year. The higher amount of rainfall towards the later part of the season in 1963 might account for the lower amount of protein in the kernels.

Vitreous Kernels

The vitreousness of wheat kernels was effected by the various rates of planting studied, especially in 1962 (Table 11). Wheat planted at 14 kg. per dunum resulted in kernels that were less vitreous and more starchy than that planted at six and ten kg. per dunum. The grain produced in 1963 was less vitreous than that grown in 1962 with an average index of 3.22 and 2.42, respectively.

Correlations Between Wheat Characters

The grain yield was highly correlated with the number of heads per square meter and the results were consistent in the two years (Table 12). Positive correlation were obtained between grain yield and plant height but only in 1962 the correlation was statistically significant. Grain yield and 1000 kernel weight showed a significant positive correlation in 1963. Positive correlations between grain

TABLE 11. Effect of rate of seeding and row-width spacing on the vitreous index of winter wheat during 1962 and 1963 at the University farm.*

Row-width Spacing (in cm.)	Rate of seeding, kg./dunum					
	6 kg. (r1)		10 kg. (r2)		14 kg. (r3)	
	1962	1963	1962	1963	1962	1963
15 (s1)	2.04	2.97	2.35	3.21	2.69	3.67
30 (s2)	2.25	2.70	2.31	3.49	3.07	3.27
45 (s3)	2.40	3.16	2.27	3.21	2.49	3.23

	1962		1963	
	LSD (5%)	LSD (1%)	LSD (5%)	LSD (1%)
Rate	.43	.72	.97	1.61
Spacing	.31	.43	.37	.52

Rate:

1962			1963		
(r3)	(r2)	(r1) #	(r3)	(r2)	(r1)
2.75	2.31	2.23	3.39	3.31	2.95

Spacing:

1962			1963		
(s2)	(s3)	(s1) #	(s1)	(s3)	(s2)
2.54	2.38	2.36	3.28	3.20	3.16

#_______. Treatment means underlined by the same line do not differ significantly at the 5 % level.

* Scale use for vitreous kernels: 1, vitreous and 5, starchy.

TABLE 12. Correlation coefficient between different characteristics in wheat grown at the University farm in 1962 and 1963.

	r values	
	1962	1963
1. Grain yield and number of tillers per square meter.	.3471	.2738
2. Grain yield and number of heads per square meter.	.5111**	.8779**
3. Grain yield and plant height.	.7795**	.3352
4. Grain yield and 1000 kernel weight.	.3409	.5021**
5. Grain yield and protein content.	.3054	.1036
6. Number of tillers per square meter and number of heads per square meter.	.8234**	.8612**
7. Yield of straw and number of heads per square meter.	.6035**	.5014**
8. Protein content and vitreous index.	-.8604**	-.7096**

** Statistically significant at the 1 % level.

yield and 1000 kernel weight were also obtained by other workers (7, 13, 54). The grain yield was not influenced by the number of tillers per square meter. Also the protein content of the grain was not affected by the yield in the two years of this study.

The number of heads per square meter was found to be consistently correlated with the number of tillers per square meter and the yield of straw. A highly negative correlation was observed between the vitreous index and protein content in wheat kernels during the two years of this trial. This is consistent with the results of other investigators (7, 26).

SUMMARY AND CONCLUSIONS

Two-year trials were conducted under dry land conditions during the 1961-62 and 1962-63 seasons. The study involved the evaluation of the effect of various plant populations on the grain yield, yield of straw, grain/straw ratio, number of tillers per square meter, number of heads per square meter, height of plants, protein content, 1000 kernel weight and vitreousness of the wheat kernels.

Rates of seeding of 6, 10 and 14 kg. per dunum and row-width spacings of 15, 30 and 45 cm. were found to have little influence on the grain and straw yield during the two years of this experiment in the Beqa'a plain in Lebanon. The grain/straw ratio was not affected by these various plant populations.

The higher rates of sowing (10 and 14 kg./dunum), however, produced higher number of tillers and heads per square meter than the lowest rate (6 kg./dunum). With the increase in row-width spacing, the number of tillers and heads per square meter were found to be decreased.

