THE EFFECTS OF PHYSIOLOGICAL AGE OF SEED POTATOES

ON THE GROWTH AND DEVELOPMENT OF THE

SUBSEQUENT CROP

by

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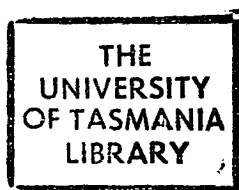Master of Agricultural Science

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, and to the best of my knowledge and belief contains no copy or paraphrase of material previously published or written by another person, except when due reference is made in the text of the thesis.

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SUMMARY

Four field trials were conducted to determine whether physiological age (p-age) of seed tubers affects the subsequent growth of Kennebec and Russet Burbank.

Seed potatoes were physiologically aged by allowing them to sprout prior to planting. The degree of aging was quantified as the number of day degrees above a baseline of $4^{\circ}C$, from the time of dormancy break until the time of planting. In the first experiment five p-ages of 0, 250, 500, 750 and 1200 day degrees above $4^{\circ}C$, were imposed on both cut and round seed tubers of Kennebec. The affects of p-age were studied in terms of the growth of the resulting crop. By increasing p-age of seed at the time of planting, emergence was more rapid, a leaf canopy was more quickly established, tuber initiation occurred earlier, and early tuber yields were greater. Physiological age also affected the number of stems per plant so that the maximum number occurred on plants of 250-500 day degrees $>4^{\circ}C$. Although final yields were not significantly different, significant differences occurred with number of tubers and mean tuber weight. With increasing p-age there was a significant increase in mean tuber weight and a simultaneous decline in the number of tubers per plant. There were no significant differences between cut and round seed in their response to p-age.

In Experiment 2 the effect of p-age on Russet Burbank was investigated and compared to the effects observed on Kennebec in Experiment 1. Again, p-older seed emerged sooner and established a leaf canopy earlier. Increased p-age encouraged early stolon growth and tuber initiation. These effects were comparable to the response of Kennebec. However further effects of p-age on Russet Burbank were relatively small in comparison to the p-age response of Kennebec. Where Kennebec produced most numbers of stems from seed of P-250 – P-500, Russet Burbank produced the least from these treatments. Yield was not significantly affected by p-age but was found to be proportional to the total light receipts intercepted by each treatment. Mean tuber weight increased with p-age but not to the extent which was recorded for Kennebec. Maximum numbers of tubers per hectare occurred for P-500 – P-750 plants which was converse to Kennebec which had the greatest numbers of tubers from P-younger plants.

The effect of plant density on the physiological age response was examined by planting seed of P-0, P-500 and P-1200, at 3, 6 and 15 plants per square metre. Certain characteristics of the p-age response described in Exp. 1 were observed across all planting densities. They included increased rate of emergence, and reduced time till crop senescence with increasing p-age. Maximum numbers of stems per plant were achieved at P-500, and yields were reduced when physiological age was P-1200. When plant density was increased, increasing p-age reduced the numbers of tubers which developed on each stem and hence affected the mean tuber weight.

The effect of seed type on the physiological age response of Kennebec was examined by p-aging seed to P-0, P-500 and P-1200 and cutting it into splitters, commercially cut and heel-end sets just prior to planting. The p-age response observed for Kennebec in Exp. 1 was again seen in this trial for splitters and to a lesser degree, heel-end sets. Differences in their response were explained by the poor emergence and reduced stem production of the heel-end sets. Commercially cut seed was comprised of a high proportion of heel-end sets and sets from the apical portion of the mother tuber. Their response to p-age was midway between that of heel-end sets and splitters.

0. INTRODUCTION

0.1 PREFACE

In the United Kingdom, Allen et al (1980) have developed an objective method of measuring the maturity of seed potatoes in storage, which they describe as physiological age. Using their varieties which have been selected for the fresh market, they found that the physiological age of seed potatoes at the time of planting, influenced the growth and final yield of the subsequent crop.

In Tasmania, potatoes are a major crop with production approaching 200,000 tonnes per annum. The two most commonly grown varieties are Kennebec and Russet Burbank yielding 44 tonnes/ha on Kraznozem soils of the North West Coast. These two varieties alone supply the processing market which utilizes the bulk of Tasmania's potatoes. Over the last decade the proportion of Russet Burbank has increased so that it appears it will replace Kennebec as the main processing variety. Both these varieties were originally bred in the U.S.A.

This thesis reports the results of four field experiments on the effects of physiological age of seed potatoes on their subsequent growth and development of yield in Tasmania.

The first two experiments quantify these effects for Kennebec and Russet Burbank. The third and fourth investigate the relationships between planting density and seed type respectively on the effects of physiological age.

0.2 LITERATURE REVIEW

0.2.1 INTRODUCTION

For most forms of life the aging process is measured chronologically. However, the maturity of potatoes is not just a function of their chronological age since many factors, particularly high temperatures during the tubers' storage period, speed up the rate of aging (Murphy et al, 1967).

The term 'physiological age' (p-age) is used to distinguish biological aging from the wholly time-dependent chronological aging process.

Various authors have studied p-age, and have developed different concepts or models to quantify it. Krijthe (1962) characterised the age of potatoes by determining 'sprouting capacity' of whole desprouted tubers under controlled conditions. Madec and Perennec (1955) identified an incubation phase which starts immediately after dormancy and continues until tuber formation. They related p-age to the degree of incubation of seed tubers.

In this review a concept of p-age developed by Allen and Scott (1980) will be described. They have attempted to quantify the accumulation of p-age between the break of tuber dormancy and planting. The importance of this stage of the tubers' development, the sprouting period, to the tubers' p-age will be explained, as so will the effect of p-age at planting on the yield of the subsequent crop. The latter is of great commercial interest since p-age can be manipulated by growers aiming to increase yields.

Environmental and cultural factors during the storage period and the previous season, which influence p-age and may also be controlled by the grower will be discussed.

0.2.2   ACCUMULATION OF P-AGE DURING STORAGE

0.2.2.1   Physiology of Dormancy

As tubers develop underground, the buds (eyes) become dormant in acropetal
succession.   Eventually the tuber reaches its final size and the apical bud
also enters dormancy (Moorby, 1978).   This stage is defined by Milthorpe
and Moorby (1967) as the start of true dormancy of the entire tuber.
Respiration rate slows, cell division and expansion in the tuber stop and
although the tuber may be given optimum growing conditions, sprouting will
not occur.

In Tasmania the growth of many seed crops is stopped abruptly by the
practice of haulm destruction.   By so doing, the optimum yield of seed
tubers (< 250 g) is attained and the risk of viral infection from aphid
vectors is reduced.

Once the haulm is destroyed, or the tuber is separated from the mother
plant, the buds become dormant.   However, before these tubers can enter
true dormancy, rapid metabolism of the periderm (Ali et al, 1975) and
inhibition of the starch synthesizing enzymes occurs (Burton, 1965).   This
activity delays the onset of true dormancy by several weeks for some
varieties after haulm destruction (Wurr, 1978 b).

In this review dormancy may comprise the 'resting period' and part of the
'sprouting period'.

The resting period is the period during which the tuber will not sprout even
given favourable growing conditions (Moorby, 1978).   For the variety
Kennebec, the resting period is approximately 6 weeks at a storage
temperature of $20^{o}C$ (Bogucki and Nelson, 1980) but this period can be
considerably extended by lower temperatures and the degree of immaturity of
the tuber at the time of haulm destruction (Wurr, 1978 b).   The effect of
the growing conditions of the previous season only influences the length of
the rest period when extremes of temperatures and water stress are
experienced by the growing crop (Wurr, 1980; Burton, 1966).

Between the resting period and the date of planting is the sprouting period. The onset of the sprouting period is recognised by the seed tuber sprouting when it is given suitable growing conditions. However, when tubers are stored at temperatures non conducive to sprouting, i.e. below $4^{o}C$ (Allen et al, 1980), the start of the sprouting period may pass unobserved since sprouts will not develop.

'Dormancy break' is generally taken as the date when sprout activity becomes visible after storage temperatures climb above the critical $4^{o}C$ limit only after the completion of the resting period.

Ambient temperatures commonly experienced during Tasmanian winters in shed storage release the tuber from the resting period during July. The apical sprout is the first to develop and over several weeks the remaining sprouts 'move' in basipetal succession (Milthorpe and Moorby, 1967). The rate of growth of the apical sprout is a function of temperature (Short & Shotton, 1968) and where warm conditions prevail the main sprout which has benefited from a longer growing period, exerts apical dominance over the small lateral sprouts. Therefore by planting time, such tubers bear relatively few growing stems.

Apical dominance can be avoided by storing tubers at sprout-inhibiting temperatures until all the buds have an equal opportunity for growth and apical dominance has less chance to establish itself (Morris, 1966).

0.2.2.2 P-aging during the Sprouting Period

It is now generally accepted that commencement of sprout growth marks the start of the p-aging process (Reust, 1978, Allen et al, 1980, Wurr 1980). O'Brien et al (1983) identified the onset of p-aging after the appearance of a 3 mm sprout. It has also been shown that the rate of sprouting is affected by temperature . Wurr (1978) calculated that total sprout length is a linear function of the sum of the day degrees above $0^{o}C$ but Headford (1962) and Short and Shotton (1970) described it as a quadratic relationship. Allen et al (1980) observed that for many varieties the length of the longest sprout, which is usually from the apical bud, is linearly related to the sum of the 'day degrees' above $4^{o}C$ after the end of

the rest period .

The significance of such a relationship means that the concept of p-age can be described mathematically as day degrees above $4^{\circ}C$.

$$P\text{-age} = \sum_{SPO}^{SPt} (\text{average daily temperature} -4^{\circ}C)$$

SPO is the beginning of the sprouting period.

SPt is the number of days elapsed during the sprouting period or until planting.

Using this model, p-age is entirely dependent on the date of the beginning of the sprouting period and the temperature regime thereafter.

High average temperatures accelerate the rate of p-aging whilst maintaining seed at $4^{\circ}C$ holds the p-age at zero. A more complex relationship exists where seed is stored below $4^{\circ}C$ (Allen et al. 1980).

To reiterate, the consequence of preventing the accumulation of p-age by storing potatoes at $4^{\circ}C$ after the rest period, is that all buds are slowly released from dormancy. Thereafter, when storage temperatures are raised, the sprouts compete equally and multi-sprouted tubers, which are still p-young, would be produced.

However, where tubers are stored at temperatures greater than $4^{\circ}C$, the apical sprout, being the first to be released from dormancy, begins growth and successfully inhibits the growth of the lateral sprouts as soon as they emerge from dormancy. In this case tubers, which are also p-young, tend to have fewer sprouts.

Where such tubers are not planted immediately and are maintained in warm storage conditions, the apical dominance which inhibited the lateral sprouts has been observed to weaken as the tuber ages. Eventually the lateral sprouts overcome the inhibition, particularly so for the sprouts towards the stem end of the tuber, and commence uninterrupted growth. The tuber then becomes multi-sprouted although in this case, because of the long exposure to warm temperatures, it is p-old.

The number of sprouts on seed tubers can therefore be greatly influenced by management of storage temperatures during the sprouting period. Iritani et al (1983) observed that increasing p-age tended to increase the number of stems which were produced from each set.

One of the causes of yield loss to Kennebec growers is the high percentage of oversize tubers this variety produces which have a tendency to internal cavities commonly called 'hollow heart'.These are unacceptable to either the fresh market or to the processors. To reduce such losses, growers presently plant at high densities so encouraging interplant competition and reducing average tuber size. A less costly method of reducing tuber size would be to increase stem density by manipulating p-age so as to produce multi-sprouted tubers.

0.2.2.3 P-aging during the Rest Period

Allen et al (1980) emphasized that p-aging cannot begin until the rest period is complete. Indeed the p-age at the end of the rest period is defined as zero day degrees.

The effects of temperature on shortening the length of the rest period have been described earlier in this review and substantiate the concept that the co-ordination of morphological and physiological processes within the potato is based on a heat activated internal mechanism (Sale, 1974; Hacket, Sands and Nix, 1979).

Although the internal clock of a resting tuber may be ticking at a different rate to that in a sprouting tuber, it is thought that the resting tuber is also influenced by temperature (Fedorets, 1977).

0.2.3 EFFECT OF P-AGE OF SEED AT PLANTING ON SUBSEQUENT GROWTH AND DEVELOPMENT

Of much greater importance to the potato industry than the length of the dormancy period or commencement of sprouting is the effect of the p-age of seed potatoes at planting on the development of the crop in the field

(Toosey,1964).

Allen et al, (1980) observed that increasing p-age at planting by increasing
the storage temperature and/or duration of sprouting, resulted in:

    (i)   earlier plant emergence

    (ii)   earlier tuber initiation

    (iii)   fewer tubers being set per ha

    (iv)   smaller final plant size and consequently reduced tuber
                 bulking rate

    (v)   increased susceptibility to water stress

    (vi)   increased optimum N applications

    (vii)   earlier senescence

While the extent of these effects may vary considerably between varieties,
the yield potential of all varieties is regulated by p-age at planting
(Allen et al, 1980, Iritani, 1968).

Figure 1 shows that p-older seed at planting is quicker to emerge and
initiate tubers and therefore gives a greater early yield.   For main crop
varieties the advantages of using p-older seed to produce high early yields
are less marked that in early varieties.

For most varieties p-younger seed gives higher yield from late harvests
where the season is of sufficient length to allow the development of the
full potential yield (Allen et al, 1980).   However, seed of zero p-age at
planting is often slow to emerge as sprouting has not commenced, and a crop
planted with such seed may never attain its potential yield (Allen et al,
1980).

Fig. 1.   The relationship between physiological age and tuber yield for cv.
Desiree and Pentland Javelin (Allen et al, 1980).

Number of Day.degrees above 4°C.
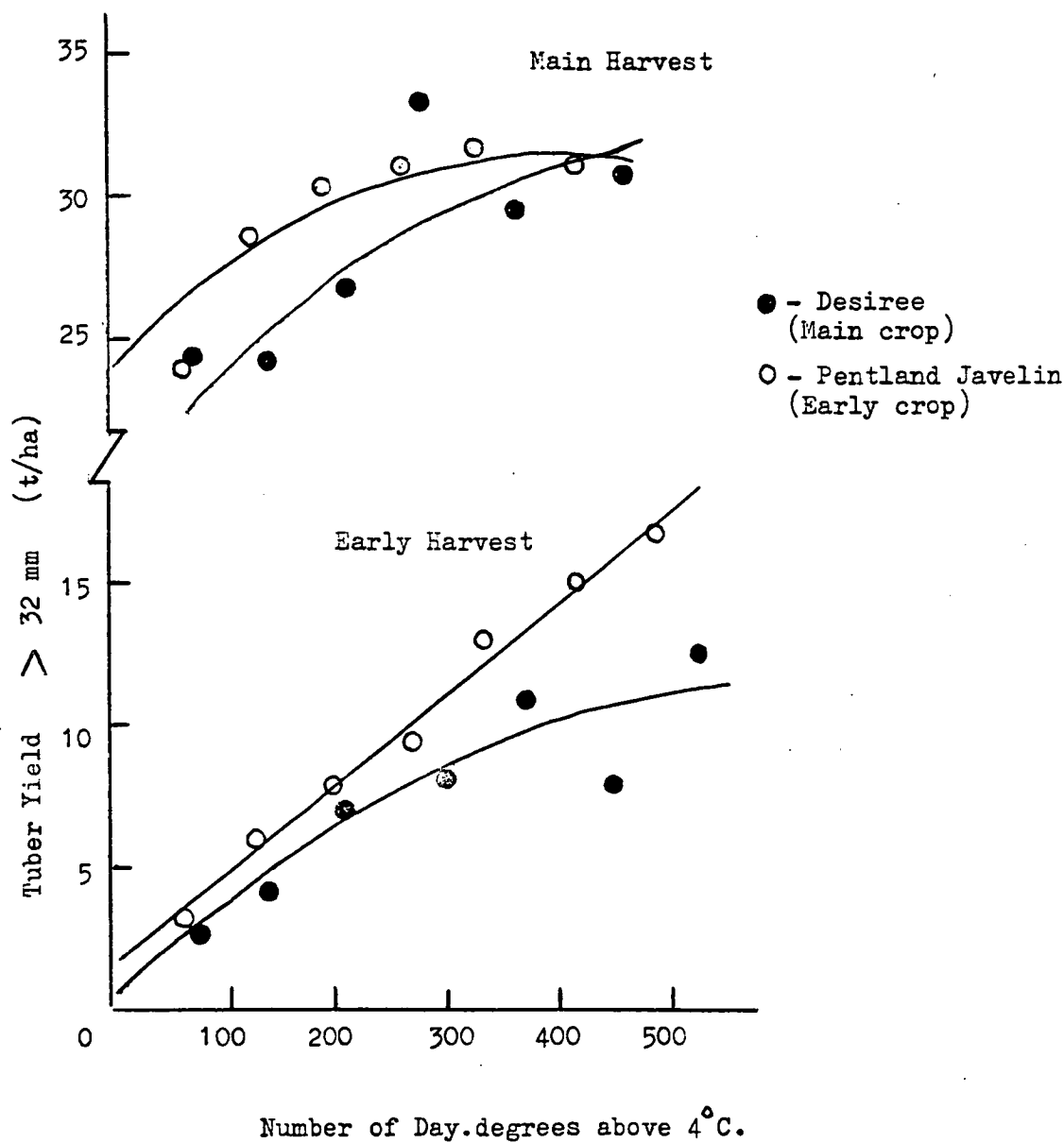
0.2.4 OPTIMUM P-AGE AT PLANTING

The most suitable p-age for seed at planting depends on the intended usage for the crop as well as on the variety.

0.2.4.1   Early Ware Growers:

The highest prices are generally received for the earliest marketed crop and hence growth is restricted to a very short period.   Use of p-old seed will maximize early yields by reducing the times to emergence and tuberization (Allen et al, 1979).

Early crops are normally harvested well before maturity i.e. before the stage where the growth from p-old seed is out-yielded by p-young seed.

In Tasmania, the early ware crop represents only a small percentage of the total annual production. Varieties which are specifically grown for the early ware market are Pink Eye and Bismark (Chapman, 1977).

0.2.4.2.   Processing and Main Crop:

The major proportion of the total potato production in Tasmania is produced for processing into french fries. Varieties grown for processing are Kennebec and Russet Burbank. The bulk of processed potatoes are sold interstate (Chapman, 1977).

Fresh market production mainly supplies local Tasmanian markets and as it represents only a fraction of the total crop it tends to rely on surplus Kennebec and Russet Burbank for its main varieties.

Growers supplying the factories as well as the fresh market aim at reducing costs at the same time as increasing yields.

Seed with a low p-age produces optimum yields over a long growing season. The exact p-age corresponding to the maximum final yield would be expected

to vary considerably between varieties.   It has yet to be determined for Kennebec and Russet Burbank.

0.2.4.3   Seed Growers:

Seed growers are restricted by both the length of the growing season and the size of the tubers required.   Traditionally seed growers plant at high densities, aiming to reduce mean tuber weight by inter-plant competition. The strategic use of physiological aging to increase stem number per tuber and hence aid small tuber production through intra plant competition may be adopted.

0.2.5   FACTORS CONTROLLING THE RATE OF P-AGING

Although the measure of sprout length appears to give a reasonable indication of the physiological age of a seed tuber and an accurate prediction of the subsequent growth in the field, sprout length does not always reflect the physiological state of seed tubers (Wurr, 1980).   The most obvious example occurs when p-old tubers are desprouted.   Even without sprouts, they still remain as p-old tubers.

A number of factors will control the sprout development of a seed tuber however, these factors need not always affect p-age or the growth in the following season.

0.2.5.1 Light Intensity During Storage

The effect of light strongly inhibits elongation of the sprouts (Morris, 1967).   During the sprouting period, the sprouts become short, thick, and green, although their development continues with the initiation of root and stolon primordia (Breyhan, 1964).

After planting in the field, light-exposed sprouted tubers have been observed to perform equally against a crop grown from the same tubers stored

in the dark (Short & Shotton, 1968).Although the rate of sprout elongation is retarded by light, there is no evidence suggesting that the rate of accumulation of p-age is also reduced.

0.2.5.2 Relative Humidity in Storage

Van Vliet (1978) observed that low relative humidities during storage reduce the length of the rest period and may even affect the sprouting rate.   On the contrary, Davidson (1958) found no such effects by the humidity on the rest period.

It is still uncertain how the relative humidity affects the physiological aging process of tubers in storage.

0.2.5.3   Temperature during Storage

The control of rate of p-aging by storage temperatures on both the length of the rest period, and also the rate of sprouting, have already been quantified in this review.

However, temperatures during the rest period have been noticed to subtly interfere with the subsequent rate of sprout elongation, i.e. when tubers were stored at high temperatures (20°C) during their rest periods, the sprouting rate was significantly lower (Bogucki and Nelson, 1980).

Therefore the temperature during the rest period may be expected to contribute to the rate of p-aging apart from its direct influence on the length of the rest period.

0.2.5.4 Variety

Earlier in this review the length of the rest period was shown to be variety dependent.   The sooner the rest period ends, the more time there is available for p-age to accumulate.

Bogucki and Nelson (1980) studied ten different American varieties over their resting and sprouting periods. Throughout a range of temperature treatments Russet Burbank and Kennebec consistently required longer rest periods, produced fewer sprouts and showed slower sprouting rates than the other varieties tested. Allen and Scott (1980) noted that early varieties tended to produce a greater response to p-age.

Wurr (1978a) and Allen et al, (1980) compared the effect of accumulated p-age during the sprouting period on the growth in the field by different varieties. Optimum growth in the field coincided with significantly different p-ages at planting for all the varieties studied. For some varieties increasing the p-age reduced the number of tubers set per plant (Allen et al, 1979). These varieties are common to the U.K. whilst Australian varieties which generally descend from U.S.A. lines have not been studied.

0.2.5.5   Effect of Previous Season

Although a number of environmental factors operating during the development and growth of seed crops, affect their potential for growth in the next season it is still unknown how they act (Went, 1959, Bodleander, 1973, McCown & Kass, 1977).

However, it is believed that early planting and harvesting, water stress, high temperatures and nutrient deficiency which all encourage rapid aging of the crop in the field, can bring forward the cessation of growth and the onset of dormancy (Reust, 1978, Wurr a & b, 1978, Umaerus & Roslund, 1979, Wurr, 1980).

Wurr (1978 b) observed that an early rest period induced by defoliation or high growing temperatures was followed by an early sprouting period. Consequently the extent that p-aging can occur before the next season's planting date, for such seed, would be considerably more than for seed produced under ideal management.

O'Brien et al (1986) observed that by planting seed crops of advanced physiological age, the progeny seed tubers had a shortened dormancy and

slightly increased sprout lengths at replanting. However, they concluded that any carry-over effect from the previous season was small, and of no commercial significance.

Furthermore, O'Brien and Allen (1986) found that where and how seed crops were grown in the previous season was not significant as a factor controlling yield of the resulting progeny crops. Differences in yield could be explained by the different storage temperatures between the time of harvesting and replanting. Thus any differences in the growth of the progeny crops were explained by differences in their physiological age at replanting.

0.2.6   APPLICATION OF PRINCIPLES

Once the optimum age of seed for a variety has been determined with regard to the purpose of the subsequent crop, seed of this p-age may be produced by manipulating the temperature of storage in relation to the end of the rest period and the expected date of planting. The use of an accumulated day degree scale allows seed of the required age to be produced each year if the appropriate control of temperature is available.

As few commercial growers in Tasmania have adequate control over sprouting temperatures, at present their direct manipulation of p-age is restricted. However, by recording their storage temperatures they can accurately predict the rate that their seed will p-age. Working backwards from the optimum p-age for their planting date and intended harvesting time, growers can then determine the date their seed should enter the sprouting period. Since commercial growers buy seed during the storage period they should attempt to obtain seed of that p-age which will synchronize with their storage and planting regime.

The end of the resting period is affected by climate and management techniques, and should be closely correlated to planting and harvesting dates as well as the locality in which it was grown. The use of such factors to predict p-age at planting requires close liaison between seed producers and commercial growers.

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1. EFFECT OF PRE-SPROUTING KENNEBEC SEED TUBERS

1.1 INTRODUCTION

Whether seed potatoes are cool stored, or maintained at ambient temperatures, in Tasmania they are generally encouraged to sprout prior to being planted.

Degree of sprouting has been quantified by O'Brien et. al. (1983) by their introduction of the term physiological age. Physiological age is defined as the product of the number of days in which seed potatoes are stored after dormancy break until the date of planting, and the average daily temperature during this period above a base temperature of $4^{O}C$. The accumulated p-age at the time of planting was found to be proportional to the length of the longest sprout on the p-aged seed tubers (Allen et al,1980).

In Exp.1 a field trial was carried out at Elliott Research Station in order to investigate the effects of five levels of p-age imposed on both cut and round Kennebec seed.

1.1.1 Aim

The aim of Experiment 1 was to quantify the effect of physiological age of seed tubers at the time of planting, on subsequent development and yield of a Kennebec crop.

1.2 MATERIALS AND METHOD

1.2.1 Physiological Aging of Seed

Within two weeks of harvesting, seed which was to be used for Experiment 1 was placed in store and held at $4^{O}C$, to inhibit any physiological aging.

At a date determined by the requirement for physiological age of each treatment (Table 1.1), seed was transferred from the cool store into crates. Tubers were packed with their apical sprouts uppermost (Plate 1.1). Crates were then stacked in an illuminated growth chamber, which was maintained at $20^\circ C$ by a thermostatically controlled, domestic fan heater. Lighting was supplied by 3 fluorescent tubes which were suspended vertically between the stacked crates. The chamber was lined with reflective aluminium foil.

Physiological-age (p-age) treatments are detailed in Table 1.1.

Seed tubers were removed from the $20^\circ C$ chamber on the eve of planting, for cutting, weighing and bagging in preparation for planting (28/10/81).

Seed tubers which weighed between 80 to 120g were cut on the day before planting. Tubers were sliced in half through the apical bud to the stem scar.

Tubers weighing between 40 and 60g were kept as round seed.

1.2.2 Field Trial

A field trial was carried out at Elliott Research Station (E.R.S.)which is situated at an elevation of less than 300m on the N.W. coast of Tasmania at a latitude $41^\circ 04'S$, and longitude $145^\circ 46'$ E. Meteorological data for E.R.S. for 1981-82 and 1982-83 are available in Appendix 1.

The field trial comprised ten treatments which were replicated three times in two adjacent blocks; one block was intended for serial harvests (plots 1-30) and the other for a final harvest (plots 31-60). The field plan is shown in Fig. 1.1.

The ten treatments were made up of the five physiological ages (Table 1.1) and the two seed types, cut and round.

Plots 1-30 were six rows by six metres long. Two pairs of rows in each plot contained twelve subplots of eight plants. From each plot one subplot was randomly selected for serial harvests at seven to fourteen day intervals.

The eight plants (two rows by four plants) were surrounded by buffer plants. On either side was a single buffer row of Kennebec which remained unharvested. On either end of the subplots' rows were single Brownell plants. Being red-skinned, the Brownells were readily distinguished from the white skinned Kennebecs, and so reduced the possibility of inadvertently including foreign tubers whilst harvesting subplots.

Plots 31-60 were four row plots, six metres long. Three of the four rows were harvested as soon as the crop had senesced. The remaining row was a buffer row of Kennebec. At both ends of the three rows, were Brownell plants. These were also buffer plants and were not included in the final harvest.

Table 1.1 Physiological age treatments of seed potatoes

Physiological age day degrees >4°C	Date seed transferred to 20°C	Days at 20°C until planting
0	–	0
250	12/10/81	16
500	27/9/81	32
750	11/9/81	47
1200	14/8/81	75

Although the seed bed and furrows were prepared mechanically fertilizer placement and planting was done by hand. Fertilizer was 5:6:9: N:P:K, and applied at 2500 kg/ha. Sets were placed on top of the fertilizer, 200mm apart along the rows. Rows were 810mm wide. Planting density was 6.4 plants per square metre. After planting, the furrows were harrowed in. Weeds were controlled by cultivation and plants were hilled when they had grown to 300mm height. The trial was irrigated when estimated soil water deficit approached 35mm, with the amount applied being sufficient to return

Fig. 1.1   Experiment 1 Field Plan

51	52	53	54	55	56	57	58	59	60
0	500	1200	750	250	0	500	750	1200	250
R	C	C	C	C	C	R	R	R	R

41	42	43	44	45	46	47	48	49	50
0	750	500	250	1200	750	250	500	0	1200
R	C	R	R	R	R	C	C	C	C

31	32	33	34	35	36	37	38	39	40
0	250	750	1200	1200	250	750	500	500	0
C	C	R	R	C	R	C	R	C	R

21	22	23	24	25	26	27	28	29	30
750	250	0	1200	500	1200	0	250	500	750
R	C	R	C	R	R	C	R	C	C

↕ 1.1m

11	12	13	14	15	16	17	18	19	20
250	250	1200	0	1200	750	500	500	750	0
C	R	C	R	R	C	R	C	R	C

1	2	3	4	5	6	7	8	9	10
250	500	1200	500	0	250	750	1200	750	0
R	R	C	C	C	C	C	R	R	R

↕ 6m

o   Kennebec buffer plant

●   Kennebec experimental plant

◉   Brownell buffer plant

eight-plant subplots

the soil to field capacity. Consequently the crop received eight waterings, at approximately ten day intervals from mid December.

1.2.3 Method of harvest and measurement

Subplots were harvested throughout the crops' growth period on the dates outlined in Table 1.2.

Entire plants excluding the roots were dug manually by fork. Haulms were weighed and leaf area was recorded on a 500g sample from each plot, using a planimeter. Total leaf area and leaf area index (L) for the subplots were then calculated.

The presence of any primary and secondary stolons and tuber initials were recorded, on all plants from the subplots. Any tubers greater than 1g were weighed individually. Definitions of potato plant parts are shown in Fig 1.2.

Plant height was measured with as little disturbance to the crop as possible by holding a metre ruler vertically in the crop and estimating the average height of apical buds of adjacent plants. Measurements were taken in three different positions in each plot for plots 31-60.

Light interception was recorded by tube solarimeters (Delta T. Instruments, Cambridge, U.K.) strategically placed within the crop; again using the large plots 31-60. One solarimeter tube was placed below the canopy to measure the amount of sunlight which was transmitted by the crop, S_L. A second solarimeter tube was mounted above the canopy to record the total radiation available, S_o. As the solarimeter tubes were approximately 900mm in length, the tubes below the canopy were angled across the 810mm rows so that they straddled the furrows with either end resting on the crown of adjacent ridges. If the tops of the ridges were not level, the lower end was supported, making the solarimeter tube horizontal. In-coming radiation was measured over a five minute interval, with recording occurring only between 10.00 a.m. and 3.00 p.m. A third solarimeter tube was mounted in the ERS meteorology station, to collect total light receipts over the growing

TABLE 1.2   Serial Harvests, dates and records

Harvest Number	Date	Plant Records				
		Light Interception	Height	Haulm	L	Tuber Weights
1.	20/11/81	-	-	*	*	-
2.	1/12/81	*	*	*	*	*
3.	8/12/81	*	*	*	*	*
4.	16/12/81	*	*	*	*	*
5.	23/12/81	*	*	*	*	-
6.	31/12/81	-	-	*	*	*
7.	11/1/82	*	*	*	*	*
8.	26/1/82	-	*	*	*	*
9.	9/2/82	-	-	*	*	*
10.	23/2/82	-	-	*	-	*
11.	10/3/82	-	-	-	-	*
12.	13/5/82	-	-	-	-	*
13.	13/5/82	-	-	-	-	*

Fig. 1.2   The Potato Plant
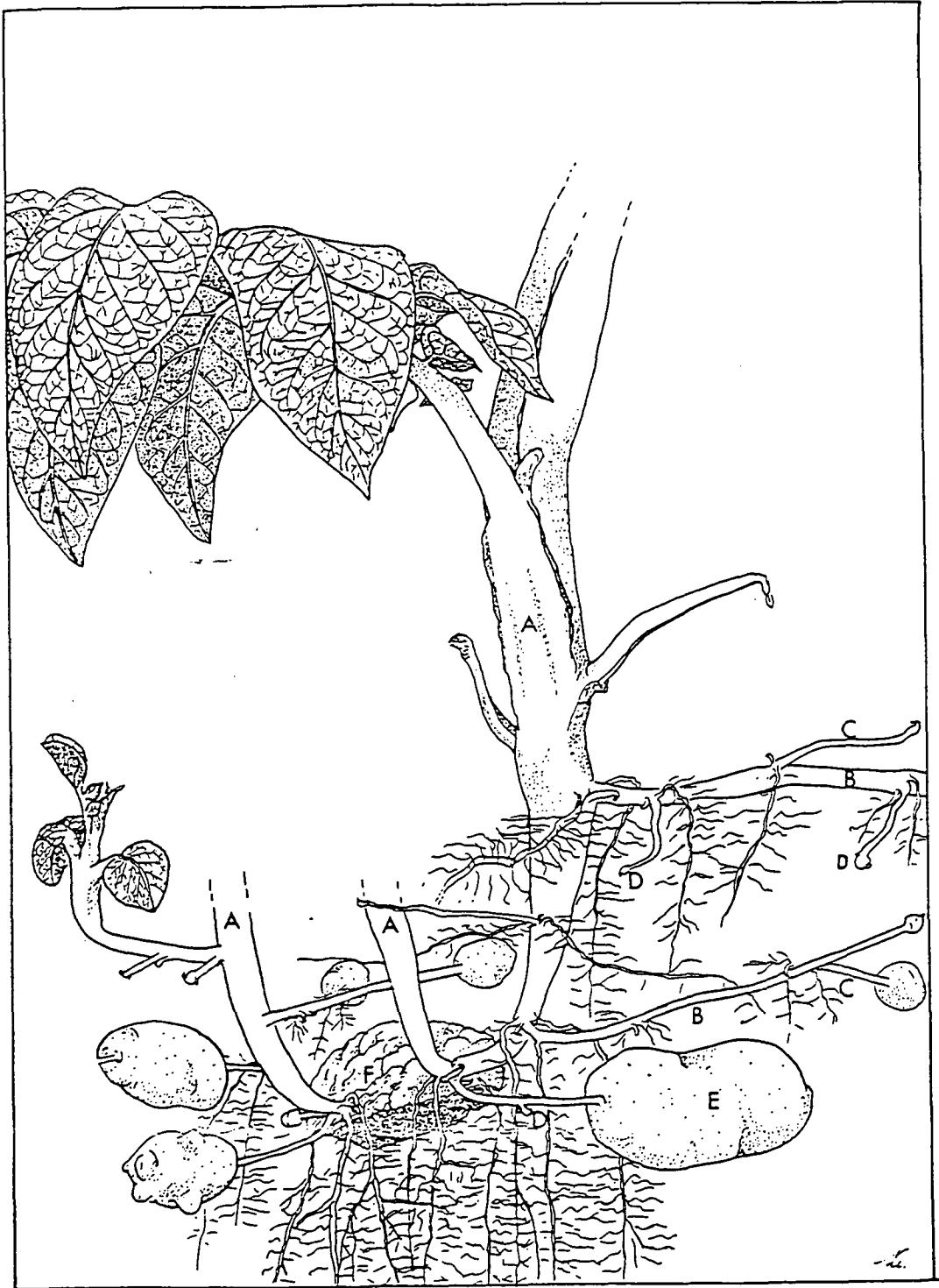
A = Main stem
B = Primary stolon
C = Secondary stolon
D = Tuber initial
E = Tuber
F = Mother tuber

season. The tubes measure total incoming short wave radiation, including visible and infra-red. Visible, or photosynthetically active radiation accounts for about 50% of incoming radiation.

