J. agric. Sci., Camb. (1969), **72**, 109–117
Printed in Great Britain

A comparison of methods of growing sugar-beet seed

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(*Received* 22 *July* 1968)

SUMMARY

Two experiments with sugar-beet seed crops at Dunholme Field Station, Lincolnshire, 1955–7, one at Broom's Barn, Suffolk, 1963–4, and two in Bedfordshire, 1965–7, compared transplanting with various direct-drilling techniques. The early experiments were made with multigerm varieties and the 1965–7 experiments with genetic monogerm varieties.

At Dunholme direct drilling under a barley cover crop controlled virus yellows and yielded more multigerm seed suitable for processing than did transplanting. In later experiments transplanting gave variable yields; pests damaged plots transplanted in autumn and those transplanted in spring were susceptible to drought. Many transplants lodged and ripened late, and direct drillings produced seed that germinated better.

Direct drilling during July with no cover crop consistently yielded better than undersowing or open drilling in August. To establish a regular, dense stand of plants, which is essential for large yields of seed of good germination, was more difficult with than without cover crops. The time the cover crop was removed did not consistently affect yield. Crops sown in summer without cover yield most seed but are most susceptible to disease and are unsuitable for areas with a disease risk.

INTRODUCTION

Between 1935 and 1955 the main object of experiments with sugar-beet seed crops in Great Britain was the control of disease (Hull, 1954, 1961; Byford & Hull, 1967), but others have been added as the needs to mechanize and cheapen methods of seed growing have increased (Coy, 1966). The Danish method of sowing stecklings under barley cover crops (Jensen, 1963), to be grown on where sown, was widely adopted and gave good disease control (Hull, 1954). As demand increased for processed seed, graded for size, the large clusters in raw seed became useless and methods of growing uniformly small seed were needed (Scott, 1967). Until 1963 nearly all seed used in Great Britain was multigerm, but as monogerm varieties were developed the emphasis changed to growing monogerm seed of good germination capacity and vigour.

EXPERIMENTAL

1. *Transplanting versus direct drilling*, 1955 *and* 1956

Experiments 1 and 2, started in 1955 and 1956 respectively on thin, stony, limestone soil at Dunholme Field Station, near Lincoln, compared direct drilling with transplanting, the traditional method of growing sugar beet for seed (Scott, 1967). The effects were determined of (1) different densities of barley cover, obtained from sowing 1 or 2½ bushels/acre, (2) two amounts of fertilizer, and (3) gapping direct-drilled plots. Also, in Exp. 2, transplanting in spring was compared with autumn transplanting, and topping the inflorescence stalk with no topping.

Methods

Beet and barley were sown on 3 May in both years, the beet in rows 24 in apart with two rows of barley 8 in apart between them. Natural sugar-beet seed sown at 10 lb/acre resulted in 20 plants/yard in unthinned plots at harvest. After the barley was harvested in August the ground between the sugar-beet rows was cultivated with a rotary hoe. On 21 March in Exp. 1, and 12 November and 26 March in Exp. 2, some plots were gapped, leaving plants 12 in apart, and the stecklings removed were transplanted 12 in apart in 24 in rows in other plots. The plants in some of the transplanted plots in Exp. 2 were topped when 18 in high. The nine treatments of Exp. 1 and ten treatments of Exp. 2 were replicated in four randomized blocks of plots 8 ft wide by 24 ft long.

The plants were free from yellows in both years.

The transplants lodged in summer gales in 1956 and made much secondary growth, whereas the direct-drilled plants remained upright. During 1957 the plots transplanted in spring always looked poor because growth was impeded by drought.

The direct-drilled plots were ready for harvesting first, but were not cut until the transplanted plots were ready 2 weeks later. The plants were cut with a mower, left on the ground for a few days and then dried on tripods before thrashing.

