SOWING OF SPRING CEREALS IN BROAD BANDS AND THE EFFECT OF SOWING RATE, ROLLING AND IRRIGATION ON THE RESULTS

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Abstract. In 1971 two large field experiments, one for spring wheat and the other for barley, were carried out on silty clay soil in southern Finland. Three sowing methods were compared at three sowing rate levels (wheat: 140, 275 or 400 kg/ha, barley: 100, 200 or 300 kg/ha), at two levels of rolling (not rolled or rolled by a Cambridge-roller, 330 kg/m), and at two levels of irrigation (not irrigated or irrigated twice in June, 30 mm at both times).

Wheat produced 9 ± 2 % higher grain yields sown with a 12.5 cm spacing between coulters in 7 cm bands than in rows of 2 cm. The increases in yield were almost equal irrespective of the seeding rate, rolling or irrigation. The sowing methods had no noteworthy influence on the ripening or the weight of the wheat grains. Barley responded to the sowing methods to a lesser extent than did wheat.

Bands 7 cm wide with 12.5 cm spacing resulted in 5 ± 2 % higher wheat yields and 2 ± 1 % higher barley yields than did bands 10 cm wide with 25 cm spacing. The results indicate that the band method with relatively small spacings between the bands is worth further and more detailed study.

An increase in the seeding rate from low to »normal» increased the yields, speeded up ripening and decreased the weight of grains, but when normal seeding rates were exceeded the grain yields were not further improved. Rolling speeded up ripening but did not significantly increase the grain yields. Of the factors included in the study, the sprinkler irrigation affected the yields most by increasing the grain yields of wheat by 23 ± 22 % and those of barley by 29 ± 9 %.

Spring cereals are usually sown in rows with a spacing of 12—15 cm between the coulters. This is not the best possible sowing method. A uniform distribution of plants on a growing area presupposes a markedly smaller spacing, about 5 cm row (Heege

1967, 1970, Möller 1967, Heinonen 1970). Reducing the spacing between the rows has improved yields in several trials (Foth et al. 1964, Strand 1968). The better yields are supposed to be a result from a better utilization of light by plants in photosynthesis and from unfavourable living conditions for weeds and plant pathogens.

However, a reduced row spacing makes the working of a sowing machine more difficult. Particularly, as the machine becomes more liable to clogging it has been considered that a smaller row spacing than that of 10—12 cm is not feasible in practice (Strand 1968, Heege 1970). A more uniform seeding can also be attained without diminishing the spacing between the coulters by changing the form of coulters so that the seeds are not sown in narrow rows but in broad bands. In the present paper an attempt is made to study the possible advantages of this band method compared to the row method.

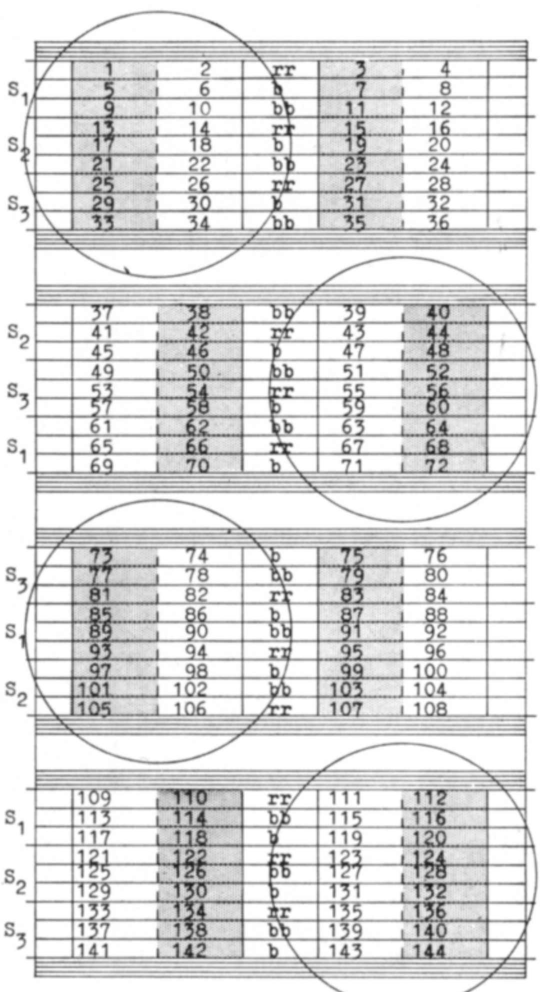

Fig. 1. Design of the experimental fields.