Harvesting of plots 31-60 occurred on the same date as harvest 12 of plots 1-30. Each of the three rows per plot was individually harvested by a single row digger and bagged manually. Tubers of the middle rows were later individually weighed, whilst the two outer rows were hand graded, weighed and counted into the following size categories; 0-80g, 80-120, 120-250, 250-350, 350-450 and greater than 450g.

Individual tuber weights were recorded automatically by a Mettler top loading balance which was coupled to an Apple micro-computer. Data from the Apple was later transferred to a PDP11 mini-computer for further analysis. The individual tuber weights were also copied onto Micro-fische (Appendix 2).

Plate 1.1   Seed tubers of greater physiological age had larger sprouts with
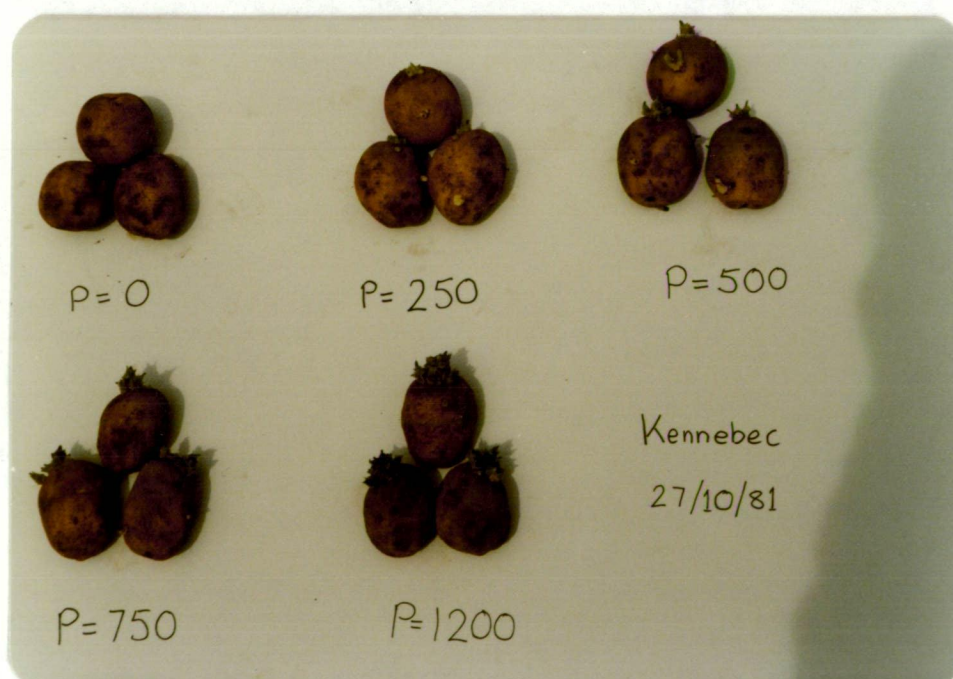lateral branching, 27/10/81.

Plate 1.2   Individual seed potatoes after physiological age treatments. Note
the greater subapical sprout growth on p-young seed, 27/10/81.

1.3 RESULTS

1.3.1 Seed Treatments

The degree of sprout growth on seed tubers by the time of planting was dependent on the physiological age treatments (Table 1.3, Plate 1.2).

TABLE 1.3. Sprout Development at the Time of Planting

P-age	No. of Days at $20^{O}C$	Length of Apical Sprout mm	No. of Sprouting Eyes
0	0	0	0
250	15.6	11.1 ± 2.2*	6.6 ± 1.3
500	31.2	16.7 ± 4.8	5.4 ± 0.7
750	46.8	15.7 ± 3.4	6.1 ± 1.1
1200	75.0	22.5 ± 4.9	4.5 ± 2.0

* Standard error from 10 randomly selected tubers/treatment.

Sprouting of seed tubers, maintained at $4^{O}C$ was inhibited. The apical sprout on tubers which were exposed to the various periods of time at $20^{O}C$, showed initial rapid growth of over one mm/day. However, the rate of sprout elongation declined with time so that tubers which had been at $20^{O}C$ for 75 days (P-1200) averaged apical sprouts of 22.5 mm. Simultaneously, lateral growth of the apical sprout was observed to be greatest on apical sprouts of the P-1200 seed tubers.

The rate of sprout growth was greatly influenced by light intensity. Apical sprouts which were not directly illuminated were longer than the average apical sprout for each treatment.

Subapical sprout growth appeared to be inhibited by increasing physiological age, as indicated by the decline in the number of sprouted eyes from 6.6 for P-250 to 4.5 for P-1200.

1.3.2 Emergence

Emergence of potato plants is variable and may take some weeks. Consequently, date of emergence was arbitrarily set as when 50% of the sets had emerged. It was calculated for each treatment by interpolation of plant emergence counts, which were recorded every 2-3 days around the time of 50% emergence.

The rate of emergence (Table 1.4) was dependent on physiological age of seed at planting. Seed of P-500 or more, attained 50% emergence 16 days after planting; the physiologically younger, P-0 seed required a further 6 days. The rate of emergence was not significantly affected by cutting seed.

TABLE 1.4   Number of days to 50% Emergence after planting on 28/10/81

P-age	Cut Seed	Round Seed
0	22	22
250	17	18
500	16	16
750	16	16
1200	16	16

TABLE 1.5.   Percentage Emergence on 20.11.81

| P-age	Cut Seed	Round Seed
0	75.4%	86.1%
250	96.8%	86.4%
500	95.4%	90.7%
750	97.9%	97.9%
1200	93.6%	98.2%

1.3.3 Stems

Emergence was not complete on 20/11/82, when the last plant count was recorded (Table 1.5). However, field observation during the growing season indicated that emergence approached 100% for all the round seed treatments except the P-1200 seed which may not have exceeded the 98% emergence recorded on 20/11/81. By cutting seed, final emergence was reduced, particularly for the physiologically older treatments. It was estimated that emergence of the P-1200 cut sets did not increase over the 94% in Table 1.5.

Only primary stems originating from the parent tuber (Fig 1.2) were included in the number of stems per hectare. Branching of mainstems rarely occurred below ground. However on such occasions, branched (secondary) stems were included in the stem count when they had a sufficient number of underground nodes bearing stolons and tubers.

Destructive sampling was used to determine stem numbers in the serial harvest (plots 1-30), and hence there was no confusion in identifying primary stems. However stems of the final harvest plots (plots 31-60) were counted after senescence of the haulms. By this time some of the stems had started to decay and were difficult to count. Branching of these stems were detected by pulling stems as they were counted.

Stem numbers are shown in Fig. 1.3. For both sets of data, stem numbers increased with increasing p-age up to 250-500 day degrees $> 4^{O}C$ and decreased thereafter with stem numbers being comparable for 0 and 1200 p-age treatments. Stem numbers were consistently greater for round seed. This difference was more than could be accounted for by the 2-5% difference in emergence.

Fig 1.3 Effect of physiological age on the number of stems per hectare
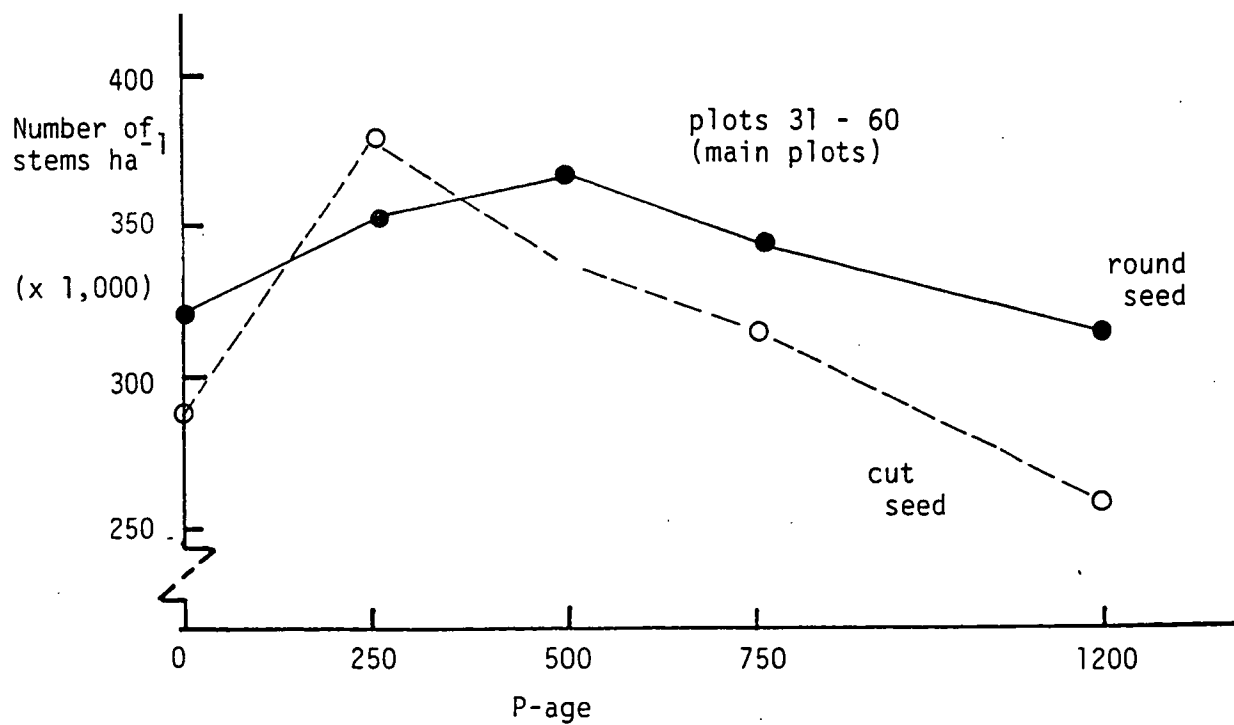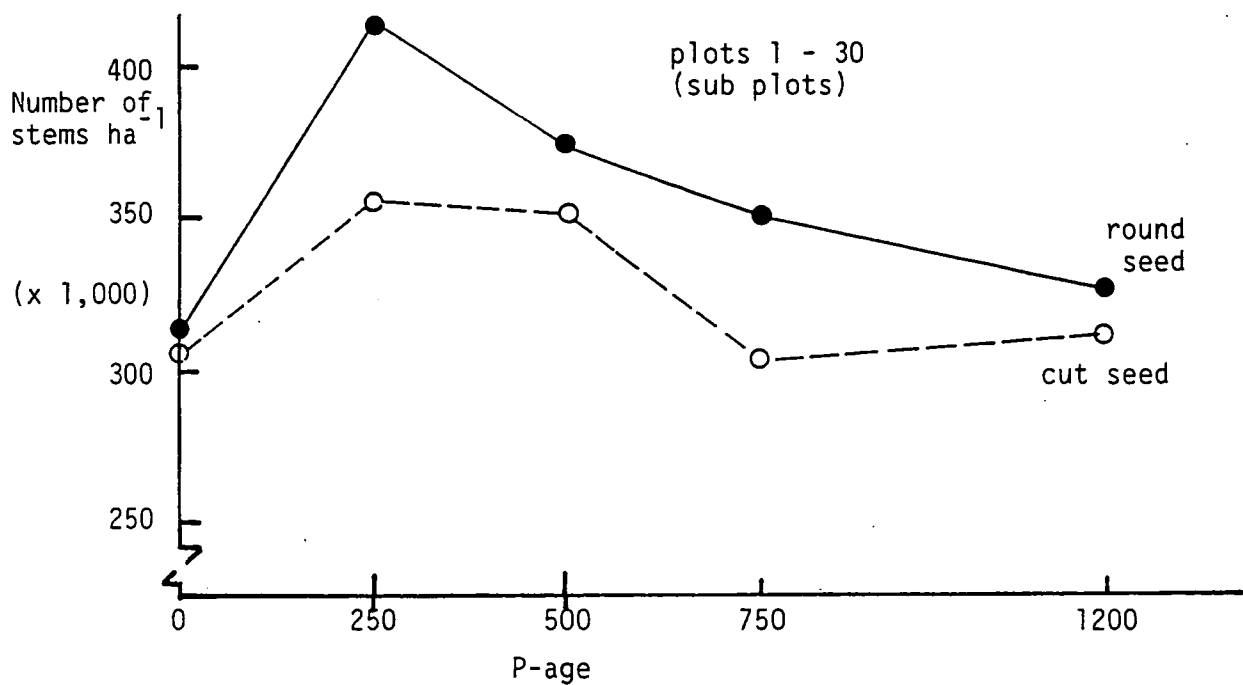
1.3.4 Development of Stolons and Tuber Initials

Stolons were observed on 20/11, within one week of emergence of plants. Tuber initiation was visible on p-older plants by 1/12, but was delayed until 16/12 for p-zero treatments.

On 9/2/82, by which time no more stolons or initials were likely to develop, eight plants were harvested from each physiological age treatment of the round seed, and the stolons and tuber initials counted on each stem. Stolons were classified into two categores, primary and secondary. Primary stolons were those originating from the main stem, and secondary stolons were those branching off the primary stolons (Fig 1.2).

Tuber initials were counted on both primary and secondary stolons. Stolons were classed as 'initiated' when the tip had swollen to at least twice the diameter of the rest of the stolon. Where stolons were broken during harvest, it was assumed this was due to the weight of a tuber and consequently broken stolons were counted as having initiated tubers. Of the primary stolons tuber initiation occurred on approximately 90% with little variation between treatments.

Initiation on the secondary stolons ranged from 17 to 33%. The numbers of stolons and tuber initials were affected by the physiological age of seed (Table 1.6). With increasing p-age, primary and secondary stolons increased, as well as proportional increases in the number of initials on both. Primary stolons increased from around 5 to 6 per stem with a similar increase in their initials. Secondary stolons were more significantly affected by physiological age, increasing from less than 1 to around 3 per stem, but on these the number of tuber initials even on the p-old treatments still averaged less than one per stem.

TABLE 1.6.   Numbers of Stolons and Tuber Initials as Affected by
              Physiological Age of Seed

	Physiological age				
	0	250	500	750	1200
Primary stolons/stem	5.08±1.36*	5.50±1.48	5.37±1.62	5.96±2.83	6.11±2.21
Primary initials/stem	4.97±1.36	5.12±1.39	5.16±1.44	5.22±2.65	5.60±2.28
Secondary stolons/stem	0.86±1.19	2.73±2.54	1.79±2.24	2.91±3.20	3.14±3.25
Secondary initials/stem	0.15±0.44	0.47±0.99	0.60±1.10	0.97±1.53	0.90±1.40

Standard error of the mean, when n = number of stems from
  sample of eight plants grown from round seed.

1.3.5 Plant Height

Physiological age of seed prior to planting, affected the early rate of
plant growth and the final crop height (Fig. 1.4). Although the P-0 seed's
emergence was retarded by six days, their early rate of growth was similar
to that of the other treatments. P-250 plants were also slow to emerge, but
showed a faster early growth rate than the P-0 plants, enabling them to
attain the same height as the other treatments by early December. By mid
January the P-0's equalled the height of the other treatments, and as they

continued to grow when the remaining treatments had begun to lodge, the P-0's eventually produced the tallest canopy. Lodging was not observed in any treatment until the end of January. Final heights of plants were inversely proportional to their physiological ages at planting; the P-0's achieved 0.69 m and the P-1200's only 0.59 m.

There were no significant differences in the crop heights at any time between plants from cut or round seed of the same p-age (Fig. 1.5) although round seed tended to produce a taller canopy for each treatment, with the possible exception of P-250.

1.3.6 Crop Canopy

Haulm weights and leaf area indices (L) are recorded in Tables 1.7 and 1.8.

In Fig.1.7 a non linear regression of the form:

$$L = a \times days^b (125 - days)^c$$

was fitted for leaf area index (L) against time (days). This equation has no biological interpretation but was used to smooth data to highlight trends shown in Table 1.8. The resulting curves showed consistent trends for the effects of p-age on the development of L over time for both cut and round seed.

Although P-1200 plants emerged earlier and produced more leaves in the first month of growth they were soon overtaken by p-younger plants. P-250 plants from both cut and round seed attained the largest canopies with L approaching 7. P-0 plants were delayed in their emergence but managed to eventually achieve greater canopies than all the treatments except those of P-250. For both cut and round seed, P-1200 plants produced the smallest canopy with their leaf area indices peaking at 5.1 and 5.3 respectively.

Fig 1.4 Effect of physiological age on plant height
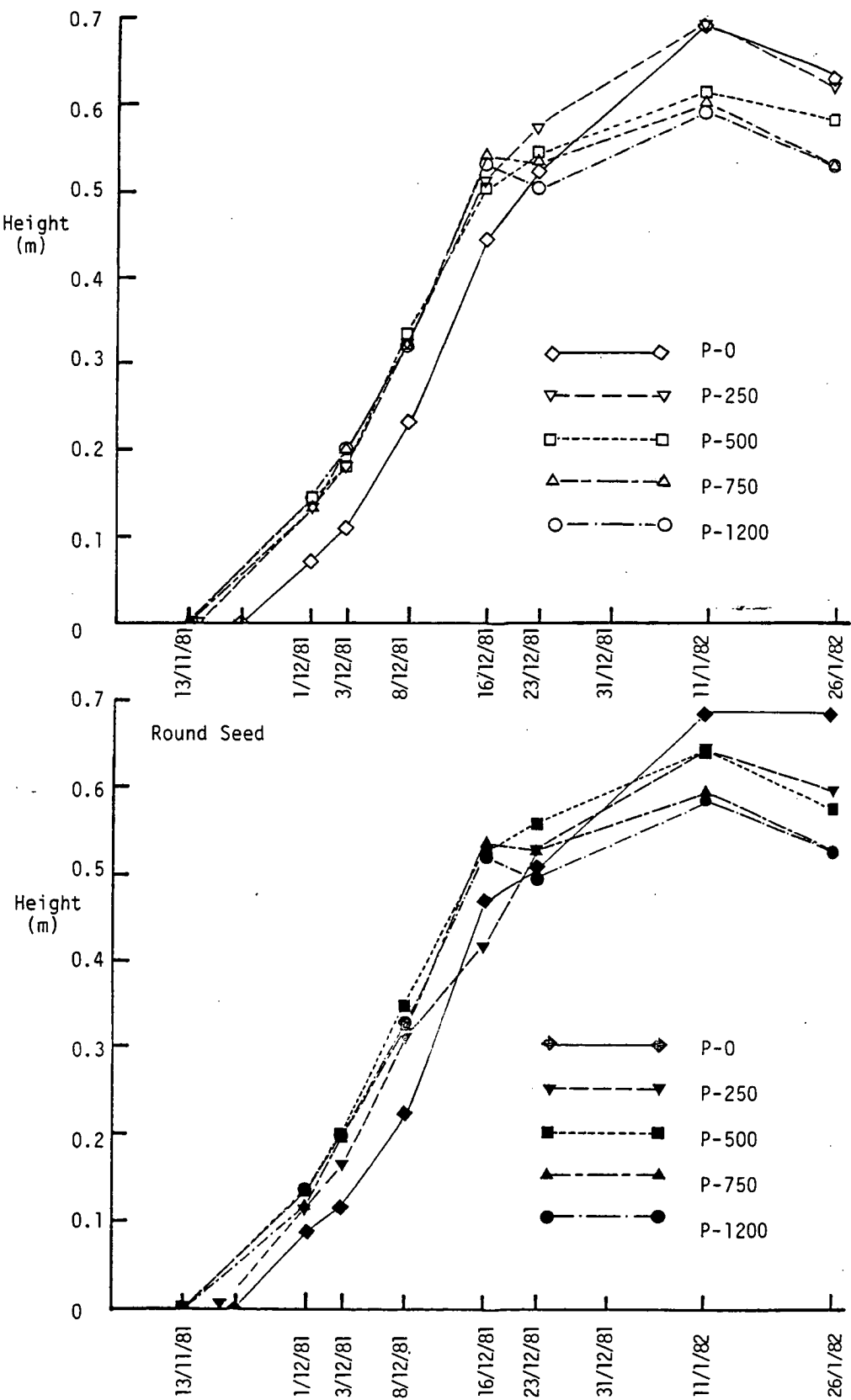
Fig 1.5 Physiological age and the effect of cutting seed on plant height
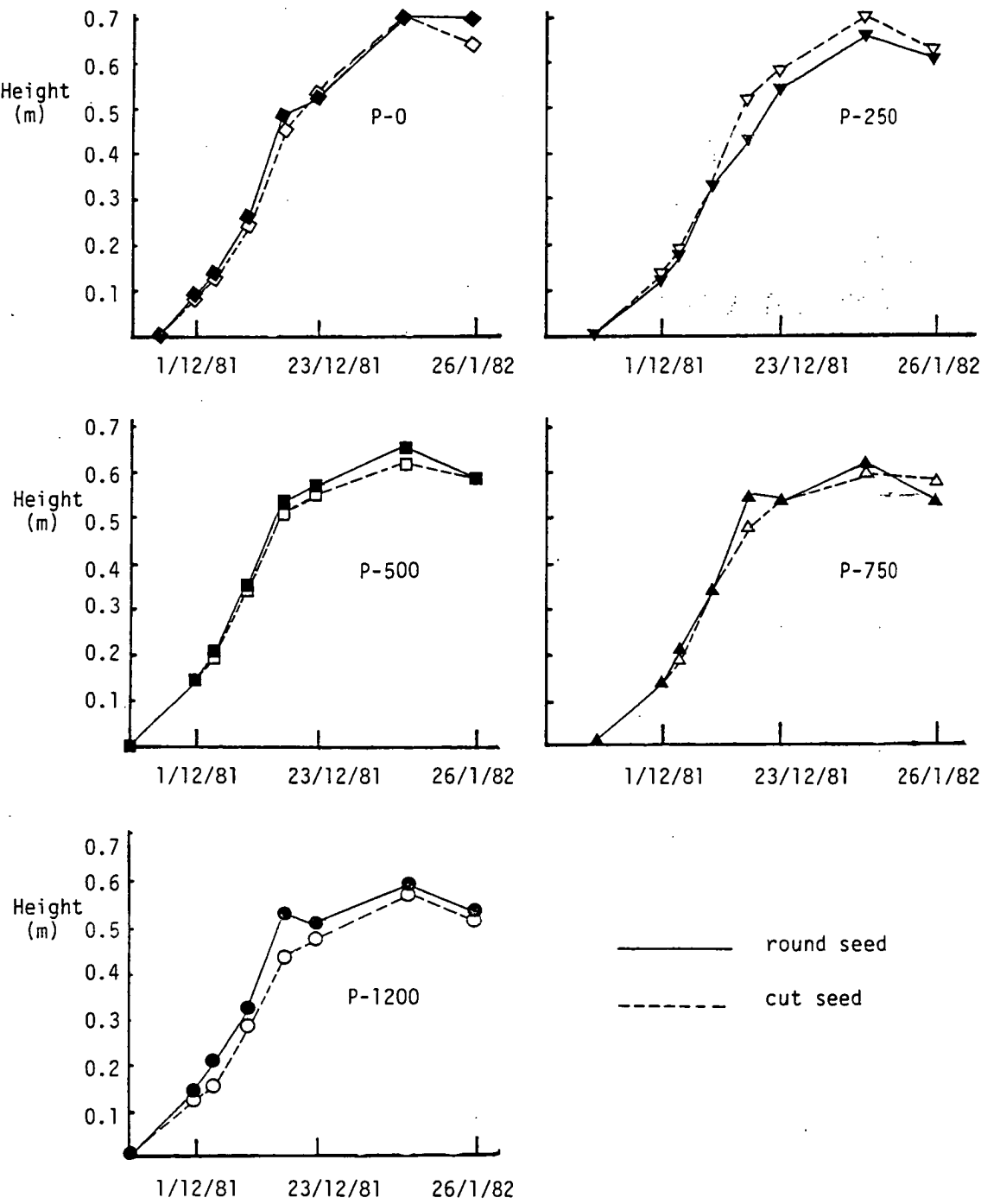
Fig 1.6 The effect of physiological age on the relationship between Leaf Area Index (L) and height
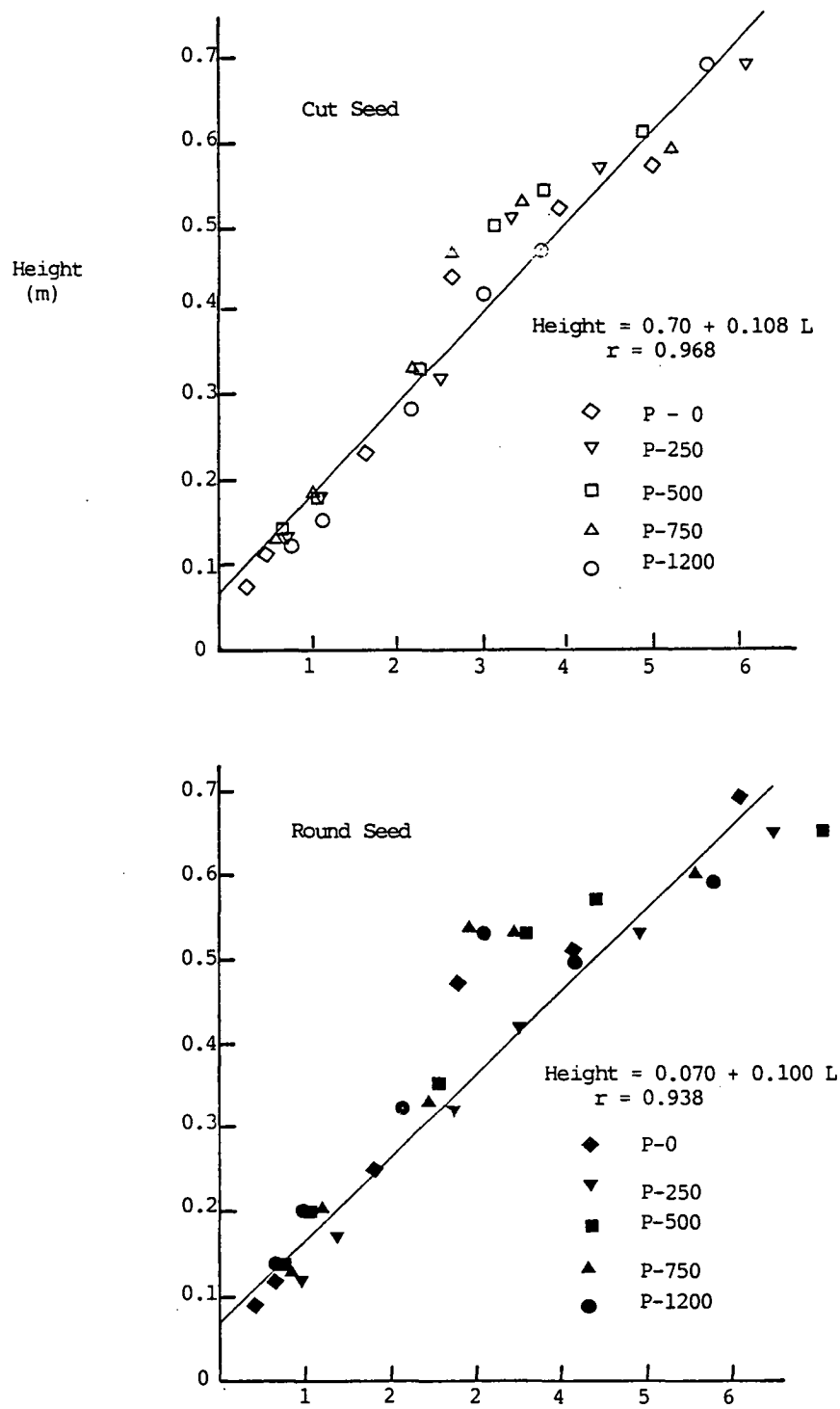

Cut Seed

Height = 0.70 + 0.108 L
r = 0.968

◇ P – 0
▽ P-250
□ P-500
△ P-750
○ P-1200

Round Seed

Height = 0.070 + 0.100 L
r = 0.938

◆ P-0
▼ P-250
■ P-500
▲ P-750
● P-1200

Height (m)

TABLE 1.7. Haulm fresh weight (t/ha)

Harvest No.	Date	Treatment (P-units)									
		\multicolumn{2}{c}{0}	\multicolumn{2}{c}{250}	\multicolumn{2}{c}{500}	\multicolumn{2}{c}{750}	\multicolumn{2}{c}{1200}
		Cut,	Round	Cut,	Round	Cut,	Round	Cut,	Round	Cut,	Round
1	20/11	.02,	.29	1.48,	1.52	1.47,	2.00	1.04,	1.48	1.28,	1.43
2	1/12	4.54,	5.90	10.14,	12.18	9.74,	12.11	8.94,	10.14	10.37,	9.14
3	8/12	16.07,	17.34	24.51,	26.08	22.11,	24.25	21.34,	23.48	21.18,	20.63
4	17/12	26.09,	27.31	33.05,	34.15	31.32,	34.80	26.15,	28.31	29.63,	30.29
5	23/12	34.21,	35.82	38.08,	42.49	32.41,	37.99	30.22,	29.90	32.51,	36.01
6	31/12	42.48,	45.42	45.93,	48.50	36.95,	52.93	39.26,	42.57	37.81,	43.18
7	11/1	39.41,	49.66	53.78,	47.39	41.39,	41.05	41.88,	36.39	39.58,	33.45
8	26/1	38.73,	44.15	44.75,	47.58	33.79,	37.78	33.43,	34.17	28.97,	36.13
9	9/2	39.02,	30.66	33.96,	37.71	26.35,	34.70	27.33,	26.97	31.13,	26.20
10	23/2	11.71,	6.36	10.16,	3.54	7.57,	6.49	4.73,	3.11	5.63,	1.32

TABLE 1.8. Leaf area index (L)

Harvest No.	Date	Treatment (P-units)				
		0	250	500	750	1200
		Cut,Round	Cut,Round	Cut,Round	Cut,Round	Cut,Round
1	20/11	0.02, 0.02	0.15, 0.16	0.15, 0.20	0.11, 0.15	0.13, 0.15
2	1/12	0.51, 0.66	1.14, 1.37	1.10, 1.09	1.01, 1.14	1.17, 1.03
3	8/12	1.67, 1.80	2.54, 2.71	2.30, 2.52	2.22, 2.44	2.20, 2.14
4	17/12	2.67, 2.79	3.38, 3.50	3.21, 3.56	2.68, 2.90	3.03, 3.10
5	23/12	3.95, 4.14	4.40, 4.91	3.75, 4.39	3.49, 3.46	3.76, 4.16
6	31/12	5.67, 6.06	6.13, 6.47	4.93, 7.07	5.24, 5.68	5.05, 5.76
7	11/1	5.08, 6.40	6.93, 6.10	5.40, 5.29	5.39, 4.69	5.15, 4.31
8	26/1	5.43, 6.53	6.61, 7.03	4.99, 5.58	4.94, 5.05	4.28, 5.34
9	9/2	4.54, 3.57	3.95, 4.35	3.07, 4.04	3.18, 3.14	3.62, 3.05

By 26 January leaves of p-older plots had visibly yellowed more than the p-younger plots and L tended to decline earlier for p-older plots.

In Fig 1.6 L is plotted as a linear regression of H and a straight line is fitted to the data. A more convincing function may be a curve, however the important feature is that all the treatments are equally distributed along the line, with no treatments consistently falling above or below it.