Table 1 gives the yield of seed after cleaning on a moving, inclined belt. Barley seeding rate and amount of fertilizer did not affect beet seed yield, cluster size, or percentage germination in either year and results are averaged for these treatments. Percentage germinations were kindly determined by B.S.C. Central Laboratory. In both experiments direct-drilled plants gave more seed than transplanted. Gapping direct-drilled plants and topping transplants decreased yield in Exp. 2.

Clusters of diploid varieties with diameters greater than 14/16 in are too large for rubbing. In both experiments transplanting gave a greater proportion of oversize seed than direct-drilling. Seed from direct-drilled plants germinated better than seed from spring transplants in both experiments, but no better than from untopped autumn transplants in Exp. 2. Gapping direct-drilled plants increased and topping transplants decreased the proportion of oversize seed and both treatments decreased germination percentage.

These experiments indicated that direct drilling under a cover crop yielded more seed suitable for processing than transplanted stecklings. Early ripening and less risk of lodging were additional advantages of a method suitable for mechanization and applicable to large-scale farming. The proportion of seed crop grown in this way increased from the mid-1950s (Byford & Hull, 1967).

2. *Transplanting versus three methods of direct drilling*, 1963–4.

Summer sowing under mustard (which gives cover for game) became popular, especially in Essex, from 1958 onwards and 42 % of all steckling beds were sown in this way in 1960 (Byford & Hull, 1967). There was, however, an abrupt decrease in the use of the method after 1962 because it increased the incidence of downy mildew. Until 1962 crops drilled in summer without cover were prohibited everywhere, but from 1962 onwards they were permitted in areas where root crops were few, i.e. west of Great North Road, A.1 and south of the Thames.

In Exp. 3 at Broom's Barn sowing in summer with and without mustard cover were compared with spring drilling under barley and with transplanting. Plots of each growing method were split

Table 1. *The effect of methods of growing at Dunholme on yield, cluster size and germination*

	Experiment 1			Experiment 2					
		Direct drilled		Autumn transplanted		Spring transplanted		Direct drilled	
Method of growing ...	Trans-planted	Gapped	Not gapped	Not topped	Topped	Not topped	Topped	Gapped	Not gapped
Yield of clean seed (cwt/acre)	18·5 (±0·59)	20·9	20·8 (±0·42)	18·9	16·7	13·0	11·0 (±2·10)	19·1	21·6
Percentage weight of seed: Exp. 1 / Exp. 2									
Retained by $\frac{18}{64}$ in sieve / $\frac{14}{64}$ in sieve	3·7	1·5	2·3	37·8	35·6	35·2	34·8	31·2	31·1
Retained by $\frac{14}{64}$ in sieve / $\frac{9}{64}$ in sieve	59·1	52·9	57·8	58·5	59·4	59·5	58·3	64·1	62·9
Retained by $\frac{7}{64}$ in sieve / $\frac{7}{64}$ in sieve	37·1	45·6	39·9	3·7	5·0	5·3	7·0	4·7	6·1
Percentage germination	45·0	54·0	62·0	67·0	56·0	56·0	44·0	60·0	67·0

for an early and a late treatment; thus there were eight treatments:

(A) Sown on 7 May under barley with cover removed on 6 August or 6 September 1963.

(B) Sown under mustard cover on 19 July or 15 August 1963.

(C) Transplanted from a steckling bed (sown nearby on 2 August) in December 1963 or March 1964.

(D) Sown without cover on 19 July or 15 August 1963.

Methods

The four main treatments, each split for the appropriate time factor, were replicated in five randomized blocks. Three blocks had received 1·1, 1·2, 1·2 cwt/acre of N, P_2O and K_2O_5 respectively, in preparation for potatoes on 8 April and the other two blocks received 0·5, 0·3, 0·3 cwt/acre of N, P_2O_5 and K_2O respectively on 6 May after the area had been allocated for the seed crop experiment.