Field experiments

Experimental soil and plants. In 1971 two large experiments, described in Fig. 1, were carried out on the same field. Spring wheat (variety Ruso) was the experimental plant in one trial and barley (variety Kristiina) in the other. The area of the trials, both of which contained 144 experimental plots, was 65 × 125 m^2. The soil characteristics are given in Table 1.

Table 1. Soil of the experimental fields.

	Depth cm	Particle-size composition % < 2 μm	2—20 μm	20—200 μm	> 200 μm	Org. C %	pH_{CaCl_2}
Wheat	0—20	52	35	12	1	3.3	5.7
	30—40	62	29	9	0	0.5	5.8
Barley	0—20	46	37	15	2	3.0	6.0
	30—40	69	21	10	0	0.5	6.0

The experimental fields were cultivated and fertilized lengthwise, at right angles to the plots. The harrowing depth was 7—8 cm. As a dressing 750 kg/ha of a compound fertilizer was placed in rows with a spacing of 16 cm and at a depth of 8—9 cm. Thus, 113 kg N, 65 kg P and 93 kg K were applied per hectare.

Factors. The field experiments were laid out in a split-plot design (Steel and Torrie 1960) and contained four factors (Fig. 1): as whole plots two levels of irrigation (I), as subplots two levels of rolling (R), as subsubplots three levels of sowing rate (S), and as subsubsubplots three sowing methods (M). Thus, with four replicates, both experiments included 48 comparisons of the sowing methods.

The principle and a result in practice of the sowing methods are shown in Fig. 2. Sowing was carried out with Finnish »Tume»-combine drills without fertilizing coulters. For sowing in rows (rr) and in bands (bb), the same machine but different coulters were used. Thus the spacing between the coulters was the same, 12.5 cm, but in the former case, the seeds were sown in 2 cm narrow rows instead of 7 cm broad bands as in the latter case. In method b, another machine and other coulters were applied for sowing seeds with a 25 cm spacing in 10 cm broad bands. The sowing depth was adjusted so as to be as nearly as possible the same, for wheat 45 mm and for barley 60 mm. According to the study made after sowing on the rolled plots, the average sowing depths with least significant differences (LSD) were as follows:

	rr	bb	b	LSD
wheat	43	42	44	3
barley	57	59	61	3

The seeding rates, kg/ha (relative values in parentheses), were adjusted, allowing for a margin of error of ± 1 %, as follows:

	S_1 = low	S_2 = »normal»	S_3 = high
wheat	140 (51)	275 (100)	400 (145)
barley	100 (50)	200 (100)	300 (150)

