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Effects of date of planting on plant emergence, leaf growth, and yield in contrasting potato varieties

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SUMMARY

Five experiments which studied the effects of a wide range of dates of planting on contrasting potato varieties in Pembrokeshire are reported. In three experiments (1975–7) four early varieties (Home Guard, Arran Comet, Irish Peace and Ulster Sceptre) were sprouted from the end of dormancy and compared at four dates of planting, which began as soon as soil conditions allowed (February in 1975 and 1976 and March in 1977). In these experiments all early-emerging treatments were damaged by frost and in 1975 and 1976 date of planting had little effect on leaf area index or yield. In 1977 planting in late April delayed and increased peak leaf area index but reduced yields throughout harvesting. In all experiments the emergence of varieties was affected by date of planting. The varieties with the longest sprouts emerged first only from the earliest plantings; at late plantings all varieties emerged together, which suggests that rate of post-planting sprout elongation decreased in this old seed as planting was delayed despite increasing soil temperatures. The implications for testing of early varieties are discussed.

In two further experiments two early varieties (Home Guard in both years and Red Craigs Royal and Arran Comet in 1 year) were compared with three maincrop varieties (Désirée, Maris Piper, Stormont Enterprise) using seed which did not begin to sprout until January at dates of planting beginning in March. Sprout length was again poorly related to earliness of emergence. Delaying planting delayed and increased peak leaf area index in all varieties but only increased yields in the early varieties which had the smallest leaf areas. In maincrop varieties date of planting had little effect on final yields. In these years there were long periods without rain and in 1976 yields were limited by the amount of water available from the soil, for as each treatment exhausted this supply bulking ceased.

INTRODUCTION

Published results suggest that delaying planting of maincrop potatoes up to early April has little effect on final yield but further delays progressively reduce yield (Bremner & Radley, 1966). Ministry of Agriculture, Fisheries and Food (Agricultural Development and Advisory Service Short-term leaflet No. 182) calculations suggest that after 13 April yield decreases at a rate of 1·75 t/ha/week, which agrees with the rate calculated earlier by Dyke (1956). Although most growers aim to begin planting before the end of March, they rarely complete their plantings by 13 April and consequently the effects of delayed planting are important to most maincrop producers. In some areas of the U.K. considerable areas are planted in May. Bremner & Radley (1966) and Allen (1977) have shown that varieties differ in their response to delay in planting and the latter also found effects of physiological age of seed (O'Brien & Allen, 1981). In early varieties (Ulster Chieftain and Home Guard) delay in planting has been shown to increase peak leaf area and final tuber yield. In Home Guard, Allen (1977) found this effect only in young seed. Such effects are of considerable importance in early production areas such as Pembrokeshire, where crops are harvested from late May until July at yields from 10 to 50 t/ha. In this area, Allen (1977) reported effects of date of planting beginning in mid-March, which is somewhat

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later than the beginning of planting in most seasons. Planting in early February exposes plants to much lower soil and air temperatures and shorter daylengths than planting in mid-March and also increases the likelihood of frost affecting emerged plants. There is no published information on the effects of frost damage on the yield of early crops.

This paper presents the results of five experiments carried out over three seasons, which extended the work of Allen (1977) by commencing planting of four early varieties as early as possible and comparing younger seed of early varieties with maincrop varieties at a range of planting dates from March to May.

In two of the three seasons a prolonged period without rain occurred. As the treatments produced a wide range of leaf growth patterns some analysis of the water use of the different crops was possible, although no direct measurements were made.

THE EXPERIMENTS

General methods

The experiments were carried out from 1975 to 1977 at the University College of Wales' Field Station, Trefloyne, near Tenby on Old Red Sandstone soils of the Pembroke or Milford series (Soil Survey Record, 1974, No. 24). Owing to variation in soil depth, however, there were important differences between the experimental sites. In 1975 (Expt 1) considerable amounts of stone occurred only 30–40 cm down the soil profile and the workable soil depth was 10–20 cm less than in subsequent years. Experiments 1–3 used seed multiplied in mid-Wales which was allowed to sprout soon after harvesting and produced well developed sprouts by the first planting. The other two experiments (Expts 4 and 5) used imported Scottish seed which produced limited sprout growth by the first planting.

All the experiments followed spring barley and with the exception of Expt 4, for which the land was ploughed in early February, the stubbles were ploughed in September or October. The land for most experiments was prepared by the combined use of spring-tine harrows and power-driven rotary harrows and ridged just prior to planting. However, as the autumn of 1975 was exceptionally dry it was possible after two passes with spring-tine harrows to draw ridges for Expt 2 in early November and no further cultivations were necessary before the first planting. To try to achieve a similar tilth for each planting date, all ridges were drawn at the same time and some, especially in Expt 2, were open for a long time before closing. Ridges were drawn with 3-row rear-mounted bodies and closed with a similar front-mounted implement. Row width was 66 cm in Expts 1 and 4 (1975) and 71 cm in all other experiments. Fertilizer was applied by hand over open ridges just prior to planting. Sprout growth during storage was recorded on ten randomly selected, numbered tubers of each seed size from each treatment. Within 10 days of planting, the experiments were sprayed with a trietazine-linuron residual herbicide. Observations of all experiments at 4–7 day intervals from soon after planting recorded the general pattern of emergence. The progeny tubers from Expts 4 and 5 were to be kept for seed and these two experiments were sprayed at intervals with a fungicide–aphicide mixture. Initial applications were with mancozeb with a change to tin-based chemicals by the end of June. The aphicide was dimethoate throughout. Growth analysis techniques were essentially the same as those described by Allen (1977).

Table 1. *Varieties and dates of planting Expts* 1–3

(Varieties: Home Guard, Arran Comet, Irish Peace, Ulster Sceptre.)

Expt 1 1975	Expt 2 1976	Expt 3 1977
11. ii	5. ii	9. iii
25. ii	18. ii	23. iii
11. iii	3. iii	6. iv
25. iii	17. iii	27. iv

Experiments 1–3, 1975–7

Treatments in each experiment were all combinations of the four early varieties and four dates of planting shown in Table 1, arranged in three randomized blocks. Plots were three rows wide and 11 m long. Samples for growth analysis and yield estimates were taken from the centre row of each plot, the outer two rows acting as interplot guard rows. All the seed was produced at Rhayader (270 m above sea level) from Scottish or Irish stocks, planted, 'burnt off', harvested and boxed at the times shown in Table 2. Following grading, the seed used in Expt 1 was stored in an unheated glasshouse at Trefloyne until planting. In Expts 2 and 3 the seed was stored in an unheated glasshouse at Aberystwyth until it was transported to Tre-

Table 2. *Dates of planting, 'burning off' and harvesting of the seed crop grown at Rhayader for Expts* 1–3

	Expt 1 1975	Expt 2 1976	Expt 3 1977
Planting	9. iv	9. v	12. iv
'Burning off'	24. vii	1. viii	23. vii
Harvesting and boxing	Mid-Sept.	20. viii	Early Sept.