A 'Stanhay' drill, fitted with the belt for natural seed, sowing Sharpe's Klein E mother seed in rows 20 in. apart, was followed by a corn drill sowing two rows of Rika barley between the rows of beet. Seed for treatments B and D, treated with 'Saphizon', was sown with a 'Bean' drill set as in Exps. 1 and 2. When drilling treatment B, beet and white mustard seed were mixed in 6:1 ratio by weight and small quantities fed into hoppers at a time, to avoid the two types of seed separating during sowing.

All direct-drilled plots were sprayed with 'Metasystox' insecticide in August and September to control aphids and prevent spread of yellows. July-sown stecklings were infested with *Aphis fabae* by this time.

The mustard cover was mown and raked from the plots during February 1964; 0·6, 0·3, 0·3 cwt/acre of N, P_2O_5 and K_2O respectively was applied to the experimental area on 9 March and the spring transplanting was done on 10 March. On some plots many plants got downy mildew (Table 2) and the whole experiment was sprayed with 'Maneb' five times during May.

Plants of treatment A, especially when the barley was cut early, ripened first and were cut on 18 August. July sowings both under mustard and without cover were cut on 20 August, and August sowings and transplanted plots during the following week. After cutting, plants were allowed to wilt, placed on tripods and thrashed with a combine harvester in early September. As at Dunholme, many transplants lodged; individual plants differed

Table 2. *The effects of methods of growing at Broom's Barn on plant stand, plants with downy mildew and yellows, yield of seed, cluster size and germination*

Method of growing	Stecklings direct drilled: Under barley, removed: August	September	Under mustard, sown: July	August	Without cover, sown: July	August	Stecklings transplanted in: December	March
				October 1963				
Plants/yd. ...	8·2	6·6	14·8	16·5	17·1	20·5	—	—
Virus yellows (%)	0·2	0·1	0·3	0·1	0·2	0·1	—	—
Downy mildew (%)	0·1	0·1	1·7	1·0	1·0	2·6	—	—
				April 1964				
Downy mildew (%)	3·2	4·0	11·5	16·0	12·2	27·0	5·8	5·2
				June 1964				
Plants/yd	7·6	7·1	11·0	13·2	14·1	12·7	1·6	2·7
Virus yellows (%)	2·1	1·7	1·6	1·7	1·2	1·6	1·0	2·1
Downy mildew (%)	7·3	8·3	8·2	7·8	7·4	6·1	9·4	6·5
Yield of clean seed (cwt/acre (±0·78))	17·6	16·9	17·1	12·7	17·5	13·6	13·2	14·1
% weight of seed retained by								
$\frac{14}{64}$ in sieve (±0·69)	8·8	8·5	7·0	6·3	6·5	6·3	13·5	10·4
$\frac{11}{64}$ in sieve (±0·92)	42·5	42·0	40·5	42·1	40·5	42·5	44·9	43·0
$\frac{8}{64}$ in sieve (±1·24)	43·0	44·0	48·0	47·0	48·0	46·7	38·3	42·8
Thro' $\frac{8}{64}$ in (±0·71)	5·7	5·5	4·5	4·6	5·0	4·5	3·3	3·8
Germination (%)	72·0	73·0	67·5	63·5	69·5	66·5	65·5	70·0
Germination transformed (±1·72)	58·0	58·9	55·2	52·7	56·4	54·6	53·9	56·6

in maturity and seed ripened at different times in different positions on the same plant more markedly than on smaller, less branched, direct drilled plants.

Seed was cleaned on a 'Boby Bedford' machine fitted with $\frac{20}{64}$ in top screen and $\frac{7}{64}$ in bottom screen and then on an inclined moving-belt separator. Cluster size distribution was determined on a machine developed by Chas Sharpe and Co. installed at the B.S.C. Central Laboratory. Germination percentages were determined by the 'in sand' method for natural sugar beet seed used at the Official Seed Testing Station, Cambridge.