Fig 1.7   Effect of physiological age on the development of leaf area index (L).
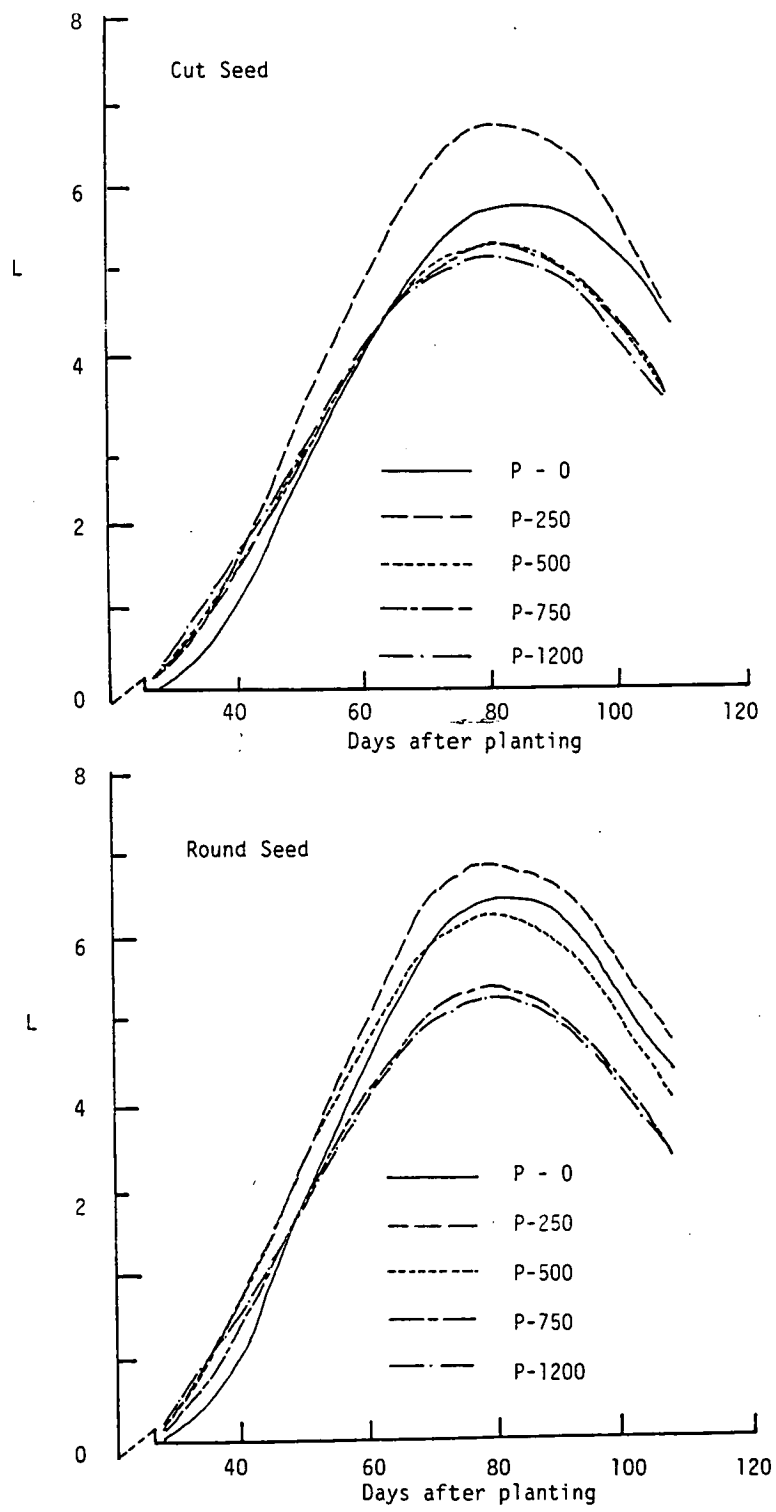
1.3.7 Light Interception

Total solar radiation at Elliott Research Station throughout the trial period is shown in Appendix 1. There was considerable variation in daily radiation within any one month. For example, radiation on 24/12 was only 3.0 MJ/m^2, whereas on the 30/12 it was up to 32.7 MJ/m^2. Over the four months of the trial, solar radiation fell as measured by the monthly averages of 23.1, 22.7, 22.2 and 21.5 MJ/m^2/day for November, December, January and February respectively.

The proportion of light intercepted by the canopy can be expressed as a percentage:-

$$\text{Light intercepted } \% = 100 \left(1 - \frac{S_L}{S_O}\right)$$

where S_L is the radiation transmitted through the crop

and S_O is the total available radiation.

The proportion of intercepted light for each treatment throughout the growing season is shown in Fig 1.8.

On 1/12/81, interception of light by the various treatments ranged between 18 and 44%. Except for round P-1200 plants, p-older treatments tended to intercept more light at this early stage and the p-younger less. However, variation of measurements within any one treatment was great due to the relatively large size, yet few numbers of the potato leaves.

A week later except for P-0 treatment, p-younger treatments tended to intercept more light than the p-older treatments. Canopy closure between the rows was observed in all but the P-0 and P-1200 treatments (23 December). P-1200 plants were never able to achieve true canopy closure, whereas canopies of P-0 plants closed between rows in early January.

Fig 1.8   The effect of physiological age on percentage of radiation intercepted as a function of time
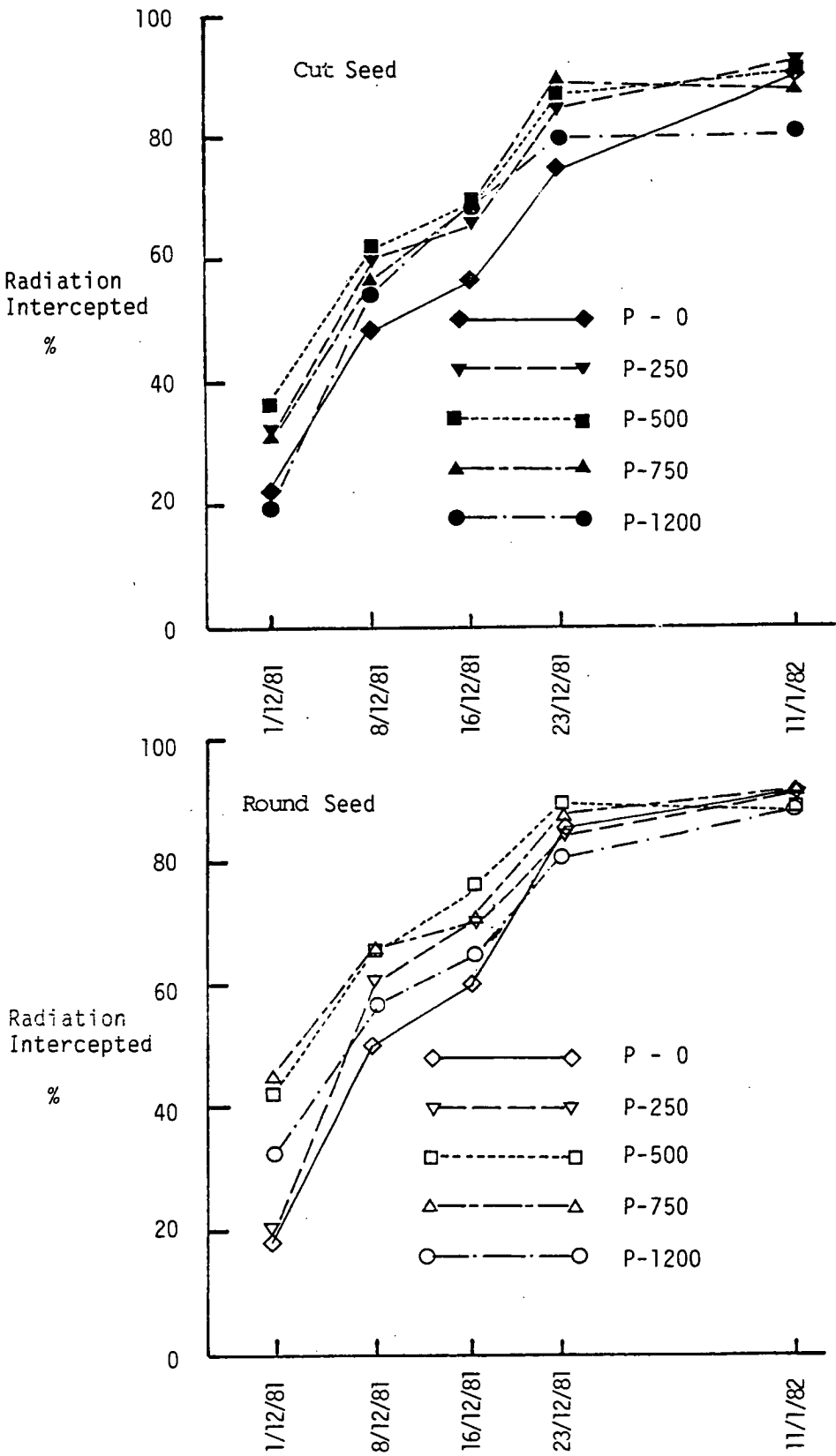
Intercepted radiation reached a peak value around 90% for the p-younger treatments and as low as 80% for the p-older treatments. The latest radiation recording was taken in the crops on 26/1. By this date the crop was lodging and leaves were losing colour.

In Fig. 1.9 the amount of light which was able to penetrate through the crop, the transmitted light, is plotted against L. The data is transformed through the natural logarithm, e. A linear regression of the transformed data produced an r squared value of 88.5% and an extinction coefficient of k = 0.42. When the regression was forced through the Y intercept at 4.605 (natural logarithm of 100) the extinction coefficient was only marginally reduced to k = 0.41.

For each value of L, no particular treatment could be shown to consistently intercept or transmit more or less radiation.

Cumulative intercepted radiation is shown in Table 1.9.

A consistent trend towards maximum cumulative intercepted radiation occurs over time for P-500 - 750 plants. P-ages less than P-500 were slow to accumulate intercepted radiation and although P-1200 plants were established earlier, they were not able to maintain the rate of cumulative intercepted radiation of the other treatments. Round seed tended to intercept more radiation than cut seed.

1.3.8 Tuber Development

Destructive harvests of subplots from plots 1-30 at approximately weekly intervals were used to monitor tuber development.

Tubers were first observed in the p-older treatments on 1/12, but were delayed as much as two weeks for p-zero treatments.

Development of yield is shown in Fig. 1.10. Retarded early tuber growth for the p-young treatments is reflected in their lower yields until mid January, at which stage all treatments appear to have comparable yields.

Fig 1.9 Natural logarithm of percentage transmitted radiation (T) versus leaf area index (L)
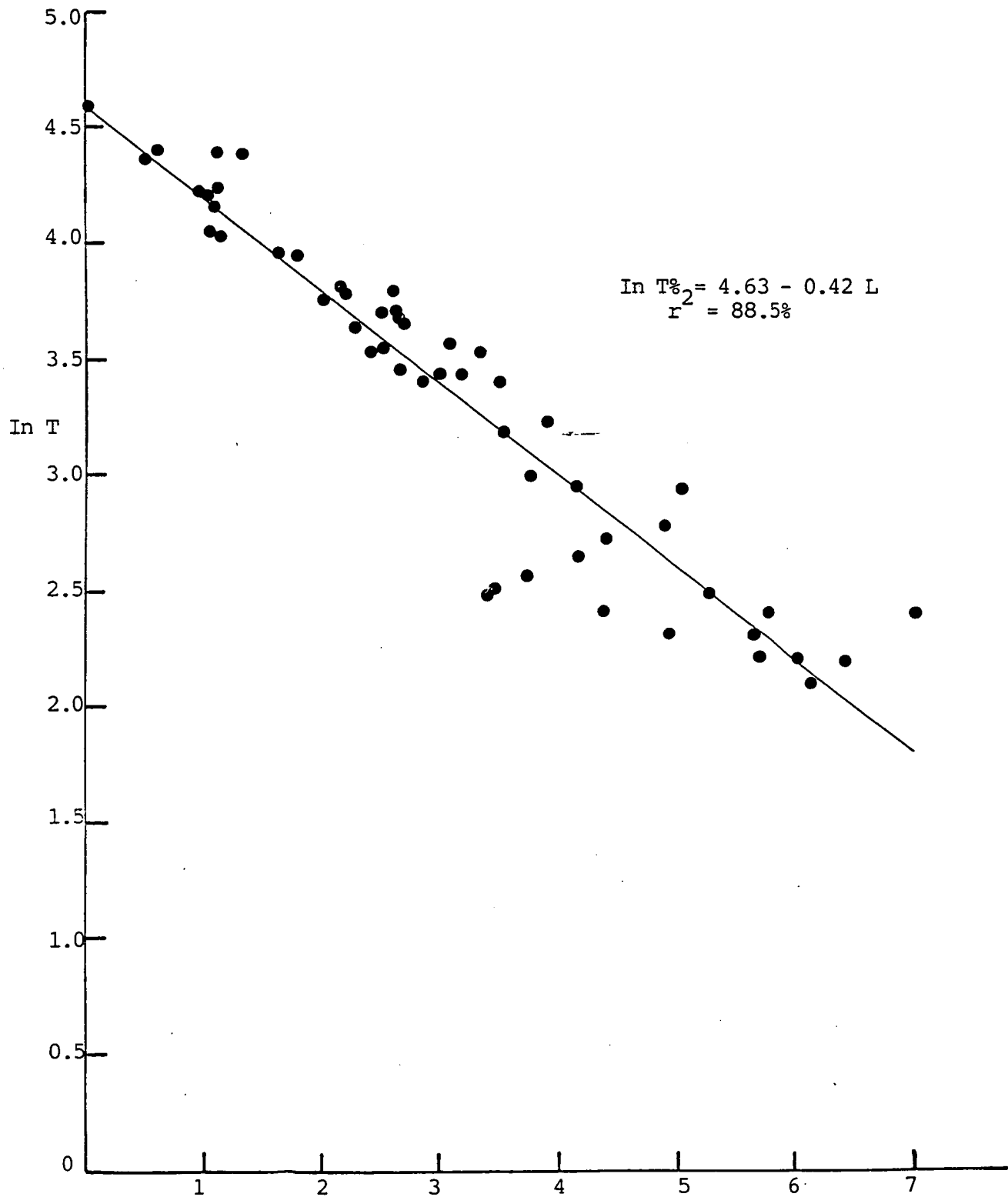

$$\ln T\% = 4.63 - 0.42 \, L$$
$$r^2 = 88.5\%$$

TABLE 1.9 Cumulative Total Radiation Intercepted for each physiological age treatment. (MJ/m^{-2})

Date	0		250		500		750		1200	
	Cut	Round	Cut	Round	Cut	Round	Cut	Round	Cut	Round
13-1/12/81					78	91	69	95	41	69
14-1/12/81			19							
15-1/12/81				38						
19-1/12/81	31	26								
1-8/12/81	78	72	125	93	144	163	129	170	91	129
8-16/12/81	176	176	244	217	268	296	246	298	208	245
16-23/12/81	289	302	374	350	402	438	380	438	336	370
23/12-11/1/82	635	673	746	717	774	812	750	810	674	727

Physiological Age (day degrees >4°C)

At the time of the final destructive harvest, P-250 cut and P-500 round treatments had the greatest yields (Table 1.10); they could not be shown to be statistically significantly different from the other treatments. However, to support this trend the greater yields from the final harvests of plots 31-60 occurred in treatment P-500 for both cut and round seed. Again, differences between these final yields were not statistically significant. A discrepancy occurs between the yields from plots 1-30 (each figure representing three subplots of eight plants) and from plots 31-60 (three

47

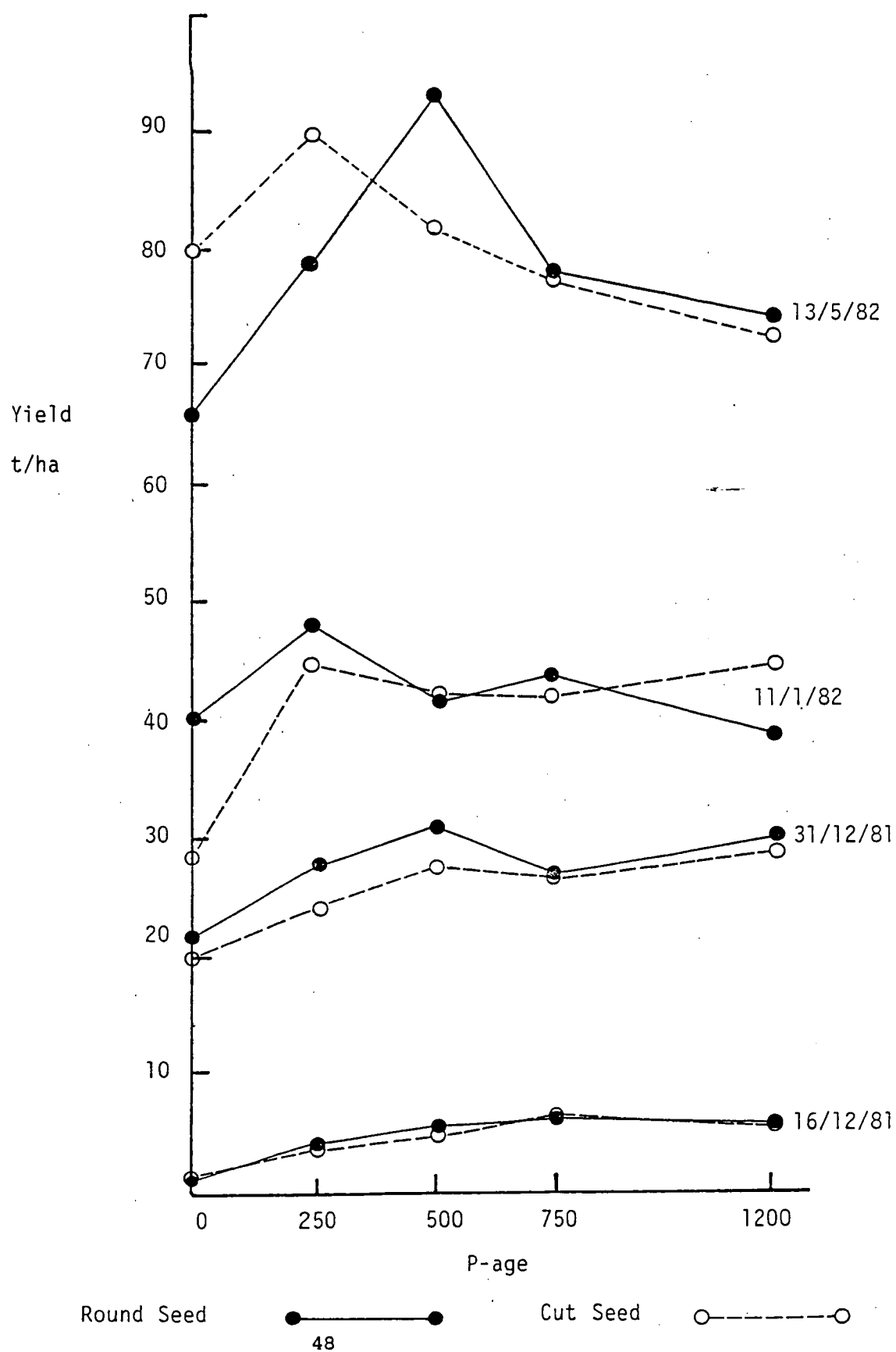Fig 1.10 Effect of physiological age on the development of yield

TABLE 1.10 Comparison of final yields from plots 1-30 and 31-60 (t/ha)

Physiological Age	Cut Seed		Round Seed	
	plots 1-30	plots 31-60	plots 1-30	plots 31-60
0	79.27	61.76	66.80	65.68
250	89.65	64.22	78.83	63.60
500	81.63	65.01	95.79	67.62
750	76.99	62.15	78.68	67.10
1200	71.49	60.99	74.73	62.53

rows of twenty eight plants), which were all harvested on the same day. Yields from plots 31-60 average 19% less in terms of tonnes/ha than the yields from plots 1-30, and differences between treatments were much less.

Possible sources of error which could have contributed to the difference in yield include method of harvest (manually verses mechanically harvested), mis-allocation of neighbouring tubers to subplots, inaccuracy of measuring-balances, and excessive soil on the tubers. These factors have been investigated and were not considered likely causes. One factor which could have benefited subplot yields in comparison to the row yields of plots 31-60, was the use of the cv. Brownell between subplots. The Brownell seed tubers had been p-aged to the same level of treatment as the experimental plot which they were buffering. However Brownell plants tend to be less competitive than Kennebec, and may have encouraged compensatory growth by the adjacent Kennebec plants. The plant spacing of 6.6 plants m^{-2} was sufficiently close to induce interplant competition, and hence, enhance

yields from more competitive plants.

Throughout the growing season, tubers harvested from plots 1-30 were individually weighed. Fig. 1.11 shows the resulting changes in the tuber size frequency distribution for each p-age treatment. In the initial harvests, most of the tubers fell into the smallest size category, 0 - 50g. As tuber bulking occurred the numbers in this category increased until larger tubers outgrew the 50g limit and subsequently were included in the 50-100g category. For each treatment, a bimodal frequency distribution resulted with one peak declining but stationary at 0-50g and the other increasing and moving to the right with time as individual tubers successively outgrew their tuber size category. Eventually the growth of tubers out of the 0-50g interval was such that this peak was absorbed into a skewed Normal frequency distribution. For increasing physiological age, at any one time, the modal value tended to be further to the right, indicating a greater proportion of tubers in the larger size categories. Furthermore the variation in tuber sizes around the mode was also greater for p-older treatments.

Individual tuber weights recorded from a single row from each of plots 31-60, harvested on the same date as the final harvest of Fig. 1.11, are shown as histograms in Fig. 1.12. They substantiate that the younger the p-age, the greater the proportion of small tubers, and likewise the older the p-age the greater the proportion of larger tubers. Also, p-younger treatments produced more tubers than p-older treatments (Table 1.11). However, comparing the final yields of the two sets of plots (1-30 and 31-60) a greater number of small tubers weighing less than 50g were recorded in plots 1-30 for all p-age treatments. Two possible reasons for this difference exist. Firstly, the experimental plants in plots 1-30 may have benefited from their less competitive Brownell buffer plants and been able to maintain a population of small tubers without any significant tuber re-absorbtion. Secondly, plots 31-60 were harvested mechanically, making the very small tubers weighing less than 10g difficult to pick up.

Fig 1.11 Tuber size frequency distributions from cut and round seed of physiological ages P-0,250,500,750 and 1200, from serial harvests of plots 1-30.

Fig 1.11a   Tuber size frequency distribution on 1/12/81
  "   b   "   "   "   "   "   8/12/81
  "   c   "   "   "   "   " 16/12/81
  "   d   "   "   "   "   " 23/12/81
  "   e   "   "   "   "   " 31/12/81
  "   f   "   "   "   "   " 11/1/82
  "   g   "   "   "   "   " 26/1/82
  "   h   "   "   "   "   "   9/2/82
  "   i   "   "   "   "   " 23/2/82
  "   j   "   "   "   "   " 10/3/82
  "   k   "   "   "   "   " 13/5/82
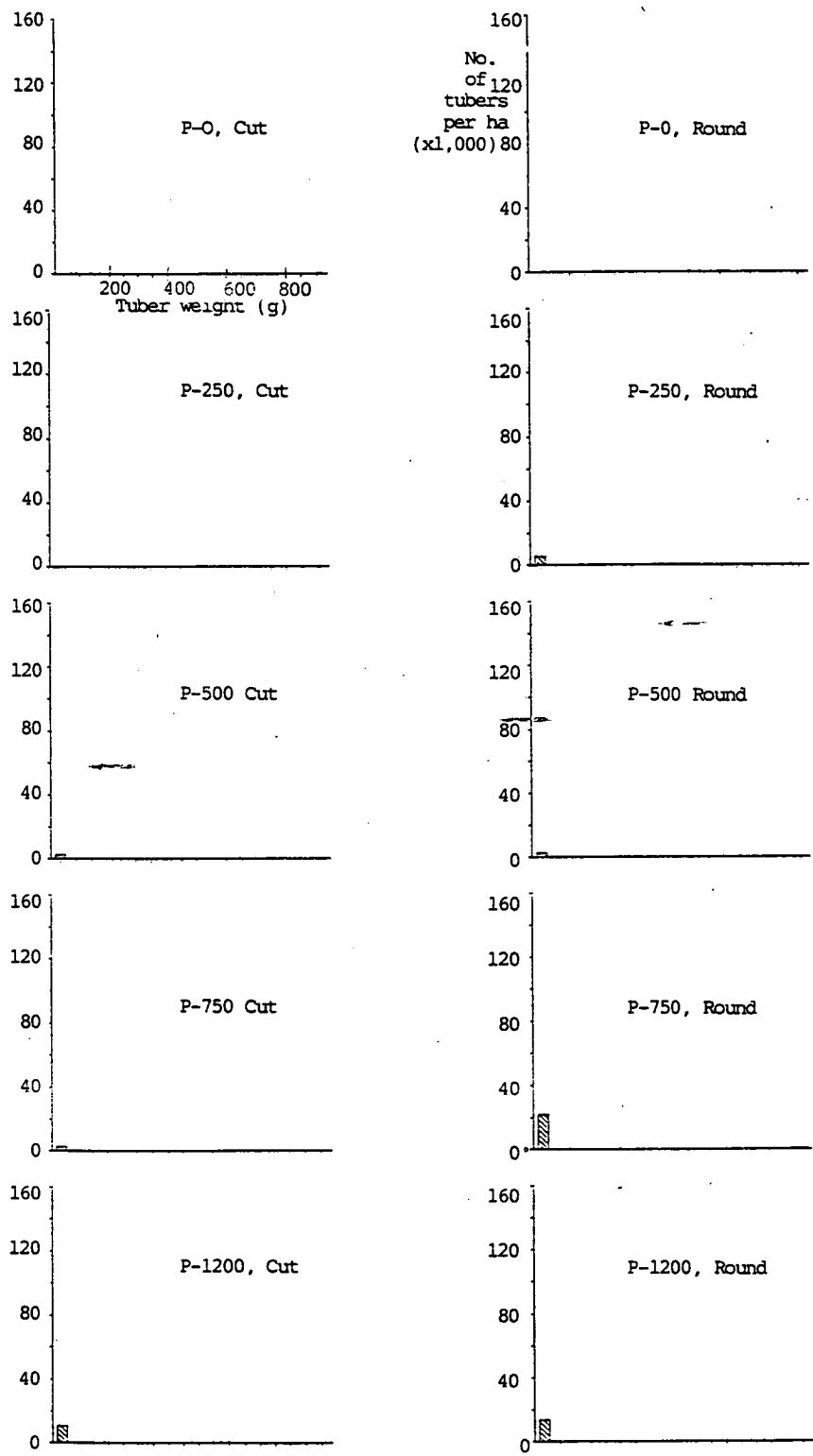
Fig 11a. Effect of P-age on tuber size frequency distributions

- 1/12/81

P-O, Cut

Tuber weight (g)

No. of tubers per ha (x1,000)

P-O, Round

P-250, Cut

P-250, Round

P-500 Cut

P-500 Round

P-750 Cut

P-750, Round

P-1200, Cut

P-1200, Round
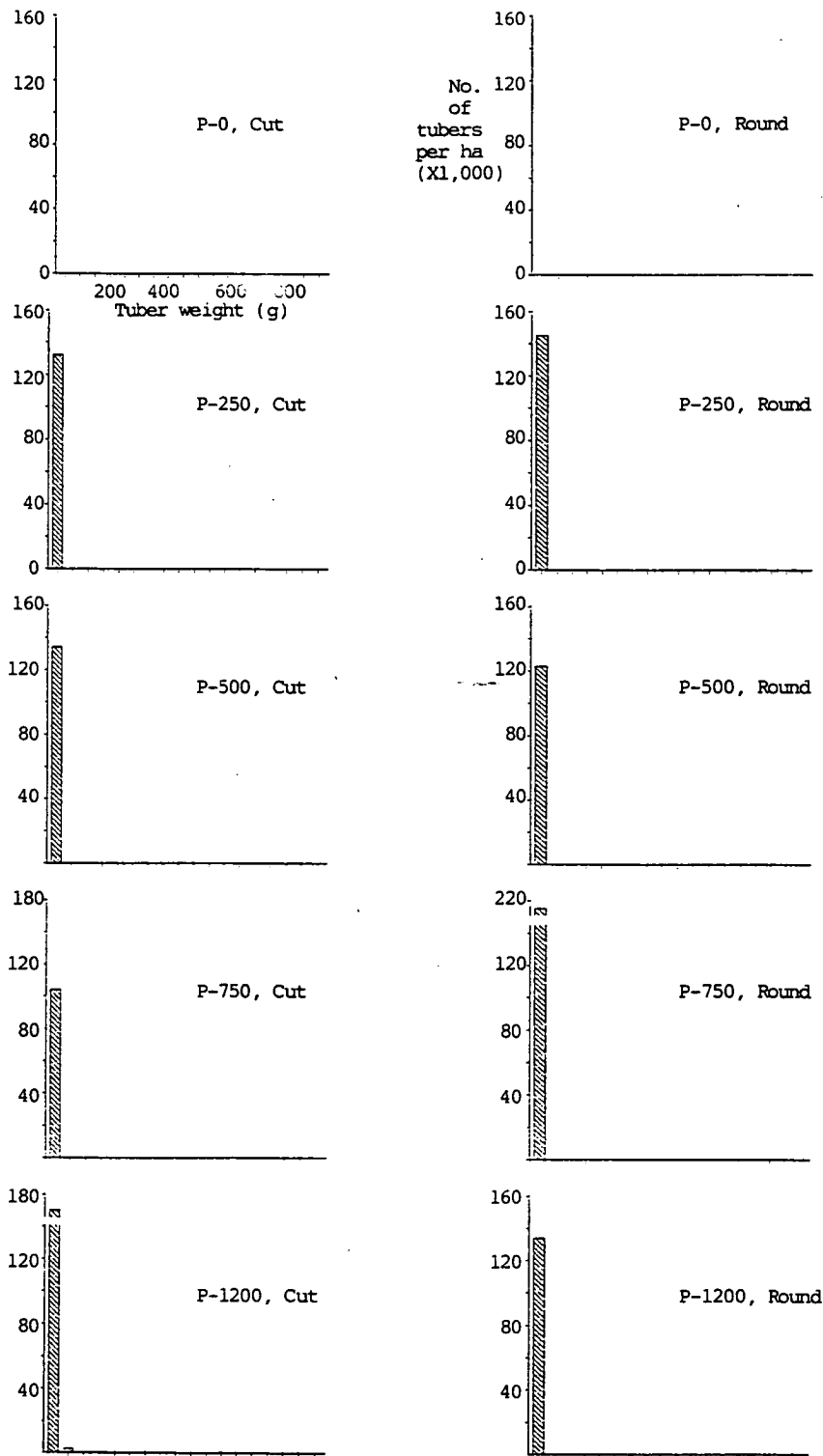
Fig 11c. Effect of P-age on tuber size frequency distributions

- 16/12/81

P-0, Cut

P-0, Round

No. of tubers per ha (X1,000)

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round
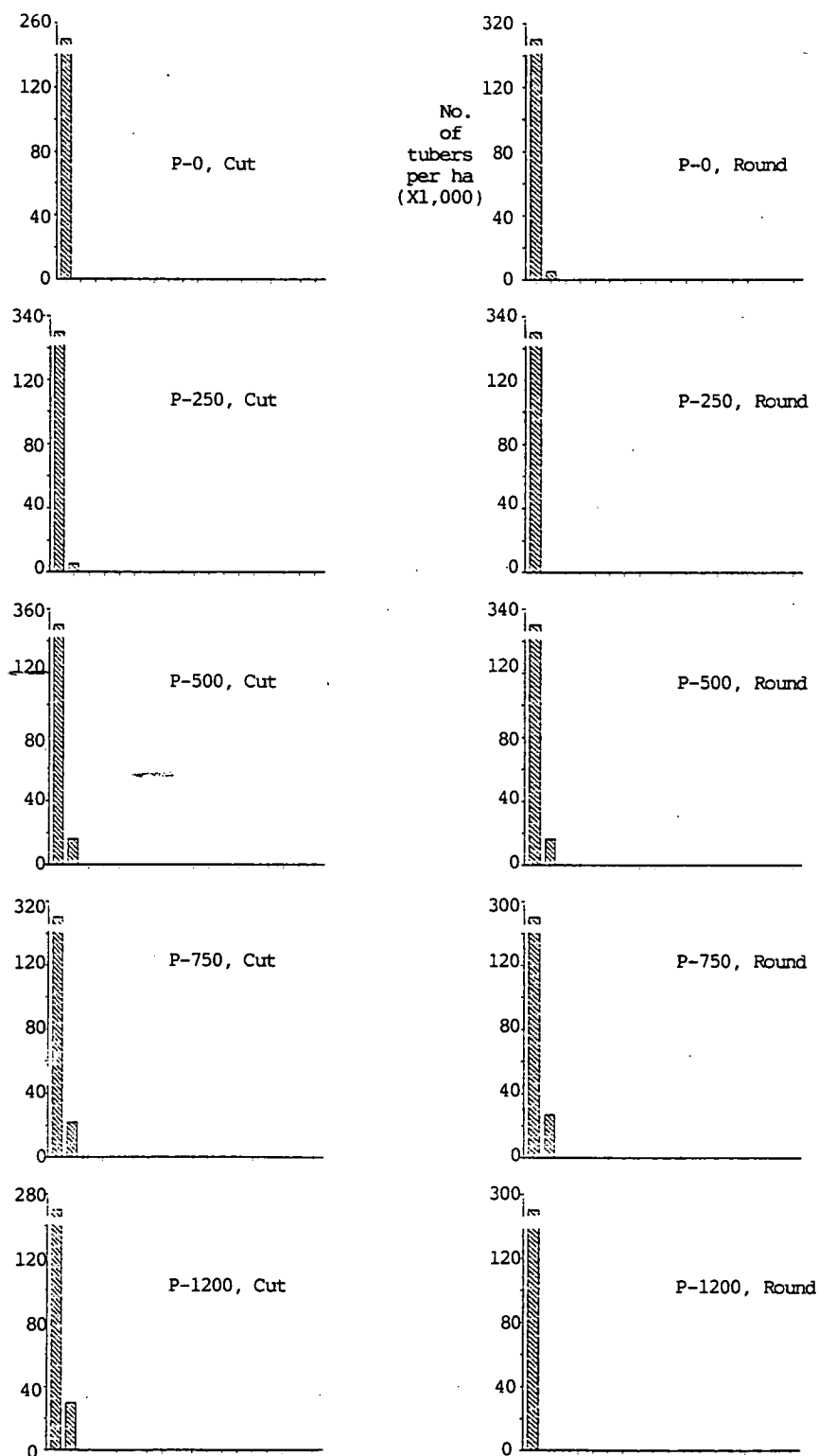
Fig 11d. Effect of P-age on tuber size frequency distributions
– 23/12/81

