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EFFECT OF TIME OF PLANTING ON THE SEASONAL YIELDS OF PISUM SATIVUM

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SUMMARY

Better growth and yields were recorded for mid-season plantings than for early and late-season plantings. The relationships of plant growth to temperature, daylength and total solar radiation were investigated but only the negative temperature interaction was found to be significant. Variations in plant weight, number of leaves and plant height indicated the degree to which interplant competition is affected by time of planting. Reduced yields of later plantings indicated that increased relative growth rates did not compensate for the shorter growing periods.

I. INTRODUCTION

In south-eastern Queensland peas (*Pisum sativum* L.) can be planted from April to August. Field observations have indicated that although the crops maturing in winter (June-August) have a potential for optimum yields, these are seldom realized because of frost damage. To avoid this damage, plantings are usually scheduled to allow the crop to mature in the spring period (September-November). By delaying these planting, yields are progressively reduced.

To maximize yields at different times of the season it is important to know what factors are limiting productivity. Boswell (1926) working in the northern hemisphere studied the seasonal growth and production of peas over a 3-month period from March to May and concluded that, of the climatic factors studied, the temperature effect was the most important at all stages of growth. The successful application of the heat unit system of harvest prediction in pea crops (Seaton 1955; Arnold 1959; Hope 1962) is in itself an indication of the importance of temperature in the seasonal growth of the plant.

The aim of the experiments reported here was to establish the effect of time of planting on the growth and productivity of plants and to investigate the factors operating in the control of this production.

II. METHODS AND MATERIALS

The experimental area was located at the Redlands Horticultural Research Station on a typical krasnozem soil as described by Stephens (1962).

The variety used in these experiments was Providor, a Massey x Meteor selection developed locally by D. W. Dowdles (unpublished). Seed was selected for uniformity of size and freedom of disease. Laboratory germination tests were carried out before each planting and in all cases germination exceeded 92%. Standard spacings of 7 in. (17·78 cm) between rows and 3 in. (7·62 cm) within rows were used for all plantings.

Seven plantings were made at 3-weekly intervals from April to October, 1963 (Table 1). Areas of 16·5 ft (5·03 m) x 120 ft (36·58 m) were allocated for each of the planting times. Because of the differing irrigation requirements, it was not practicable to randomize dates of sowing.

The trial area was subdivided to allow for both growth and maturity harvests. Plant samples were taken from each of three 9-row x 5 ft (2·44 m^2) quadrats at weekly intervals for recording of plant dry weight and morphological characters and yield component data. Significant points in the development of plants were considered to be sowing, emergence, flowering and pea maturity.

The Maturity Index (M.I.) of peas was determined by the use of a maturometer (Lynch and Mitchell 1950). In this study an M.I. value of 250 was taken as Optimum Harvest Time (O.H.T.). Samples were taken at regular intervals as the plants approached maturity, and after removing peas from haulm in a small plot rotary viner, the M.I. values were determined. A main yield sample of four 3-row x 17 ft (2.76 m^2) quadrats was taken when O.H.T. was reached. Pea size grader distribution was determined after grading in a vibratory size grader.

A second-order weather observing station was located within 200 m of the plots. Autographic records of total solar radiation (Rotitzsch-Fuess type bimetallic actinograph) were also kept. Heat unit summations were calculated after the method of Arnold (1959) by subtracting a base temperature from the mean of the daily minimum and daily maximum. The results are termed degree days and are summed daily.

III. RESULTS

(a) Development in Time

By delaying plantings, the total number of days to maturity increased until June 12, but then the number of days decreased (Table 1). This effect is seen in all phases of development. The effect is presented graphically in Figure 1, which includes mean daily temperature ((daily maximum + daily minimum)/2), total radiation and daylength data each presented as a weekly mean. Linear regression analyses were used to investigate the effect of these environmental factors, calculated as daily means, on the length of each development phase. The correlation coefficients are presented in Table 1. The negative relationship with temperature was highly significant in all development phases, but no significant relationship with radiation or daylength was recorded.

TABLE 1

EFFECT OF TIME OF PLANTING OF PEAS ON THE NUMBER OF DAYS IN EACH DEVELOPMENT PHASE AND CORRELATION WITH TEMPERATURE, MEAN DAILY RADIATION AND DAYLENGTH

Planting Date	Sowing to Emergence	Emergence to Flowering	Flowering to Maturity	Total
T1—10.iv	5	18	39	62
T2— 1.v	6	21	58	85
T3—22.v	8	28	55	91
T4—12.vi	9	34	49	92
T5— 3.vii	14	27	44	85
T6—24.vii	9	25	37	71
T7—14.viii	8	22	34	64
Correlation coefficients				
Temperature	−0·91**	−0·91**	−0·98**	
Mean radiation	−0·85	−0·42	−0·64	
Daylength	−0·68	−0·66	−0·75	

L.S.D. 5% = 1·2; 1% = 1·6.