Table 3. *Seed weights (g) and fertilizer dressings Expts* 1–3

		Expt 1 1975	Expt 2 1976	Expt 3 1977
Seed weight		45–60	40–50	40–50
		60–80	50–60	50–60
		80–110	60–75	60–75
Fertilizer dressing	N	160	151	151
(kg/ha)	P	70	66	66
	K	185	159	159

Table 4. *Dates of full growth analyses, foliage analyses and yield estimates in Expts* 1–5

Experiment	Full growth analysis	Foliage analysis	Yield estimate
1 (1975)	30. iv	28. v	21. v
	14. v	11. vi	28. v
	21. v	25. vi	11. vi
		9. vii	9. vii
2 (1976)	26. iv	25. v	25. v
	7. v	14. vi	14. vi
	20. v	12. vii	12. vii
	24. vi		
3 (1977)	4. v	13. vi	13. vi
	17. v	28. vi	28. vi
	31. v	12. vii	12. vii
			8. viii
4 (1975)	9. v	20. vi	6. vi
	23. v	18. vii	20. vi
	6. vi		18. vii
	4. vii		20. ix
	31. vii		
	22. viii		
	4. ix		
5 (1976)	4. v	7. vi	7. vi
	17. v	22. vi	22. vi
	7. vi	15. vii	15. vii
	3. viii	17. viii	7. ix
			(19. ix)

Table 5. *Varieties and dates of planting Expts* 4 *and* 5

Varieties: Early; Home Guard, Red Craigs Royal (Expt 4 only), Arran Comet (Expt 5 only). Maincrop; Désirée, Stormont Enterprise, Maris Piper.

Expt 4 1975	Expt 5 1976
19. iii	10. iii
9. iv	30. iii
2. v	21. iv

floyne a few days before each planting. Seed of the different grades shown in Table 3 was used for the three replicates of each experiment and spaced 23 cm apart in the row. The fertilizer dressings are also presented in Table 3.

Two adjacent plants per plot were removed for full growth analysis, or just the foliage for determination of leaf area (L), on the dates shown in Table 4. This Table also shows the dates of yield estimates in the three experiments from a 1·8 m length of row (eight plants). For the final yield estimate of Expt 1 only, a 2·3 m length (ten plants) of row was taken.

Experiments 4 *and* 5, 1975–6

Treatments in each experiment were all combinations of the five contrasting varieties and three dates of planting shown in Table 5, arranged in two randomized blocks. Plots were 7·3 m long and four rows wide. Samples for growth analysis and yield estimates were taken from the two centre rows. The seed was Scottish F.S. or A.A. grade, delivered to Aberystwyth and boxed in early January of each year. It was then stored in an unheated glasshouse before being transferred to Trefloyne a few days before planting. Seed weighing 45–55 and 55–70 g was used for the two replicates and spaced 30·5 cm apart in the row. Fertilizer dressing of 160 kg N, 70 kg P and 185 kg K and 170 kg N, 103 kg P and 196 kg K/ha were applied to Expts 4 and 5 respectively. Dates of full growth analyses, foliage analyses and yield estimates, from a 2·44 m length of row (eight plants) are shown in Table 4. In Expt 5 the final yield estimate of all plantings of Home Guard, Arran Comet, Désirée and Maris Piper and the first planting of Stormont Enterprise was taken on 7 September while those of the second and third plantings of Stormont Enterprise were taken on 19 September.

Weather

Weather data were recorded at Trefloyne during the three experimental years, but because no staff were permanently based at the site, there were omissions. Wherever this occurred, however, data from Orielton Field Study Centre, near Pembroke, were used. The maximum and minimum temperatures for the experimental period are shown in Table 6 and the rainfall in Fig. 1. Relatively dry weather in late January in 1975 and 1976 allowed the first plantings of Expts 1 and 2 to take place in good conditions early in the season. However, in 1977 persistent wet conditions prevented planting before mid-March and soil conditions remained poorer than in previous years throughout planting. In 1975 there was a long period of low temperatures from mid-March to mid-April and the first planting of Expt 4 was planted when soil temperatures were

Table 6. *Mean weekly air temperatures (°C) at Trefloyne* (1975–7)

1975		Max.	Min.
February	11–17	8·7	4·2
	18–24	7·5	3·4
March	25–3	9·0	4·3
	4–10	11·6	4·1
	11–17	7·9	2·5
	18–24	6·9	1·0
	25–31	7·7	0·6
April	1–7	10·2	−3·1
	8–14	10·9	0·5
	15–21	12·6	6·6
	22–28	13·9	8·1
May	29–5	12·0	5·3
	6–12	13·1	5·6
	13–19	13·8	4·5
	20–26	19·6	5·1
June	27–2	17·1	4·4
	3–9	16·7	6·7
	10–16	24·8	9·1
	17–23	16·9	7·7
	24–30	22·7	10·2
July	1–7	23·1	6·9
	8–14	20·7	14·3
	15–21	19·0	13·4
	22–28	(19·9)	14·3
August	29–4	(24·6)	12·1
	5–11	(18·0)	14·9
	12–18	(19·1)	11·4
	19–25	(18·6)	8·9
September	26–1	(21·7)	10·0
	2–8	(19·4)	7·8
	9–15	(16·0)	7·4

1976		Max.	Min.
February	5–11	(8·0)	(1·9)
	12–18	(6·1)	(1·4)
	19–25	(9·5)	(4·3)
March	26–3	(9·2)	(3·7)
	4–10	(6·5)	(1·2)
	11–17	(8·8)	(2·2)
	18–24	11·5	1·3
	25–31	11·3	6·3
April	1–7	11·7	4·4
	8–14	12·0	3·2
	15–21	12·3	3·9
	22–28	13·6	1·3
May	29–5	11·6	3·6
	6–12	15·4	5·9
	13–19	12·9	7·2
	20–26	14·5	6·2
June	27–2	15·1	5·6
	3–9	17·9	9·1
	10–16	17·0	10·4
	17–23	18·6	10·0
	24–30	26·0	12·8
July	1–7	27·7	12·7
	8–14	22·1	13·0
	15–21	19·8	10·8
	22–28	20·7	8·2
August	29–4	19·9	7·3
	5–11	23·7	7·7
	12–18	25·0	8·9
	19–25	24·8	12·0
September	26–1	23·7	10·4
	2–8	18·1	9·0
	9–15	(13·9)	(9·0)
	16–22	(16·3)	(9·9)

1977		Max.	Min.
March	9–15	10·3	5·4
	16–22	11·0	5·4
	23–29	9·0	2·9
April	30–5	8·3	1·1
	6–12	9·9	−0·3
	13–19	11·4	3·0
	20–26	10·9	6·7
May	27–3	12·0	3·4
	4–10	12·1	2·9
	11–17	13·8	4·9
	18–24	19·5	5·9
	25–31	20·0	9·1
June	1–7	19·3	5·1
	8–14	14·8	4·9
	15–21	15·4	9·0
	22–28	18·5	6·9
July	29–5	19·6	9·9
	6–12	24·2	12·4
	13–19	19·1	8·4
	20–26	19·8	9·8
August	27–2	19·2	7·8
	3–9	20·0	8·8

Values in parentheses are from Orielton Field Study Centre, Pembroke.

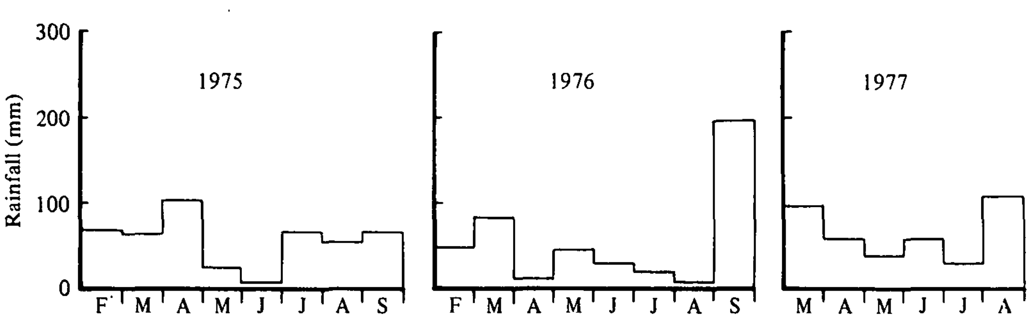

Fig. 1. Monthly rainfall at Trefloyne (1975–7).