P-0, Cut

P-0, round

No.
of
tubers
per ha
(X1,000)

P-250, Cut

P.250, Round

P.500, Cut

P.500, Round

P.750, Cut

P.750, Round

P.1200, Cut

P.1200, Round

Fig 11e. Effect of P-age on tuber size frequency distributions
– 31/12/81

P-0, Cut

P-0, Round

No. of tubers per ha (X1,000)

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round

Fig 11f. Effect of P-age on tuber size frequency distributions
- 11/1/82

No. of tubers per ha (X1,000)

P-0, Cut

P-o, Round

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round

Fig 11g. Effect of P-age on tuber size frequency distributions

- 26/1/82

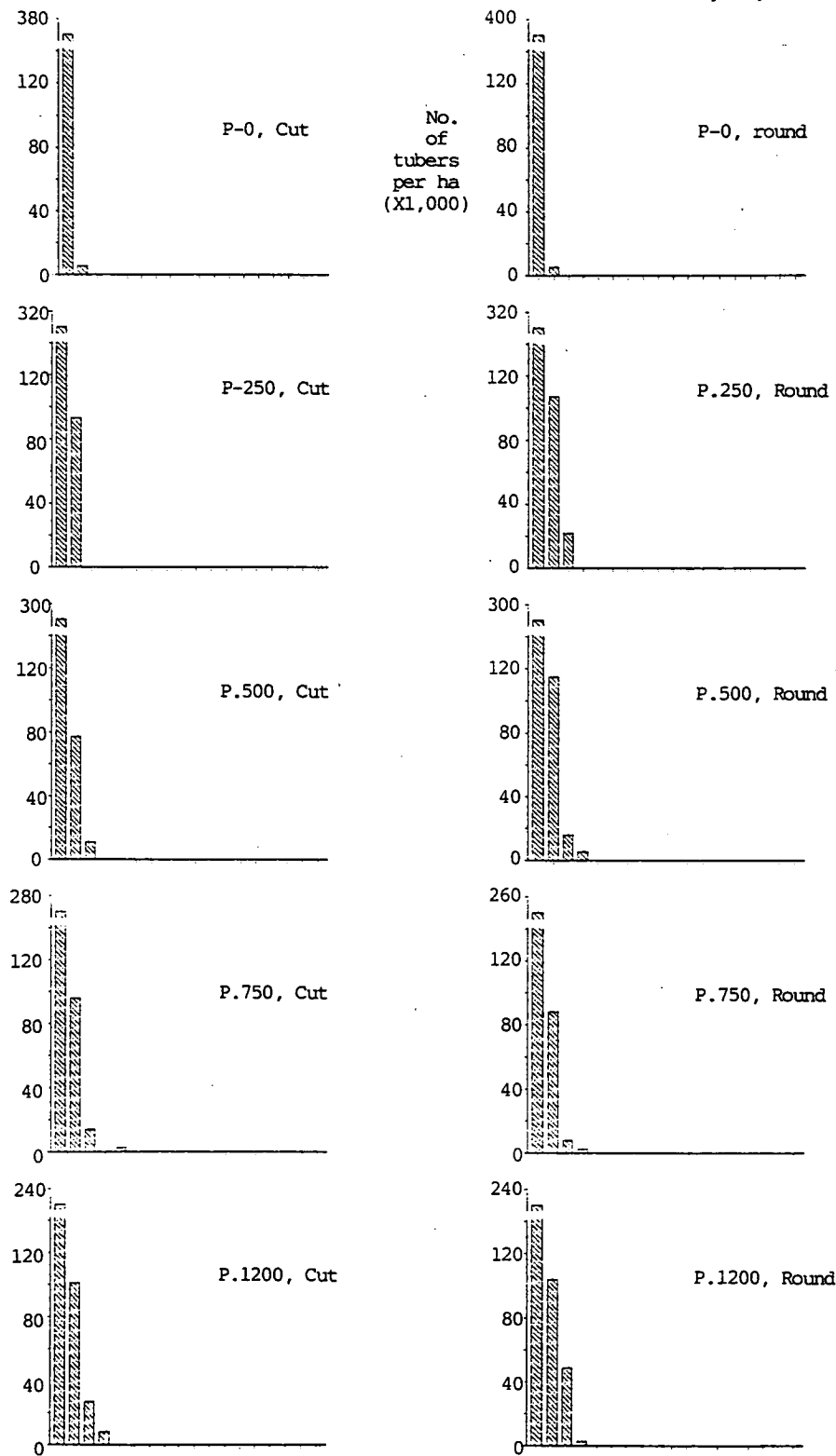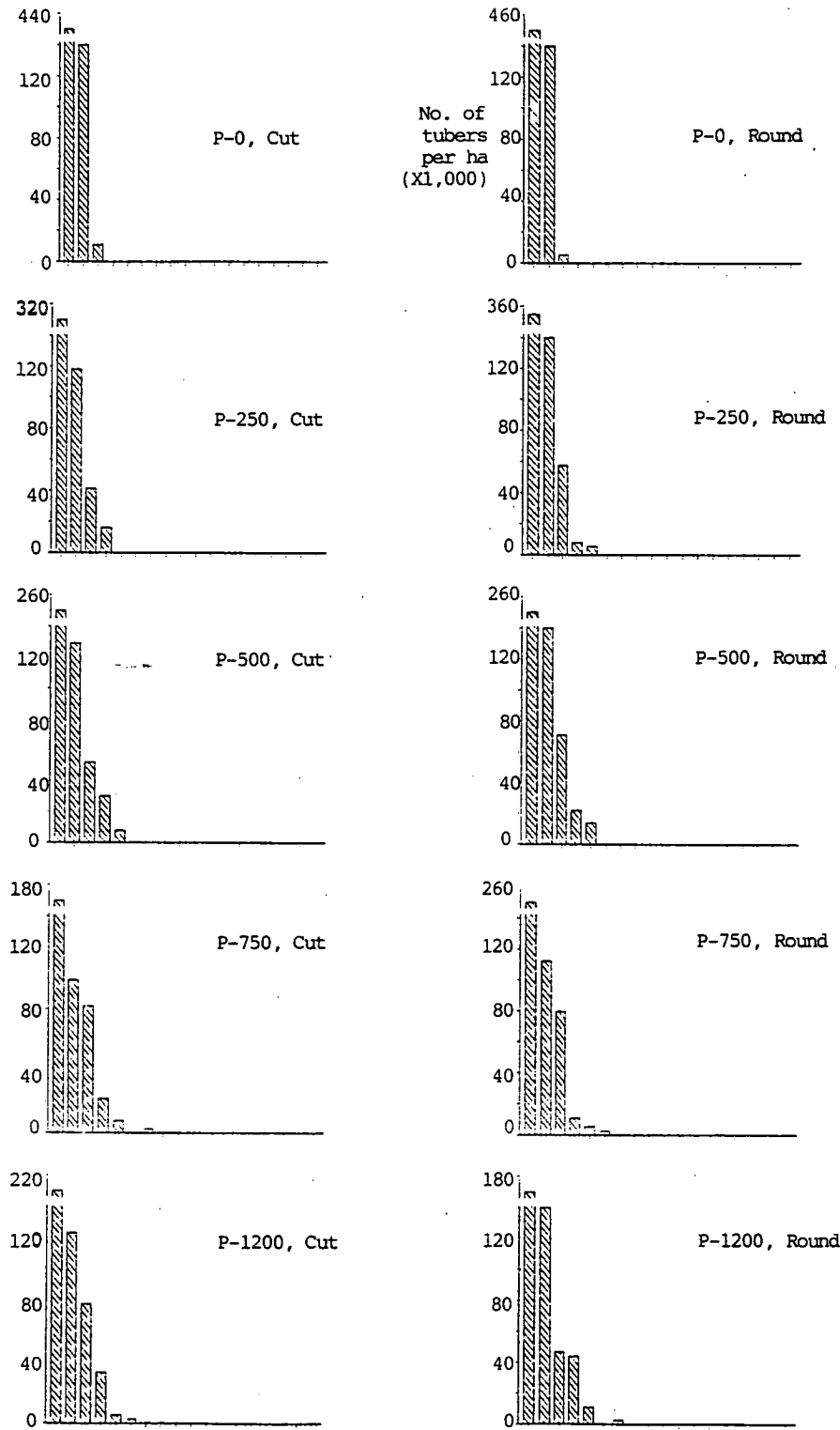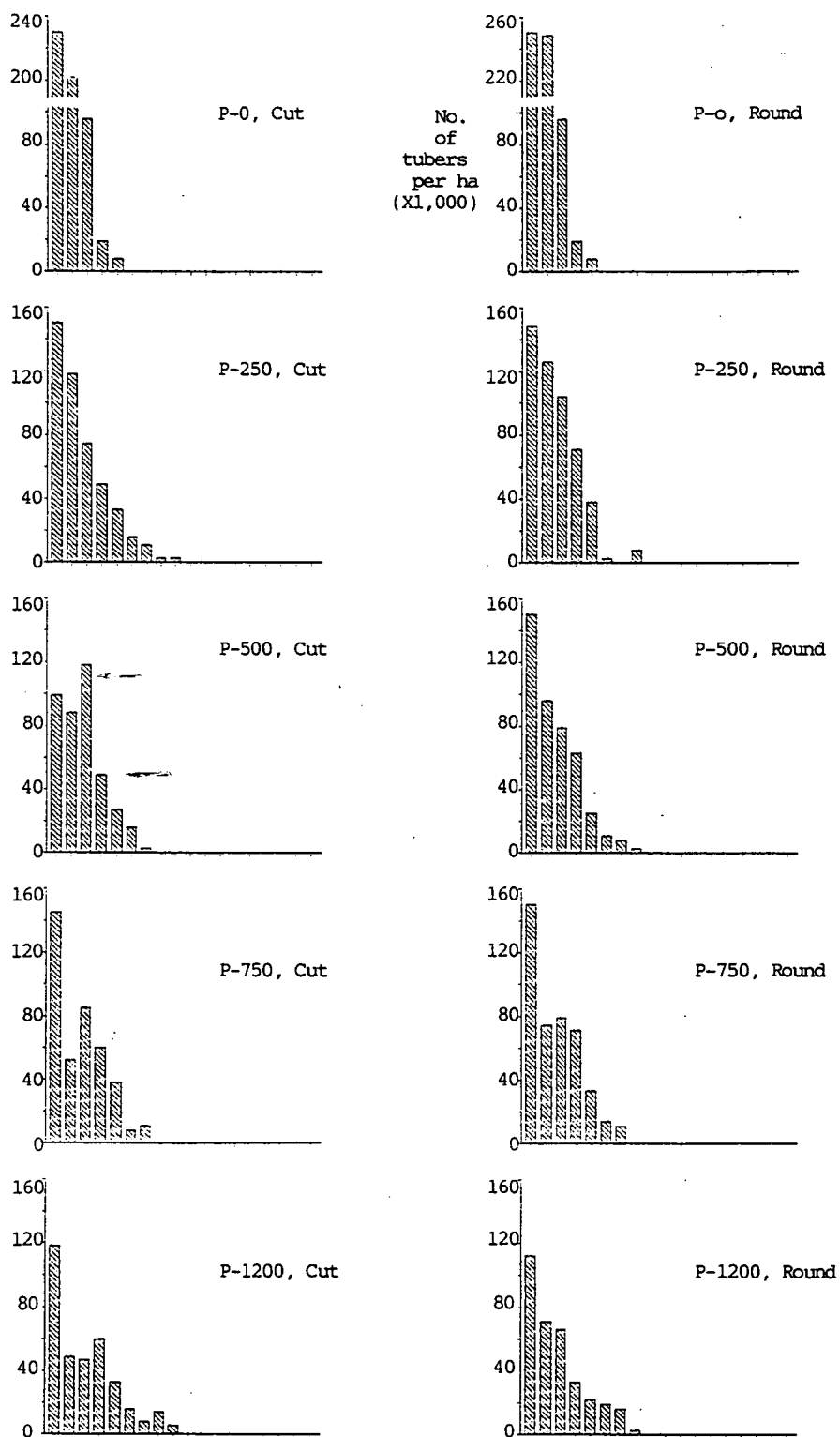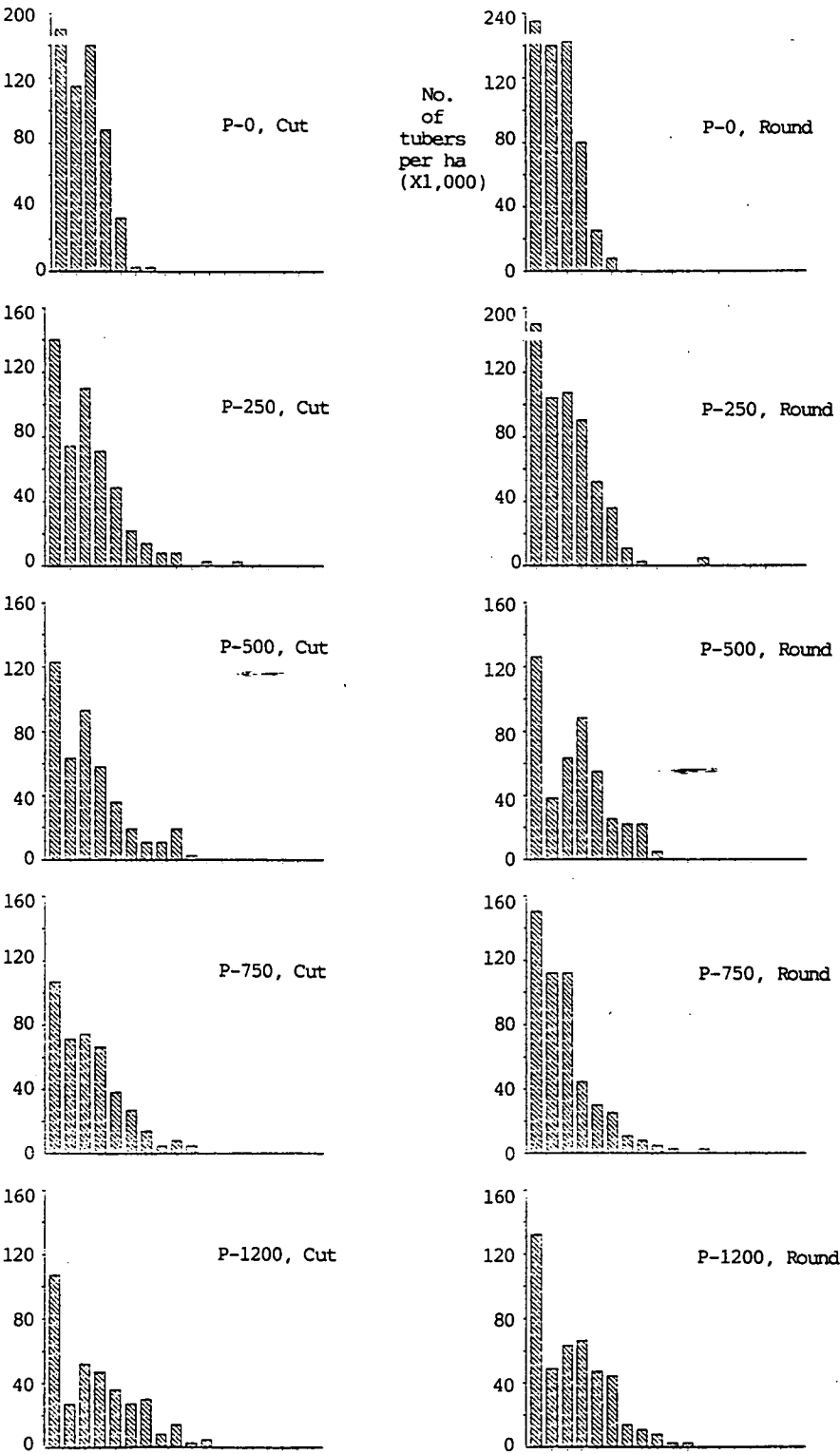**Fig 11h. Effect of P-age on tuber size frequency distributions**

- 9/2/82

P-0, Cut

No. of tubers per ha (X1,000)

P-0, Round

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round
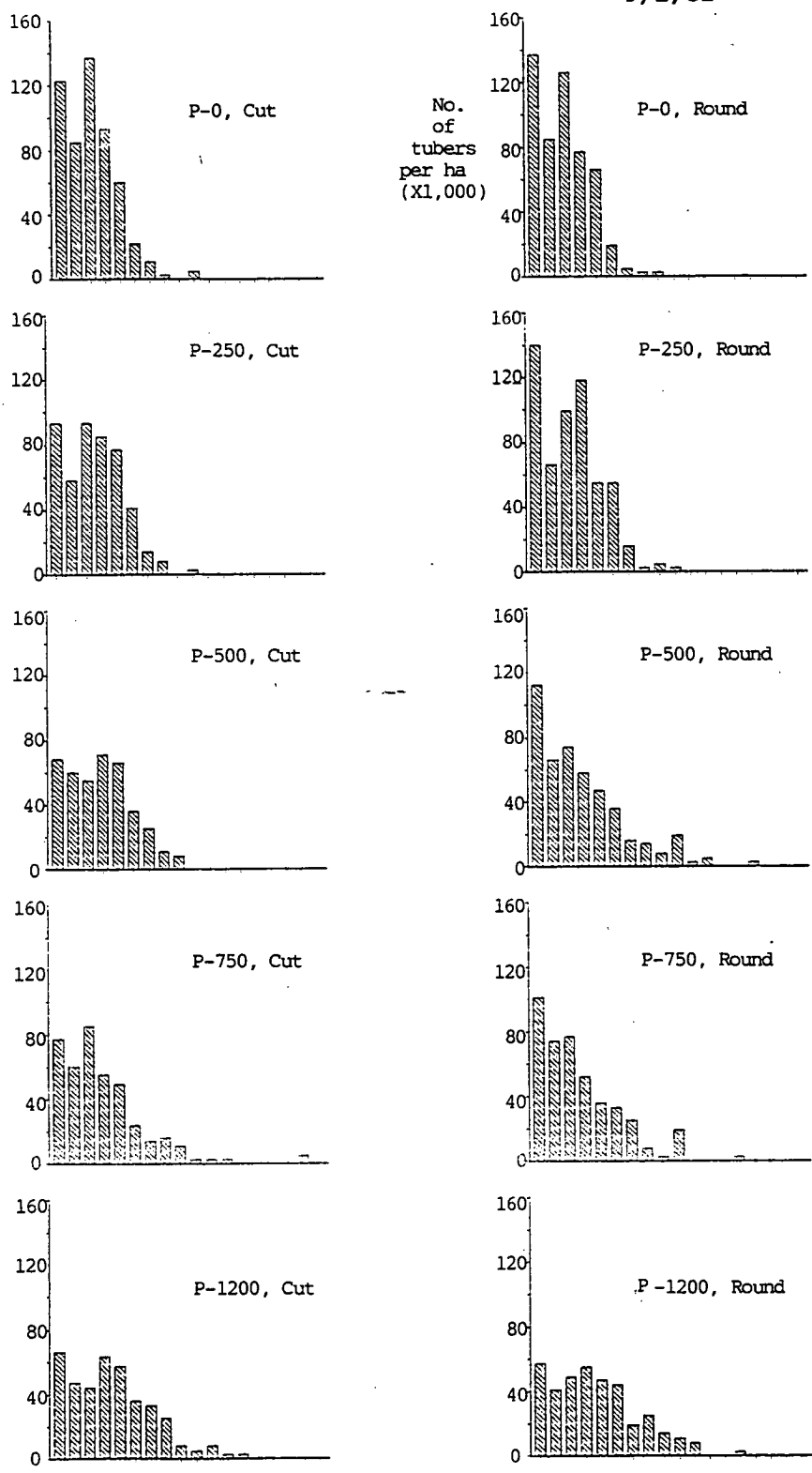
Fig 11i. Effect of P-age on tuber size frequency distributions
- 23/2/82

No. of tubers per ha (X1,000)

P-0, Cut

P-0, Round

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round

Fig 11j. Effect of P-age on tuber size frequency distributions
- 10/3/82

P-0, Cut

P-0, Round

P-250, Cut

P-250, Round

P-500, Cut

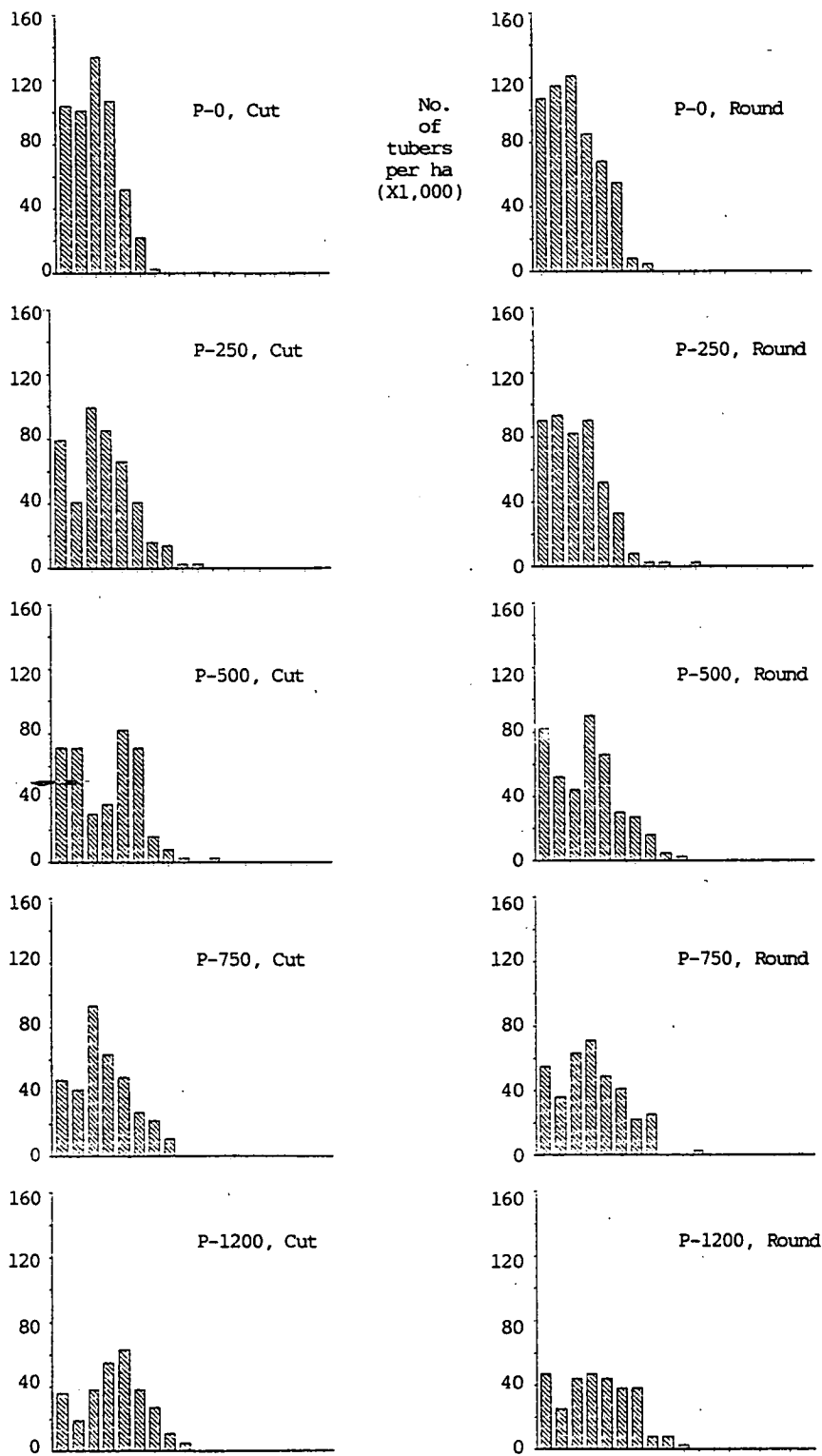P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round
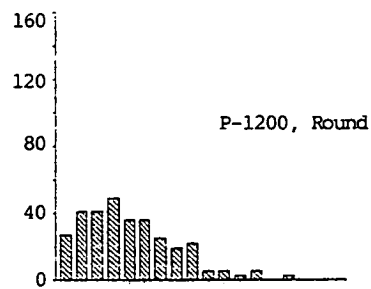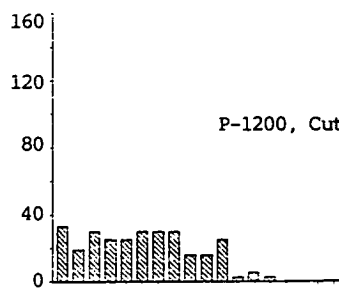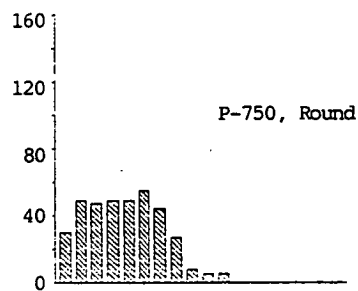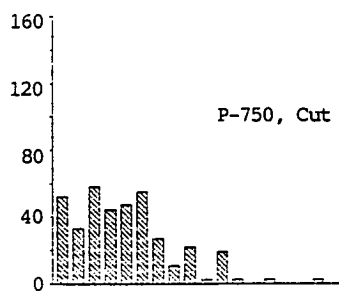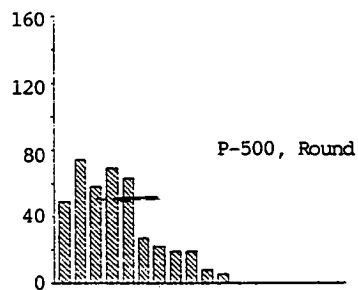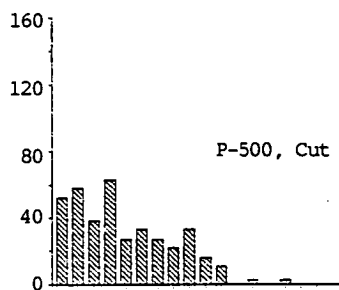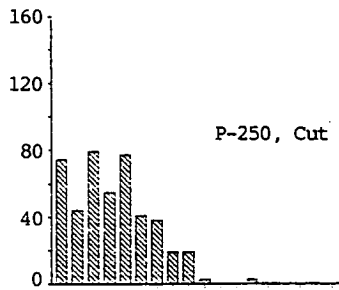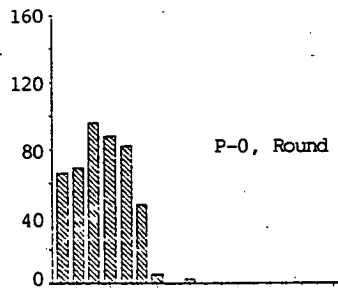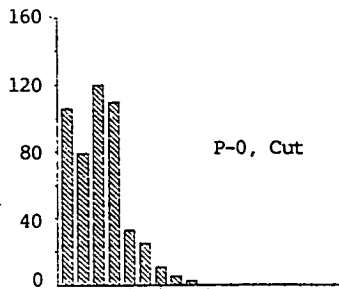
Fig 11k. Effect of P-age on tuber size frequency distributions

- 13/5/82

P-0, Cut

P-0, Round

No. of tubers per (ha) (X1,000)

P-250, Cut

P-250, Round

P-500, Cut

P-500, Round

P-750, Cut

P-750, Round

P-1200, Cut

P-1200, Round
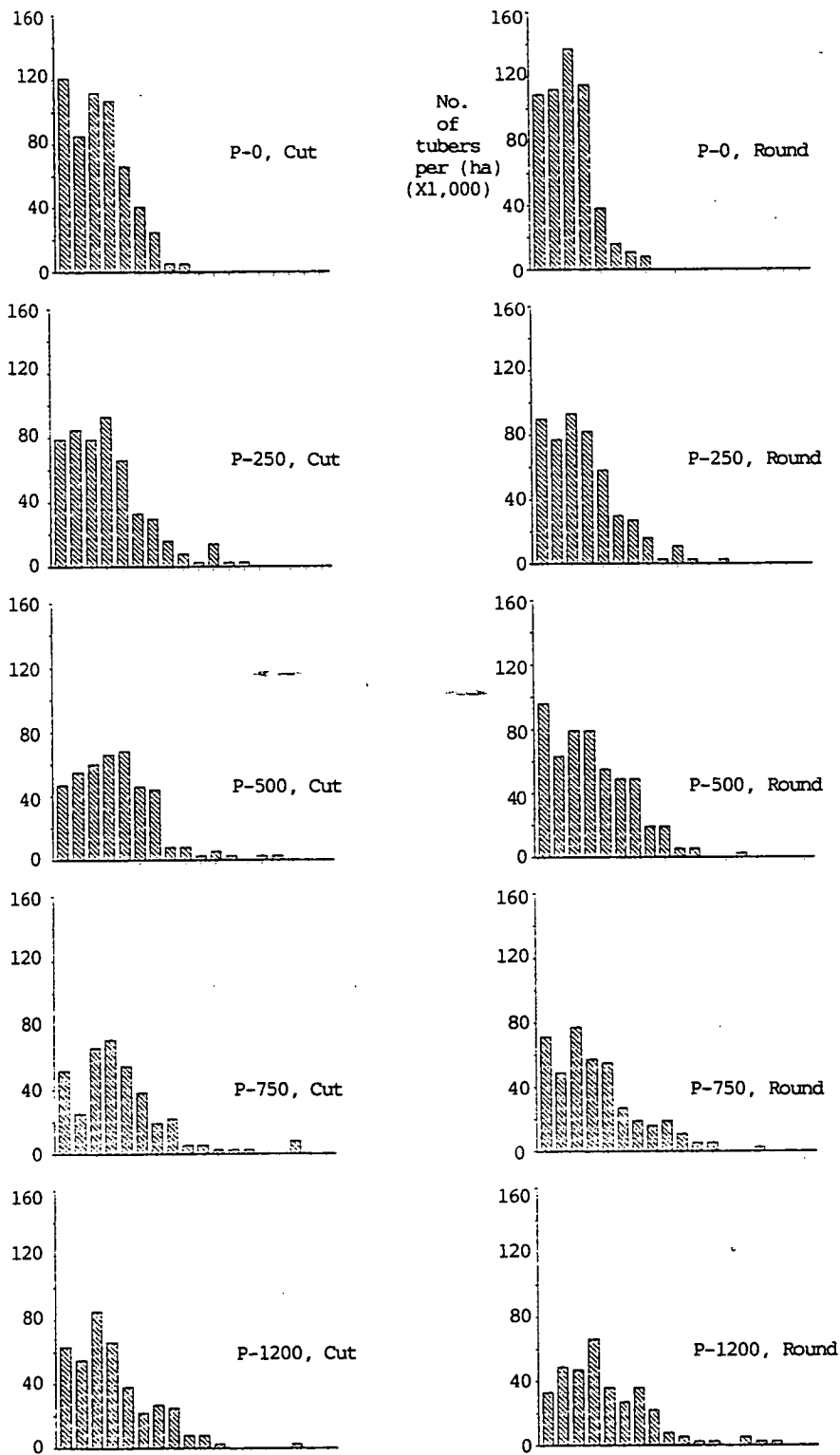
Fig 1.12   Tuber size frequency distributions from cut and round seed of physiological ages P-0,250,500,750 and 1200, from the final harvest of plots 31-60 on 13/5/82.

Fig 12. Effect of P-age on final tuber size frequency distributions
- 13/5/82
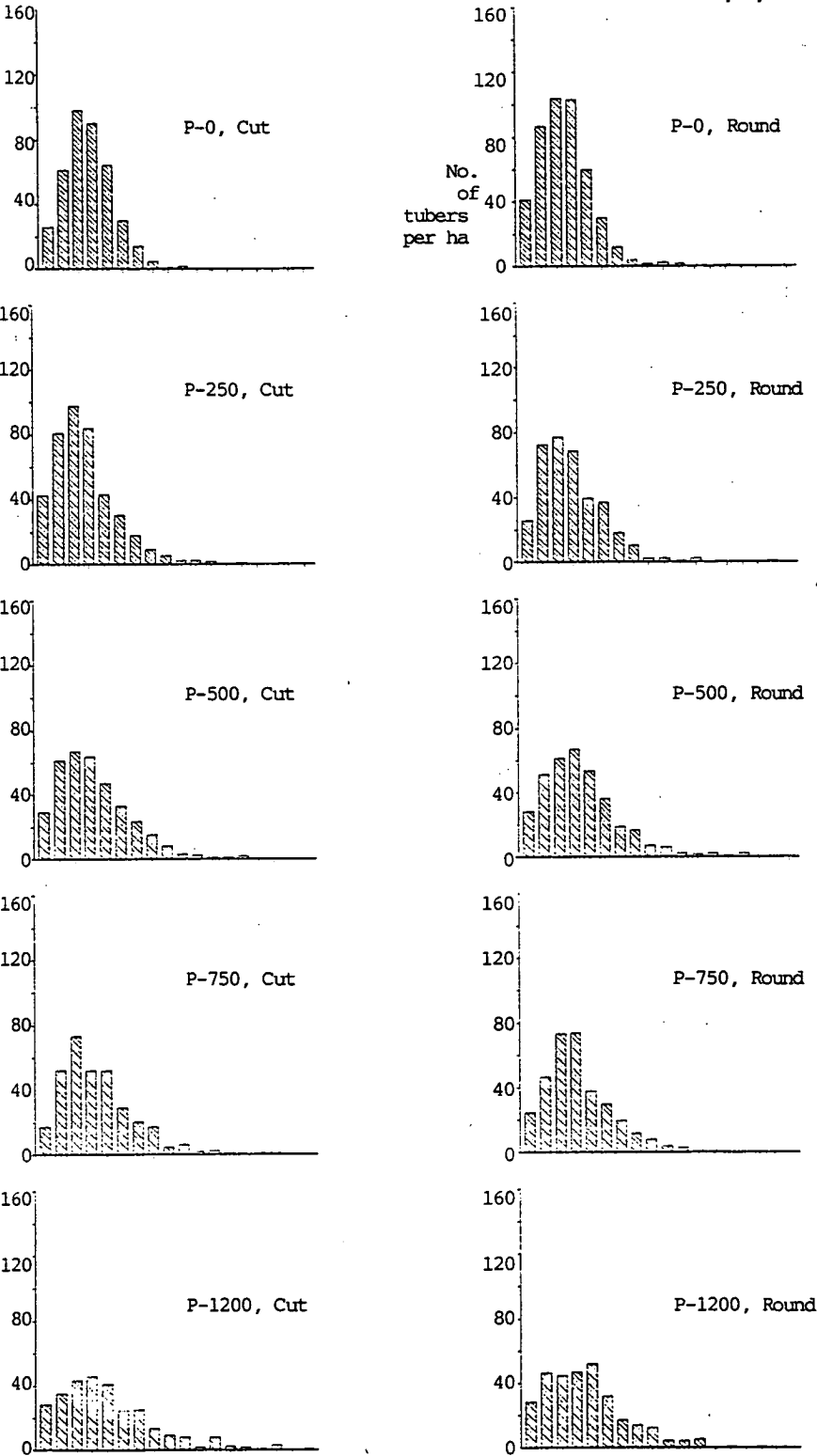
TABLE 1.11   Effect of Physiological Age on Numbers of tubers, and tuber size distribution.