** Significantly different at 1% level.

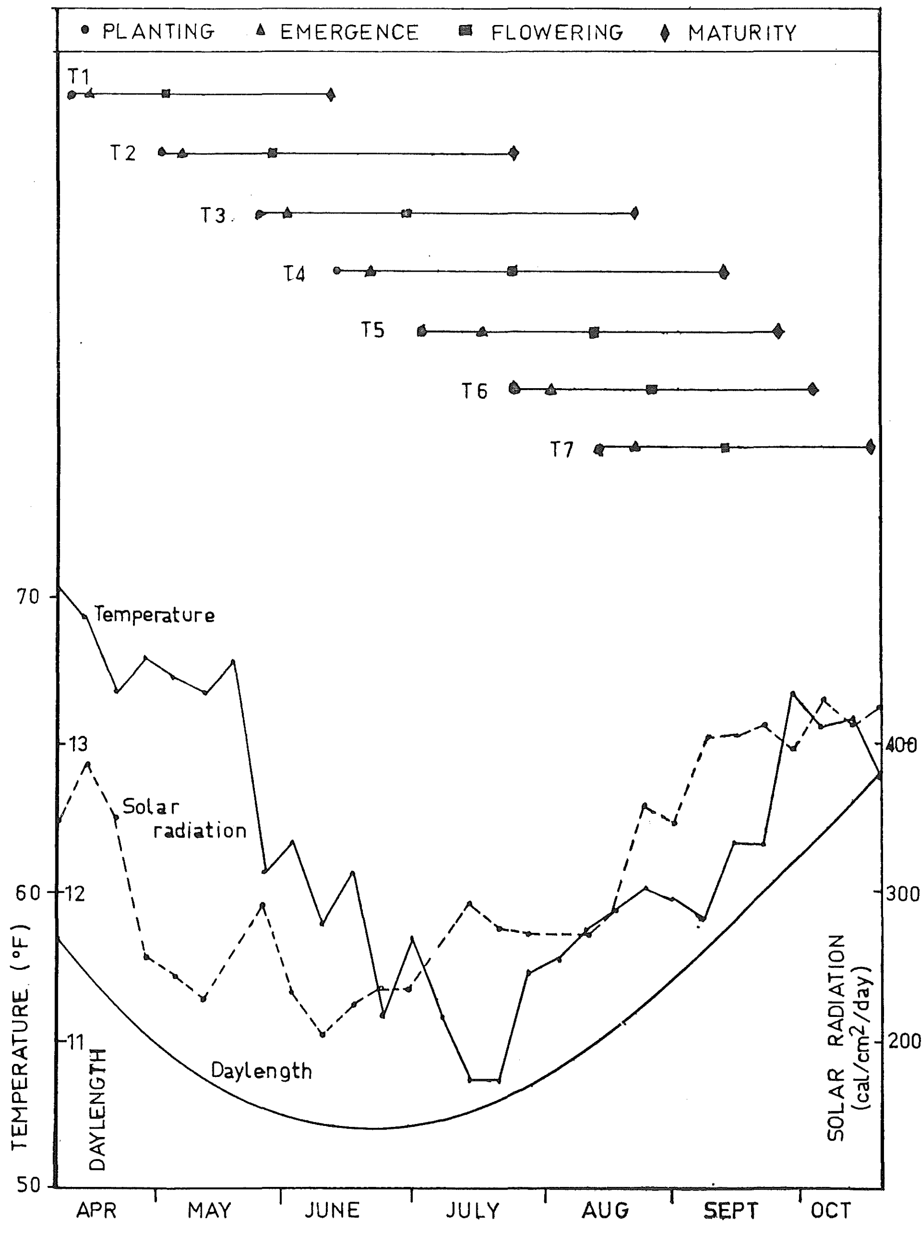

Fig. 1.—Plant development in relation to time.

Degree days were calculated using base temperatures of 43, 44, 45 and 46°F (Table 2). Coefficients of variation are presented; they are at a minimum of 45°F, which indicates that it is the most applicable base temperature. By using these data, mid-season plantings could have been accurately scheduled, but errors of ± 3–4 days would have occurred with early and late-season plantings.

TABLE 2

Degree Days Calculated with Base Temperatures of 43, 44, 45 and 46°F

Time of Planting	Mean Daily Temperature (°F)	Time to Maturity (days)	Degree Days with Base Temperatures (°F)			
			43	44	45	46
1	65	62	1,357	1,295	1,233	1,171
2	60	85	1,410	1,325	1,240	1,155
3	58	91	1,347	1,256	1,165	1,074
4	58	92	1,362	1,270	1,178	1,086
5	59	85	1,337	1,252	1,167	1,082
6	61	71	1,264	1,193	1,122	1,050
7	62	64	1,242	1,178	1,114	1,057
Mean	60·4	79	1,331	1,253	1,174	1,096
Coefficient of variation	..	..	3·11	2·96	2·93	3·05

(b) Vegetative Development

Total dry weight.—The total dry weight is presented on a $\log_e$ basis in Figure 2. The slope of the curve gives an indication of Relative Growth Rate (R). The mean R and Crop Growth Rate (C) over the whole growing period are presented in Table 3 together with mean dry weight at OHT for each planting time. Maximum dry weights were recorded for mid-season plantings, lower values being obtained from both early and late plantings. C values also indicate this effect. The significant increase in overall R with later plantings compensates to some degree for the shorter growing period.