Results

More plants established from summer sowings, especially without a cover crop, than from spring sowings with a cover crop (Table 2). The 'Stanhay' drill sowed slightly more seed than the 'Bean' drill and differences in plant stand from spring and summer sowings were caused by the barley competing for moisture with the stecklings early in the year, when some stecklings died.

Summer-sown crops were infected with downy mildew soon after they emerged and 1–2% of plants infected in the autumn resulted in mildew being prevalent the following spring.

Pheasants and hares destroyed many of the transplanted plants during the winter and more of those sown in summer than in spring, possibly because stecklings undersown in barley in spring were small and less attractive food.

Yields of clean seed, all at 15% moisture (Table 2), were not affected by fertilizer applied to the seed bed but were greater from spring and July direct drillings than from transplants. August sowings, both under mustard and in the open, were much less vigorous than July sowings. Moreover, they were damaged by birds while they remained standing after other plots were cut.

As in the Dunholme experiments, more of the seed from transplanted plants was too large for processing than from direct drilling. Only in transplanted plots did time of treatment affect cluster size; the December transplanted plots, which had the thinnest stand of plants, gave a greater proportion of oversize seed than any other treatment, and the thinner stand from undersowing in barley produced a greater proportion of oversize seed than other direct drillings.

Table 2 shows laboratory germinations, i.e. percentage of clusters producing at least one healthy seedling. Seed from the early ripening plots undersown in barley germinated best and the late ripening seed from the August sowings and December transplanting germinated worst.

This experiment clearly showed the susceptibility of summer-sown crops to downy mildew and underlined the importance of not growing seed crops in this way in areas where root crops are grown. Two further experiments comparing methods of growing were started in 1965 and 1966 respectively in Bedfordshire where fewer root crops were grown. By this time promising monogerm varieties had been developed by many breeders and further experiments determined how methods of growing affected the yield and quality of their seed.

3. *Comparison of methods of growing monogerm varieties*, 1965–67.

Experiment 4 was in Wrest Park, Silsoe, Beds, by kind permission of the National Institute of Agricultural Engineering, and Exp. 5 was on a commercial farm near Great Gransden, Beds. An open-pollinated monogerm variety was unobtainable in England and seed of variety C.S. 36 for Exp. 4, and C.S. 42 for Exp. 5 was supplied by Dr F. H. Peto, British Columbia Sugar Refining Company, Vancouver, Canada.

Methods

Three methods of growing were compared at Wrest Park, (*a*) sowing under barley on 7 May with

Table 3. *The effect of methods of growing on crop and plant weight in August* 1966 *at Wrest Park*

	Direct drilled: Barley cover cut		Direct drilled: Without cover sown		Transplanted in	
	Early	Late	July	Aug.	Nov.	Dec.
Fresh wt of haulm (tons/acre, ± 1·13)	12·5	12·1	16·3	14·6	11·5	13·0
Fresh wt of roots (tons/acre, ± 0·20)	3·5	2·9	5·8	3·7	2·7	2·4
Leaf dry wt/plant (g, ± 0·70)	6·6	3·5	2·1	1·5	11·5	10·7
Stem dry wt/plant (g, ± 8·20)	65·4	34·3	21·6	13·5	117·7	121·6
Root dry wt/plant (g, ± 2·03)	26·6	12·6	10·5	5·2	42·3	24·6
Total dry wt/plant (g, ± 10·60)	98·6	50·4	34·2	20·2	171·5	156·9

the barley removed when 'binder-ripe' on 6 August or 'combine-ripe' on 26 August; (*b*) sowing without cover crop on 16 July or 12 August, and (*c*) transplanting on 11 November or 16 February from a steckling bed sown on 16 July. To test reports from Germany that large stecklings produced large monogerm fruits (the 'seed' of commerce) which are most suitable for precision drilling and give vigorous seedlings, an earlier open-sowing was included in the Great Gransden experiment. At Great Gransden early and late maturing barley varieties were sown on 29 April and removed on 8 or 25 August, open drillings were on 3 June, 18 July or 15 August, and transplanting on 28 October and 3 February from a steckling bed drilled on 18 July. Half the stecklings from the 3 June sowing were grown-on where sown and half transplanted on 2 November.