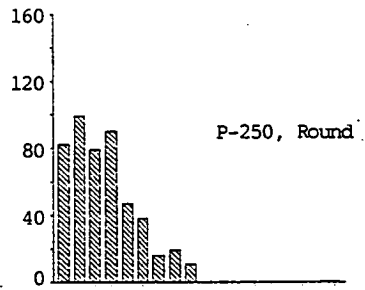| Physiological Age x seed treatment	Number of Tubers per ha. (x1,000)	Square root mean $g^{0.5}$	Square root variance $g^{0.5}$	Mean tuber weight g	Coeff. of var. %
0 Cut	391	12.31	10.99	162.5	26.9
0 Round	445	11.88	12.64	153.8	29.9
250 Cut	420	12.18	15.26	163.6	32.1
250 Round	356	12.53	15.21	172.2	31.1
500 Cut	356	12.97	17.55	185.8	32.2
500 Round	356	13.34	19.40	197.4	33.0
750 Cut	330	13.34	17.15	195.1	31.0
750 Round	332	12.99	15.71	184.5	30.5
1200 Cut	295	14.09	27.15	225.7	37.0
1200 Round	311	13.52	22.55	205.3	35.1

In order to simply describe the distributions of tuber sizes for each treatment in the final harvest some concise summary statistics were required. This was done according to the methods of Wallace (1983) by fitting probability distributions to the data. Initially the Normal, Gamma and Weibull distributions were tried. However these were not adequate. So transformations of the data which make the distributions resemble the normal

distribution were tried. The transformations which were tried were from the family of BOX-COX power transforms. The best transform (estimated by maximum likelihood) was 0.47 which was not significantly different from a square root (0.50) transformation. See Fig 1.13 for examples of the square root transform and the fitted normal curve and Fig 1.14 for the fitted curve on the original scale. Since the fitted curves were adequate, nearly all the information contained in the individual weights can be summarized by three statistics:

- number of tubers
- mean of the square root of tuber weights, square root mean

and - variance of the square root of tuber weights, square root variance.

These statistics can be re-expressed as the more meaningful statistics:

- number of tubers
- total yield
- coefficient of variation of the square root of weights

where,

total yield = number of tubers x mean tuber weight

mean tuber weight = $((\text{square root mean})^2 + \text{square root variance})$

coefficient of variation = $\dfrac{\text{square root variance}}{\text{square root mean}}$

They are shown for each treatment in Table 1.11.

With increasing p-age for both cut and round seed square root mean and square root variance increased. Increases were particularly evident for P-1200 square root variances for both cut and round seed. Mean tuber weight and the coefficient of variation also increased with increasing p-age for both cut and round seed. Crops with both large mean tuber weights and large square root variances have a greater proportion of tuber falling into the larger size grades.

In Fig 1.14 the individual tuber weights for single plots of the final

harvest, plots 49,48 and 50, of the three treatments P-0, P-500 and P-1200 respectively are compared to the fitted curves which can be generated from the three statistics using the following equation:

$$f(x) = N \ (8 \pi s^2 x)^{-.5} \ \exp \ ((x^{.5} - \mu)^2/2s^2)$$

where,

N is the number of tubers

x is the weight in grams of individual tubers

u is the mean of the square root weights = square root mean

s^2 is the variance of the square root weights = square root variance

The advantages of using this function to describe the tuber size frequency distribution are several.

Firstly, the curve smooths out the random variation which occurs in the histograms and by overlaying the fitted curves, a better comparison of the tuber size distributions can be made. In Fig 1.15 the three curves for P-0, P-500 and P-1200 are plotted on the one graph, and clearly demonstrate the effect of increasing p-age on increasing the proportion of larger-sized tubers.

Secondly, because the fitted curves smooth out the random variations in the histograms, a better prediction can be made of graded yields. The graded yield between upper (u) and lower (l) tuber sizes is computed as follows:

$$\text{Graded yield} = \int_{l}^{u} x \ f(x) \ dx$$

Thirdly, models can be fitted to the parameters of the distributions, tuber number, total yield and coefficient of variation. By doing so the distribution of tuber sizes for example, P-600, could be estimated even though P-600 was not one of the treatments.

To date, potato researchers have concentrated on total yields, sometimes

total tuber number and to a lesser extent, the particular graded yields which are required by industry at the time. Total yields and numbers represent only one aspect of potato production, as they do not reflect the variation around the mean tuber weight and so provide no estimate of graded yields. However grading the total yield into arbitrary size grades has led to the obsolescence of research work after the size grades are changed according to the needs of industry.

The above problems are overcome by measuring individual tuber weights and fitting the normal curve to the square root of the weights. With the three summary statistics of numbers of tubers, square root mean and variance, yield and number of tubers for any size grade can be calculated.

Fig 1.13 Histograms of transformed (square root) tuber weights and fitted Normal curves for cut seed, P-0, P-500 and P-1200 plots from replicate 2 of the final harvest.
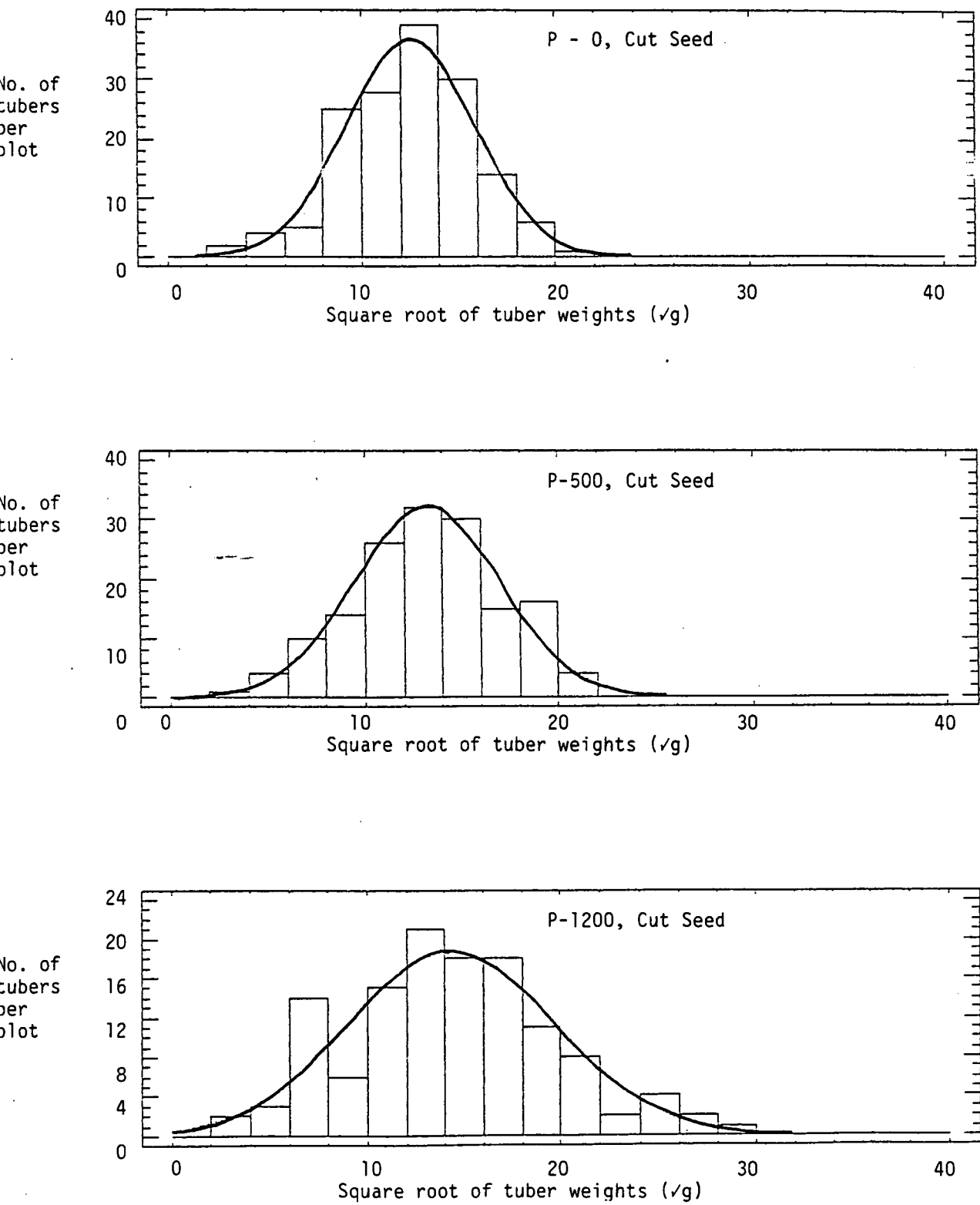
Fig 1.14 Histograms of tuber weights and fitted curves for cut seed, P-0, P-500 and P-1200 plots from replicate 2 of the final harvest.
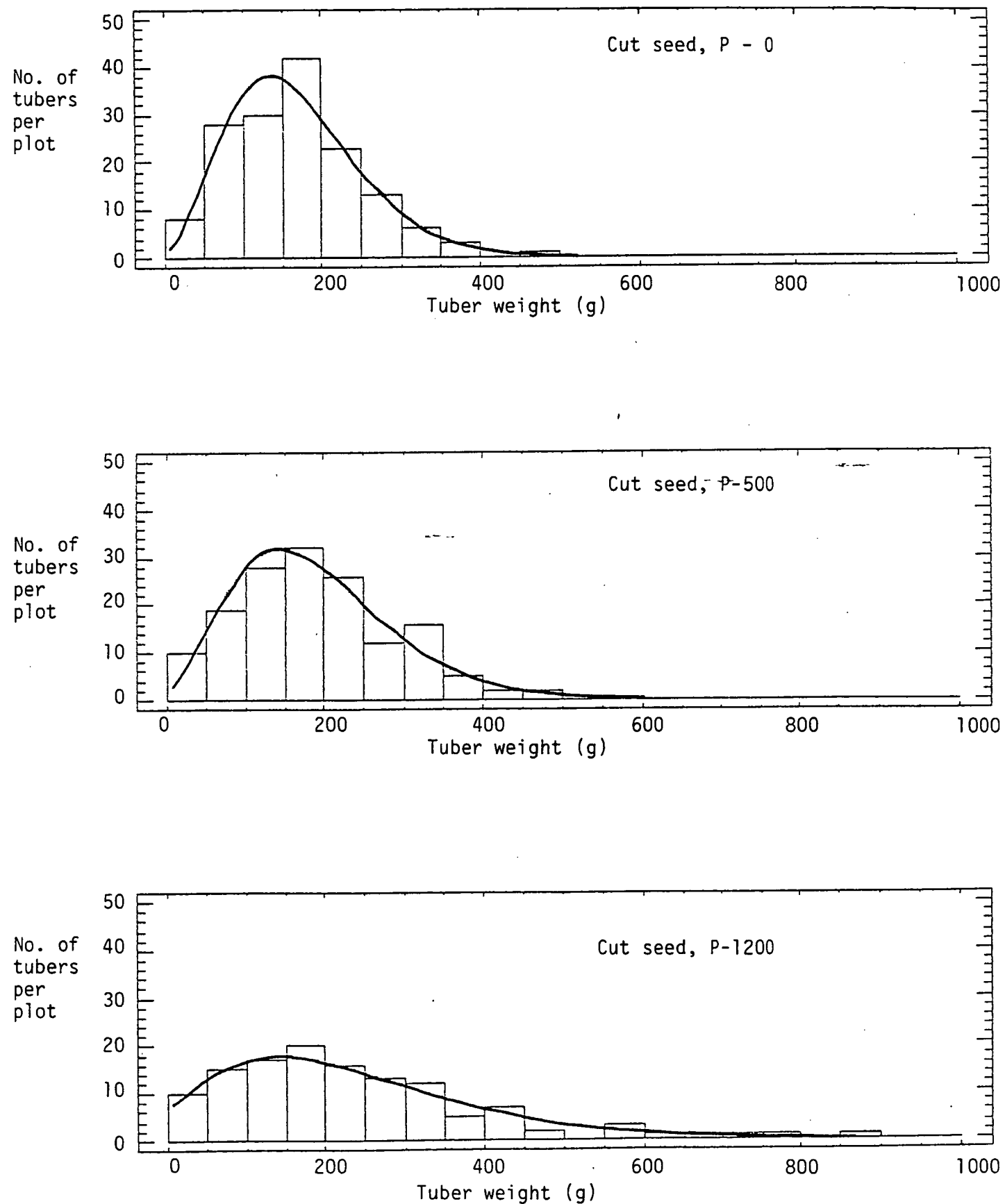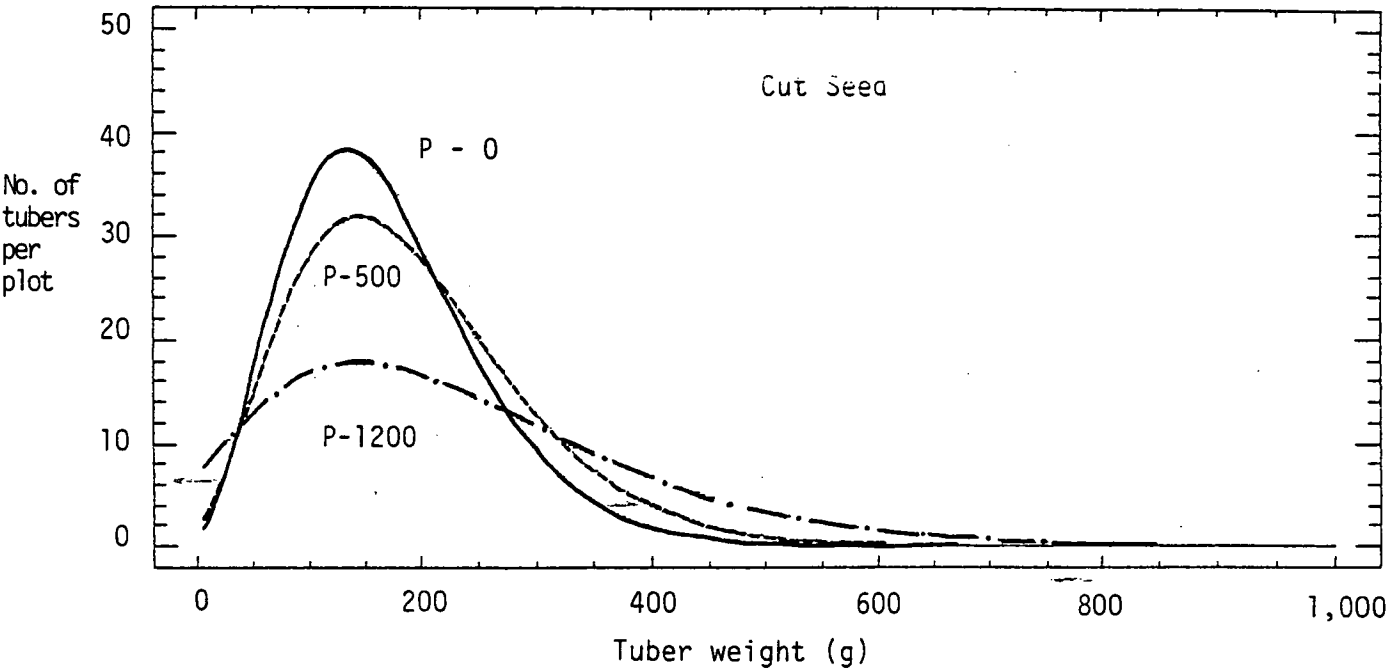
Fig 1.15 Fitted curves for cut seed, P-0, P-500, and P-1200 plots from replicate 2 of the final harvest.

1.4 DISCUSSION

The degree of sprouting of seed tubers affects many aspects of the resulting crop's growth including the rate of emergence, development of leaf canopy and final yield (Madec and Perennec, 1955). Although the relationship was first recognised more than thirty years ago, it is only in the last decade that successful attempts have been made to quantify it (Allen et al , 1979).

Physiological age was measured by integrating the temperature during the sprouting period of the seed tubers until planting. A base line of $4^{\circ}C$ above which day-degrees were calculated more accurately quantified physiological age than other base-line temperatures including $0^{\circ}C$ according to O'Brien et. al. 1983. They found that the rate of sprout growth was linearly related to physiological age. Plant emergence tended to be earlier with p-aged seed, and stem number was reduced. Canopy development was earlier from p-aged seed, but final canopy size measured by leaf area index was reduced, in comparison to the larger plants grown from p-younger seed. They also observed that by physiologically aging seed, early yields were consistently greater. However, by the final harvest, the effect of physiological age was inconsistent. In one experiment, increasing p-age reduced yield. In some experiments, maximum yields were achieved with seed of p-age equal to 400 to 700 day-degrees > $4^{\circ}C$ whilst in others p-age had no significant affect on final yield. O'Brien et. al, 1983, also observed that there was a negative linear relationship between numbers of tubers and physiological age of seed, which contributed to a greater proportion of large tubers from the p-older treatments.

The effects of physiological age on growth and development of the Kennebec crop in this trial were generally consistent with the responses of the early varieties described by O'Brien et. al, 1983. However one difference occurred early in the trial. The length of the apical sprout of Kennebec at the time of planting was not a linear function of physiological age. The difference may have resulted from the strong inhibition of sprout elongation due to the well illuminated storage conditions, or alternatively to the higher sprouting temperatures of $20^{\circ}C$ as compared to $12^{\circ}C$ of O'Brien et. al (1983). Also in this experiment, the apical sprout was measured, whereas the latter used the largest sprout. Had the Kennebec sprouts been excised

and weighed, a consistent increase in sprout weight with p-age would have been observed (Plate 1.2).

Rate of plant emergence and early growth were increased by physiological age and so too was the early development of the leaf canopy by p-older plants. Stem numbers increased with increasing p-age up to P-250 - P-500 and declined thereafter. This was consistent with findings of O'Brien et. al (1983). Maximum leaf area indices which were achieved by each treatment occurred in the same pattern as stem numbers with the treatments P-250 - P-500 producing maximum L values for cut and round seed.

Tuber bulking rates followed the same trends as observed by O'Brien et. al. p-older plants tended to produce higher early yields. As the season progressed, bulking rates of p-younger treatments increased and steadily surpassed those of p-older treatments. The final yield of the serial plots indicated that maximum yields occurred from P-250 - P-500 plants. However final yields from the larger plots 31-60, were not statistically different.

Light interception was greater for p-older plants, during the early stages of the season, however p-younger plants eventually equalled and finally bettered the ability of the p-older plants to intercept light.

A trend was apparent which indicated that total radiation interception, was greater for P-500-750 treatments than very young or very old treatments. Measurements of intercepted radiation over the first half of the season showed that the lower values for the old and young treatments occurred because of the inability of the former to obtain a complete canopy cover, compared to delayed development of the canopy in the latter's case.

In this experiment, the relatively long growing season with only a small decline in radiation receipts towards the end of the season prevented any one p-age treatment gaining a significant yield advantage over another. P-older treatments better utilized the early part of the season, whereas P-zero treatments were able to compensate for their slow start by developing a greater canopy which appeared to persist for a longer period.

Burstall and Harris (1986) examined the possibility of using mixtures of seed of various p-ages so as to extend the duration of the crop canopy and

so maximize the radiation interception throughout the entire growing season, and thus the yield. Although yield advantages were obtained they were unable to relate them to increased intercepted radiation.

The variation in stem number resulting from the physiological age treatments could be expected to affect the final yield and the tuber size frequency distribution. However results from this experiment indicated that the effects of physiological age on yield and tuber size were not through its effect on stem numbers alone.

Bleasdale (1965) recognised that yield increases with increasing plant density at a diminishing rate, up to a certain plant density. Increasing plant density beyond 250000 stems/ha appears unlikely to give further increases in yield in Kennebec (Regel, 1987, personal communication). The observation is substantiated by the poor linear relationship between stem numbers and yields from plots 31-60, even though stem density varied from 250 000 to over 400 000 stems/ha.

Tuber size frequency distribution appeared to be affected by reduced stem numbers across the treatments P-250 to P-1200 . With increasing p-age treatments, stem numbers were reduced and fewer tubers of greater mean tuber weight developed. The effect of increasing p-age on the reduction in stems and consequent increase in oversize tubers was also observed by O'Brien et al (1983). However, for the two extreme treatments, P-O and P-1200, stem numbers were approximately equal yet the former had the most tubers, a large proportion of which were small, and the latter, the fewest which were of the greatest mean weight.

The possibility of physiological age affecting both yield and tuber size independently of its effect through stem numbers, is studied in a subsequent field trial involving physiological age and planting density (see Exp.3).

In the UK crops are planted with round seed, and all studies on the effects of physiological age have been carried out using round seed. In Tasmania, varieties which tend not to produce an abundance of small tubers are grown. Consequently seed is routinely cut to approximately 50g sets just prior to planting.

It was anticipated (E.J. Allen, 1985, personal communication) that cutting sprouted seed would interfere with the dominance established by the apical sprouts, and so reduce any effects of physiological age on resulting growth.

In this trial there were no significant differences between growth characteristics from cut and round seed. Unlike commercially cut seed, all the experimental cut sets had originated from approximately 100g tubers which had been split in half through the apical sprout to the stem end attachment.

It is feasible that such sets would behave just as round seed, since the entire cross section of sprouts from apical to stem end were present on every cut set, and apical dominance may not have been affected.

The use of round seed and cut seed (cut according to the method in this experiment) is of little relevance to commercial practices, because round seed and 100g seed split longtitudinally, represent only a small proportion of commercial seed.

In Experiment 4, the effect of cutting seed as done commercially by potato growers, will be studied in relation to the physiological age response.

1.5 REFERENCES

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2. EFFECT OF PRE-SPROUTING RUSSET BURBANK SEED TUBERS

2.1   INTRODUCTION

Due to the changing demands on the processing industry, Russet Burbank is replacing Kennebec as the major processing variety. Russet Burbank is a long potato with shallow eyes and greater specific gravity, making it more suitable for processing than Kennebec. However, growers find it more difficult to produce as it is inclined to form many small tubers when planted at the conventional six plants per square metre, and if planted at a wide spacing, it will often produce miss-shaped tubers. Also it requires a longer growing season than Kennebec. One advantage which it does have over Kennebec, and which benefits the growers is its relative disease resistence.

As Russet Burbank is a later variety than Kennebec it would be expected that it is less responsive to the effects of p-age (Allen and Scott, 1980). On the other hand tuber size can be readily manipulated by planting density. Consequently the effects of p-age could be expected to be more strongly manifested in Russet Burbank on such characteristics as mean tuber weight and numbers of tubers.

In this experiment the effects of physiological age on Russet Burbank will be studied and compared to the effects found in Kennebec from Experiment 1.

2.1.1 AIM

The aim of Experiment 2 was to quantify the effect of physiological age of seed tubers at the time of planting, on subsequent development and yield of a Russet Burbank crop. The effects of physiological age on Russet Burbank will be compared to those which have been quantified for Kennebec in Experiment 1.

2.2   MATERIALS AND METHOD

2.2.1 Physiological Aging of Seed

The method of p-aging seed in Exp.2 was the same as that used for Exp.1. Again, five p-age treatments were used as well as a seed treatment which corresponded to commercially stored seed at ambient temperatures. Physiological-age treatments are detailed in Table 2.1.

The commercially stored seed was maintained at ambient shed temperatures over the dormancy period at Tewkesbury Research Station, and transferred on the 9/9/82 to Elliott Research Station. The accumulated day degrees above $4^{o}C$, over the sprouting period of the commercially stored seed, totalled approximately 400 day degrees above $4^{o}C$, using the daily ambient temperatures for Tewkesbury and Elliott.

The seed used in Exp.2 was cut as "splitters" as in Exp 1 for which tubers of 80-100g were sliced in half through the apical bud to the stem scar.

2.2.2 Field Trial

A field trial was carried out at Elliott Research Station, using the same management regime which was described for Exp.1. However plant spacing was 4.1 plants m^{-2} with 810 mm between rows and 300 mm between plants along rows. Fertilizer was again 5:6:9 (N:P:K) but applied at 3000 kg/ha.

The field trial comprised six treatments which were replicated three times in two adjacent blocks; one block was intended for serial harvests (plots 1-18) and the other for a final harvest (plots 19-36). The field plan is shown in Fig. 2.1.

The six treatments were made up of the five physiological ages (Table 2.1) and commercially stored seed.

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TABLE 2.1   Physiological age treatments of seed potatoes.

Physiological age day degrees >4°C	Date seed transferred to 20°C	Days at 20°C until planting
0	-	0
250	4/10/82	16
500	19/9/82	31
750	3/9/82	47
.1200	6/8/82	75

Plots 1-18 were thirteen rows by six metres long. Each plot comprised fifteen subplots, one of which was randomly selected at each harvest. The subplots were made up of nine plants, three plants from each of three adjacent rows. The nine plants were surrounded by buffer plants of the same physiological age as the treatment of that plot. On either end of the subplots' rows were single Brownell plants, which had been p-aged to the same treatment as that of the experimental plot which they were buffering.

Plots 19-36 were five row plots, six metres long. The three internal rows were harvested as soon as the crop had senesced. The two outer rows were buffer rows of Russet Burbank of the same physiological age as the treatment of that plot. At both ends of the three inner rows, were Brownell plants. These were also buffer plants and were not included in the final harvest.

Fig 2.1   Field Plan

1	2	3	4	5	6
500	750	250	0	1200	C.S.

7	8	9	10	11	12
250	0	750	1200	C.S.	500

13	14	15	16	17	18
C.S.	250	750	500	0	1200

19	20	21	22	23	24
500	0	250	750	1200	C.S.

25	26	27	28	29	30
750	C.S.	250	0	500	1200

31	32	33	34	35	36
1200	750	0	C.S.	250	500

6m

↕1·1m

a

○   Russet Burbank buffer plant

●   Russet Burbank exp. plant

⊙   Brownell buffer plant

80
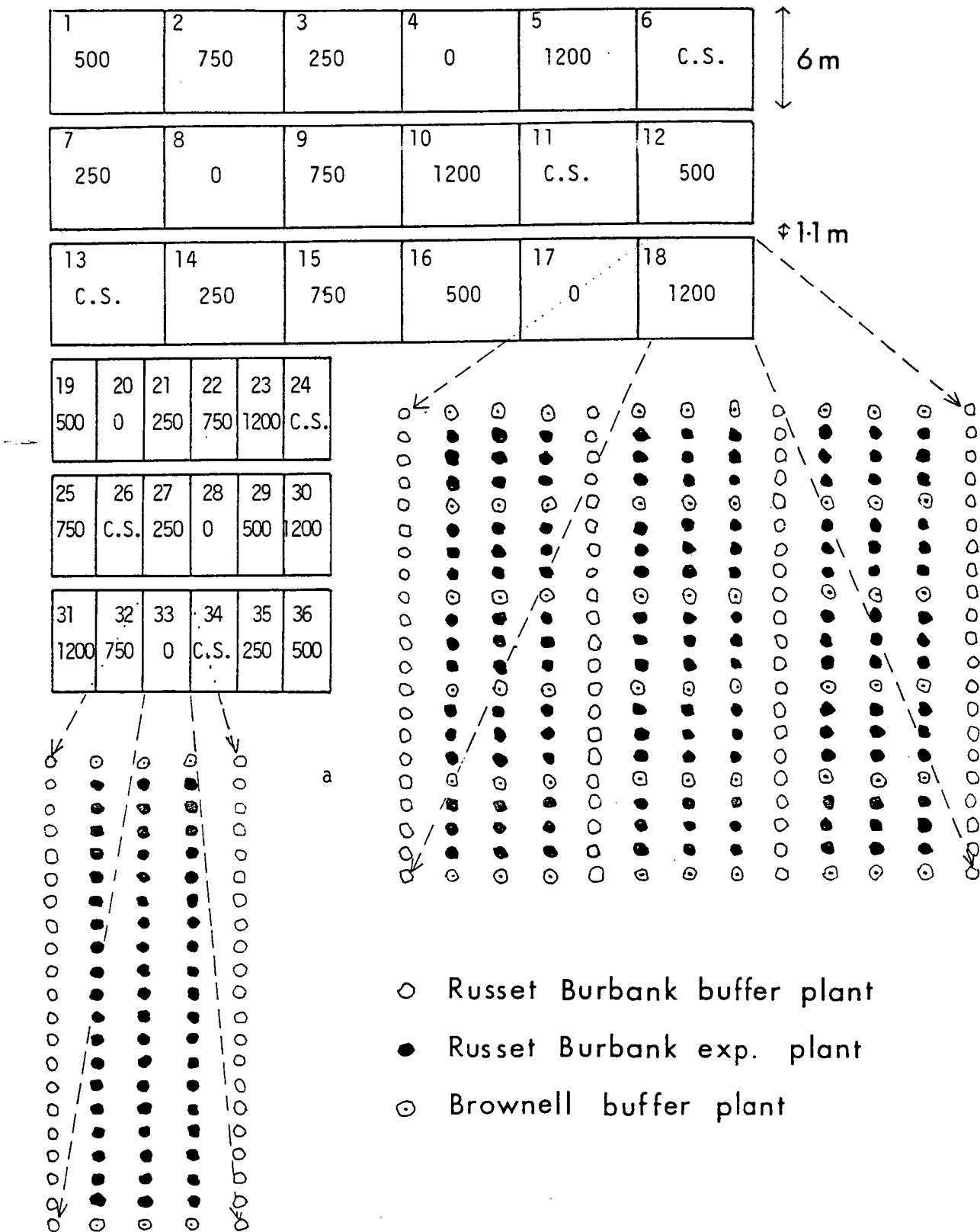
2.2.3 Method of harvest and measurement

Subplots were harvested throughout the crops growth period on the dates outlined in Table 2.2.

Entire plants excluding the roots were dug manually by fork. Haulms were weighed in order to calculate leaf area from a 500g sub-sample from each plot, using a planimeter. Leaf area index (L) for the subplots was then calculated.

The presence of any primary and secondary stolons and tuber initials were recorded, on all plants from the subplots. Any tubers greater than 1g were weighed individually.

Light interception and plant height were recorded using the same method as described in Exp.1.

Harvesting of plots 19-36 occurred on the same date (11 March 1983) as harvest 14 of plots 1-18. Each of the three rows per plot was individually harvested by a single row digger and bagged manually.

Individual tuber weights were recorded as in Exp 1.

2.3   RESULTS

2.3.1 Seed Treatments

Elongation of sprouts of Russet Burbank increased exponentially with time on seed potatoes exposed to $20^{\circ}C$ (Table 2.3, Fig.2.2). In comparison the rate of sprout growth of Kennebec in Exp.1 decreased with increasing accumulated day degrees, with the maximum length 22 mm at P-1200, or less than half that on Russet Burbank.

TABLE 2.2   Calendar of Events

Harvest Number	Date	Plant Records					
		Light interception	Height	Haulm	IAI	Tuber weights	Crop colour
1	23/11/82	*	–	*	*	–	–
2	30/11/82	*	–	*	*	–	–
3	11/12/82	–	–	*	*	–	–
4	18/12/82	–	–	*	*	–	–
5	23/12/82	*	*	*	*	–	–
6	29/12/82	–	–	*	*	*	–
7	5/1/83	*	*	*	*	–	–
8	12/1/83	*	–	*	*	*	*
9	19/1/83	*	*	*	*	*	–
10	26/1/83	–	–	*	*	*	*
11	9/2/83	–	–	*	*	*	–
12	17/2/83	–	–	*	*	*	*
13	24/2/83	*	–	*	*	*	*
14	11/3/83	–	–	–	–	*	–
15	11/3/83	–	–	–	–	*	–

The number of sprouted eyes was also strongly dependent on p-age and like those of Kennebec in Exp.1, decreased with increasing p-age (Table 2.3,Fig 2.3). By interpolating the curves in Figs 2.2 and 2.3, the p-ages which corresponded to the sprout length and sprout number of the commercially stored seed were 245 and 561 p-units repectively.