TABLE 3

Relative Growth Rate, Crop Growth Rate and Plant Dry Weight at Optimum Harvest Time

Time of Planting	R (g/g/day)	C (g/day)	Plant Dry Weight at OHT (g)
1	0·0705	0·739	3·57
2	0·0704	1·577	11·13
3	0·0744	2·010	14·17
4	0·0700	2·039	13·33
5	0·0778	1·544	8·77
6	0·0832	2·166	10·53
7	0·0978	1·831	7·80
L.S.D. 5%	0·0032	0·1669	0·94
L.S.D. 1%	0·0044	0·2317	1·30

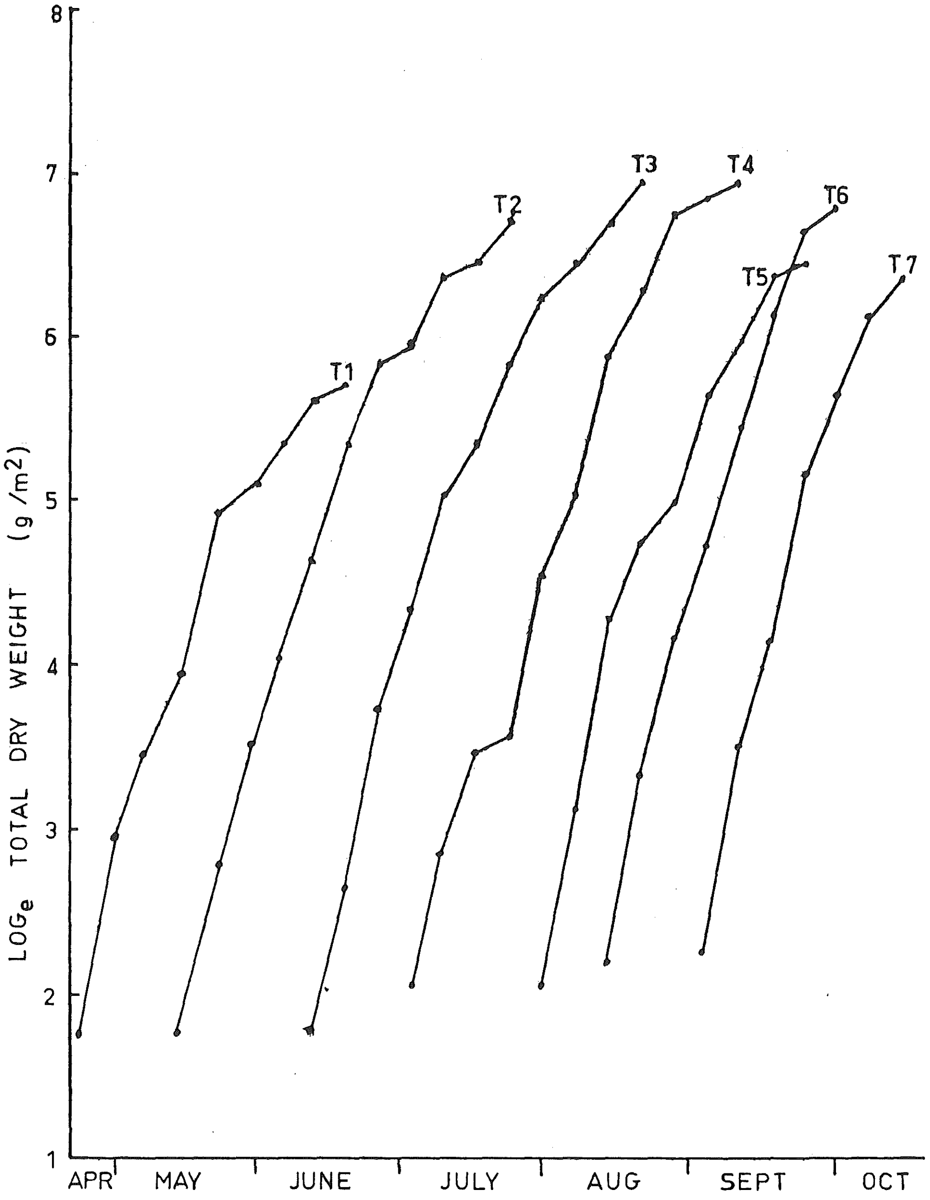

Fig. 2.—Vegetative development: total dry weight at various times.

Number of leaves.—The number of leaves produced is given in Figure 3. This reaches a maximum with mid-season plantings and then falls slightly with delayed plantings. The rate of leaf production calculated from total number of leaves and period of growth and expressed as number of leaves produced is also presented in Figure 3. It remains relatively constant for early and mid-season plantings but shows an increase with later plantings.