In both experiments main treatments were arranged in 4 randomized blocks of plots with 20 rows 45 ft long and subplots of 10 rows 45 ft long. All sugar beet seed was treated with an organo-mercury fungicide and 'Saphizon', and drilled in rows 20 in apart with a 'Stanhay' precision drill spacing the seed at $1\frac{1}{2}$ in. Two rows of barley were sown with a 'Nordsten' drill between the beet rows, on the same day as beet were sown at Great Gransden. At Wrest Park every third row of a spring barley crop was killed with paraquat and the sugar beet was sown in the spaces. Fertilizer in the first year was 0·5, 0·8, 0·8 at Silsoe and 0·5, 1·00, 1·00 at Great Gransden, cwt/acre of N, P_2O_5 and K_2O respectively, and in the second year 1·0, 1·0, 0·8 cwt/acre was applied at Silsoe and 1·5 cwt/acre N at Great Gransden.

After the barley was cut and carried from the plots, a small hand rotovator cultivated between the sugar-beet rows. Stecklings were lifted by hand, 'topped' and 'tailed' and transplanted 15 in, apart in rows 20 in. apart. Both experiments were hoed frequently during the first year and 4 lbs/acre pyrazon was applied over the experimental areas in the spring of the harvest year. This did not harm the sugar beet but stunted *Stellaria media*, which was always the most troublesome weed.

Much seed was lost during tripoding and threshing at Broom's Barn and trials in 1964 gave more accurate yields when plants were cut with a sickle, placed loosely in beet pulp sacks and blown overnight with unheated air on a platform drier, then allowed to mature in the sacks in an open barn. The method had obvious advantages for experiments at a distance from Broom's Barn. On three occasions (23, 31 August and 6 September 1963) 150 sq.ft was taken from the centre six rows of each plot at Silsoe. At Great Gransden 200 sq.ft was taken from the centre of the plot when individual treatments were ripe; plots undersown in barley on 22 August; those grown-on after June and July sowings on 24 August; those grown-on after August sowing and transplanted plots on 29 August.

Threshing was done with a stationary 'Allis Chalmer 60' combine modified for easy and efficient cleaning. Seed was cleaned and germination tested as in the Broom's Barn experiment.

Results

Drilling beet into a growing barley crop at Silsoe resulted in severe competition for water, because the barley developed much leaf. After the leaf died back, large cracks appeared between the barley rows and it seemed that few sugar-beet seedlings would survive. On the small plots weeds could be kept in check and the stand of undersown plants retained (Table 4), but this would not have been practical on a field scale. At Great Gransden a thicker, more regular plant stand developed under the barley crop than at Broom's Barn or Wrest Park, but was sparser from open summer drilling than in the earlier experiments. Hares damaged autumn transplants at Wrest Park and these plots had a thinner stand than those of spring transplants. More autumn transplants survived until harvest at Great Gransden, especially the large June-sown stecklings, but pigeons almost defoliated transplants during March and April; the early sown stecklings recovered soonest.

Downy mildew appeared first in the August open-drilled stecklings in both experiments, and the last sowings were always the worst affected. The Wrest Park experiment was sprayed with 'Maneb' every 2 weeks during autumn and spring, which restricted spread of the disease. Dressing seed with 'Saphizon' and frequent spraying with 'Metasystox' kept plants free from yellows during the first year, but some became infected during the second, especially where the plant stand was thin. The Great Gransden experiment was almost free from yellows, but downy mildew spread from a neighbouring experiment which was planted with infected stecklings from another bed; plants on all plots became infected (Table 4) and many died during the winter.