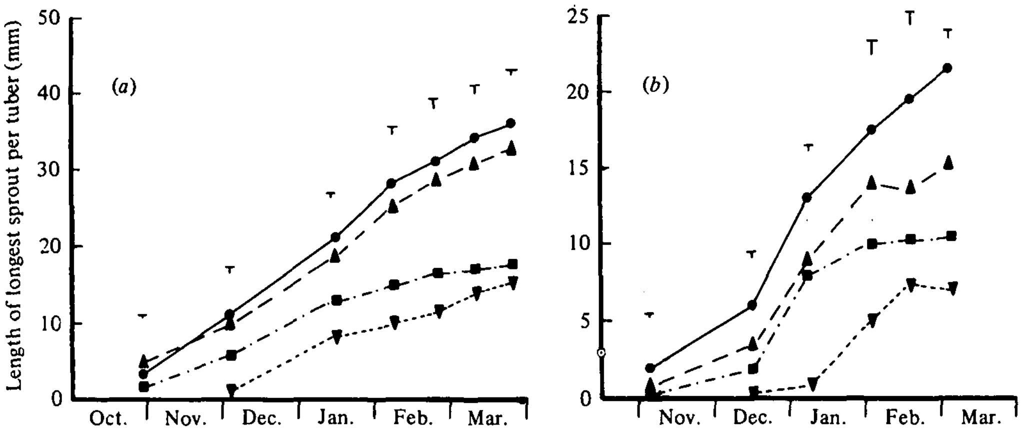

Fig. 2. Effect of variety on length of longest sprout per tuber. (*a*) Expt 1, 1975. (*b*) Expt 2, 1976. ●——●, Home Guard; ▲———▲, Arran Comet; ■—·—■, Irish Peace; ▼·····▼, Ulster Sceptre. T S.E.

low. By the middle of June in 1975 most of the plants in all treatments of Expt 1 and a few plots in Expt 4 were obviously suffering water stress, for they were wilted for much of the day. Heavy rainfall in July revived most of Expt 4, but the whole of Expt 1 had senesced too much. The remainder of the growing season was well supplied with rainfall and as a consequence most of Expt 4 continued bulking until mid-September. In 1976, following a dry April, good growing conditions throughout May and June resulted in large plants and ensured that tuber bulking was not restricted. Nonetheless, from early July to early September there was very little rainfall and plants in all treatments in both experiments eventually wilted. The spring of 1977 was exceptionally wet. There was a short period of dry weather in late May and early June, but for most of the season adequate rainfall permitted uninterrupted growth.

RESULTS

The results of these experiments have been fully reported in a thesis (Jones, 1981) and only the more important findings are discussed in this paper. Since there were some significant interactions between varieties and date of planting the results for each variety are generally presented in full.

Sprout growth and emergence

The four varieties in Expts 1–3 differed considerably in the time at which they 'broke dormancy' (mean length of longest sprout > 3 mm) and in their subsequent sprout growth. Home Guard generally had the longest sprouts, while Arran Comet, Irish Peace and Ulster Sceptre had progressively shorter sprouts (Fig. 2). The sprout length per tuber at planting was less in Expt 2 than in Expts 1 and 3.

These varietal differences in sprout length influenced the time of emergence and early crop growth when planting occurred in February; varieties with the longest sprouts were the first to emerge (Table 7). From later plantings in March and April, although there were still large differences in sprout length, all varieties emerged at approximately the same time. This simultaneous emergence of all varieties suggests that at higher post-planting temperatures (Table 8) the short sprouts of Ulster Sceptre elongated much faster than the longer sprouts of the other varieties. Assuming that all the seed tubers remained in a vertical position after the rows were closed and taking the mean distance from the top of the tuber to the surface of the ridge as 100 mm, the mean daily rate of sprout elongation was estimated. Table 9 shows that the rate of sprout elongation generally increased with delay in planting, but the increase was greater in Irish Peace and especially Ulster Sceptre, than in Home Guard and Arran Comet. In Home Guard, in Expt 1, high temperatures following the first planting, as well as the longer sprouts, were clearly responsible for its early emergence. The sprouts of the other varieties may have elongated but they did not emerge and the lower temperatures after 18 March further delayed their emergence. In Expt 3, where the sprouts of Home Guard were very long the response in the rate of sprout elongation to a rise in temperature was very small (Table 9).

Similarly in Expts 4 and 5 sprout length at

Table 7. *Interpolated dates of* 50 % *plant emergence and in parentheses the number of days from planting* (*Expts* 1–3)

Expt 1 (1975)

Date of planting	11. ii	25. ii	11. iii	25. iii	Mean
Home Guard	18. iii	10. iv	18. iv	25. iv	
	(35)	(45)	(38)	(31)	(37)
Arran Comet	1. iv	12. iv	20. iv	25. iv	
	(49)	(46)	(40)	(31)	(42)
Irish Peace	9. iv	13. iv	23. iv	28. iv	
	(57)	(47)	(43)	(34)	(45)
Ulster Sceptre	16. iv	19. iv	26. iv	25. iv	
	(64)	(53)	(46)	(31)	(49)
S.E.		(2·4)			(1·2)
Mean	(51)	(48)	(42)	(32)	
S.E.		(1·2)			

Expt 2 (1976)

Date of planting	5. ii	18. ii	3. iii	17. iii	Mean
Home Guard	29. iii	29. iii	9. iv	20. iv	
	(53)	(40)	(37)	(34)	(41)
Arran Comet	4. iv	7. iv	13. iv	20. iv	
	(60)	(49)	(41)	(34)	(46)
Irish Peace	1. iv	10. iv	17. iv	21. iv	
	(56)	(52)	(45)	(35)	(47)
Ulster Sceptre	11. iv	14. iv	21. iv	25. iv	
	(67)	(56)	(49)	(39)	(53)
S.E.		(1·5)			(0·8)
Mean	(59)	(49)	(43)	(36)	
S.E.		(0·8)			

Expt 3 (1977)

Date of planting	9. iii	23. iii	6. iv	27. iv	Mean
Home Guard	19. iv	27. iv	6. v	19. v	
	(41)	(35)	(30)	(22)	(32)
Arran Comet	19. iv	26. iv	5. v	18. v	
	(41)	(34)	(29)	(21)	(32)
Irish Peace	15. iv	24. iv	7. v	19. v	
	(37)	(32)	(31)	(22)	(31)
Ulster Sceptre	18. iv	25. iv	5. v	19. v	
	(40)	(33)	(29)	(22)	(31)
S.E.		(1·4)			(0·7)
Mean	(40)	(34)	(30)	(21)	
S.E.		(0·7)			

planting gave little indication of the order in which varieties emerged, for the response in the rate of sprout elongation to increasing temperature was far greater in the short-sprouted maincrop varieties than in the early varieties (Table 10). The data also showed that at the higher temperatures following the final plantings, there was a reduction in the rate of elongation of the relatively long sprouts of the early varieties. This resulted in an increase in the interval between planting and emergence of the early varieties as the effect more than compensated for the increased sprout length of these varieties (Table 11).