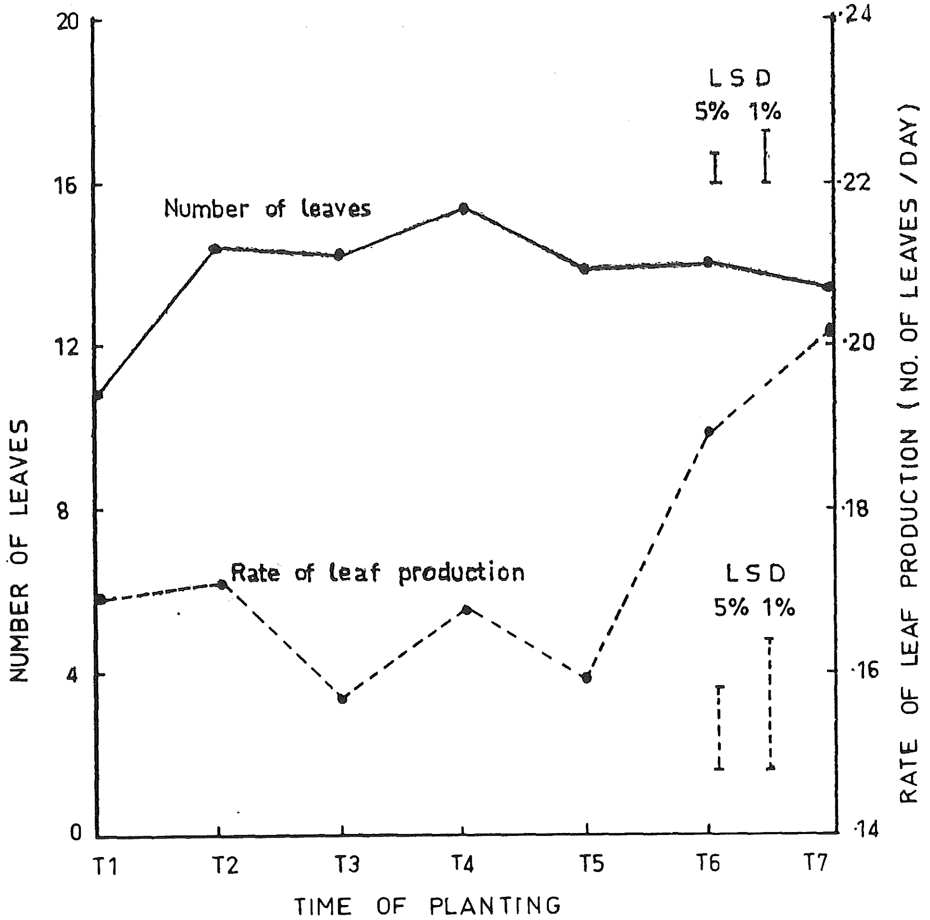

Fig. 3.—Vegetative development: effect of time of planting on number of leaves produced.

Vine length.—The effect of time of planting on vine length and mean length of internode is presented in Figure 4. Both curves show a similar trend, with greater vine length and internode length being recorded for mid-season plantings.

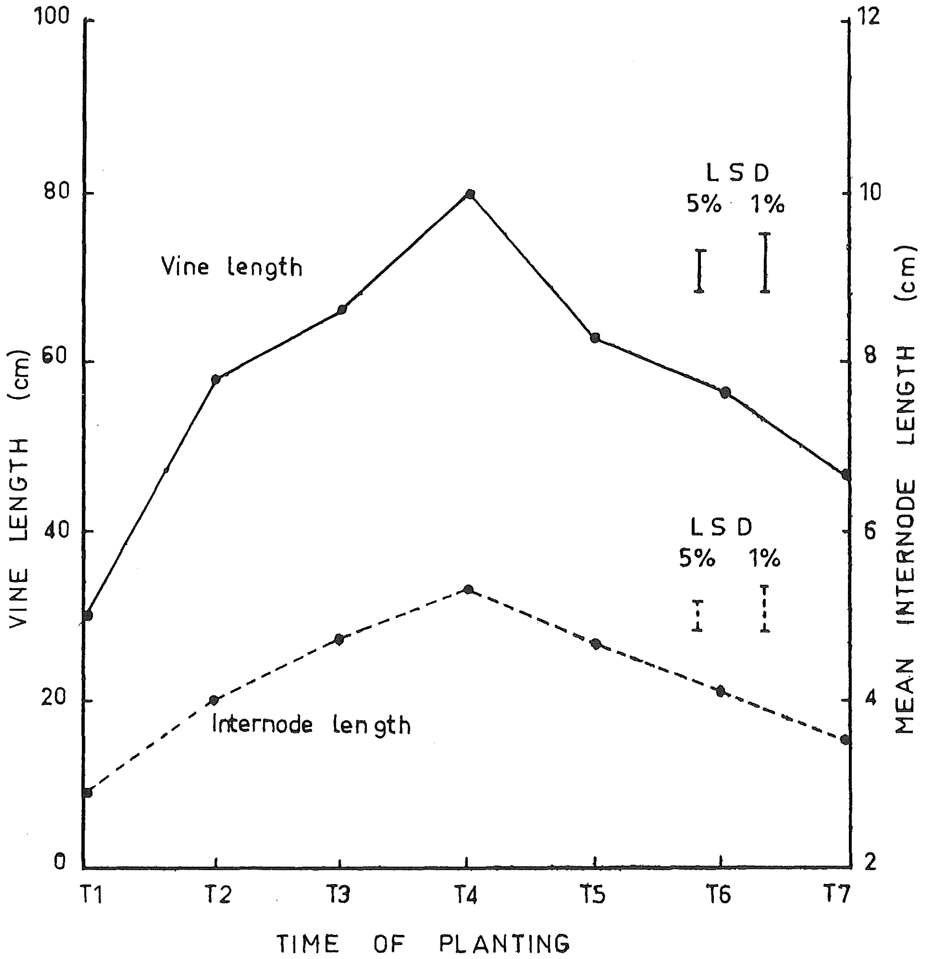

Fig. 4.—Vegetative development: effect of time of planting on vine length and internode length.