Both the monogerm varieties flowered early, characteristically of varieties tending to bolt as did those in N.I.A.B. root crop trials. At Wrest Park July-sown plants were in full flower by 4 July. August sowings were about 24 in shorter, looked nitrogen-deficient, reminiscent of the 'Docking disorder' condition in root crops, and flowered late. Plots sown under barley were intermediate, in height and flowering stage, between July and August open sowings. Table 3 shows the yields of the various parts of the plants at Wrest Park in August. Individual transplants were six times heavier than those in dense, open drillings but the

Table 4. *The effects of methods of growing on plant density, disease incidence, seed yield, size and germination at Wrest Park and Gt Gransden*

	Direct drilled							
	Barley cover, removed:		No cover, sown:		Transplanted		Sown in June	
	Early	Late	July	Aug.	Autumn	Spring	Direct drilled	Trans-planted
	Wrest Park 1965–6							
Plants/yd, 6 Apr.	6·7	5·6	15·5	22·2	1·6	2·2		
Downy mildew (%), 19 May	1·9	3·9	1·2	3·7	5·0	6·0		
Virus yellows (%), 7 July	5·2	1·5	1·0	2·3	3·2	10·5		
Yield of clean seed (cwt/acre, ±1·95)								
23 August	22·5	23·7	26·1	20·9	27·0	22·7		
31 August	14·3	17·4	19·0	19·1	17·9	18·4		
6 Sept.	12·0	12·4	16·4	13·7	20·6	17·7		
Mean (±1·77)	16·6	17·8	20·4	17·7	21·7	19·7		
No. clusters (thousands/lb)								
23 August	36·0	37·0	39·4	39·4	37·0	36·6		
31 August	33·9	32·2	34·1	38·8	31·5	35·2		
6 Sept.	29·8	31·1	30·6	34·6	32·1	31·7		
Mean (±0·32)	32·2	33·4	34·7	37·6	33·5	34·5		
Germination (%)								
23 August	52	45	57	55	43	50		
31 August	62	64	76	68	59	67		
6 Sept.	72	66	75	66	75	72		
Mean	62	58	69	63	59	63		
Mean transformed (±1·16)	51·9	49·6	56·2	52·5	50·2	52·5		
	Gt. Gransden 1966–67							
Plants/yd, 14 Apr.	10·8	11·2	10·7	8·9	2·3	3·0	10·9	2·8
Downy mildew (%), 25 May	6·0	4·0	6·1	10·3	18·1	8·9	3·1	5·6
Yield of clean seed (cwt/acre, ±1·57)	22·2	24·9	29·1	23·7	20·3	23·2	26·2	21·7
No. clusters (thousands/lb, ±1·9)	34·1	37·2	37·9	44·9	42·5	39·2	34·8	40·8
Germination (%)	66	66	63	58	56	63	78	63
Germination transformed (±2·51)	54·5	54·3	52·4	49·8	48·6	52·3	62·2	52·3

total plant material from open drillings was heavier. At both Silsoe and Great Gransden, many transplants lodged and were late and irregular to flower and mature. At Great Gransden plants open-drilled in June bolted and flowered earliest and were 7½ ft tall at harvest time, whereas July sown and undersown plants flowered slightly later and averaged 6 ft tall. As at Silsoe, August-sown plants were small and looked undernourished throughout the harvest year.

At Wrest Park birds stripped seed from all plots after the first harvest (Table 4). The tall, erect, more uniformly ripe, direct-drilled plots were more damaged than transplanted plots and more seed was lost. Autumn-transplanted plots had a fuller stand of plants than in any other experiment and their yields were as great as from July, open-drilled plots. At Great Gransden, however, autumn transplanted plots gave the least seed irrespective of steckling size. In both experiments open drilling in July gave the greatest yield of the direct-drilled treatments. At Great Gransden sowing in June gave no greater yields than sowing in July.

In Exps. 3–5 open drilling in July gave on average 4 cwt/acre more seed than open sowing one month later. Yields from undersowing in barley were little affected by removing the cover early or late, and were similar to those from August open sowing. Yields from transplanting, especially during autumn, varied most.