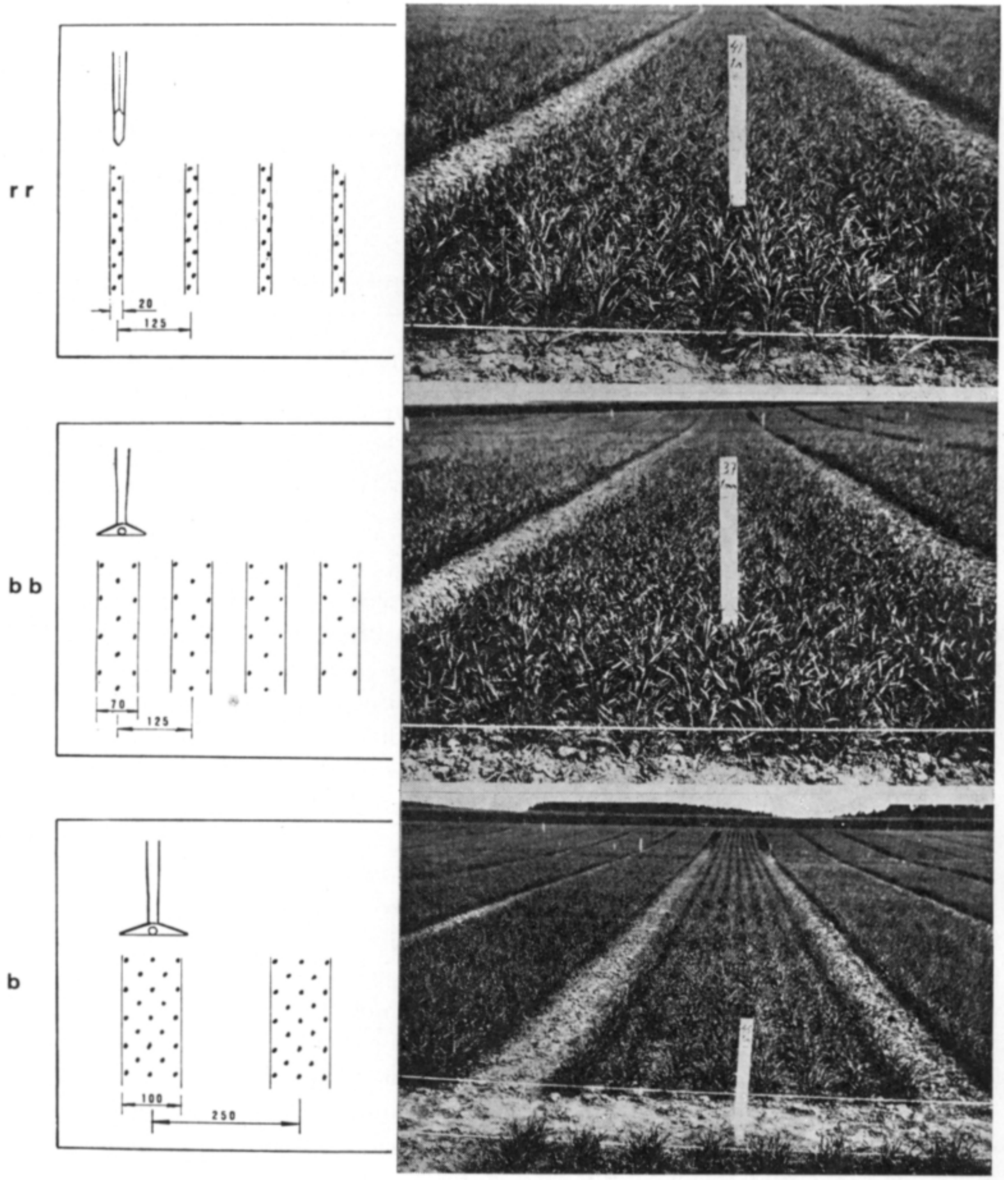

Fig. 2. Principle (on the left) and a result in practice (on the right) of the sowing methods. Photographs of adjoining barley plots on June 8.

Rolling (R_1) was carried out immediately after sowing at right angles to the plots. The weight of a Cambridge-roller with an additional loading was about 330 kg/m.

Irrigation (I_1) by rotary sprinklers was performed in the night of June 6, about two weeks after the emergence of seedlings, and on June 20. At both times, 30 mm of drainage ditch water was applied at the rate of 5 mm per hour.

E m e r g e n c e a n d l a t e r d e v e l o p m e n t. Table 2 shows that the number of seedlings per m^2, corresponding to the seeding rates S_1, S_2 and S_3, were on the wheat

Table 2. Emergence of cereals (seedlings/m²). Symbols as in Fig. 1.

	Wheat				Barley			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
rr	257	482	749	496	177	350	535	354
bb	242	516	675	478	165	332	476	324
b	265	462	687	471	149	315	472	312
Mean	255	487	704	482	164	332	494	330
LSD	57	57	57	33	25	25	25	14
Relative values	52	100	144		49	100	149	

field on an average 255, 487 and 704, and on the barley field 164, 332 and 494, respectively. In fact the relations between the rates of seeding and emergence were, allowing for a margin of error of ± 1 %, the same. On the wheat field, significant differences in emergence between the sowing methods appeared only on the plots sown by the high seeding rate (S_3). In this case the seeds emerged better in rows (rr) than in bands (bb and b). On the barley field the differences were more distinctly to the advantage of the row method.