Tillering.—With delay in plantings the amount of tillering increased (Table 4). In the first planting no plants developed secondary stems, but secondary stem development increased rapidly and in the last three plantings 90% of plants had developed secondary stems. These stems varied in length. It was only in later plantings that they contributed to yield.

(c) Reproductive Growth

First flowering node.—The effect of time of planting on the first flowering node is seen in Figure 5. All plants for all plantings flowered on either the seventh, eighth or ninth node.

TABLE 4

TILLER DEVELOPMENT IN RELATION TO TIME OF PLANTING

Time of Planting	Plants with More Than One Stem (%)	Arc Sine Transformation
1	0	0
2	26·5	·541
3	46·5	·750
4	53·4	·819
5	60·6	·893
6	63·4	·921
7	63·5	·923
L.S.D. 5%	..	·204
L.S.D. 1%	..	·283

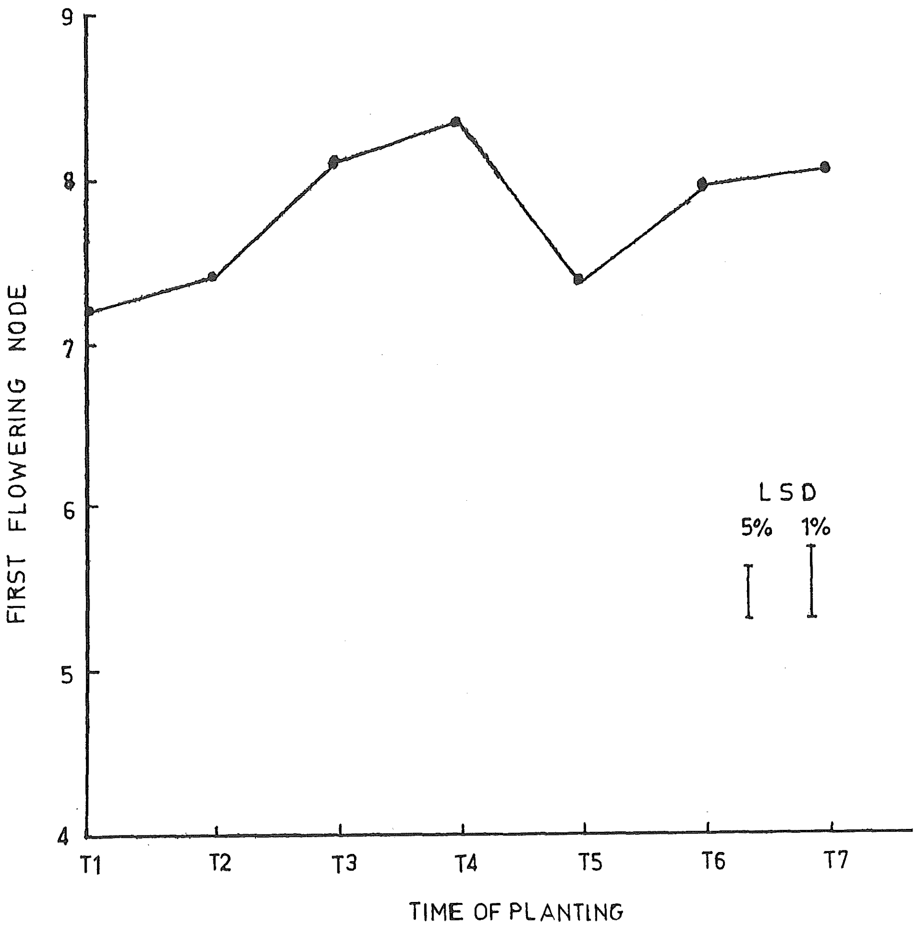

Fig. 5.—Reproductive growth: effect of time of planting on first flowering node.

Yield of peas.—The yield of peas is presented in Figure 6. By delaying plantings, significant yield improvements were recorded up until the third planting, after which yields decreased as planting was delayed. Several yield components interact to determine the yield capacity of the plants. These components include mean pea weight, number of peas per pod, percentage flowering nodes with double pods, number of pods per plant, and number of pods on the primary stem; all have been found to be significantly affected by time of planting (Table 5). The interaction of yield (y ordinate) with these factors was investigated by linear regression analyses; these and correlation coefficients are presented in Table 5. Significant correlations at the 5% level were recorded for mean pea weight and number of pods on primary stems, while the value for number of peas per pod closely approached significance at the 5% level.