Frost damage

Frost damage occurred in the earliest plantings of Expts 1–3, even in 1977 when planting did not begin until March. Owing to its earlier emergence, Home Guard was most severely affected, while slower emerging Ulster Sceptre suffered relatively little injury. Damage to newly emerged main stems resulted in a proliferation of secondary stems and the damaged treatments always had the highest stem densities (Fig. 3). Frost damage, however, did not generally result in an increase in the total number of tubers. The damaged plants recovered

Table 8. *Mean daily air temperature (°C) from planting to* 50 % *plant emergence (Expts* 1–3)

	Expt 1 (1975)			
Date of planting	11. ii	25. ii	11. iii	25. iii
Home Guard	6·3	5·1	5·0	6·3
Arran Comet	5·5	5·3	5·4	6·3
Irish Peace	5·4	5·3	5·5	6·7
Ulster Sceptre	5·5	5·6	5·9	6·3
	Expt 2 (1976)			
Date of planting	5. ii	18. ii	3. iii	17. iii
Home Guard	5·7	6·0	6·4	7·6
Arran Comet	5·7	6·4	6·5	7·6
Irish Peace	5·9	6·4	6·2	7·6
Ulster Sceptre	6·1	6·6	6·9	7·6
	Expt 3 (1977)			
Date of planting	9. iii	23. iii	6. iv	27. iv
All varieties	6·4	6·2	7·2	8·4

Table 9. *Estimated rate of post-planting sprout elongation (mm/day) (Expts* 1–3)

	Expt 1 (1975)			
Date of planting	11. ii	25. ii	11. iii	25. iii
Home Guard	2·1	1·5	1·7	2·1
Arran Comet	1·5	1·5	1·7	2·2
Irish Peace	1·4	1·8	1·9	2·4
Ulster Sceptre	1·4	1·7	1·9	2·7
	Expt 2 (1976)			
Date of planting	5. ii	18. ii	3. iii	17. iii
Home Guard	1·7	2·3	2·4	2·6
Arran Comet	1·6	2·0	2·3	2·7
Irish Peace	1·8	1·9	2·2	2·8
Ulster Sceptre	1·6	1·8	2·1	2·7
	Expt 3 (1977)			
Date of planting	9. iii	23. iii	6. iv	27. iv
Home Guard	1·6	1·8	1·8	2·0
Arran Comet	2·1	2·3	2·6	3·0
Irish Peace	2·5	2·7	2·7	3·7
Ulster Sceptre	2·4	2·9	3·1	3·9

quickly and throughout the season their L values were generally similar to the next undamaged planting. Although the plants which escaped frost damage established in the same environment in which frost-damaged plants were recovering it was surprising that their subsequent L values should have been so similar (in view of the large differences in their stem densities). Consequently there were no differences in yield between damaged and undamaged plantings. The inference to be drawn from these experiments, in which the comparison was between frost-damaged and not-emerged crops

Table 10. *Estimated rate of post-planting sprout elongation (mm/day) (Expts* 4 *and* 5)

	Expt 4 (1975)		
Date of planting	19. iii	9. iv	2. v
Home Guard	2·2	2·7	2·5
Red Craigs Royal	2·0	2·9	2·4
Désirée	2·3	3·8	6·4
Stormont Enterprise	2·2	3·6	6·1
Maris Piper	2·4	3·6	6·5
	Expt 5 (1976)		
Date of planting	10. iii	30. iii	21. iv
Home Guard	2·4	3·9	2·6
Arran Comet	2·4	3·4	2·9
Désirée	2·9	3·3	3·8
Stormont Enterprise	2·3	3·1	4·0
Maris Piper	3·0	3·4	3·6

Table 11. *Number of days from planting to interpolated dates of* 50 % *plant emergence (Expt* 5)

Date of planting (1976)	10. iii	30. iii	21. iv	Mean
Home Guard	37	20	27	28
Arran Comet	34	23	25	27
Désirée	34	29	25	29
Stormont Enterprise	47	33	25	35
Maris Piper	33	29	27	30
S.E.		2·8		1·2
Mean	37	27	26	
S.E.		0·9		

rather than frost-damaged and not frost-damaged, is that the effect of frost damage is small. No treatments suffered frost damage in Expts 4 and 5 and date of planting had little effect on stem density.

Leaf growth

In the majority of experiments delaying planting increased the size but delayed the attainment of peak L (Figs 4, 5 and 6). However, there were important exceptions, with large differences in the sizes of the leaf surfaces and the magnitude of the effects. In Expts 1–3, the effect was relatively small although peak L values ranged from only 2 in 1975 up to 4 in 1976 for all varieties. In Expt 4, the early plantings of the two early varieties and Désirée produced leaf areas little larger than those found in Expt 1. However, delaying planting to 2 May increased peak leaf areas in these varieties; in the earlies the peak leaf area was still less than 3 while in Désirée it was greater than 4. In Maris Piper and Stormont Enterprise the leaf growth patterns were of particular interest for in both there were

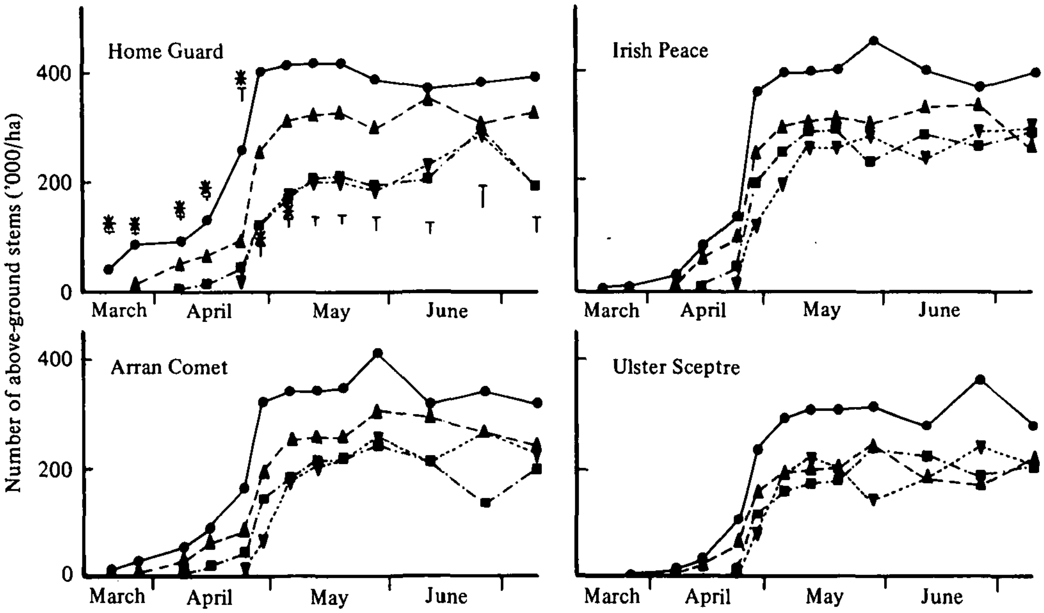

Fig. 3. Effect of date of planting on number of above-ground stems in four varieties. Expt 1, 1975. ●——●, 11. ii; ▲———▲, 25. ii; ■—·—■, 11. iii; ▼-----▼, 25. iii; T s.e. for comparison of any two points within one date of sampling and * denotes a significant interaction ($P = 0{\cdot}05$) on a particular date.