TABLE 2.3.   Sprout Development at the Time of Planting

P-age	No. of Days at 20°C	Length of Apical Sprout mm	No. of Sprouting Eyes
0	0	0	0
250	16	5	7.8
500	31	9.2	5.1
750	47	24.2	4.2
1200	75	49.5	2.1
Commercially stored		4.2	4.6
s.e. of treatment mean		2.6	0.6

Fig 2.2 Effect of P-age on sprout length at the time of planting

Sprout length $= e^{0.788 + 0.003 \, P\text{-age}}$

$r^2 = 67 \cdot 7 \, \%$
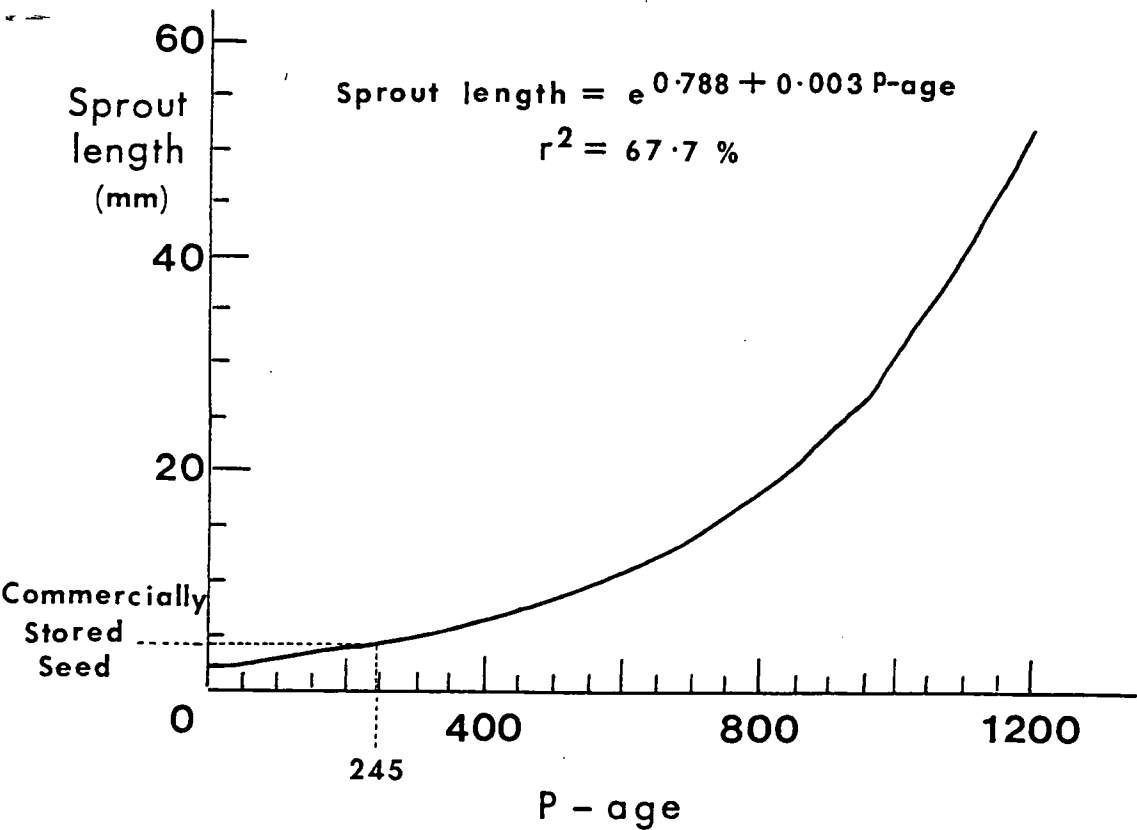
Fig 2.3   Effect of P-age on number of sprouted eyes at the time of planting.

Number of sprouted eyes (SE)

Commercially stored seed

$$SE = e^{(2\cdot38 - 0\cdot002\ p\text{-age})}$$

$$r^2 = 53\cdot4\ \%$$

P-age

0   400   561   800   1200
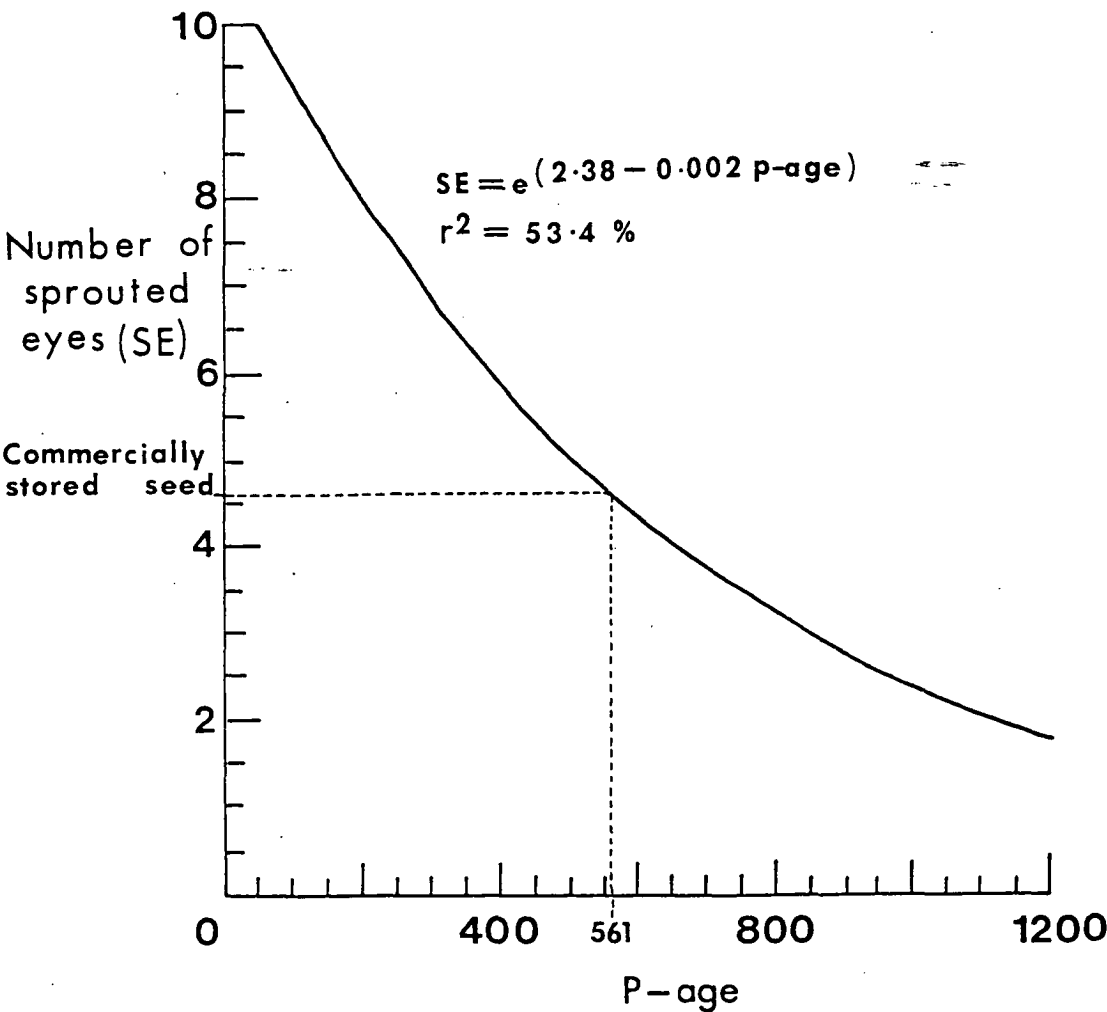
2.3.2 Emergence

Date of emergence was defined as when plants from 50% of the sets had emerged. It was calculated for each treatment by interpolation of plant emergence counts, using the same method as described in Exp.1.

The rate of emergence was affected by physiological age of seed at planting. There was a trend towards delayed emergence with p-younger seed (Table 2.4), with P-750 emerging four days earlier than P-0 seed. However P-1200 seed emerged one day after P-750 seed. The overall trend of delayed emergence occurring with increasing p-age was also evident in Kennebec crops in Exp.1.

TABLE 2.4   Dates of 50% Emergence

P-age	Russet Burbank Cut Seed
0	15/11/82
250	13/11/82
500	12/11/82
750	11/11/82
1200	12/11/82
Commercially Stored	13/11/82

The final plant emergence was recorded on 26/11/82, thirty-seven days after planting (Table 2.5). Most of the p-age seed treatments approached 100%

except the P-1200 treatment which had a reduced final plant emergence of 91.7%.

TABLE 2.5.   Final Plant Emergence   26/11/82

P-age	Plant Emergence %
0	99.4
250	98.1
500	98.4
750	100.0
1200	91.7
Commercially Stored	99.7

2.3.3 Stems

Unlike the growth habit of Kennebec, Russet Burbank tended to produce mainstems which branched below ground. Branching mainstems occurred particularly for the P-0 plants, as the mainstem consistently divided into two to four stems of equal vigour, approximately 10-20 mm distal from the mother tuber. These branched stems were included in the count of primary stems only when they had a sufficient number of underground nodes bearing stolons and tubers.

Identification of primary stems was carried out during destructive sampling of the serial harvests (plots 1-18). Stem numbers are shown in Table 2.6.

Whereas Kennebec showed a trend towards increased stem numbers when p-age was increased to P-250 - P-500, the effect of P-age on stem numbers of Russet Burbank was not clear. Maximum stem numbers occurred for P-0 Russet Burbank and although there was no statistical difference amongst the remaining P-age treatments, there was a trend towards increasing stem numbers with increased p-age . The commercially stored seed had significantly fewer stems than any of the p-age treatments.

Table 2.6   Number of Stems

P-age	Number of Stems/ha x 1000	Number of Stems/Plant[*]
0	173	4.2
250	143	3.5
500	140	3.4
750	152	3.7
1200	156	3.8
Commercially Stored	127	3.1
s.e. of treatment means	3.4	0.08

* assuming plant emergence rate = 100%

2.3.4 Development of Stolons and Tuber Initials

Stolon production and in some cases tuber initiation were observed on immature plants in the first destructive harvest on 23/11/82. Although stolons were present on most plants there were fewer on those from p-younger treatments. The percentage of stems bearing at least one tuber initial was also affected by p-age. No tuber initials were evident on P-0 plants on 23/11/82, but with increasing p-age, a greater number of stems carried tuber initials, so that at P-1200, 25% of stems had at least one tuber initial (Table 2.7).

Table 2.7   Number of Stolons and Initials on Immature Plants.

P-age	Number of stolons/stem			Percentage of stems with atleast :					
				one initial			four initials		
	23/11	30/11	11/12	23/11	30/11	11/12	23/11	30/11	11/12
0	1.63	3.1	5.6	0	59.1	98.2	0	0.	83.6
250	2.27	6.0	7.2	1.1	81.2	100	0	11.6	87.6
500	4.03	6.8	7.2	2.8	78.4	100	0	22.6	96.5
750	3.67	7.0	6.7	16.0	92.7	97.9	0	16.2	95.9
1200	3.13	6.4	7.3	25.2	64.7	99.1	0	34.2	91.6
commercial storage	2.93	5.5	5.9	0	32.8	100	0	3.5	90.7
s.e. of treatment means	0.40	0.4	0.4	1.9	15.3	1.2		8.7	3.1

By 30/11/82, P-0 plants tended to have a lower proportion of stems with at least one tuber initial than the other treatments, but by 11/12/82, nearly 100% of stems had at least one initial for all treatments.

The proportion of stems with at least four initials tended to be greatest for older p-ages up to P-750 on 11/12/82. Commercially stored seed appeared to be slower than P-250 plants to develop stolons and initials, but not as retarded as the P-0 plants.

Stolon production and tuber initiation continued for all treatments after 11/12/82 so that by 19/1/83 (Table 2.8) the average number of primary stolons per stem across all treatments was 7.5. By this date there were no significant differences between the numbers of primary and secondary stolons, and primary and secondary initials for any of the p-age treatments.

Russet Burbank tended to produce more primary and secondary stolons than Kennebec, and proportionately more initials on both types of stolons.

Table 2.8   Numbers of Stolons and Initials on Mature Plants (19/1/83).

P-age	Number of stolons/stem		Number of initials/stem	
	Primary	Secondary	Primary	Secondary
0	7.51	3.03	7.12	1.46
250	7.41	2.71	6.56	0.68
500	7.31	3.44	6.35	1.55
750	8.02	6.22	6.28	3.08
1200	7.94	2.00	7.47	0.31
Commercially stored	6.77	2.41	6.17	1.07
s.e. of treatment means	0.47	1.06	0.51	0.70

2.3.5 Plant Height

Plant height was measured on three occasions (Fig 2.4). At each of these, P-1200 plants were significantly shorter than the other treatments, and P-750 tended to be the tallest. At the earliest measurement on 23/12/82, the P-0 and P-250 plants were still shorter than the other treatments excepting the P-1200's; however by 5/1/83 the P-0 plants were as tall as the other treatments. By the final measurement (19/1/83), when lodging had started, the P-0 plants had the tallest canopy.

In this experiment, Russet Burbank was affected by p-age in a similar manner as was Kennebec of Exp.1. In comparison to Russet Burbank Kennebec tended to produce a taller canopy for all treatments, perhaps resulting from a closer planting density.

2.3.6 Crop Canopy

The development of the crop canopy is presented in Table 2.9 in terms of the leaf area index (L). In Fig 2.5, data from Table 2.9 is presented as non linear regression curves of the form :

$$L = a \times days^b (125 - days)^c$$

when a,b and c are constants.

In comparison to the marked effects of physiological age on the development of L for Kennebec in Exp.1, the response of Russet Burbank to p-age in terms of L was less. Again, plants of P-0 treatment were slow to develop a leaf canopy, but once established achieved a greater and more persistent canopy than most of the other treatments. P-750 plants produced the greatest canopy with L approaching 3.7, which was only about half of the peak leaf area reached in Kennebec. The response of plants to P-250, P-500, P-1200 and commercial storage in terms of L, could not be separated.
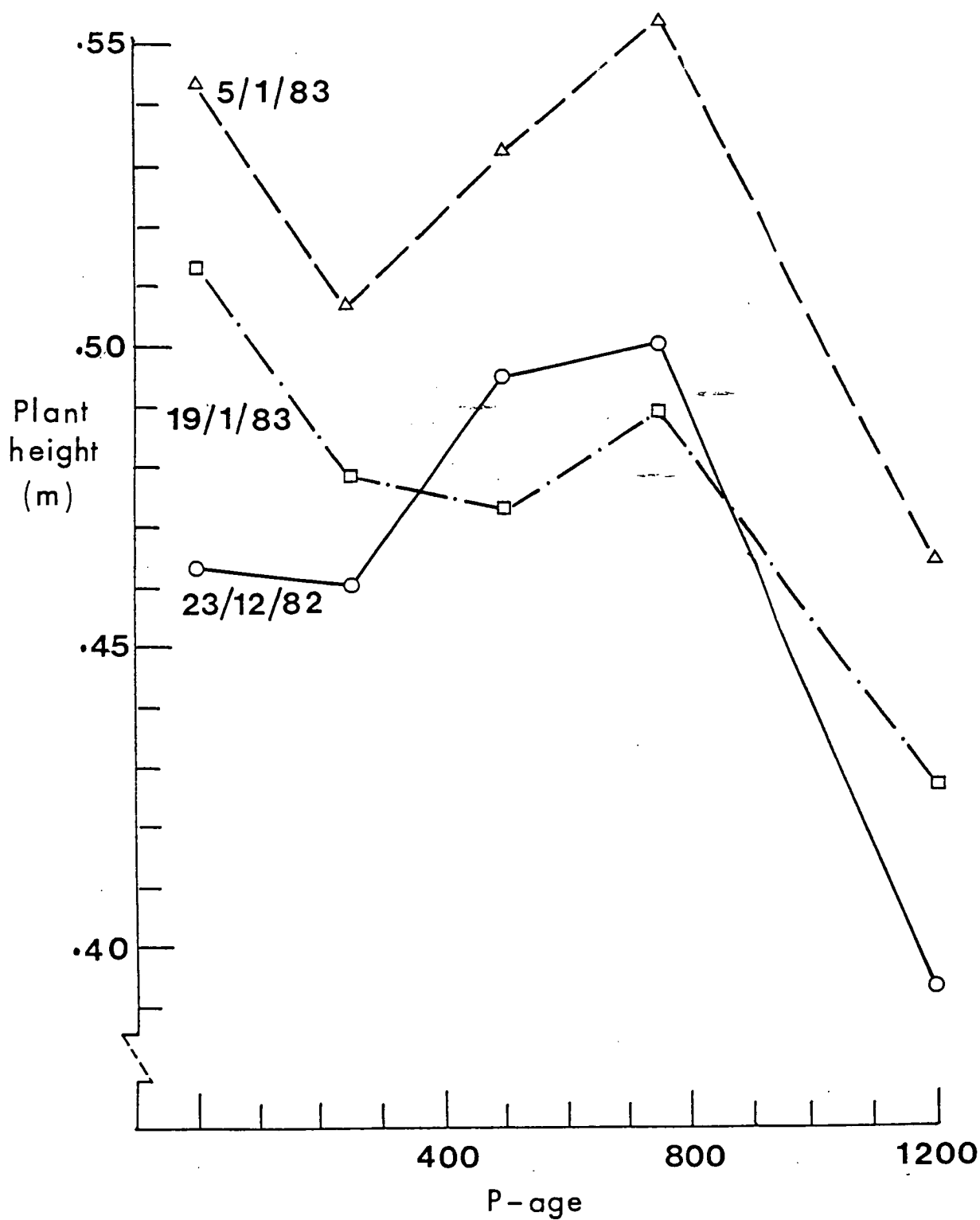
Fig 2.4   Effect of P-age on plant height

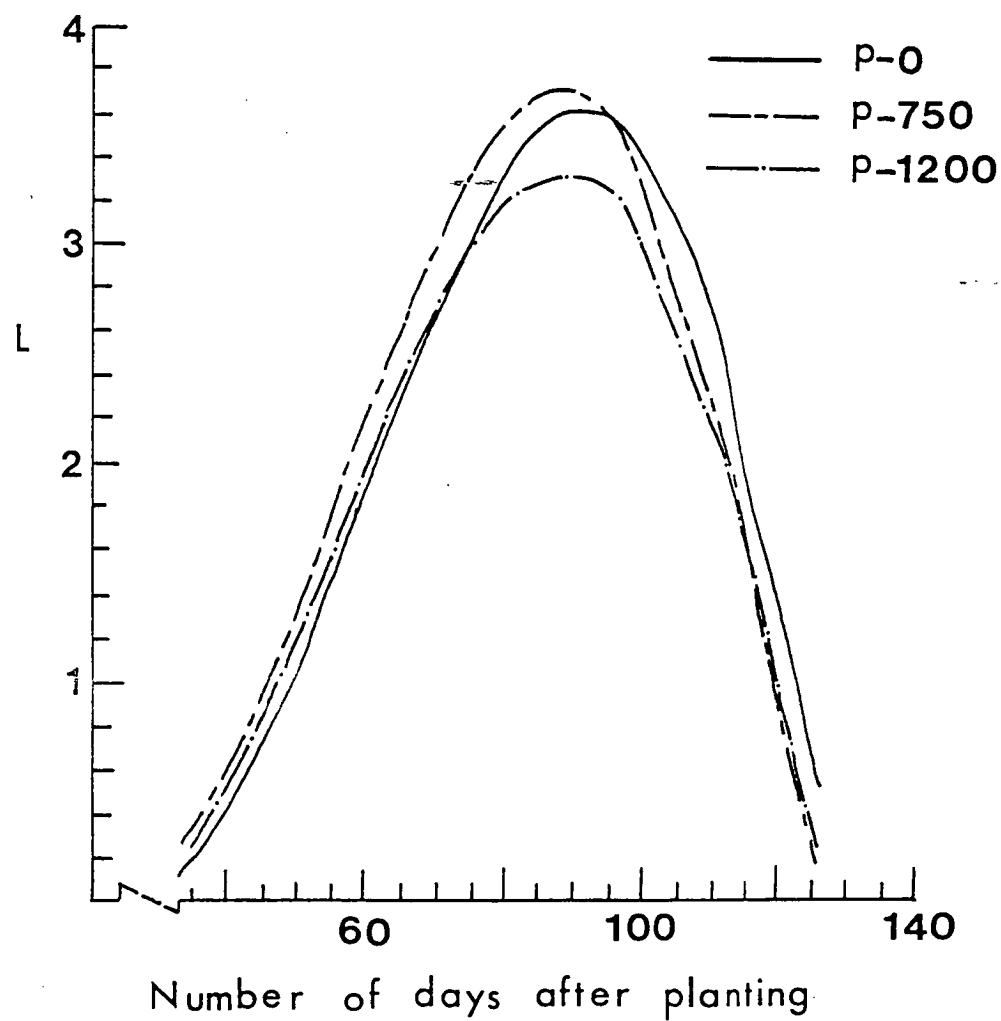Fig 2.5   Effect of P-age on leaf area index

Table 2.9 Effect of Physiological Age on the Development of the Leaf Area Index (L).

Date	0	250	500	750	1200	commercial storage
			Physiological age			
23/11	0.041	0.158	0.220	0.295	0.253	0.143
30/11	0.323	0.546	0.619	0.764	0.727	0.470
11/12	1.074	1.400	1.321	1.591	1.272	1.106
18/12	1.702	1.884	2.169	2.189	1.845	2.111
23/12	2.106	2.414	2.164	2.258	2.010	2.271
29/12	3.199	3.339	2.988	3.188	3.424	2.894
5/1	3.050	2.593	3.120	2.941	2.692	2.767
12/1	3.478	3.097	3.257	3.422	3.079	3.147
19/1	2.729	2.928	3.197	3.292	2.949	3.257
26/1	3.877	3.293	3.234	3.924	3.354	3.059
9/2	2.76	2.57	2.24	2.73	2.17	2.67
17/2	1.43	0.98	0.66	0.76	1.08	1.04
24/2	0.64	0.37	0.17	0.34	0.19	0.29

The degree of persistence of the crop canopies was also measured by a subjective colour rating system as detailed below:

Rating :	Canopy Description :
10	Vigorous,green
8	Losing depth of colour
6	Visible yellowing
4	Predominantly yellow
2	Visible browning
0	All leaf tissue brown

In Fig 2.6, the relative change in colours of the different p-age treatments is shown. Like the Kennebec P-0 plants, the Russet Burbank P-0's maintained a greener canopy for longer. However, unlike the rapidly senescing Kennebec P-1200 plants, the Russet Burbank P-1200's did not mature significantly faster than the P-250 and P-500 treatments. The P-750's proved to be more persistent than all the treatments except the P-0's. This relationship between the p-ages is supported by the decline of L in Fig 2.5.

2.3.7 Light Interception

On the 23/11/82 the proportion of light intercepted by the young plant canopies ranged from 3.6 to 17.5%, with the p-older intercepting more light at this early stage .

In Fig 2.7, a non linear regression of the form:

$$\text{Light intercepted\%} = a \times \text{days}^b (140 - \text{days})^c$$

was fitted to the data, so as to highlight trends and smooth out the large fluctuations which result from the use of solarimeter tubes under a large-leafed crop such as potatoes.

The P-750 plants were able to intercept the most light, up to 80% of the total available, whilst the P-1200 plants only managed to intercept a maximum of 60%. The P-0 plants managed to intercept 77% of available light but this peak was attained later than the peak values of the other treatments. Light interception by the P-250 and P-500 plants followed trends which consistently fell between those of the P-1200 and P-0 plants.

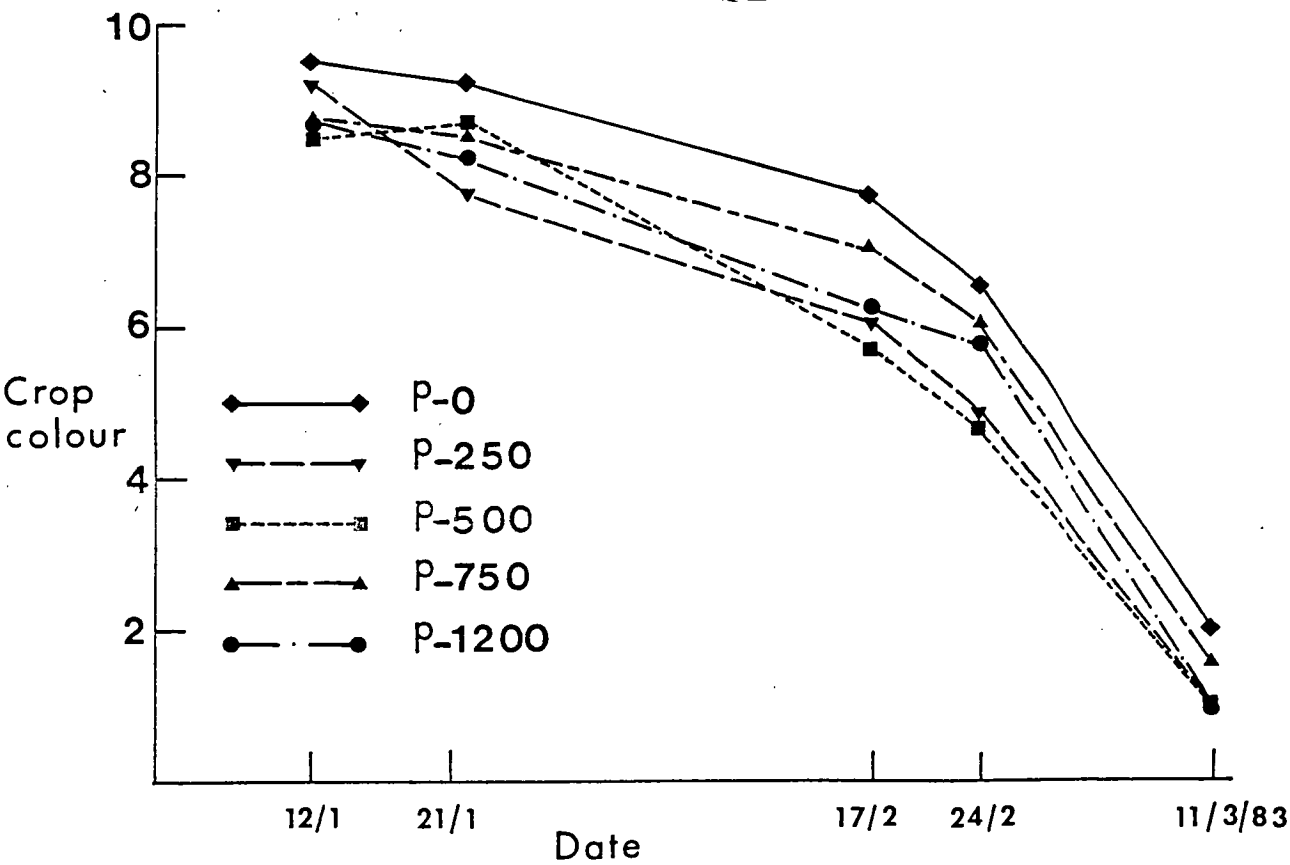Fig 2.6 Effect of p-age on crop colour

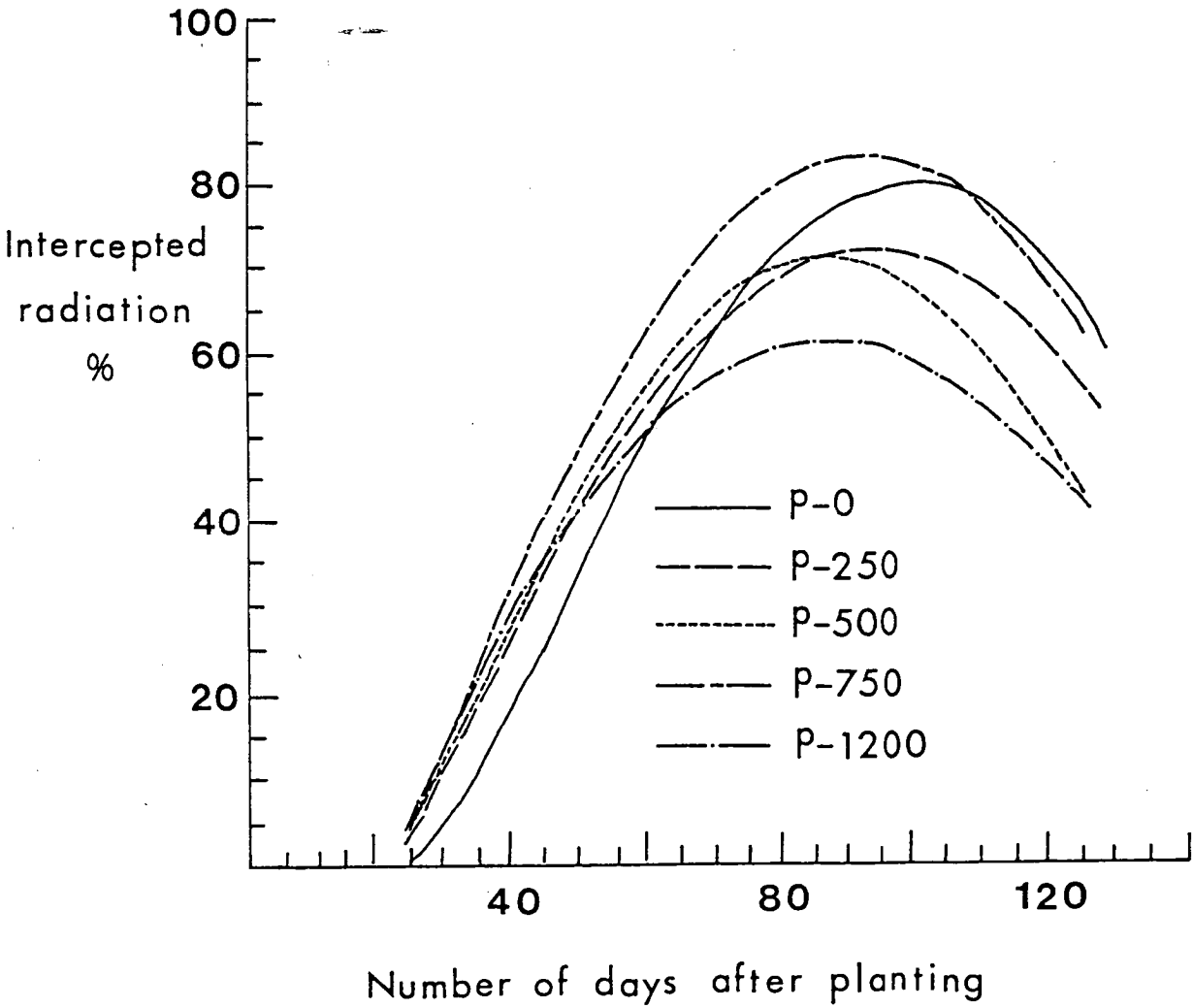**Fig 2.7 Effect of P-age on percentage intercepted radiation**

Intercepted radiation %

P-0
P-250
P-500
P-750
P-1200

Number of days after planting

Table 2.10 Effect of Physiological Age on Total Accumulated Intercepted Radiation , $MJ\ m^{-2}$

Date	P - age				
	0	250	500	750	1200
23/11/82	3.64	12.64	13.9	16.6	17.5
30/11/82	18.6	36.6	40.8	54.1	54.4
23/12/82	190.5	251.1	260.8	330.9	282.2
5/1/83	345.1	441.0	459.0	551.7	448.4
12/1/83	453.3	543.6	567.6	669.1	543.5
19/1/83	567.8	651.0	673.4	782.9	630.2
24/2/83	1057	1084	1058	1266	956.0

In Exp 1 the peak values of intercepted radiation ranged between 80 - 90% with the p-younger treatments attaining the highest values. The consistently lower values of Russet Burbank can be explained by the wider plant spacing which was used in this trial.

In Fig 2.8, the total accumulated intercepted radiation is plotted against time, using a non linear regression function of the equation:

$$\text{Total accumulated intercepted radiation} = \frac{a^{time}}{b + c(\ a^{time})}$$

Maximum accumulated intercepted radiation occurred with the P-750 plants achieving 1250 MJm^{-2}. P-1200 plants only intercepted a total of 950 MJm^{-2} whilst the remaining three treatments P-0, P-250 and P-500 intercepted approximately 1050 MJm^{-2}. Radiation interception by the P-0 treated plants was significantly delayed in comparison to all the other treatments.

The percentage of light which penetrated through the crop, the transmitted light, is plotted against L in Fig.2.9. The data is transformed through the natural logarithm, e . A linear regression of the transformed data produced an r^2 value of 70.3% and an extinction coefficient of k = 0.32. When forced through the Y intercept at 4.605 (natural logarithm of 100) the extinction coefficient was increased to k = 0.42. In contrast, in Exp 1 Kennebec had extinction coefficients of k = 0.42 and 0.41 respectively. The higher values for the latter may have been a result of the closer planting density of Kennebec.

2.3.8   Tuber Development

Destructive harvests of subplots from plots 1 - 18 at approximately weekly intervals were used to monitor tuber development.

Development of yield is shown in Fig 2.10. Late in December, P-750 plants were highest yielding, and maintained the yield advantage throughout most of the growing season. In contrast, rate of yield development of P-1200 plants was strong initially, but by mid January had dropped, and yields thereafter were consistently lower than most of the other treatments. Although development of P-0 yields were initially retarded, by mid January P-0 yields equalled P-1200 yields, and continued at the same levels as the P-1200's.