The uniformity in emergence, lengthwise the rows and bands on the S_2-plots, was measured by calculating the numbers of seedlings per successive 10 cm intervals. The standard deviations, in numbers of seedlings/10 cm, did not differ between different sowing methods when the twofold amount of seedlings in bands sown by the method b is taken into consideration (the numbers in parentheses have been obtained by dividing the standard deviations by $\sqrt{2}$):

	rr	bb	b
wheat	3.0	2.7	3.8 (2.7)
barley	2.1	2.1	3.1 (2.2)

In spite of the dry growing season with a precipitation of 13 mm in May, 15 mm in June, 15 mm in July and 90 mm in August, the growth was very good, the cereals ripened uniformly and they were almost free from weeds and plant diseases. The grains were harvested with a combine-harvester, air-dried and winnowed.

Results

The reliability of the results was tested by the analysis of variance according to the split-plot design (Steel and Torrie 1960). The least significant differences (LSD) between means were calculated at the 95 % confidence level. The significance of the interactions has been indicated at the confidence levels of both 95 % (*) and 99 % (**).

G r a i n   y i e l d s (Table 3). The grain yields were fairly good. The wheat yields varied, depending on the treatment, between 3090 and 5520 kg/ha, the range of the barley yields was 4380—7930 kg/ha.

Table 3. Grain yields kg/ha, moisture 15 %. Symbols as in Fig. 1.

	S_1			S_2			S_3		
	rr	bb	b	rr	bb	b	rr	bb	b
				Wheat (W)					
I_0R_0	3090	3660	3730	3690	4200	3720	3770	4200	4070
R_1	3300	3560	3450	3750	4140	4030	4040	4160	4000
I_1R_0	3570	3990	3970	4570	4900	4610	4600	4860	4700
R_1	4230	4610	4290	5080	5520	5220	5060	5320	4860
				Barley (B)					
I_0R_0	4560	4380	4540	6220	5930	5790	5700	5760	5700
R_1	5320	5130	5170	6290	5890	5660	6000	5910	5560
I_1R_0	6570	6760	6520	6930	6980	7080	7350	7410	7230
R_1	6760	6950	6610	7430	7330	7410	7930	7840	7610

Means and least significant differences (LSD)

	W	B		W	B		W	B		W	B
rr	4060	6420	S_1	3790	5770	R_0	4110	6190	I_0	3810	5530
bb	4420	6360	S_2	4450	6580	R_1	4370	6490	I_1	4670	7150
b	4220	6240	S_3	4470	6670	LSD	300	740	LSD	850	490
LSD	100	90	LSD	190	210						

Significant interactions: what ebarley M × I* S × I**

The wheat yields were significantly affected by the sowing methods, independently of the other factors. The band method with a 12.5 cm spacing (bb) proved to be the best one. Compared to the row method (rr) it increased the grain yields on an average by 360 ± 100 kg/ha or 9 ± 2 %, and compared to the band method with a 25 cm spacing (b), the increase was 200 ± 100 kg/ha or 5 ± 2 %. The difference in yields between the methods b and rr was 160 ± 100 kg/ha or 4 ± 2 %.

The sowing methods had less effect on barley than on wheat. The average difference in yields between the methods rr and bb, 60 ± 90 kg/ha or 1 ± 1 %, was not statistically significant. However, the barley yields obtained by the method b were on an average 180 ± 90 or 3 ± 1 % lower than the yields obtained by the method rr and 120 ± 90 kg/ha or 2 ± 1 % lower than the yields obtained by the method bb. The differences were more distinct on the unirrigated than on the irrigated plots.

The decrease in the seeding rate from »normal» decreased the wheat yields on an average by 660 ± 190 kg/ha or 15 ± 4 %, the decrease in the barley yields was 810 ± 210 kg/ha or 12 ± 3 %. The increase in the seeding rate from normal significantly increased the yields only on the irrigated barley plots. This increase was 370 ± 300 kg/ha or 5 ± 4 %.

The effect of rolling on the wheat yields averaged + 260 ± 300 kg/ha or 6 ± 7 % while the effect on the barley yields was + 300 ± 740 kg/ha or 5 ± 12 %. The increases were not statistically significant.