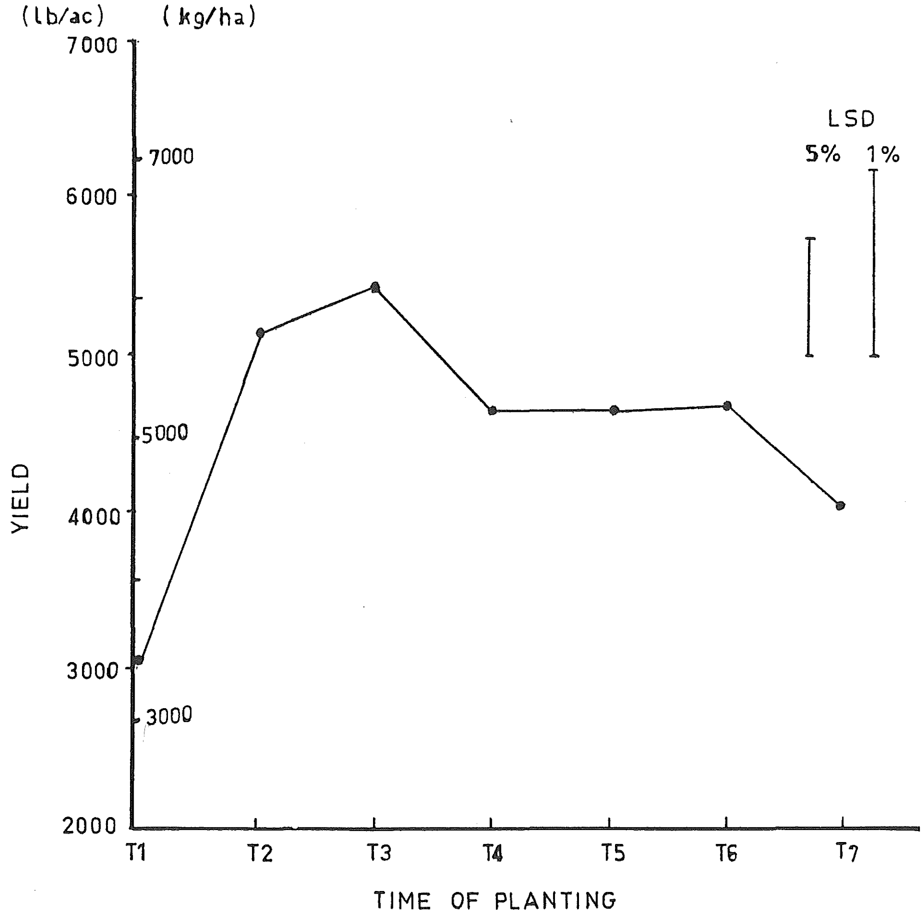

Fig. 6.—Reproductive growth: effect of time of planting on yield of peas.

Number of pods.—The number of pods per plant and the number of pods on the primary stem are presented graphically in Figure 7. The difference between the two lines represents the contribution in pod number of the secondary stem to total yield. This is not great for any planting except the sixth, when it apparently resulted in yield increases.

Size of peas.—When a size grade analysis of green peas was made, it was found that 85–90% of total yield of peas was in the size grade $\frac{5}{16}$ to $\frac{7}{16}$ in. (7·94 to 11 mm) for all plantings except the first (Table 5 and Figure 8). In the first planting only 67·8% were in this range, the remainder being larger as indicated by mean pea weight data (Table 5).