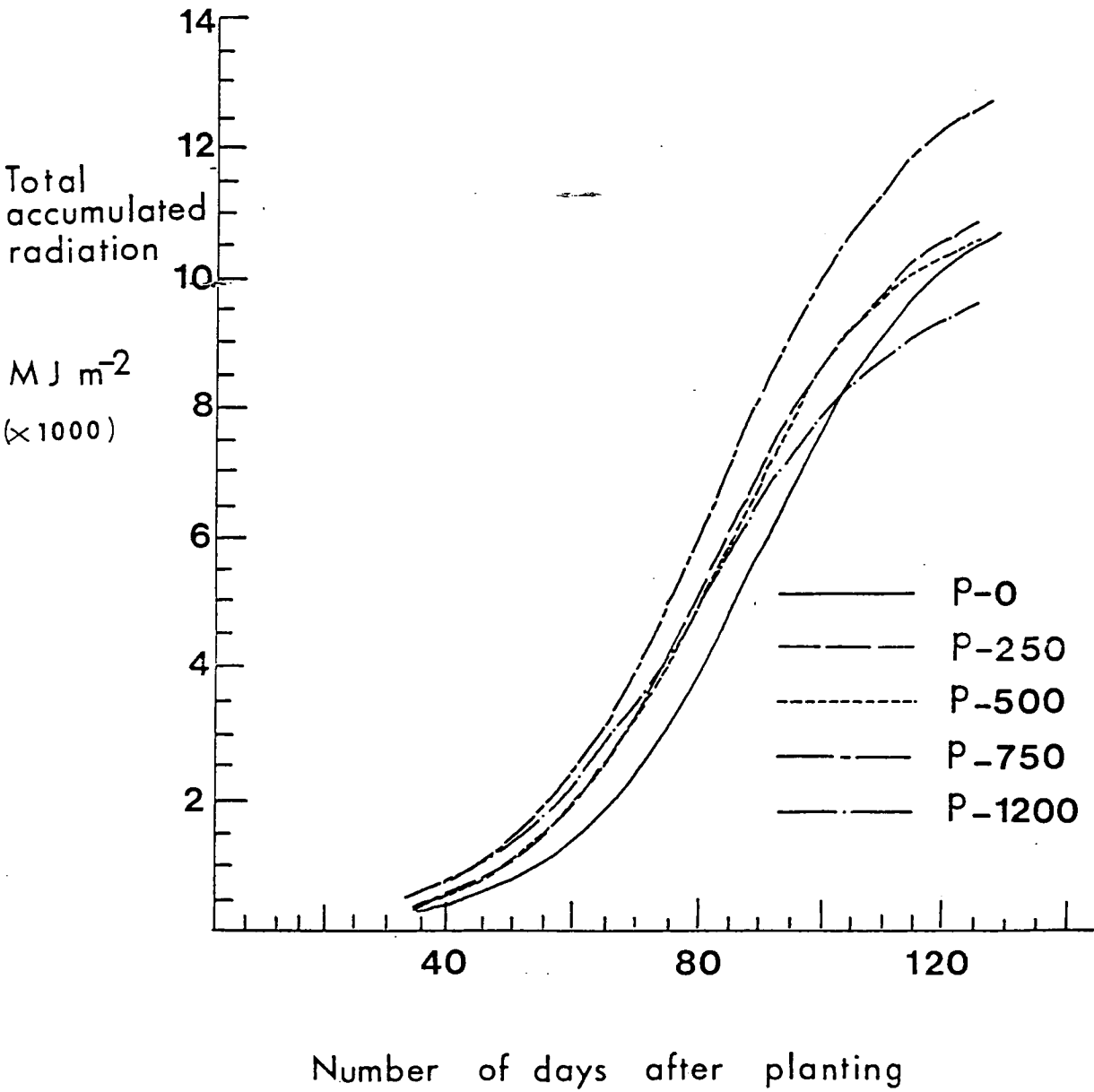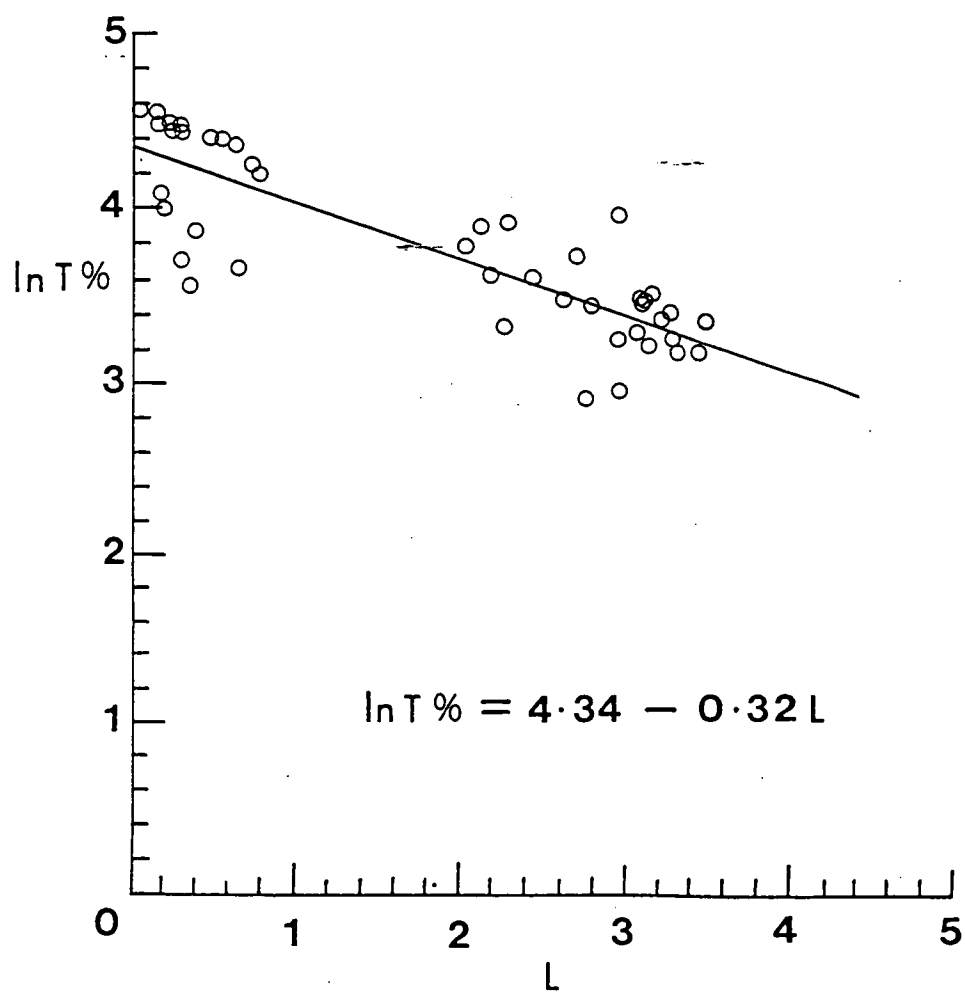Fig 2.8   Effect of P-age on total accumulated radiation versus time.

Fig 2.9   Natural logarithm of percentage transmitted light (T) plotted against Leaf Area Index (L) for Russet Burbank.

$$\ln T \% = 4 \cdot 34 - 0 \cdot 32\,L$$

Plants from P-250 and P-500 treatments produced yields which tended to fall between those of the high yielding P-750 and the lower yielding P-1200 and P-0 plants.

Final yields from both the subplots from plots 1-18, and the main plots 19-36, are shown in Table 2.11. The yields from the subplots when transposed to t/ha, tend to be 10% greater for each treatment than the yields from the mainplots. This pattern was also evident in Kennebec in Exp 1, and was explained by the greater potential in the subplots for the experimental plants to successfully compete against their neighbouring Brownell buffer plants.

Yields tended to be greatest for P-750 plants for both of the final harvests. Yields from P-500 plants were between those of P-750 and the remaining p-age treatments. However no significant differences could be detected between the yields of any of the p-age treatments. Commercially stored seed produced yields between those of P-500 and P-750 treatments for both harvests.

For most of the destructive harvests and the final harvest, tubers were weighed and counted individually. By the end of December each treatment had produced its total potential number of tubers. For destructive harvests after this date , the total number of tubers was observed to steadily decline. The decline in tuber numbers from December until the final harvest in April represented 15% of tubers, and occurred in all treatments. By the end of December, there was a total of 565,000 tubers/ha on average across all the treatments. By April the average had fallen to 477,000 tubers/ha. As harvesting techniques were consistent, and no significant tuber-rotting diseases were evident, the loss of 15% of the total tuber number over the growing season can only be attributed to re-absorption of small tubers.

Table 2.12 shows the final numbers of tubers per hectare for each treatment for both the subplots (plots 1 - 18) and the final plots (19 - 36). Like the total yield data, a discrepency exists between the subplot and mainplot tuber number per hectare. More tubers per hectare developed in the subplots than in the mainplots and this effect was particularly pronounced for the P-

Table 2.11   Final Yields, t/ha.

P-age	Plots 1 - 18 (3 x subplots of 9 plants)	Plots 19 - 36 (9 x rows of 19 plants)
0	49.8	44.9
250	50.8	42.4
500	51.0	46.6
750	54.2	50.3
1200	50.1	44.5
commercial storage:	51.0	47.7
s.e. of treatment means	4.6	2.1

0 treatment. As the adjacent Brownell buffer plants are now recognised as being less competitive than the Russet Burbank, the nine plants in each subplot were able to utilize a greater relative area than the mainplot plants. The reason why this should particularly benefit the P-0 subplot treatment in terms of numbers of tubers per hectare cannot be explained.

For both the subplot and mainplots, P-1200 plants produced the fewest tubers. There was no consistent pattern for the remaining p-age treatments.

In contrast, in Exp 1 , increasing p-age from P-0 to P-1200 for Kennebec resulted in a consistent decline in production of the number of tubers.

Table 2.12   Effect of Physiological Age on the Final Number of Tubers per Hectare

P-age	Numbers of Tubers per hectare (x 1000)	
	Plots 1 - 18	Plots 19 - 36
0	529	389
250	459	384
500	477	415
750	497	407
1200	422	340
Commercial storage:	491	407
s.e. of treatment means	27	12

Changes in the tuber size frequency distribution for each treatment are shown in Fig 2.11 as a series of histograms. As witnessed in Kennebec in Exp 1 , the movement of tubers from the smallest to larger size categories occurrs throughout the growing season. At any time, increasing p-age tends

to increase the proportion of tubers which fall in the larger size categories. This trend in Russet Burbank is not as pronounced as it was for Kennebec.

A comparison between the tuber size frequency distributions of the final harvests of the subplots (plots 1 - 18) and main plots (plots 19 - 36) are made in the histograms shown in Fig 2.12 . Due to the difference in tuber numbers between these plots, particularly at younger p-age treatments, the histograms are not the same for each treatment. However a similar trend is evident in that by increasing p-age, a greater proportion of tubers fall in the larger size categories.

Transforming the individual tuber weights so that the histograms approached symmetric normal distributions as described in Exp 1, the family of Box-Cox power transforms produced an overall best transform (estimated by maximum likelihood) of 0.54 which did not differ significantly from the more convenient square root (0.50) transformation.

In Table 2.13, the square root transformation of mean and variance of individual tuber weights is shown along with the coefficient of variation for the main plots (plots 19 -36).

For Kennebec in Exp 1 the square root means and variances consistently and significantly increased with increasing p-age, whilst in this trial, there were no significant trends across the treatments except for P-1200 which had a significantly greater square root mean and variance. However when the square root mean and variance are converted to mean tuber weight values, a more consistent trend is apparent, with increasing p-age generally resulting in increasing mean tuber weight.

The coefficient of variation of the tuber weights was generally lower for Russet Burbank than it was for Kennebec.

Table 2.13   Effect of Physiological Age on Numbers of Tubers, and Tuber Size Frequency Distribution from the Final Harvest of Plots 19 - 36.

P-age	Number tubers/ha (x 1000)	Sq. Rt Mean g	Sq. Rt Variance g	Yield t/ha	Mean tuber weight g	Coefficient of variation %
0	389	10.3	9.2	44.9	115.3	29.6
250	384	10.1	8.1	42.4	110.5	28.0
500	415	10.2	7.4	46.6	112.3	26.1
750	407	10.8	7.8	50.3	123.6	26.0
1200	340	11.0	10.3	44.5	130.8	29.1
Commercial Storage	407	10.4	8.2	47.7	117.2	27.5
s.e. of treatment means	12	0.2	0.5	2.1	4.5	0.8

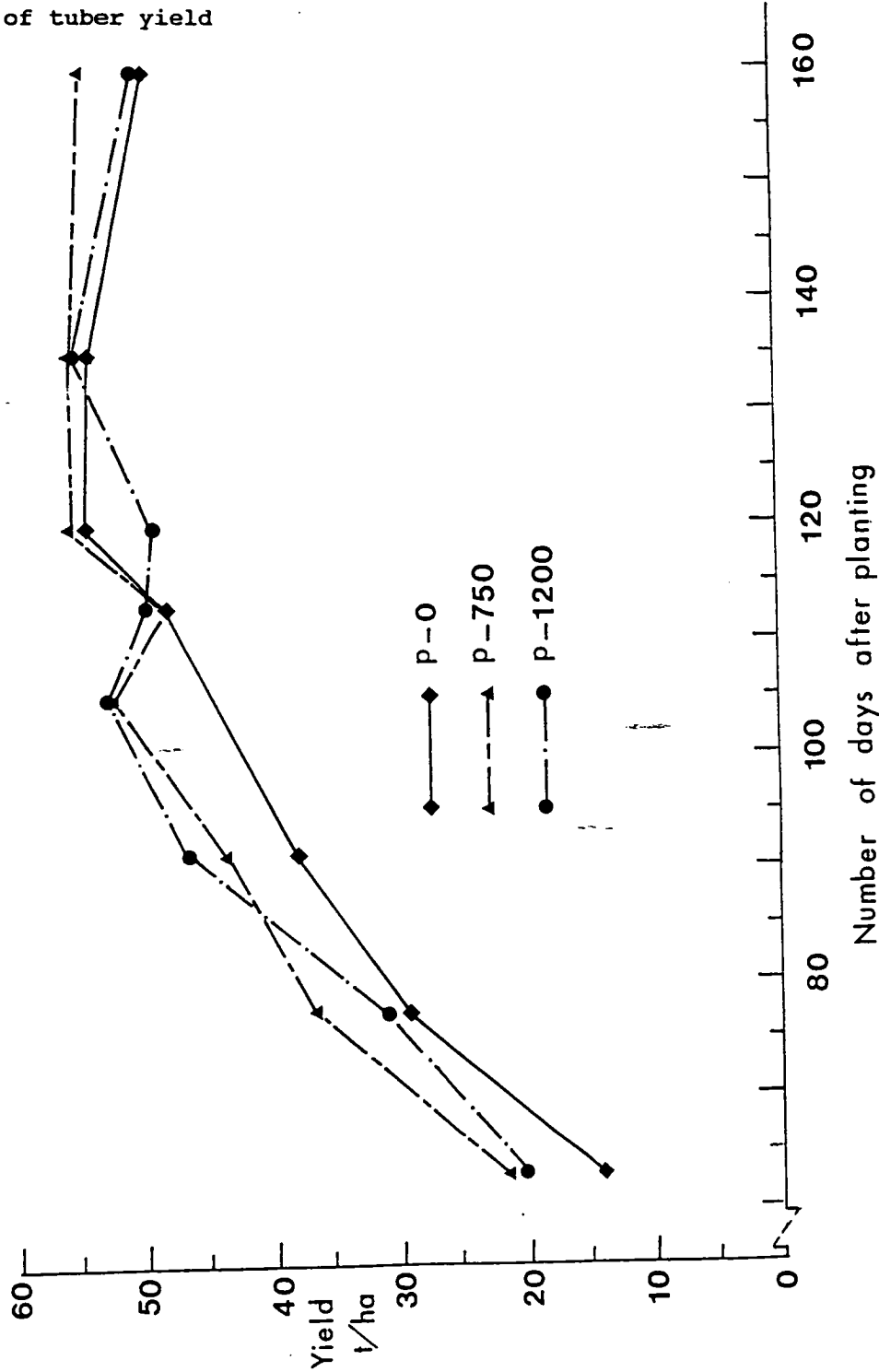Fig 2.10   Development of tuber yield

Fig 2.11 a) Effect of P-age on the changes in tuber size frequency
distributions   - 29/12/82

Fig 2.11 b) Effect of P-age on the changes in tuber size frequency
distributions   - 12/1/83

Fig 2.11 c) Effect of P-age on the changes in tuber size frequency
distributions   - 26/1/83

No. of
tubers
per ha
(x1,000)

Tuber weight (g)

Fig 2.11 d) Effect of P-age on the changes in tuber size frequency distributions – 9/2/83

Fig 2.11 e) Effect of P-age on the changes in tuber size frrequency
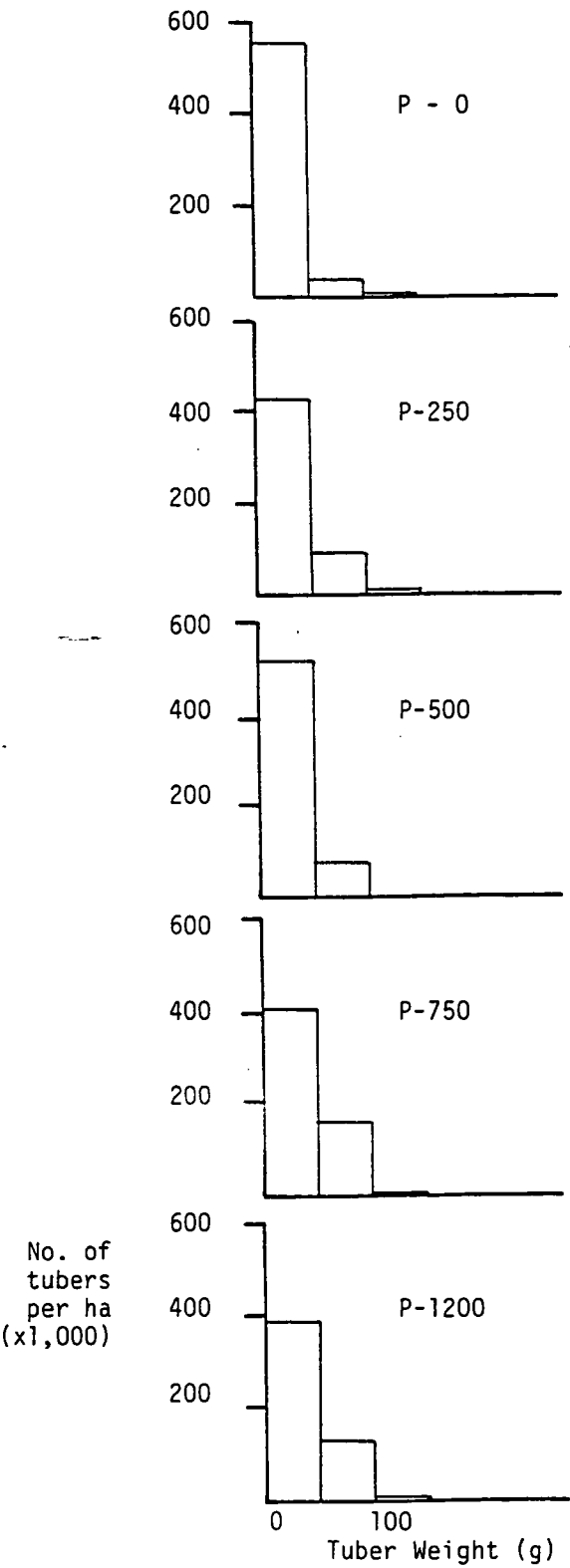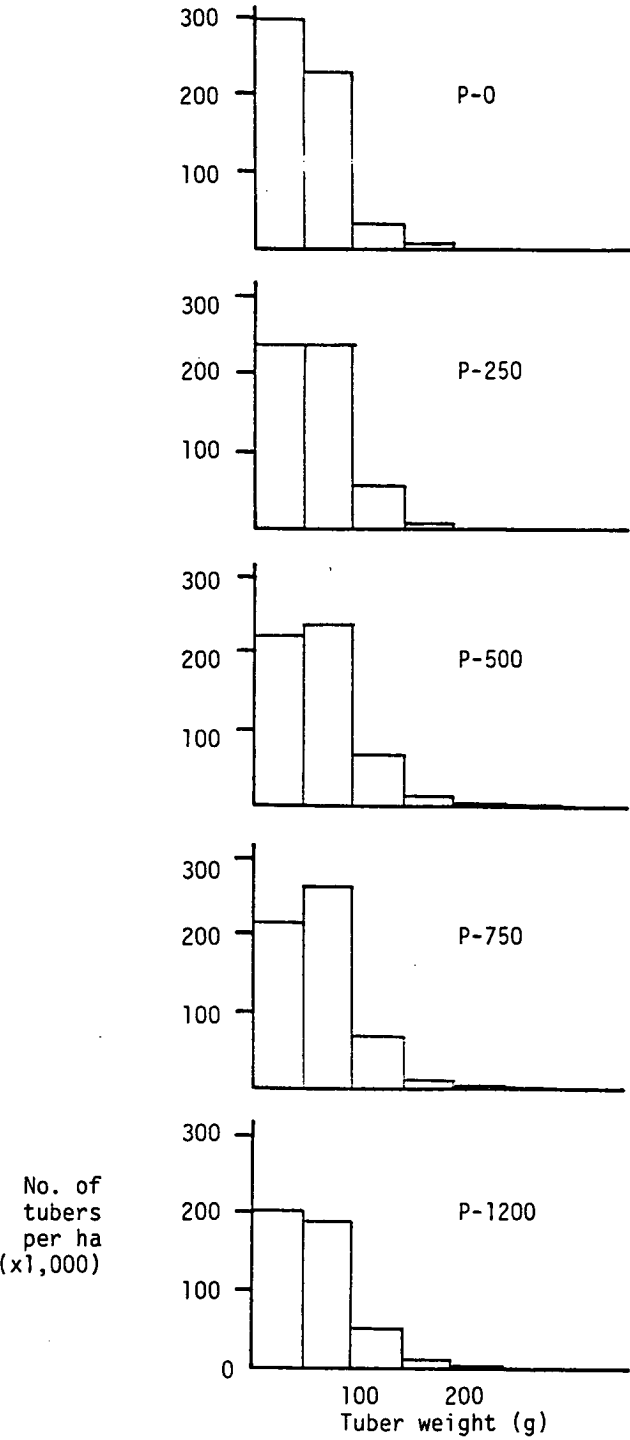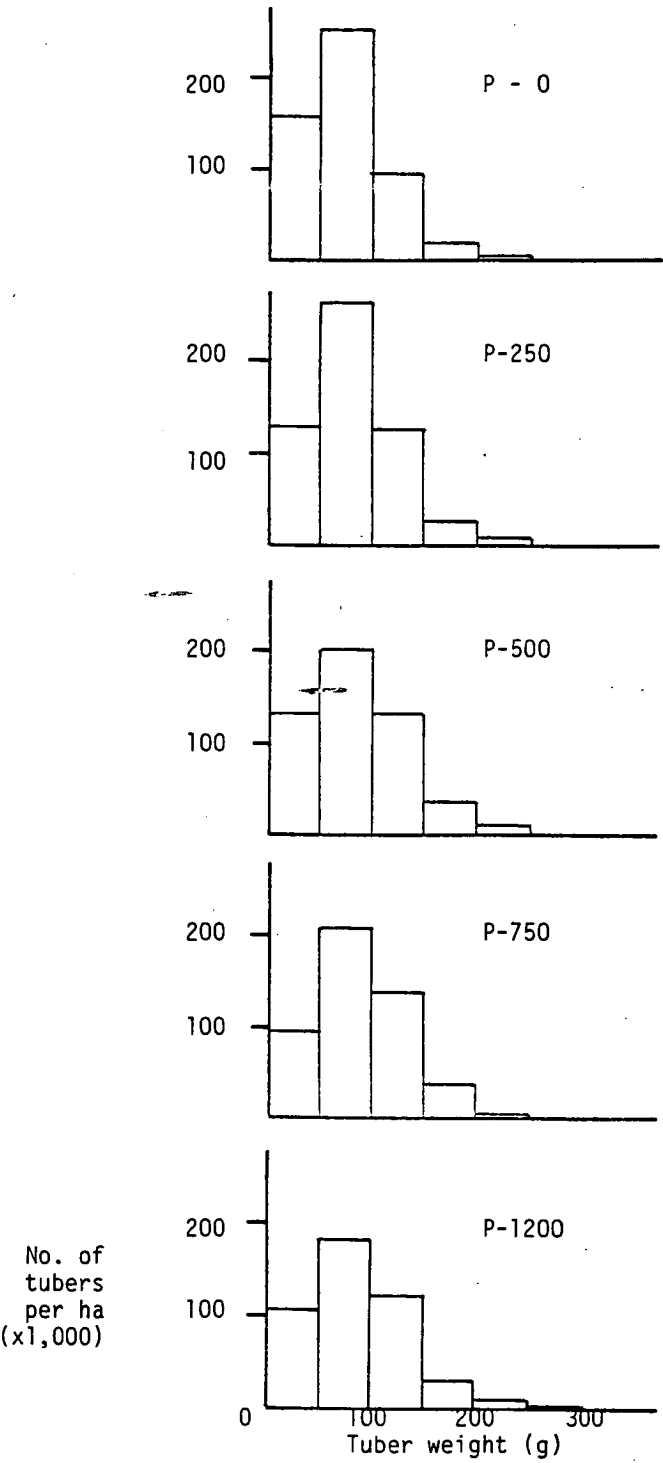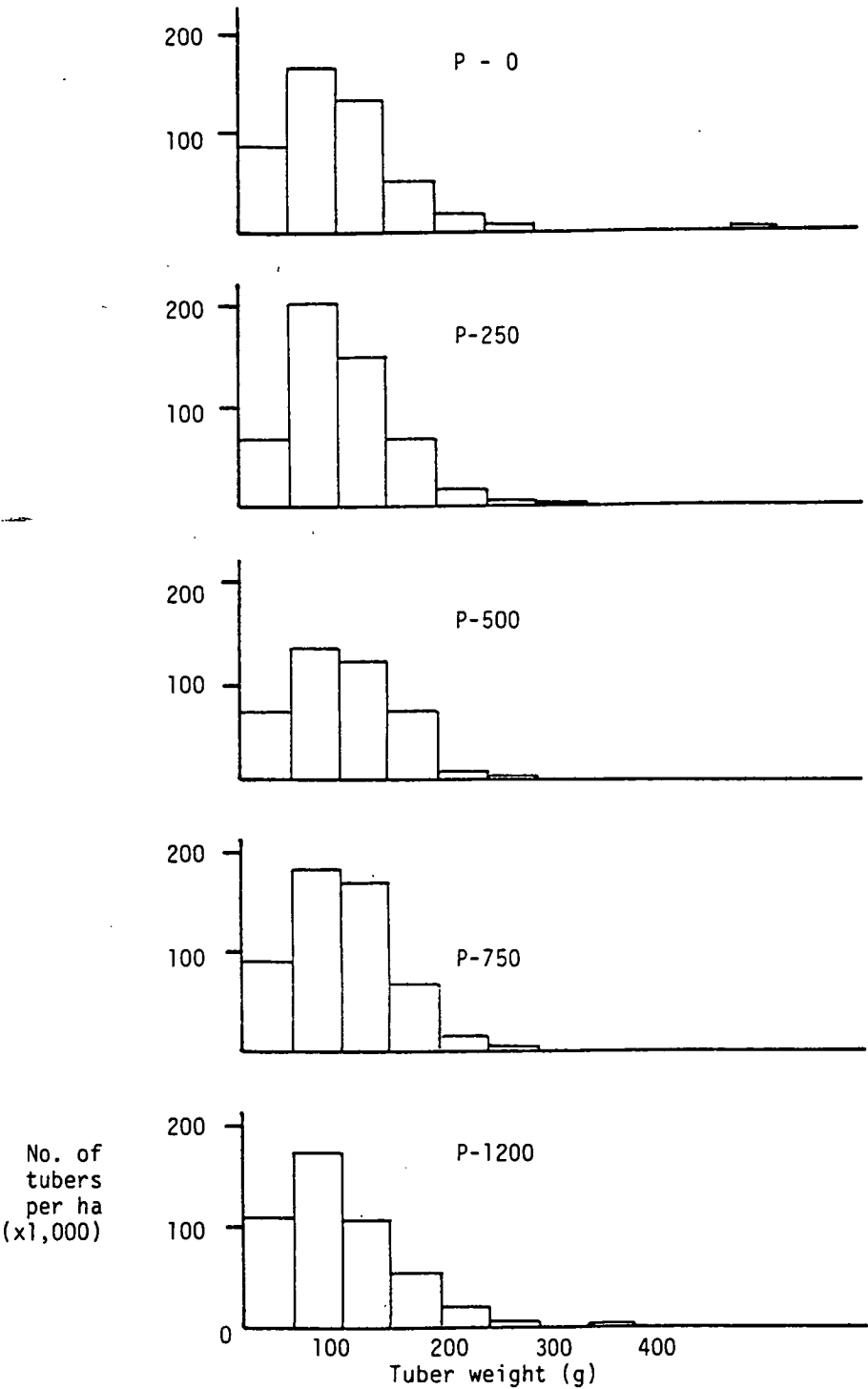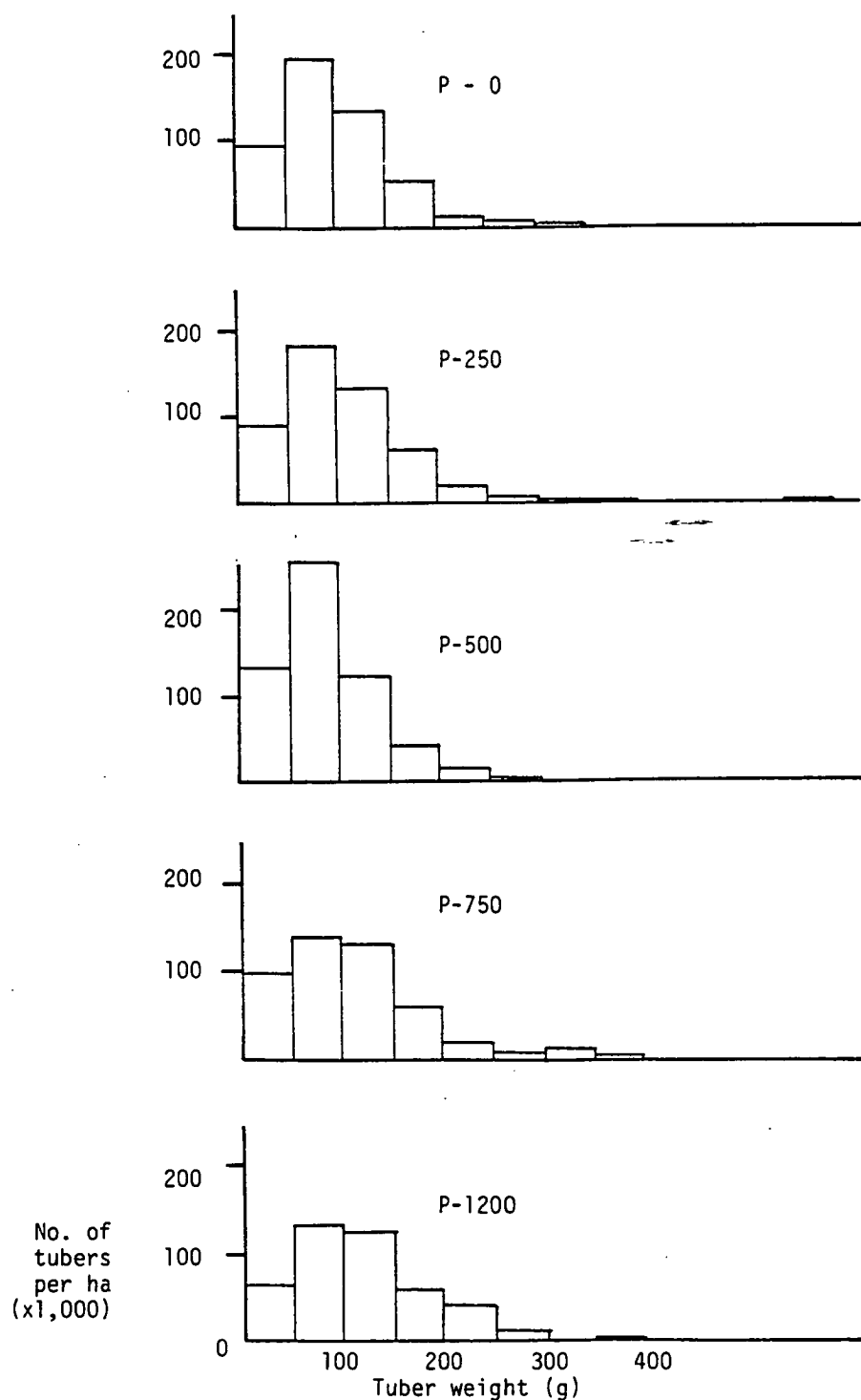distributions   - 17/2/83