Irrigation increased the wheat yields on an average by 860 ± 850 kg/ha or 23 ± 22 %. There were no significant interactions between irrigation and other factors. Barley yields were increased by irrigation on an average by 1620 ± 490 kg/ha or 29 ± 9 %. However, the effect of irrigation was significantly dependent on the sowing method and on the sowing rate. The increases caused by irrigation were on an average 1480 kg/ha or 26 % on the rr-plots, 1710 kg/ha or 31 % on the bb-plots, and 1680 kg/ha or 31 % on the b-plots. In fact, the effect of irrigation was better on the seedling bands than on the rows. The increases in the barley yields on the S_1-, S_2- and S_3-plots were on an average 1840 kg/ha or 38 %, 1230 kg/ha or 21 %, and 1790 kg/ha or 31 %, respectively. Thus, the response to irrigation was highest when a low or a high seeding rate was used, while the response was smaller when coupled to the normal seeding rate.

Table 4. Moisture of grains at the harvest, %. Symbols as in Fig. 1.

	S_1			S_2			S_3		
	rr	bb	b	rr	bb	b	rr	bb	b
				Wheat (W)					
I_0 R_0	20.0	19.0	18.4	18.5	17.4	17.6	16.9	17.3	16.7
R_1	18.5	18.7	17.8	17.1	17.0	16.7	17.2	16.6	16.5
I_1 R_0	27.9	28.4	25.6	24.9	24.1	23.2	23.0	21.6	20.8
R_1	22.6	23.8	23.0	21.6	20.8	20.8	20.0	20.1	19.7
				Barley (B)					
I_0 R_0	19.3	19.1	18.2	16.9	16.3	16.0	15.7	15.0	15.5
R_1	16.8	17.4	17.1	15.3	15.5	15.6	15.0	14.9	15.3
I_1 R_0	21.0	21.2	22.3	17.1	16.5	17.1	15.7	15.9	16.0
R_1	19.2	20.5	21.6	16.4	17.2	16.8	16.1	16.9	16.3

Means and least significant differences (LSD)

	W	B		W	B		W	B		W	B
rr	20.7	17.0	S_1	22.0	19.5	R_0	21.2	17.5	I_0	17.7	16.4
bb	20.4	17.2	S_2	20.0	16.4	R_1	19.4	16.9	I_1	22.9	18.0
b	19.7	17.3	S_3	18.9	15.7	LSD	1.6	0.9	LSD	3.4	1.2
LSD	0.5	0.4	LSD	1.0	0.6						

Significant interactions: wheat S × I* barley M × R* M × I* S × R* S × I**

M o i s t u r e o f g r a i n s a t h a r v e s t (Table 4). The sowing methods had only a slight effect on the ripening of the cereals. At harvest time, the moisture content of wheat grains on the b-plots was on an average 0.7 ± 0.5 %-units lower than that on the bb-plots, and 1.0 ± 0.5 %-units lower compared to the rr-plots. The ripening of barley was even less affected by the sowing methods.

The decrease in the seeding rate from normal retarded the ripening by increasing the moisture content of wheat grains on an average by 2.0 ± 1.0 and that of barley by 3.1 ± 0.6 %-units. The increase in the seeding rate from normal decreased the moisture content of wheat on an average by 1.1 ± 1.0 and that of barley by 0.7 ± 0.6 %-units.

The differences in ripening caused by the seeding rates were more distinct on the irrigated than on the unirrigated plots, and on the unrolled than on the rolled plots.

The wheat grains from the rolled plots were on an average by 1.8 ± 1.6 %-units drier than those from the plots not rolled. The ripening of barley was significantly affected by rolling only when the row method or the low seeding rate was used.

Table 5. 1000-grain weights, g. Symbols as in Fig. 1.

	S_1			S_2			S_3		
	rr	bb	b	rr	bb	b	rr	bb	b
				Wheat (W)					
I_0 R_0	40.5	40.7	41.3	39.6	39.6	39.8	37.9	38.7	37.8
R_1	40.6	41.0	41.4	39.0	39.2	39.9	38.2	38.5	37.9
I_1 R_0	41.5	42.1	42.4	41.0	41.0	41.1	40.3	40.2	40.2
R_1	41.6	42.5	41.8	42.3	42.1	42.6	40.9	40.9	40.6
				Barley (B)					
I_0 R_0	52.9	53.2	53.2	51.2	51.0	50.9	49.1	49.8	49.6
R_1	53.0	52.5	53.5	49.7	49.6	50.4	48.4	48.3	48.5
I_1 R_0	54.0	54.4	54.0	50.0	49.9	50.9	48.9	49.6	49.7
R_1	53.5	53.8	55.0	50.1	51.1	50.7	49.7	49.7	49.3