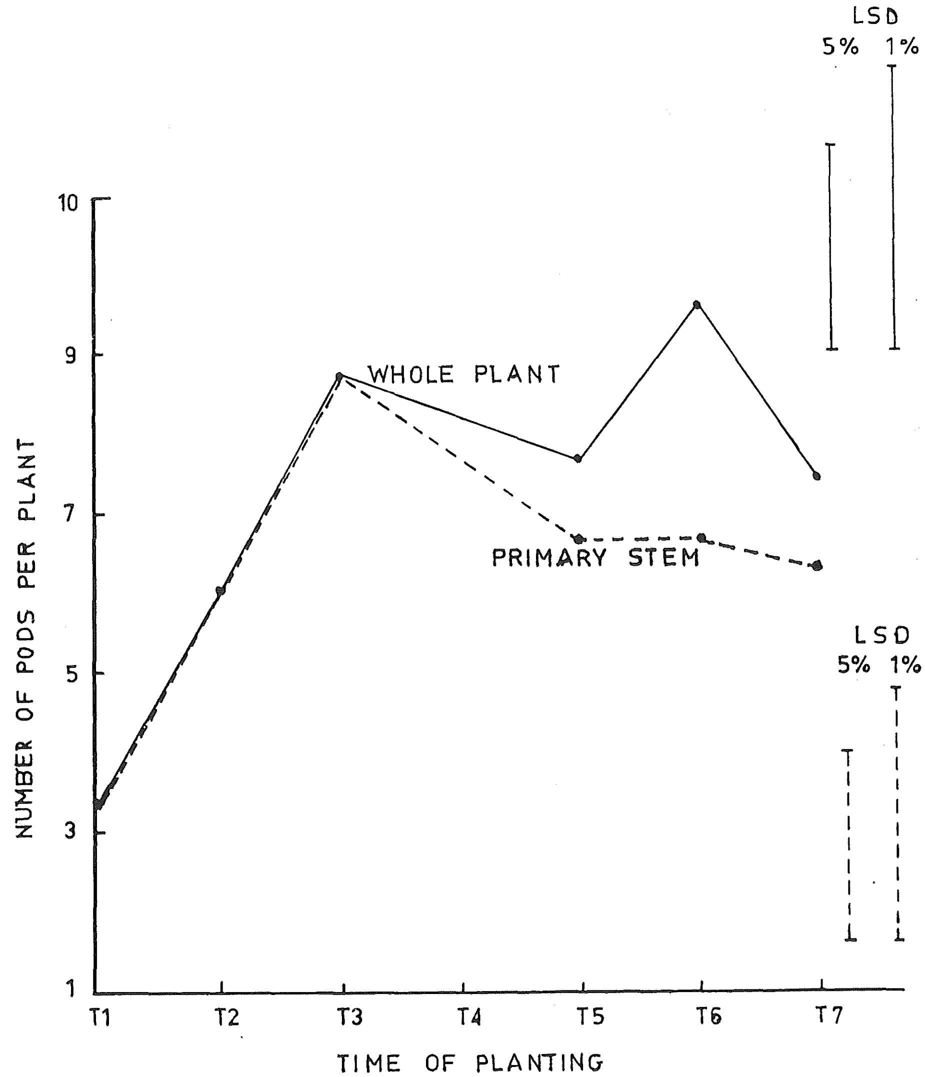

Fig. 7.—Reproductive growth: effect of time of planting on number of pods per plant.

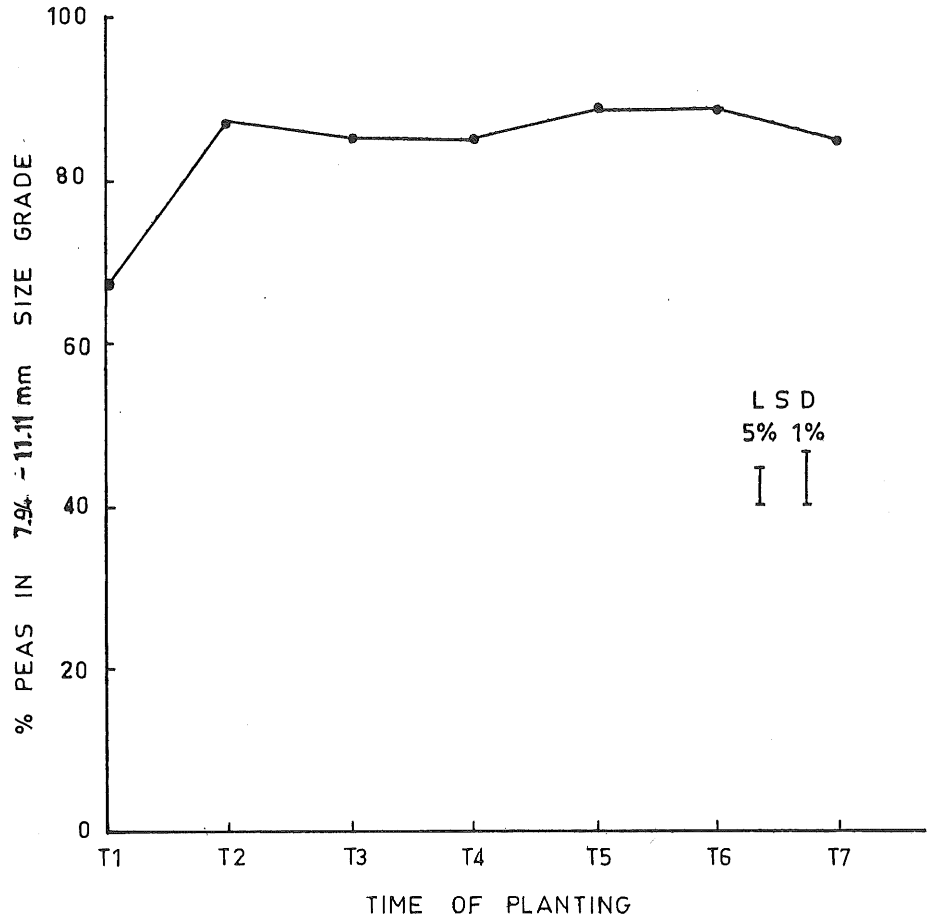

Fig. 8.—Reproductive growth: effect of time of planting on size grade of peas.

IV. DISCUSSION

The close inverse relationship of time of development to a certain stage and mean temperature of that period, recognized by Boswell (1926), is evident in this work. The non-significant correlation of daylength and solar radiation with time of development does not necessarily indicate that they are not involved, but rather that temperature is the most important. The application of the heat unit system of maturity prediction further indicates the major importance of temperature. The variations in heat summations for early and late-season plantings would lead to errors of ± 3–4 days in maturity estimation. Arnold (1959) recognized such errors and found that they were directly related to trends in the climatic conditions under which the crop was grown.