The first harvest at Silsoe gave more seeds/lb from open-direct-drilled treatments than from undersown or transplanted—a similar effect to that in Exp. 3. At Great Gransden the open-drilled plots again gave lighter seeds than undersown, but pigeon damage to transplants delayed maturity and prevented full development of seed. Seeds from the large, June-drilled transplants were no heavier than from small, July-drilled stecklings.

The germination percentages of seed from all plots at Silsoe increased between 23 and 31 August and at these early harvests July open-drilled plots, which ripened earliest, gave seed with the greatest percentage germination. There was no further increase in germination of seed from open-drilled plots after the second harvest, but the germination of late-ripening undersown and transplanted treatments continued to increase until the final harvest. The percentage of germinating seeds that gave only one seedling was greater where plant density was greater—80·1, 78·7, 76·5 from open-drilled, undersown, and transplanted plots respectively.

The germination percentage of seed from Great Gransden was also greatest from the earliest ripening plots, i.e. open-drilled in June. It was least from late-ripening, August-drilled plants and from autumn-transplanted, July-drilled, stecklings. The latest ripeners gave the lightest seeds, a large proportion of which gave only one seedling, 95·9 % and 96·0 %, compared with 88·9 % of the heavier clusters from undersowing. More clusters of variety C.S. 42 grown at Great Gransden gave only one seedling than of C.S. 36 grown at Silsoe.

DISCUSSION

The average total yield of seed from transplanted crops in these experiments was 2·3 cwt/acre (11 %) less than from direct-drilled crops. Because a greater proportion of the multigerm seed from transplants was too large for processing, an effect also reported by Coy (1966) and Sneddon (1963) and associated with the greater plant density in direct drillings, yields of useful seed were only 75 % of those from direct drilling. The plant density in transplanted crops is always much less (10–15 thousand/acre) than in direct-drilled crops (100–150 thousand/acre). In practice, plant stands differ widely in different crops grown by the same method. When the experiments were initiated there was little information about the effect of plant population on yield, and separate experiments with a multigerm variety at Broom's Barn in 1966, an open-pollinated monogerm at Great Gransden in 1966, and a mixture of monogerm male steriles and multigerm pollinators at Great Staughton, Beds., in 1967, compared the effects of transplanting in five spacings (Table 5).

At Broom's Barn 20 % of the plants were rogued out because they had downy mildew and final spacings were greater than the nominal ones. In the

Table 5. *The effect of plant spacing, in transplanted crops at (a) Broom's Barn, (b) Gt Gransden and (c) Gt Staughton*

Site		Spacing (in.) 10 × 10	15 × 15	15 × 20	20 × 20	30 × 30
	S.E. of mean	Seed yield (cwt/acre)				
(a)	±1·87	22·4	22·6	18·6	16·6	9·8
(b)	±1·31	23·1	25·7	27·2	21·6	18·5
(c)	±1·35	34·0	34·6	38·3	33·8	25·8
	Mean	26·5	27·6	28·0	24·0	18·0
		Number clusters (thousands/lb.)				
(a)	±1·25	25·0	21·6	22·7	22·0	28·9
(b)	±1·61	41·4	34·5	35·7	36·4	36·2
(c)	±1·90	53·4	54·7	51·4	47·6	51·4
	Mean	39·9	36·9	36·6	35·3	38·9
		Percentage germination				
(a)	Percentage	86	85	76	79	73
	Transformed (±1·82)	68·4	67·2	60·7	62·9	58·9
(b)	Percentage	77	74	74	73	70
	Transformed (±2·04)	61·3	59·6	59·6	58·9	56·5
(c)	Percentage	50	47	54	54	46
	Transformed (±1·10)	45·0	43·4	47·3	47·3	42·8
	Mean (%)	71	69	68	69	63