Means and least significant differences (LSD)

	W	B		W	B		W	B		W	B
rr	40.3	50.9	S_1	41.4	53.6	R_0	40.3	51.2	I_0	39.5	50.8
bb	40.5	51.1	S_2	40.6	50.4	R_1	40.6	50.9	I_1	41.4	51.3
b	40.6	51.3	S_3	39.3	49.2	LSD	0.5	0.4	LSD	1.7	0.6
LSD	0.3	0.3	LSD	0.4	0.4						

Significant interactions: wheat M × S* S × I** barley S × I* R × I*

Irrigation, in contrast to rolling, retarded especially the ripening of wheat. The increase in the moisture of wheat, caused by irrigation, was on an average 5.2 ± 3.4 and that of barley 1.6 ± 1.2 %-units. The effect of irrigation tended to be compensated by a higher seeding rate.

Weight of the grains (Table 5). The sowing methods had only a slight effect on the weight of the grains. The 1000-grain weights of wheat were on an average 0.3 ± 0.3 g higher, and those of barley 0.4 ± 0.3 g higher, from the b-plots than from the rr-plots.

The weight of the grains was more affected by the sowing rates than by the other factors. The decrease in the seeding rate from the normal increased the 1000-grain weights of wheat on an average by 0.8 ± 0.4 g and those of barley by as much as 3.2 ± 0.4 g. Correspondingly, the increase in the seeding rate from the normal decreased the 1000-grain weights of wheat by 1.3 ± 0.4 g and those of barley by 1.2 ± 0.4 g, on an average.

The differences in the weights of grains, caused by the seeding rate, were greater on the unirrigated than the irrigated plots.

The effect of rolling was slight and significant only on the unirrigated barley plots. In this case, rolling decreased the 1000-grain weights by an average of 0.8 ± 0.5 g.

Irrigation increased the 1000-grain weights of wheat on an average by 1.9 ± 1.7 g. The effect was greater when the normal or high instead of the low seeding rate was used. The increase in the weight of barley grains, caused by irrigation, was slight and statistically significant only on the plots of S_1 and R_1.

Discussion

Wheat grew significantly better in bands than in rows. Because there were no significant differences in the seed beds, sowing depths or emergence, except in the S_3-plots on which differences in emergence may be of no importance, the better yields were likely to be caused by a better utilization of growing area by the plants.

Barley responded to the band methods in a different way from wheat. The yields were either of the same quantity or slightly poorer than those obtained by the row method. The poorer results may partly be due to poorer emergence. Particularly, emergence in bands with a 25 cm spacing was poorer than in rows at all the three levels of the seeding rate (Table 2). The effect of the sowing method can also be smaller on barley than on wheat. Barley, with a good ability to tiller, can better utilize the growing area between rows than does the poorly tillering wheat. Heege (1970) has obtained results of the same kind while those by Strand (1968) are partly reversed.

When the band methods with a spacing of 12.5 cm (bb) and of 25 cm (b) are compared, the former shows significantly better yields of both wheat and barley. Because no significant differences in emergence appeared (Table 2), the differences in yields are probably caused by different sowing methods. The wide spacings between the b-bands, which were without any growth at a relatively late stage of development (Fig. 2), decreased the yields.

It seems that a band method with a relatively wide spacing must be considered only as a transitional stage in the development of sowing methods. The substituting of two 10 cm wide spacings without growth between rows by one 15 cm empty spacing between bands (Fig. 2) does not signify any decisive improvement. In studies concerning the combine drill, the band method with a 25 cm coulter-spacing resulted in equal or slightly poorer results than did the row method (according to the unpublished results by Heinonen, Köylijärvi and Larpes).

According to the present results, the band method with relatively small spacings between the bands merits further and more detailed studies. The working of coulters in unfavourable sowing conditions, and the effect of the band method on emergence, on the control of weeds and pathogens and on the resistance to lodging of cereals are important objects in further investigations.