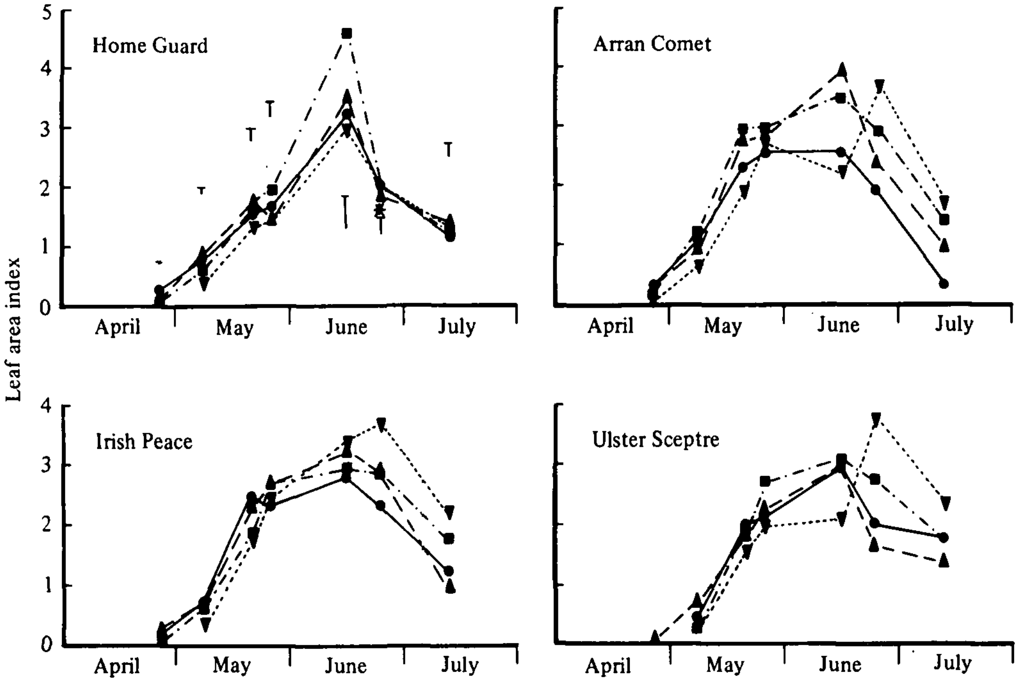

Fig. 4. Effect of date of planting on leaf area index in four varieties. Expt 2, 1976. ●——●, 5. ii; ▲———▲, 18. ii; ■—·—■, 3. iii; ▼-----▼, 17. iii; T s.e. for comparison of any two points within one date of sampling and * denotes a significant interaction ($P = 0{\cdot}05$) on a particular date.

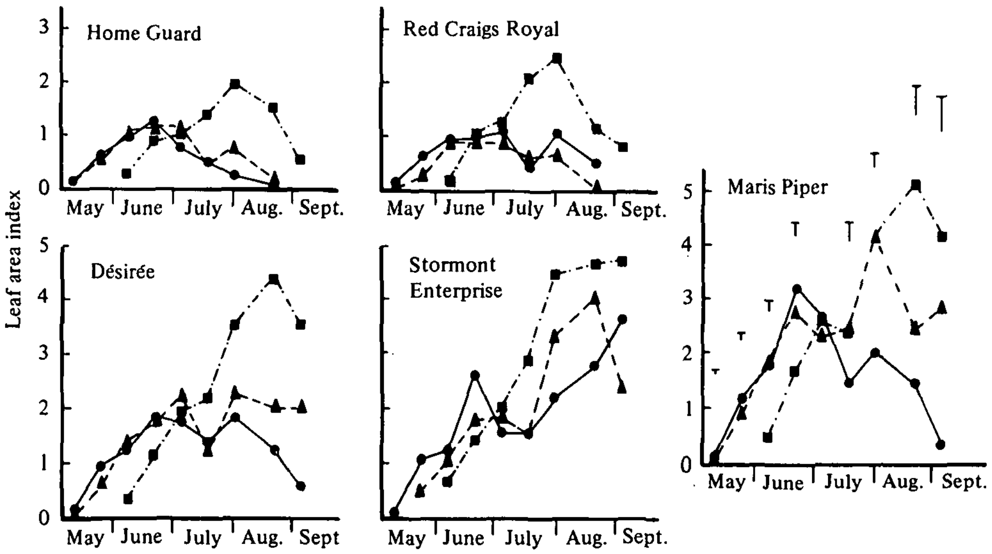

Fig. 5. Effect of date of planting on leaf area index in five varieties. Expt 4, 1975. ●——●, 19. iii; ▲– – – –▲, 9. iv; ■—·—■, 2. v; T S.E. for comparison of any two points within one date of sampling.

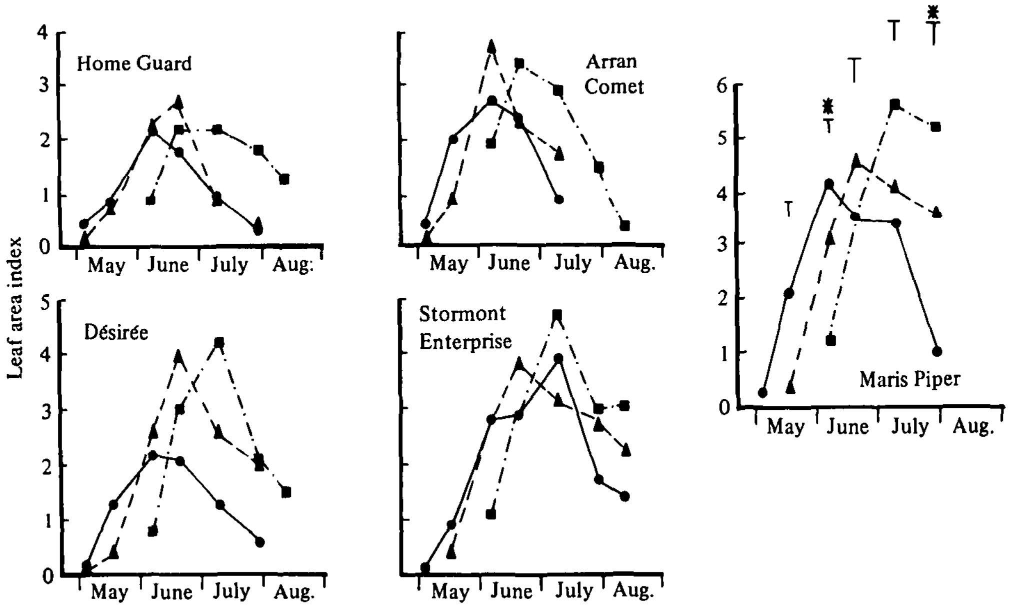

Fig. 6. Effect of date of planting on leaf area index in five varieties. Expt 5, 1976. ●——●, 10. iii; ▲– – – –▲, 30. iii; ■—·—■ 21. iv; T S.E. for comparison of any two points within one date of sampling and * denotes a significant interaction ($P = 0{\cdot}05$) on a particular date.

Table 12. *Mean daily air temperature (°C) from 1 week before 50% plant emergence to 1 week before peak L and in parentheses peak L (Expts 4 and 5)*

Expt 4 (1975)

Date of planting	19. iii	9. iv	2. v
Home Guard	10·2 (1·27)	11·6 (1·20)	13·7 (1·99)
Red Craigs Royal	11·5 (1·16)	10·8 (1·01)	14·2 (2·47)
Désirée	10·8 (1·86)	11·7 (2·25)	14·4 (4·41)
Stormont Enterprise*	(a) 10·8 (b) 13·9 (2·63) (3·72)	13·8 (4·12)	14·4 (4·75)
Maris Piper	10·8 (3·29)	13·1 (4·24)	14·4 (5·23)

* (Stormont Enterprise (*a*) 1st peak L 20. iv, (*b*) 2nd peak L 4. ix.)