The adverse effects of high temperatures on yield of peas have been referred to by Boswell (1929), Lambert and Linck (1958) and Brouwer (1959). This is probably the explanation of the yield reductions (Figure 6) recorded for both early and late plantings. As plant density at establishment was constant for all plantings and all plants survived, the yield differences must be attributed to difference in yield per plant.

TABLE 5

EFFECT OF TIME OF PLANTING ON COMPONENTS OF YIELD PER PLANT

Time of Planting	Mean Pea Weight (g)	Number of Peas/Pod	Percentage Peas in Sizes $^5/_{16}$–$^7/_{16}$ in. (7·94–11·11 mm)	Percentage Flowering Nodes with Double Pods: Mean	Percentage Flowering Nodes with Double Pods: Arc Sine Transformation	Number of Pods/ Plant	Number of Pods/ Primary Stem
1	0·55	3·2	67·8	0	0	3·5	3·5
2	0·43	5·0	86·7	2·2	0·150	6·2	6·2
3	0·48	4·5	85·5	37·4	0·658	8·9	8·5
4	0·51	..	85·6	..	..	..	..
5	0·50	3·2	89·0	8·1	0·289	7·6	6·6
6	0·49	3·7	89·5	13·9	0·382	9·6	6·7
7	0·50	3·5	85·0	18·3	0·442	7·6	6·1
L.S.D. 5% ..	0·045	0·78	4·58		0·162	1·31	1·20
L.S.D. 1% ..	0·061	1·07	6·24		0·227	1·84	1·68
Correlation with yield (y)—							
"r"	0·78	0·79		0·56		0·66	0·88*
"n"	21	18		18		18	18

* Significantly different at 5% level.

Vegetative characteristics of individual plants have also been influenced by treatments. For both early and late-season plantings there have been reductions in plant dry weight, plant height and number of leaves, which result in a general reduction of plant size and consequently density of vegetation. The degree of inter-plant competition will therefore vary throughout the season. Although R did increase with later plantings, this did not compensate in terms of yield and dry-matter production for the shorter growing period.

The basis of the effects of high temperatures on growth and development of peas has received some attention. Lambert and Linck (1958) attributed high temperature effects on growth to increased respiration, decreased concentration of nutrients and an upset in the balance of nitrogen and protein synthesis. Ketellapper (1963) considered that the effect of high temperature was a reduction in photosynthetic rate *per se,* or could involve an effect on other factors associated with photosynthesis. Thorne, Ford and Watson (1967) in a study of temperature effects on sugar beet found only small effects on E, but leaf area was affected directly by increases in rate of leaf production, expansion and senescence.

Results have indicated that the development of secondary stems increases considerably as planting is delayed (Table 4). This could be an important factor in the reduction of late-season yields. The contribution of pods from tillers towards total plant yield has been shown to be quite small in most cases (Figure 7), and this would indicate that the plant reserves used in the development of tillers could be wasted so far as total yield is concerned. However, although direct yield contribution is small, tillers may be important in the production of assimilate for translocation to developing pods on the primary stem.

Many factors have been reported to influence the development of tillers. It is inhibited by increased plant density (Reynolds 1950; Proctor 1963), low nitrogen and carbohydrate supply (Gregory and Veale 1957) and shading (Nakamura and Otono 1964) and is stimulated by exposure to light (Auda, Blaser and Brown 1966) and high nitrogen levels (McIntyre 1964). It is considered unlikely that differential nitrogen levels would be involved in this work, as heavy dressings were applied to all plantings and plants with similar dry weights from early and late-season plantings showed considerable differences in tiller development. The effects of carbohydrate supply and shading are probably most important. With the first plantings, the early development of plants would have occurred under high temperature conditions and it is unlikely that high levels of carbohydrate were present. However, in later plantings the early development under cooler conditions could have resulted in a more adequate carbohydrate supply.

The size grade distribution of peas is an important consideration in any yield study. In the variety used in this experiment, the mean pea size is rather large for commercial acceptance. It was found that 85–90% of the crop was in the $\frac{5}{16}$ to $\frac{7}{16}$ in. (7·94 to 11·11 mm) size grade for all plantings except the first, in which it was 67%. When this is considered in relation to the mean pea weight, a trend towards the development of larger peas in the first planting is indicated. For this planting the number of peas per pod and the number of pods per plant were also reduced.

In testing wheat varieties, Wellbank, French and Witts (1966) considered that the limited ear size of one particular variety could have limited its capacity to accept assimilate. The operation of a similar situation in this case could have resulted in the increased pea size. If there was such a reduction in the rate at which photosynthate was stored and utilized, a reduction in the rate of photosynthesis as suggested by Moss (1962), Humphries (1963) and Burt (1964) could have occurred. This could explain the comparatively reduced total dry-matter accumulation recorded for this planting. The pea size in later plantings could well be related to the time of development of starch phosphorylase, which, as shown by Robertson *et al.* (1962), is accelerated at higher temperatures.

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