The present study likewise gave interesting information about other experimental factors. The plants were to a great extent able to compensate the unusually low seeding rate by developing stronger individual plants with more numerous and bigger grains. This result presupposes a longer growing period which, especially under Finnish weather conditions, must be considered a disadvantage. On the other hand, a high seeding rate results in a close growth with a relatively small amount of light, water and nutrients per plant. The plants remain slender, they ripen early and their yield is not better than normal. Similar results have been reported by Valle and Mela (1965).

According to Heinonen (1971) rolling of clay soil reduces evaporation and thus conserves moisture in soil for plants. In the present study, the ripening of the cereals was promoted by rolling. The effect of rolling on the yields was not statistically significant, but on both cereals it tended to be of the same direction and quantity. These results, as well as those by Njøs (1962), call for more thorough studies of rolling and especially of its technical performance on dry clay soils.

The effect of irrigation on the grain yields was good and corresponded well with earlier results (Elonen, Nieminen and Kara 1967 a). Exceptionally, irrigation retarded ripening and increased the weight of grains (Elonen, Nieminen and Kara 1967 b). The phenomenon was possibly caused by the unusually dry middle and latter part of the summer 1971 resulting in abnormally early ripening of the unirrigated cereals (Pohjanheimo and Heinonen 1960). The interaction between irrigation and seeding rate is likewise interesting. With irrigation low seeding rates resulted in fairly good yields, but the best yields were obtained when normal or high seeding rates were used. Irrigation improves the uptake of both water and nutrients which makes it possible to increase the density of growth, i.e. the seeding rate.

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SELOSTUS

TULOKSIA KEVÄTVILJOJEN NAUHAKYLVÖSTÄ JA NIIDEN RIIPPUVUUS KYLVÖMÄÄRÄSTÄ, JYRÄYKSESTÄ JA SADETUKSESTA

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Kolmen kylvömenetelmän vertaamiseksi perustettiin kesällä 1971 maatalouskoneiden tutkimussäätiön Pakankylän tilan hiesusavipellolle Espooseen kaksi laajaa kenttäkoetta, joista toisella viljeltiin Ruso-vehnää ja toisella Kristiina-ohraa. Muina koetekijöinä olivat kylvömäärä, jyräys ja sadetus. Kylvömäärät olivat vehnällä 140, 275 ja 400 sekä ohralla 100, 200 ja 300 kg/ha. Jyräykseen käytettiin Cambridge-jyrää, jonka paino lisäpainoineen oli 330 kg/m. Sadetus suoritettiin kahdesti kesäkuussa 30 mm:n vesimäärillä.

Kevätvehnä tuotti keskimäärin 9 ± 2 % suuremman jyväsadon kylvettynä 12.5 cm:n vannasvälillä 7 cm leveisiin nauhoihin kuin kylvettynä samalla vannasvälillä 2 cm kapeisiin riveihin. Satoero ei riippunut merkitsevästi kylvömäärästä, jyräyksestä tai sadetuksesta. Kylvömenetelmillä ei ollut mainittavaa vaikutusta tuleentumiseen eikä jyvien painoon. Kylvömenetelmien vaikutus ohrasatoihin oli niinikään vähäinen.

Kylvö suurella, 25 cm:n vannasvälillä 10 cm leveisiin nauhoihin tuotti 5 ± 2 % heikompia vehnäsatoja ja 2 ± 1 % heikompia ohrasatoja kuin nauhakylvö pienellä, 12.5 cm:n vannasvälillä. Tulosten perusteella esitetään, että kylvömenetelmiä koskevat jatkotutkimukset tulisi kohdistaa pienellä vannasvälillä toimivan nauhakylvökoneen kehittämiseksi.

Kylvömäärän lisääminen lisäsi satoa, edisti tuleentumista ja vähensi jyvien painoa, mutta kylvömäärän ylittäessä »normaalin» sato ei enää lisääntynyt. Jyräys edisti viljojen tuleentumista, mutta ei merkitsevästi lisännyt niiden satoa. Tutkimukseen sisältyneistä koetekijöistä sadetus vaikutti satoihin eniten lisäten vehnäsatoja 23 ± 22 % ja ohrasatoja 29 ± 9 %.