The height of plants and the protein content in the wheat kernels were not affected by the different rates of sowing and row-width spacings in this trial.

The 1000 kernel weight and vitreousness of wheat kernel was found to be influenced by the rates of seeding. There was a trend towards lower kernel weight with the higher rates of seeding. The wheat kernels resulting from the higher rates of seeding tended to be more starchy than those from the lower rates. Neither the 1000 kernel weight nor the vitreousness of the wheat kernels were influenced by the different row-width spacings.

On the basis of the results of this research and also the results obtained by Faizullah (13) during the two previous years at the University farm at the Beqa'a plain, it appears that the higher rate of seeding do not result in more grain than the lower rates. Thus, it appears that large quantities of seeds are being wasted by the present use of 18-20 kg. per dunum in this region. By the use of machinery and improved methods of planting, a considerable amount of seeds may be saved and high yield may be obtained which will add much to the economy of this area.

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APPENDIX

TABLE 13. Analysis of variance for grain yield of wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Blocks	2	62329.01**	4833.33**
Rates	2	482.62	655.05
Error (a)	4	115.21	668.78
Spacing	2	296.08	64.01
Rate x Spacing	4	453.90	125.43
Error (b)	12	271.80	225.44

TABLE 14. Analysis of variance for yield of straw of wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Blocks	2	539632.76**	19031.86*
Rates	2	6951.00	7106.68
Error (a)	4	3247.30	1390.57
Spacing	2	2632.46	447.45
Rate x Spacing	4	565.55	193.18
Error (b)	12	2634.68	283.14

* Denotes F values significant at the 5 % level.

** Denotes F values significant at the 1 % level.

Table 15. Analysis of variance for grain/straw ratio of wheat

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	.0093	.0007
Rates	2	.0089	.0085
Error (a)	4	.0028	.0024
Spacings	2	.0031	.0055
Rate x Spacing	4	.0018	.0022
Error (b)	12	.3348	.0022

Table 16. Analysis of variance for the number of tillers per square meter of wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	49497.85*	1820.48
Rates	2	24198.55	30499.89**
Error (a)	4	3542.95	1807.37
Spacings	2	127674.20**	23767.32**
Rate x spacing	4	6973.05	1216.05
Error (b)	12	6273.26	1244.08

* Denotes F values significant at the 5 % level.

** Denotes F values significant at the 1 % level.

Table 17. Analysis of variance for the number of heads per square meter.

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	39418.12**	450.04
Rates	2	33337.63*	29909.35**
Error (a)	4	2166.86	149.27
Spacings	2	12512.60**	2759.30*
Rate x spacing	4	3105.97	1813.95*
Error (b)	12	1389.12	272.49

Table 18. Analysis of variance for plant height of winter wheat

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	934.94	150.83
Rates	2	220.05	7.86
Error (a)	4	230.00	44.89
Spacings	2	70.42	41.99
Rate x spacing	4	8.28	22.04
Error (b)	12	42.20	18.11

* Denotes F values significant at the 5 % level.

** Denote F values significant at the 1 $ level.

Table 19. Analysis of variance for 1000 kernel weight of winter wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	0.76	36.10*
Rates	2	13.23	31.28*
Error (a)	4	2.87	2.11
Spacings	2	2.13	1.30
Rate x spacing	4	1.72	1.38
Error (b)	12	3.81	2.89

Table 20. Analysis of variance for protein content of wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	55.92**	4.94
Rates	2	.36	.41
Error (a)	4	.52	1.07
Spacings	2	.01	.08
Rate x spacing	4	.06	.32
Error (b)	12	.29	.41

* Denotes F values significant at the 5 % level.

** Denote F values significant at the 1 % level.

Table 21. Analysis of variance for vitreous index of wheat.

Source	D. F.	M. S. 1962	M. S. 1963
Block	2	8.39**	1.22
Rates	2	.71	.49
Error (a)	4	.11	.58
Spacings	2	.09	.04
Rate x spacing	4	.14	.18
Error (b)	12	.09	.13

** Denotes F values significant at the 1 % level.