Expt 5 (1976)

Date of planting	10. iii	30. iii	21. iv
Home Guard	9·0 (2·19)	10·0 (2·70)	11·4 (2·18)
Arran Comet	9·0 (2·69)	9·2 (3·72)	11·9 (3·40)
Désirée	9·0 (2·20)	10·3 (4·01)	13·8 (4·15)
Stormont Enterprise	12·4 (3·89)	10·5 (3·79)	13·8 (4·67)
Maris Piper	8·9 (4·21)	10·3 (4·61)	13·9 (5·63)

decreases in leaf area in June and July which were arrested and followed by a renewed increase in leaf area in August and early September. Peak leaf areas increased with delay in sowing, but in Stormont Enterprise, when the regrowth was considered, the attainment of peak L was earlier the later the planting. In Expt 5, the first delay in planting increased peak L in four varieties (not Stormont Enterprise where there was little effect) but the effect was much greater in Désirée than in the other three varieties. A further delay in planting delayed, but had little effect on the size of peak L in Home Guard, Arran Comet and Désirée. In Stormont Enterprise a small increase in peak L occurred and in Maris Piper a much larger increase.

The results, therefore, show a considerable range of effects of date of planting which were clearly dependent on season and variety. The most obvious differences between season and dates of planting are in the soil and air temperatures experienced during the first few weeks after planting. This may be expected to affect numbers and sizes of individual leaves and hence L, as found in sugar beet (Scott *et al.* 1973; Milford & Riley, 1980).

Table 12 shows that with the exception of the final plantings of the early varieties and Désirée in

Table 13. *Mean number of living leaves per plant at peak L (Expt 4)*

Date of planting (1975)	19. iii	9. iv	2. v
Home Guard	21·0	25·0	39·3
Red Craigs Royal	27·0	28·0	52·5
Désirée	51·2	75·8	120·3
Stormont Enterprise	46·8	93·5	101·8
Maris Piper	64·5	130·3	133·5

Table 14. *Mean effect of variety on total tuber yield (t/ha) (Expts 1–3)*

Harvest date	Variety: Home Guard	Arran Comet	Irish Peace	Ulster Sceptre	S.E.
Expt 1 (1975)					
21. v	4·1	6·1	4·1	3·6	0·41
28. v	9·1	11·3	10·7	8·4	0·57
11. vi	16·2	18·3	18·1	17·6	0·87
9. vii	18·8	24·3	23·3	26·4	0·92
Expt 2 (1976)					
25. v	9·9	11·5	8·9	7·3	0·38
14. vi	25·0	29·8	27·9	28·1	1·18
12. vii	34·7	41·6	37·2	40·7	1·32
Expt 3 (1977)					
13. vi	10·4	12·2	11·6	13·5	0·59
28. vi	18·4	23·7	22·6	25·5	1·34
12. vii	24·8	30·9	30·0	31·5	1·35
8. viii	27·3	36·7	31·1	37·5	1·42

Expt 5, peak L was closely related to the mean daily air temperature from 1 week before emergence to 1 week before peak L occurred. In Stormont Enterprise in Expt 4 there was a close relationship, irrespective of whether the initial or second peak L was adopted. It should be noted that although temperatures generally rose with delayed planting, this was not necessarily so and where the mean temperature was lower there was a reduction in peak L (e.g. Red Craig's Royal in Expt 4, Stormont Enterprise in Expt 5). The poor relationships between peak L and temperature in the early varieties and Désirée in Expt 5 were probably due to large soil moisture deficits developing in the later plantings while the leaf area was still expanding.

In general the slopes of the relationships were slightly steeper in the maincrops than in the early varieties, which may be attributable to the former having more stems per plant. There was, however, little agreement between the relationships in different seasons for any variety, the rate of increase in L was always lower in the drier spring

Table 15. *Mean effect of date of planting on total tuber yield (t/ha) (Expts 1–3)*

Harvest date	Date of planting (Expt 1, 1975)				S.E.
	11. ii	25. ii	11. iii	25. iii	
21. v	6·3	5·9	2·9	2·8	0·41
28. v	11·2	10·5	10·1	7·7	0·57
11. vi	16·8	19·5	17·9	16·0	0·87
9. vii	22·3	23·1	23·2	24·3	0·92
	Date of planting (Expt 2, 1976)				
	5. ii	18. ii	3. iii	17. iii	
25. v	11·1	11·1	9·8	5·8	0·38
14. vi	27·3	29·4	28·8	25·3	1·18
12. vii	38·2	38·2	39·6	38·2	1·32
	Date of planting (Expt 3, 1977)				
	9. iii	23. iii	6. iv	27. iv	
13. vi	16·9	15·7	11·6	3·3	0·59
28. vi	25·8	24·3	22·8	17·2	1·34
12. vii	30·8	31·7	29·1	23·7	1·35
8. viii	33·5	35·9	32·3	31·0	1·42

of 1975. In these experiments delayed planting increased the specific leaf area (cm^2/g), agreeing with the findings for sugar beet (Scott *et al.* 1973) and potatoes (Allen & Scott, 1980). However, this can only partly explain the effect of date of planting on peak L, for delayed planting also increased leaf dry weight per plant. Measurements of individual leaf size were not made, but part of the effect of delayed planting in Expt 4 was due to an increase in the number of living leaves per plant at peak L (Table 13). Delay in planting had little effect on the number of stems per plant in this experiment and the increase in the number of leaves was probably due to an increase in lateral branching.

Tuber yield

In Expts 1–3, Arran Comet, on average, generally produced the largest early yields (Table 14) and as it had the least tubers it always had the highest saleable yield. Home Guard also had large saleable yields at early harvests, but for most of the season it was the lowest yielding variety. Ulster Sceptre had slightly lower yields than Home Guard at the very early harvests in Expts 1 and 2, but Irish Peace, owing to its large number of tubers, always had small saleable yields and appeared unsuitable for first early production. Arran Comet and Ulster Sceptre were the highest yielding varieties at later harvests in June and early July. Irish Peace produced similar yields at this time, but Home Guard produced unacceptably low yields.