other experiments (Table 5) 20 × 15 in spacing, equivalent to the target in transplanted plots in the experiments comparing methods of growing, gave the greatest yield. Plants at wider spacings lodged, produced secondary growth that matured late, and gave smaller yields with poorer germination. Closer spacings ripened earlier, gave lighter seed with greater germination percentages, but yielded less on average. Thus, on this evidence, it seems unlikely that the yield of transplanted plots would have compared more favourably with direct drilled had a different spacing been selected. The aim of direct drilling was to establish a plant every 2 in of row, which is regarded as the optimum commercially (Coy, 1966). Recent experiments (Scott, R. K. unpublished data) have confirmed that in 20 in rows this spacing gives the maximum yield. Narrow rows and wider spacing (10 in × 6 in) will yield more but very few commercial crops are grown in this way.

With the exception of a few plots in Exp. 2, none of the transplants in the methods of growing experiments were topped—a common practice in some areas. To test the effect on yield, half of the plots with each spacing at Great Gransden (Table 5) were topped when 30 in tall. Topped plants were 6–9 in shorter, had more secondary branches but did not yield more seed. Bornscheuer (1959), Ellerton (1947) and Sneddon (1963) also report that topping at this stage has little effect on yield.

In Denmark direct drilling under a cover crop saves £14/acre in labour costs compared with transplanting (Jensen, 1963). Largely for this reason more of the sugar-beet seed crop in England has been direct grown in recent years (Byford & Hull, 1967). Some seed producers in this and other N.W. European countries persist with transplanting partly because the method uses less valuable mother seed (Scott, 1968). In these experiments transplanted stecklings produced from 1 lb of *élite* seed gave the same gross yield as seed crop areas direct drilled with 6·2 lb.

As the root grower uses less seed, even to the stage of drilling to a stand, good germination of seed becomes essential. Despite improved techniques of processing and grading seed, the seedsman needs raw seed that germinates well. Germination percentages increase greatly as the crop ripens (Scott, 1967) and cutting when seed is immature is probably the most frequent cause of poor germination (Scott, 1968). Ellerton (1947) and Sneddon (1963) report that crops that flower and ripen earlier give seed with better germination than late crops. In our experiments, direct drillings flowered and ripened consistently earlier than transplants and gave seed with a better germination in the laboratory and better field emergence. Differences in ripening time are most important in N.W. Europe in 'late' seasons when late crops may never mature properly. Monogerm varieties tend to mature late and some monogerm seed for use in N.W. Europe is now grown in S. Europe where crops ripen early (Scott, 1968). The reliable production of monogerm seed in N.W. Europe may depend on over-wintering of direct-drilled crops, which is possible only in maritime countries where the winters are mild. To do this there must be enough mother seed.

Our results confirm commercial experience (Coy, 1966), that establishing a predetermined plant population is more difficult when undersowing than open drilling, because competition from the cover crop can kill a proportion of the sugar beet plants, resulting in a thin, uneven plant stand in the seed crop, which matures irregularly and produces more oversize seed. Removing the cover at different times did not affect yield, seed size or germination percentage in any experiment. It is probably not economic to allow direct-drilled seed crops to occupy the land exclusively for two years (Coy, 1966). A cereal cover-crop gives a return in the first year, but open drilled seed crops may be sown after some early harvested crop such as early potatoes, peas for canning or a ploughed ley. These experiments underline the importance of sowing in July rather than August to get large yields with good germination, provided the crop can be kept free from disease.

We thank the Director of N.I.A.E. for permission to have the 1965–6 experiment at Wrest Park and Mr Maughan and Mr Chitty for much assistance with it; Mr H. Marr, Leycourt Farm, Great Gransden, Beds., for allowing us to make the 1966–7 experiment at his farm and for his help with it; Dr Peto, British Sugar Refining Co., Vancouver, for supplying seed; the British Sugar Corporation Central Laboratory for screening analysis and the Official Seed Testing Station for carrying out the germination tests. We also acknowledge the assistance of the field staffs at Dunholme and Broom's Barn.

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