As would be expected from the small effects of date of planting on leaf growth, only small effects of date of planting were found on total and graded tuber yields in Expts 1 and 2 (Table 15). At the end of May, the first three plantings produced similar yields, despite frost damage to some early February plantings and all outyielded the mid-March planting. For the remainder of the season in both experiments, date of planting had little effect

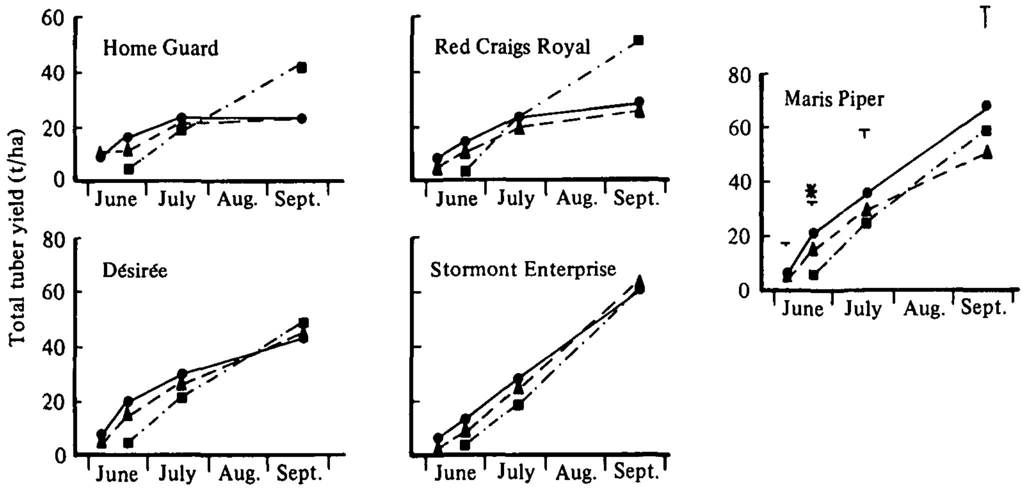

Fig. 7. Effect of date of planting on total tuber yield in five varieties. Expt 4, 1975. ●——●, 19. iii; ▲———▲, 9. iv; ■—·—■, 2. v; T S.E. for comparison of any two points within one date of sampling and * denotes a significant interaction ($P = 0·05$) on a particular date.

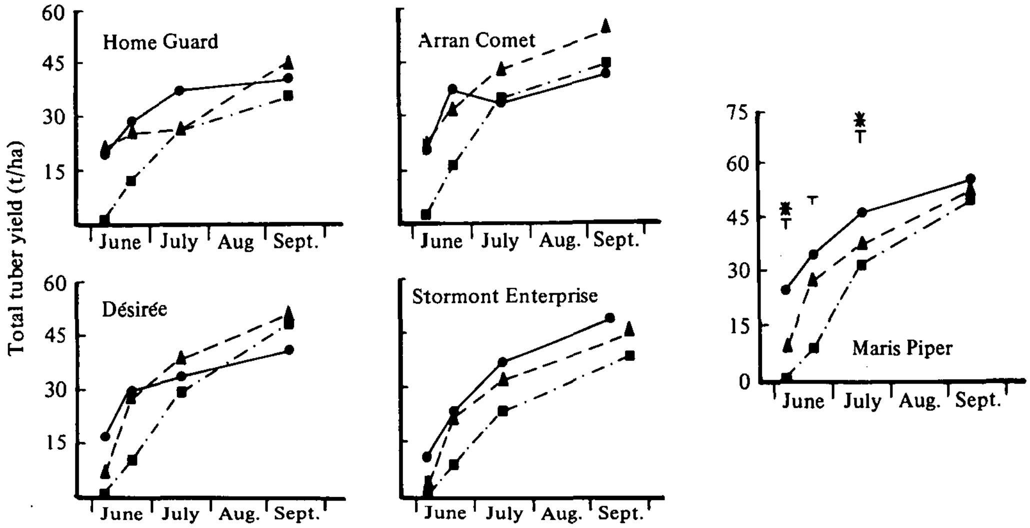

Fig. 8. Effect of date of planting on total tuber yield in five varieties. Expt 5, 1976. ●——●, 10. iii; ▲– – –▲, 30. iii; ■—·—■, 21. iv; T S.E. for comparison of any two points within one date of sampling and * denotes a significant interaction ($P = 0.05$) on a particular date.

on yield. In Expt 3, where all plantings were relatively late, crops planted in April generally remained the lowest yielding throughout harvesting.

In Expts 4 and 5 the first delay in planting generally had a much smaller effect on early yields of early varieties than the maincrop varieties and significant interactions were found at three of the six harvests before the end of July (Figs 7 and 8). In Expt 4 the highest early yields were, on average, produced by the two early varieties, but this advantage lasted only 2 weeks as a consequence of the faster rate of bulking of the maincrop varieties. In Expt 5 the highest initial yield was produced by the first planting of Maris Piper, although on average, the early varieties again outyielded the maincrop varieties. Maris Piper and Stormont Enterprise produced the largest final yields in Expt 4 and Maris Piper did so in Expt 5. The final yield of the early variety Arran Comet was similar to the yields of Désirée and Stormont Enterprise in Expt 5, while in both years Home Guard produced the smallest final yield.

In Expt 4, bulking of the first two plantings of Home Guard and Red Craigs Royal largely ceased after mid-July, while the final plantings of these varieties continued bulking throughout harvesting and produced the highest final yields. There was no effect of date of planting on final yields of the maincrop varieties in either experiment. However, the pattern of tuber bulking was different in the 2 years, for in Expt 5 bulking rates decreased with time and were smaller than in Expt 4.

DISCUSSION

The larger response of rate of post-planting sprout elongation to a rise in temperature in short sprouted, early varieties, such as Ulster Sceptre than in longer sprouted varieties such as Home Guard, is particularly significant for early variety testing. If experiments are planted very early, when temperatures are low, varieties with long sprouts will emerge much earlier than varieties with short sprouts and provided they are not damaged by frost will probably produce the earliest commercial yields. However, from later planting, when temperatures have increased, the relative performance of varieties is likely to be quite different. Varieties with short sprouts may emerge at the same time or possibly before the varieties with long sprouts and are likely, therefore, to produce the highest yields. As many experiments and harvest dates are averaged to produce yield ratings in National Institute of Agricultural Botany recommendations, the present results suggest caution in interpreting the differences reported.

For the production of early crops the obvious practical approach is early establishment of a large leaf area by early planting of varieties, such as Arran Comet and Home Guard, which will emerge and grow at low temperatures. Unfortunately, even in Pembrokeshire the advantages of early planting are often curtailed by frost killing the foliage of newly emerged plants. The results of Expts 1–3 showed that early plantings which had been frost damaged yielded as well as subsequent plantings which escaped damage. The results indicate, however, that planting later than mid-March can affect early yields more severely than frost. Thus for high first early yields it appears more sensible to plant during any dry spell in February and risk frost damage rather than waiting until March, when wetter weather could delay planting into April. Owing to slow rates of sprout extension at low temperatures, February planting of Ulster Sceptre did not produce markedly earlier emergence than plantings several weeks later and such a variety would appear unsuitable for the very earliest harvests.

In general, provided newly emerged plants were not damaged by frost and there was no moisture stress, delayed planting delayed and increased the size of peak leaf area. The magnitude of this effect, however, varied with variety and the physiological age of the seed. These findings agree with the results of other workers (Bremner & Radley, 1966; Allen, 1977) but few have attempted an explanation. Scott *et al.* (1973) found that later plantings of sugar beet, which passed through most of their development in warmer conditions than earlier plantings, had larger peak L values. Although plants of late-sown crops had fewer individual leaves, any effect of this on L was more than compensated for by an increase in their area. Similarly, Milford & Riley (1980) showed that maximum leaf area in sugar beet was positively related to temperature up to about 20 °C, owing to an increase in leaf size. Unfortunately, there are few data on the effect of temperature on leaf growth in potatoes. Relationships between peak leaf area and temperature during growth were demonstrated in Expts 4 and 5, although the relationships varied between experiments for the same variety. This difference may have been due to the seed of Expt 4 being physiologically older than the seed of Expt 5, although stem densities did not differ. The area of individual leaves was not measured in these experiments, but there was evidence that increases in peak L with delayed planting were due to increases in both specific leaf area (cm^2/g) and number of leaves per plant. This increase in the number of leaves was probably due to an increase in lateral branching, for other workers (Borah & Milthorpe, 1962; Marinus & Bodlaender, 1975) found axillary branching to increase with increase in temperature. Moreover, J. N. Bean (personal communication) had also recently found some evidence that axillary branching and the number of leaves per plant increase with delayed planting. However, in view of the effect of date of planting and temperature on the area of individual leaves in sugar beet, a similar investigation is warranted in potatoes.

The results of these experiments have shown that for first and second early harvests, early planting is advantageous, despite the increased risk of frost damage. It is not so clear, however, when maincrop potatoes should be planted. The limited effects of date of planting on final yield in the maincrop varieties of Expts 4 and 5 differ from those reported by earlier workers, for most workers have found that delayed planting after mid-April reduced the yield of maincrop potatoes. However, while some authors found little benefit from planting in March, Allen (1977) reported that the improvement in early growth with early planting in Pembrokeshire was advantageous to final maincrop yields. The first planting of all varieties in Expt 4 failed to achieve full leaf cover and the most obvious difference between this year and others at Trefloyne was the period of very low temperatures for the weeks after planting (Table 6). Similar effects of low temperatures prior to emergence on size of leaf surface have been found by O'Brien (1981) in 1975, by T. C. Gillison (unpublished data) and R. L. Griffith, S. A. Jones and E. J. Allen (unpublished) at Brancaster (Norfolk). The final plantings, however, despite establishing later and not achieving full leaf cover until the photoperiod and intensity of radiation were declining, had complete ground cover from the end of July until September. Thus, during the latter part of the season tuber bulking in the later plantings was rapid and the yield advantage of early planting was gradually reduced. In the experiments of Allen (1977) the first planting in 1974 achieved full leaf cover about a month earlier than the last and yield differences created by this were maintained to the end of the season. The spring weather in 1974 was more typical of Pembrokeshire in that temperatures were higher than in 1975–7 and there was a well-distributed supply of rainfall. None of Allen's (1977) experiments were carried out in years as dry as 1976 and although there was a period of little rainfall during May and June in 1973, tuber bulking was not affected by moisture stress. In Expt 5 there was no appreciable rainfall for the majority of the growing season and despite most plantings achieving full leaf cover, the limited effect of date of planting on final yield was the consequence of each planting relying primarily on the amount of water available from the soil for tuber growth. As this was utilized, bulking ceased and the final yields were similar. It seems clear that the effect of date of planting on final yields of maincrop varieties is determined by the combined effects of temperatures in the first few weeks after planting and the pattern of rainfall. In the absence of water stress and any frost damage, planting in early

March is likely to be beneficial if growth is immediate and emergence occurs in April. There will be a complete leaf canopy early in the season and these advantages in growth will persist to final harvest as reported by Allen (1977). Such conditions will occur most regularly in south-western areas of the U.K. under irrigation. They will occur less frequently and unpredictably in the major maincrop areas and the occurrence of frost damage will remove any advantages of early planting but on the basis of this evidence will not reduce yields relative to later plantings. Low post-planting temperatures appear to reduce the size of the leaf surface of early plantings and as such conditions occur more frequently in the east of the country any advantages in earliness of growth are often counterbalanced by reduced growth rates (as a consequence of reduced radiation interception). Consequently yields are generally little affected by date of planting up to mid-April, as in Expt 4 in these experiments and those reported by Bremner & Radley (1966). Such effects result without the occurrence of water stress, but the results of Expt 5 show that they are also caused by prolonged water stress where the yields of all dates of planting are primarily dependent on extraction of a fixed amount of soil water. These latter effects are likely to be frequent on unirrigated light soils in East Anglia. In view of these effects, the results of Beveridge (1966), which showed the consequence of having potato ridges open for different periods of time before planting, may have been determined by the weather and the light unirrigated soil.

The yields in Expt 5 were primarily determined by the supply of water from the soil and were surprisingly high which suggests large limiting deficits on these soils, especially for Maris Piper. There were no direct measurements of water use but Jones (1981) demonstrated close linear relationships between accumulated potential transpiration and tuber fresh weight. These relationships were unaffected by variety, date of planting and age of seed. Making the assumption that the relationships deviated from linearity at the onset of water stress and therefore at the limiting soil moisture deficit (D_L), he estimated the critical deficit for Maris Piper to be approximately 150 mm. The calculations for all varieties indicated limiting deficits above 40 mm and for maincrops of above 100 mm. All values were above previously published values for limiting deficits of similar varieties and suggest that the soil at Trefloyne is capable of supplying much more water than at other sites for which data have been reported. The rates of fresh-weight production per mm of water transpired in these calculations were similar to values obtained in subsequent experiments in which water use was measured directly and to published values (Penman, 1970; Bean, 1981). These results will be published in subsequent papers. At this stage there are important commercial implications for irrigation practice in these results. The limiting deficit for potatoes is clearly much more variable than hitherto accepted and to plan irrigation schedules for maincrop potatoes at Trefloyne on the basis of D_L of 80 mm (French & Legg, 1979) would result in the wastage of considerable quantities of water. The view of Penman (1970) that the objective of irrigation experiments is to determine the limiting deficits must be followed quickly and due regard must be paid to seed age and sites in order to establish useful values for practical systems. For maincrop potatoes, there would seem little justification in the installation of irrigation facilities at sites such as Trefloyne, for years as dry as 1976 are rare. The results for all varieties in these experiments are at variance with the ratings for 'resistance to drought' on the National Institute of Agricultural Botany Classified List of Potato Varieties (1981–2). Considering the results of Expts 1 and 2 and the distribution of early varieties in the United Kingdom, it is surprising that Ulster Sceptre is classified as being more resistant to dry conditions than Arran Comet. In Kent where crops are predominantly grown without irrigation, Arran Comet is by far the most popular variety. The low resistance of Home Guard to dry conditions is caused to a large extent by the seed becoming relatively old by planting and consequently it is rarely grown in poor unirrigated soils. Nevertheless, in Pembrokeshire, where the majority of growers can irrigate, Home Guard is still extensively grown. The limiting deficits of Maris Piper were apparently extremely large, yet the variety has a low rating for resistance to drought on the Classified List.

The suggestion of very large limiting deficits at this site can result only from crops having access to both water and nutrients in sufficient amounts to sustain growth at the potential rate. This may not occur at many sites, where deficiency of nutrients, particularly nitrogen, restricts growth even before water shortage occurs. Garwood & Williams (1967), working with grass, found that crops often appear to suffer water stress in dry periods with an abrupt cessation of growth, although still having access to a source of water. They suggested that unless there is excessive rainfall during the growth of a crop, the majority of any applied nutrients, especially nitrogen, remain in the top layers of the soil profile. Consequently, if there is a prolonged period of dry weather and the root system has to extract water from progressively deeper sources the availability of nutrients gradually declines. Although plants may remain capable of extracting water from the soil the concentration of nutrients can eventually fall too low to sustain growth. In 1976 the dry period was preceded by relatively wet weather which may have leached some nutrients deep into the profile. Further, Expt 5 was only the second crop following a very long-term ley and it is probable that the very deep soil of the experimental site contained considerable nitrogen. However, in the years since 1976 the general pattern of water use and nitrogen uptake has been similar, in that high yields (> 50 t/ha) have been achieved without irrigation and nitrogen accumulations have been considerably greater than that applied as fertilizer (Ifenkwe & Allen, 1983) on sites in arable crops for up to 8 years. Thus, it seems probable that large limiting deficits are a general feature of crop growth at Trefloyne.

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