Fig 2.11 f) Effect of P-age on the changes in tuber size frequency
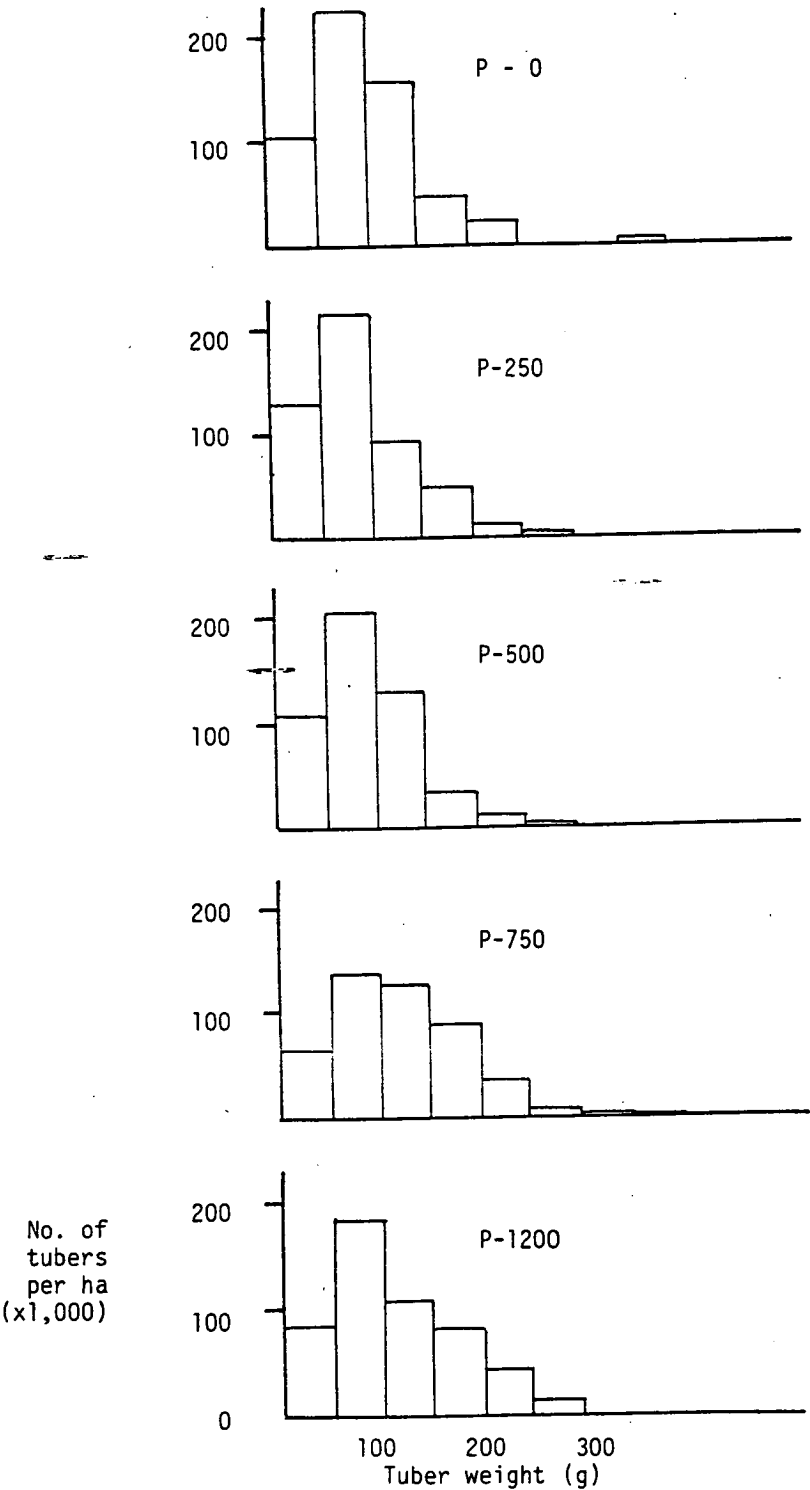distributions   - 24/2/83

Fig 2.11 g) Effect of P-age on the changes in tuber size frequency
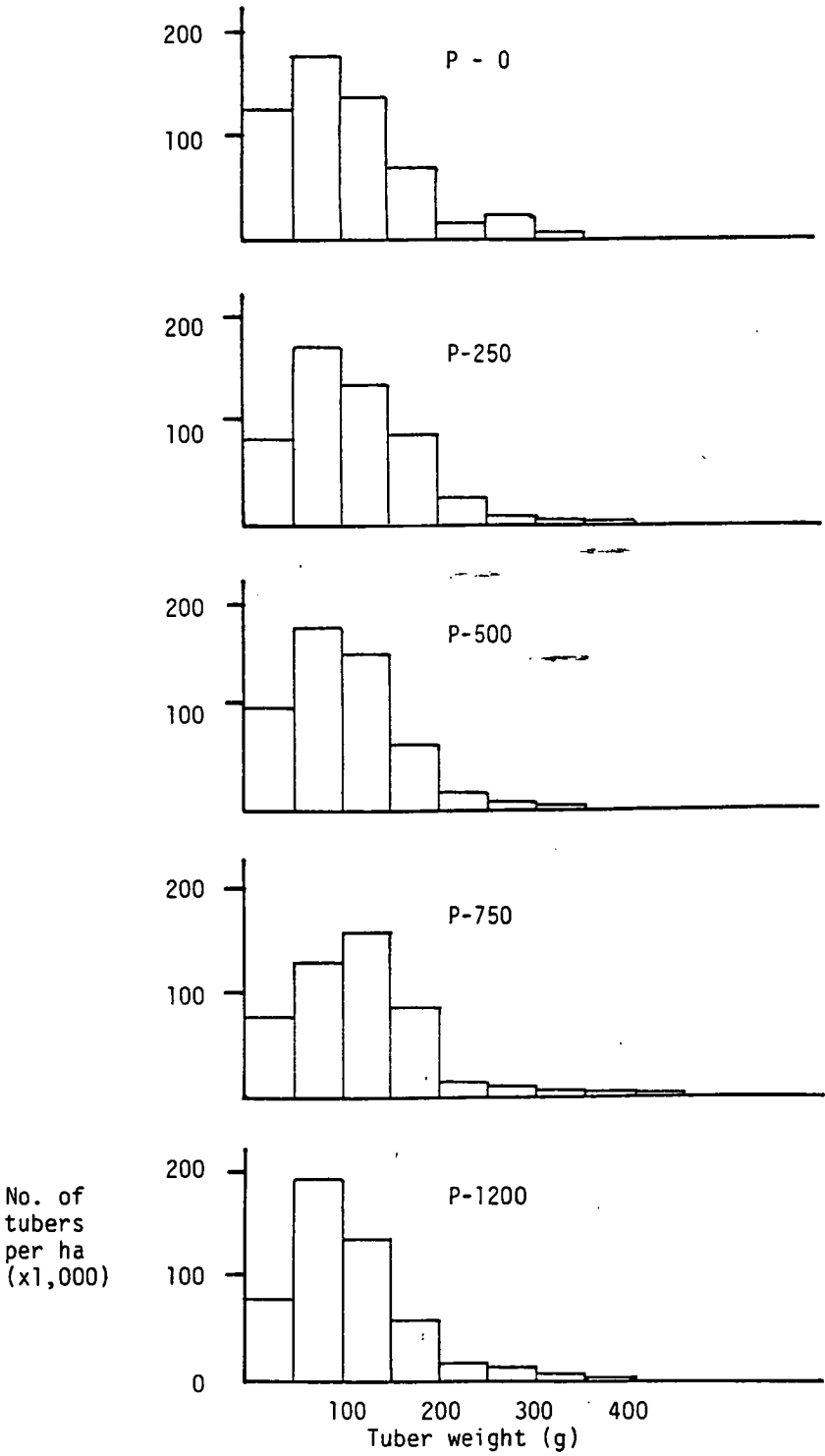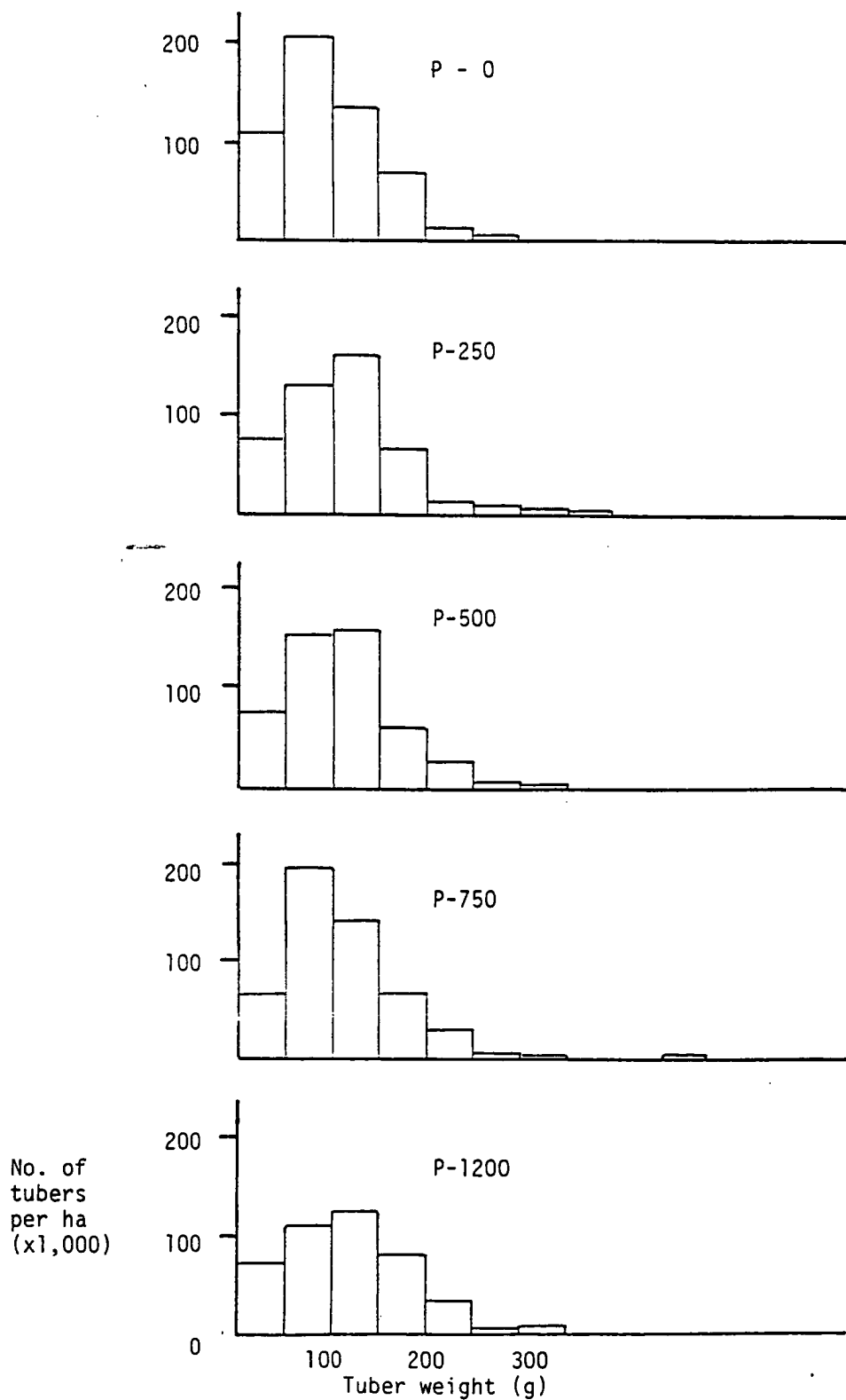distributions   - 11/3/83

No. of
tubers
per ha
(x1,000)

Tuber weight (g)

2.4   Discussion

The very early response of Russet Burbank to p-age was greater than that observed in Kennebec. Sprouting of tubers produced an exponential relationship between p-age and sprout length, and number of sprouted eyes was strongly inhibited by increasing p-age. Also plant emergence was hastened by increasing p-age.

However stem number was not so markedly affected. Whereas for Kennebec and some U.K. varieties (O'Brien et al,1986) greatest stem numbers were produced by P-250 - P-500 plants, in Russet Burbank, P-0 plants produced the greatest numbers of stems, and P-250 - P-500 plants , the least. Substantial subsurface branching of Russet Burbank mainstems may have contributed to this lack of consistency in its p-age response.

The effect of p-age on stolon and tuber initial development was apparent. Early stolon growth and tuber initiation were encouraged by increasing p-age. However as plants matured, any early developmental advantages through p-age on stolon production and tuberisation receded.

Plant height and rate of senescence was also affected by p-age in the same manner as was Kennebec. P-0 plants were slow to develop a canopy, but once established it proved to be taller and more persistent than the p-older treatments.

P-age affected the ability of Russet Burbank to intercept light. P-750 plants were most successful and P-1200 plants least successful. This is in contrast to the P-250 - P-500 plants of Kennebec which were best able to intercept light in Exp. 1.

Development of yield, in terms of total yield, numbers of tubers, and mean tuber weight, did not follow the clear responses which Kennebec showed to p-age. Initially p-older treatments produced greater early yields. However, later, there were no significant differences in final yield, and the small differences which did occur, were in proportion to the variation in total light receipts for each of the treatments. Mean tuber weight tended to increase with increasing p-age, but not to the extent as was evident in

Kennebec. Whereas in Kennebec, the maximum number of tubers per hectare occurred with the p-younger treatments, for Russet Burbank P-500 - P-750 produced the greatest numbers. The coefficient of variation for the square root mean and variance of tuber weights was consistently lower for Russet Burbank than it was for Kennebec.

The reaction of potato cultivars to physiological age is believed to be related to their 'earliness', which is measured by their duration throughout the growing season. In the United Kingdom potato varieties are classified into three maturity groups, early, second early and main crop which broadly indicate the appropriate time of harvesting. There, early varieties have been noted for their responsiveness to physiological aging (Griffith et al, 1984). In Tasmania, the average duration of a Kennebec crop is approximately 100 days (depending on the planting date), whilst Russet Burbank, a later variety, requires as much as 120 days before natural senescence. In U.S.A. Russet Burbank is considered a main crop (mid season) variety (McCown et al, 1977).

The early growth response of Russet Burbank to p-age was comparable to Kennebecs'. However it was not until the latter part of bulking that response of Russet Burbank was reduced. It is likely that the effect of p-age of the mother tuber on the progeny plant will be more intense in the early stages of development when the plant is more reliant on the mother tuber. Consequently a greater proportion of the growing season would be expected to fall under the influence of p-age of the mother tuber for early varieties in comparison to maincrop varieties. Conversely, for maincrop varieties, the influence of p-age could be expected to wane towards the end of the growing season and so explain the lack of response of Russet Burbank to p-age in terms of the final tuber size distributions.

2.5   REFERENCES

Allen,E.J. and R.K.Scott (1980) An analysis of growth of the potato crop.<u>J.agric.Sci.,Camb 94</u>:583-606

Griffith,R.L., E.J.Allen, Susan A Jones and P.J.O'Brien (1984) Comparison of growth and early yields of potato varieties of contrasting maturity classification at three sites. <u>J.agric.Sci.,Camb. 103</u>:443 - 458

O'Brien,P.J., J.L.Jones, E.J.Allen and G.S.Raouf (1986) Effects of physiological age of seed tubers on seed yield and regrowth of progeny tubers. <u>J.agric.Sci.,Camb 107</u>:307 - 327

McCown, B.H. and Kass, I. (1977) Effect of production temperature of seed potatoes on subsequent yielding potential. <u>Am.Potato J. 54</u> : 277-287.

3. EFFECT OF PLANT DENSITY ON THE PHYSIOLOGICAL AGE RESPONSE OF KENNEBEC

3.1 INTRODUCTION

In Exp. 1, Kennebec seed tubers were physiologically aged by sprouting them prior to planting. The effect on the growth and development of the resulting crop was recorded.

It was found that physiologically aged seed initially grew more rapidly, had fewer stems, developed a relatively smaller canopy, which yielded fewer, but larger sized tubers.

The resulting increase in proportion of large tubers was partially attributed to the reduced number of stems.

In Exp 2, Russet Burbank at lower planting density was found to be less responsive to p-age than Kennebec. Although the difference may have been principally due to differences in variety, the lower planting density may have contributed to the reduced response.

In this experiment stems numbers were manipulated by varying planting densities, to determine whether at which stem density, physiologically aging seed enhances the proportion of large tubers.

3.1.1 AIM

The aim of Experiment 3 was to quantify the effect of plant density on the physiological age response of Kennebec seed tubers.

3.2 MATERIALS AND METHOD

3.2.1 Physiological Aging of Seed

Physiological aging of seed was carried out in an illuminated store maintained at 20°C according to the method described in Exp. 1 . Physiological ages of P-0, P-500 and P-1200 were achieved by placing seed in the 20°C store on their predetermined dates.

As well as aging seed to known day degree values, seed was also stored from the time of harvest until planting in ambient temperatures at Tewkesbury. An estimation of the equivalent physiological age which it acquired in the interval between dormancy break and planting was 400 day degrees >4°C. Seed was removed from storage on the day prior to planting for cutting, weighing and sorting. Seed was cut in the same manner as described in Exp.1, as 'splitters'.

3.2.2 Field Trial Design

The field trial was planted at Elliott Research Station on 25/10/82 and the management regime which was used in this trial was the same as that described for Exp.1. The field trial was a randomised block design with three replicates. The three physiological ages, P-0, P-500 and P-1200 and seed from commercial storage, and three planting densities were used. Plant populations of 3.32, 6.43 and 16.37 plants per square metre corresponded to 15, 30 and 74 sets per 5.58, 5.76 and 5.58 m row respectively. All rows were 810 mm apart so rectangularity varied and was confounded with density. The six plants per square metre corresponded to the population used in Exp 1. Plots comprised 4 rows, 0.81 m apart. The two outer-most rows were planted with Kennebec of the same physiological age as the two inner experimental rows. The latter were allowed to grow to maturity for harvesting.

As for Exp. 1, Brownell buffer plants were used at either end of experimental rows. The field plan is shown in Fig 3.1.
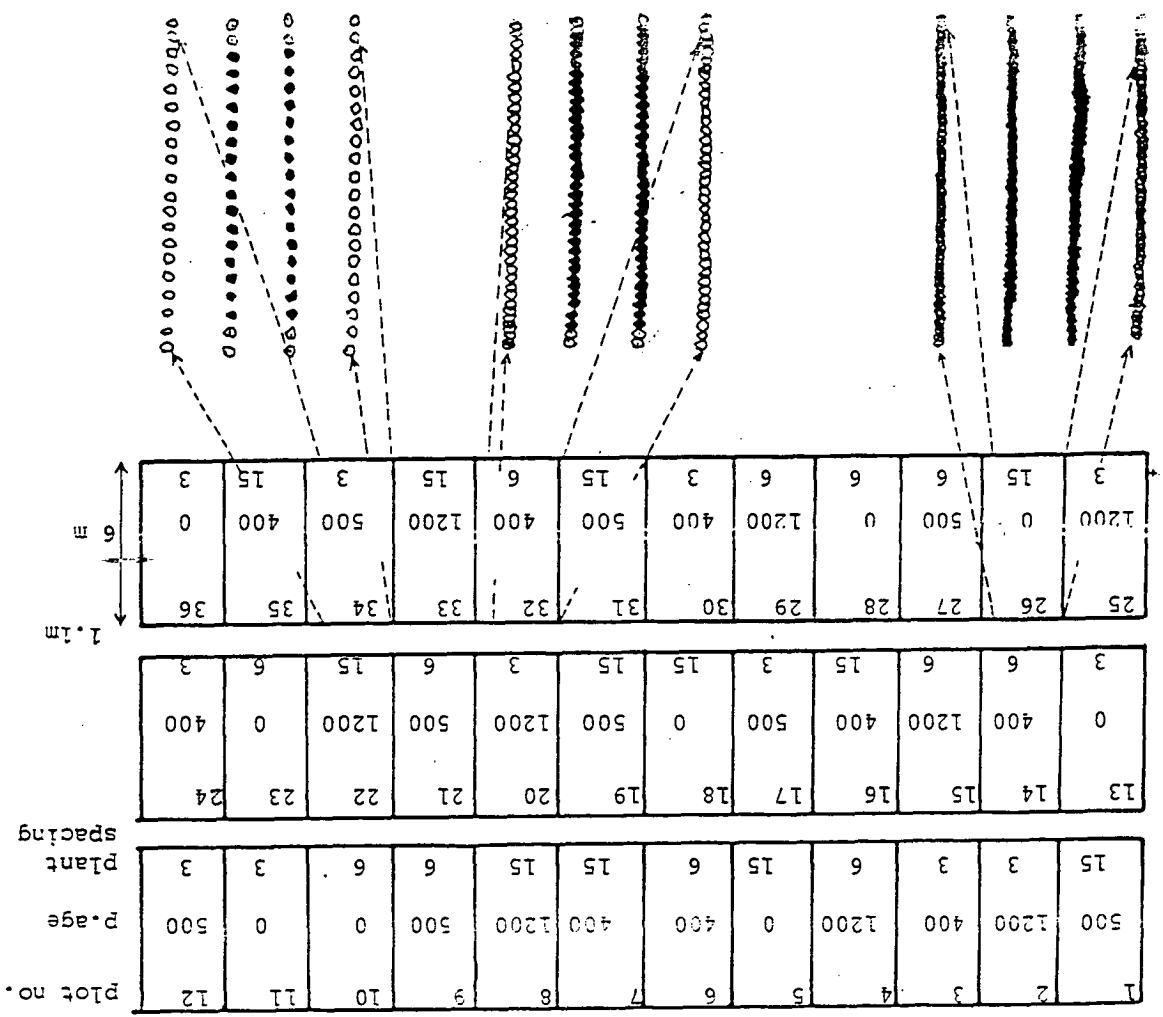
3.2.3 Method of Harvest and Measurement

The emergence rate, stem numbers and colour of the crop were monitored over the season (Table 3.1).

The date of 50% plant emergence was estimated by interpolation of the emergence results with time. Emergence was recorded for only the P-0, P-500 and P-1200 treatments.

Crop colour was calculated on the same subjective rating system described in Exp.2.Colour was estimated for each of the two experimental rows per plot.

Table 3.1 Dates of Crop Assessment

Emergence Rating	Colour Rating	Stem Counts	Harvest
10/11/82	18/1/83	28/3/83	14/4/83
12/11/82	21/1/83		
18/11/82	3/3/83		
26/11/82			

Stem number was counted at maturity of the crop by pulling individual stems. Only primary stems originating from the parent tuber were included. Branching of mainstem rarely occurred below ground.

On April 14, 1983, the trial was harvested. A single row digger was employed, and tubers were bagged manually. Yield from individual rows was separately bagged and labelled. Individual tuber weights were recorded as in Exp 1.

3.3 RESULTS

3.3.1 Emergence

Dates of 50% emergence were affected by physiological age and not by

planting density.

Over the three planting densities the average date of 50% emergence for P-0,
P-500 and P-1200 treatments was 15/11/82, 12/11/82 and 10/11/82.

3.3.2 Stems

The number of stems per hectare increased proportionately with increased
planting density (Table 3.2). Effects of physiological age are clear but
smaller than the very large differences in stem numbers across the plant
spacing treatments.

Dividing the number of stems per hectare, by the planting density, provides
an estimate of numbers of stems per plant assuming emergence reached 100%
(Fig. 3.2).

An analysis of variance on the numbers of stems per plant showed differences
occurred due to the effects of physiological age but not through the effects
of planting density.

Physiological age of P-500 produced the most stems per plant at each
planting density. Except at 6 plants per square metre, there were no
significant differences between the number of stems per plant from the
treatments P-0 or P-1200, but in each case the number of stems from P-1200
plants were higher than they were from P-0 plants.

The number of stems per plant produced by the commercial storage treatment
was not significantly different than that from the P-0 or P-1200, but less
than that from the P-500 treatment.

Table 3.2   Effect of Physiological age and Plant Spacing on the Number of Stems Per Hectare (x 1000)

Physiological Age day degrees >4°C	Planting Density		
	3 plants m^{-2}	6 plants m^{-2}	16 plants m^{-2}
0	94.0	198.0	500.1
500	129.4	248.2	585.8
1200	99.0	214.6	526.2
Commercial storage	95.9	210.6	461.5

3.3.3 Crop Colour and Rate of Senescence

Crop colour was rated on three different occasions using the same rating system as in Exp 2 when a score of 10 represented a vigorous green crop and 0, a completely senescent crop (Table 3.3).

For each date, both physiological age and planting density significantly affected colour. Significance was tested by analyses of variance for each planting date at pr<.05. The greater the planting density, the more rapidly the crop matured and changed from green to yellow and eventually brown. Increasing physiological age had the same effect on crop colour but not to such a noticeable degree. The commercial storage treatment maintained its colour nearly as strongly as the P-0 treatment.

Fig 3.2 Effect of p-age and planting density on number of stems per plant
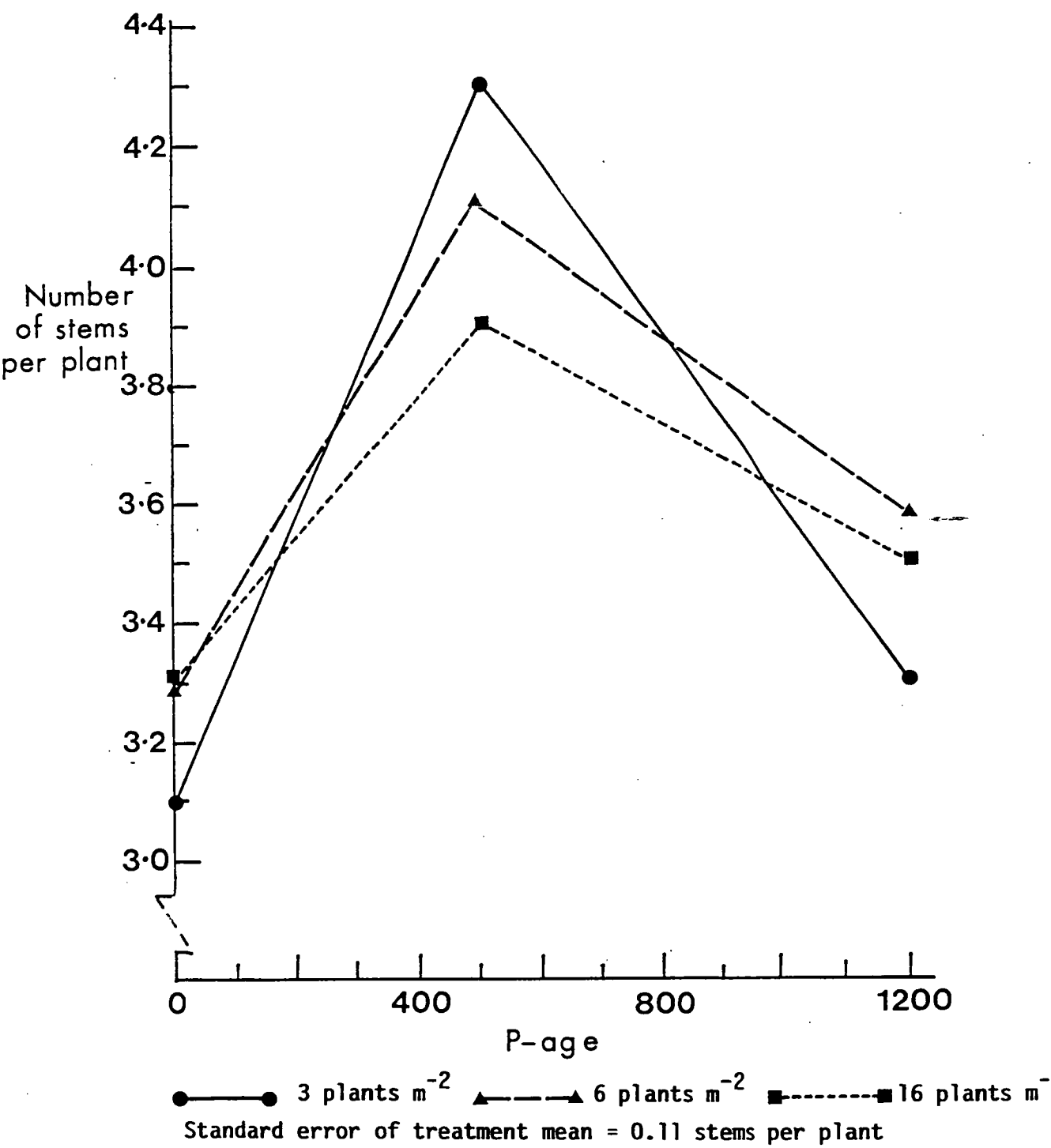
Table 3.3   Effect of Physiological Age and Planting Density
on Changes in Crop Colour with Time

Physiological Age	Planting Density (Plants m^{-2})			
	Date	3	6	16
0	18/1/83	9.5	8.7	8.2
500	18/1/83	8.2	8.0	7.2
1200	18/1/83	8.7	7.5	6.5
Commercial Storage	18/1/83	9.5	8.7	8.0
0	21/1/83	9.0	8.5	7.7
500	21/1/83	8.0	7.5	7.2
1200	21/1/83	8.0	7.2	6.7
Commercial Storage	21/1/83	8.5	8.0	8.0
0	3/3/83	2.8	1.3	0.8
500	3/3/83	2.2	1.0	0.3
1200	3/3/83	1.7	0.7	0.5
Commercial Storage	3/3/83	1.8	1.3	1.0

3.3.4 Yield

As planting density increased from 3 to 16 plants per square metre, yields
significantly increased from 45.1 tonnes/ha to 55.5 t/ha, over the p-age
treatments (Fig. 3.3). At the two lowest planting densities, the P-1200
treatment had significantly lower yields than those from P-0 treatments. At
6 plants m^{-2} there was a trend towards reduced yields from increasing p-

age, whilst at 16 plants m^{-2} the trend altered so that P-500 yields were greatest at 58.5 tonnes/ha.

In this experiment two components of yield were also measured; they were numbers of tubers per hectare and mean tuber weights of the tuber size frequency distribution.

e.g. Yield = Number of tubers/ha x mean tuber weight

and Mean tuber weight = (square root mean)^2 + square root variance

when: square root mean is the mean value of the individual tuber weights transformed through the square root function.

and square root variance is the variance of the population of square root tuber weights around the square root mean. (See Exp. 1 for derivation of the above equations.)

Number of tubers per hectare significantly increased with increased planting density (Fig 3.4). At 16 plants m^{-2} increasing p-age significantly reduced number of tubers per hectare. At 6 plants m^{-2} increasing p-age still reduced the numbers of tubers per hectare, but not to the extent that it did at 16 plants m^{-2}. At 3 plants m^{-2}, P-500 plants produced the greatest number of tubers per hectare and P-0 plants produced less than the P-1200's. The number of tubers from commercially stored seed ranged between those of P-0 and P-500 for each planting density.

Mean tuber weight was strongly affected by planting density, falling from 205.3 g/tuber for 3 plants m^{-2}, to 109.0 g/tuber for 16 plants m^{-2} (Fig. 3.5). An interaction occurred between physiological age and plant density so that at 16 plants m^{-2}, increasing physiological age resulted in increasing mean tuber weights, whereas at 3 and 6 plants m^{-2}, maximum mean tuber weight occurred at P-0 (Fig 3.5).

The coefficient of variation of the tuber size frequency distributions was unaffected by either planting density or p-age. For all treatments it was approximately 30%.

Fig 3.3 Effect of planting density and p-age on yield - t/ha

Standard error of treatment mean = 1.85 t/ha
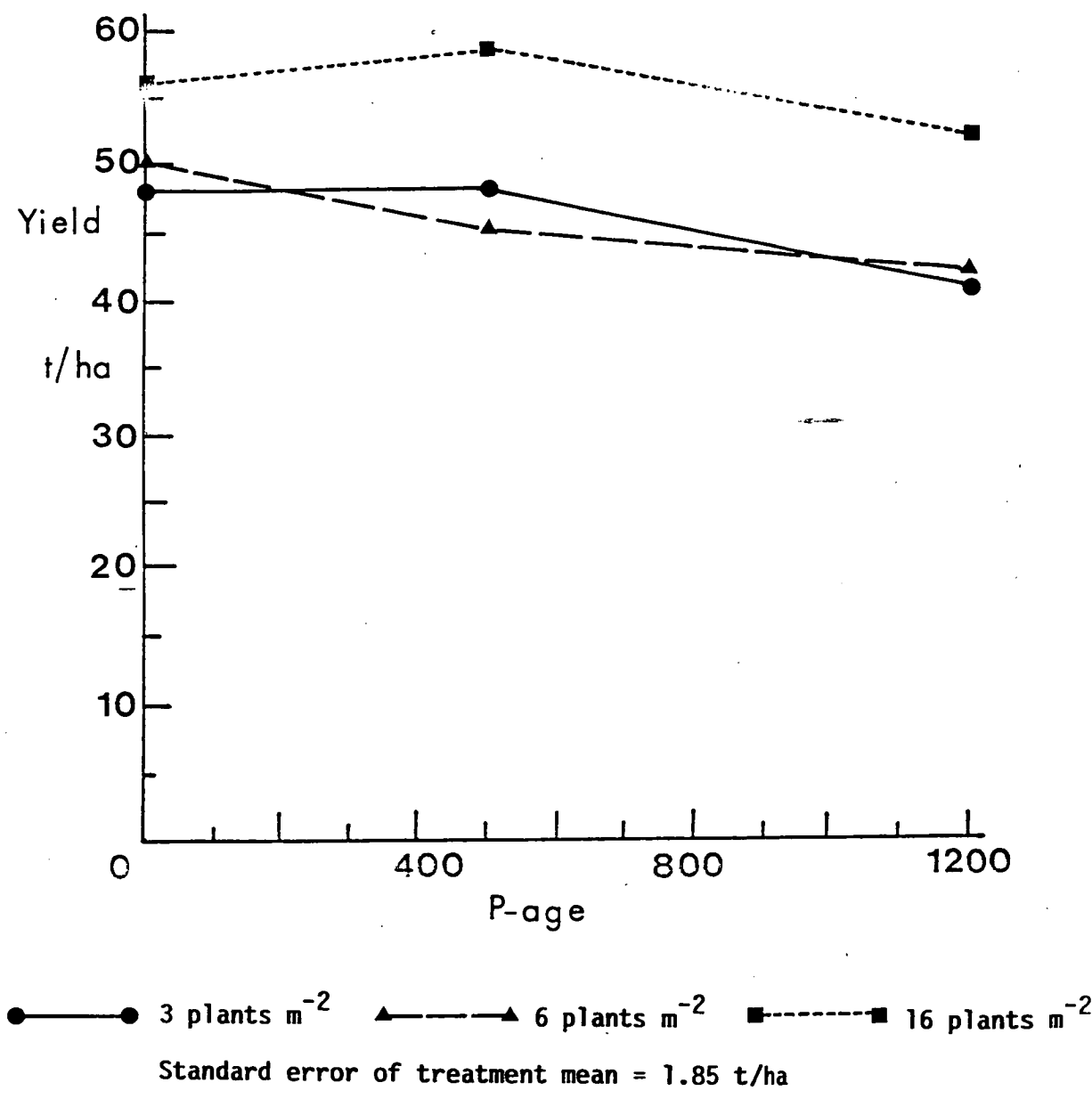
Fig 3.4 Effect of p-age and planting density on number of tubers per hectare

Fig 3.5 Effect of p-age and planting density on mean tuber weight

Mean tuber weight (g)
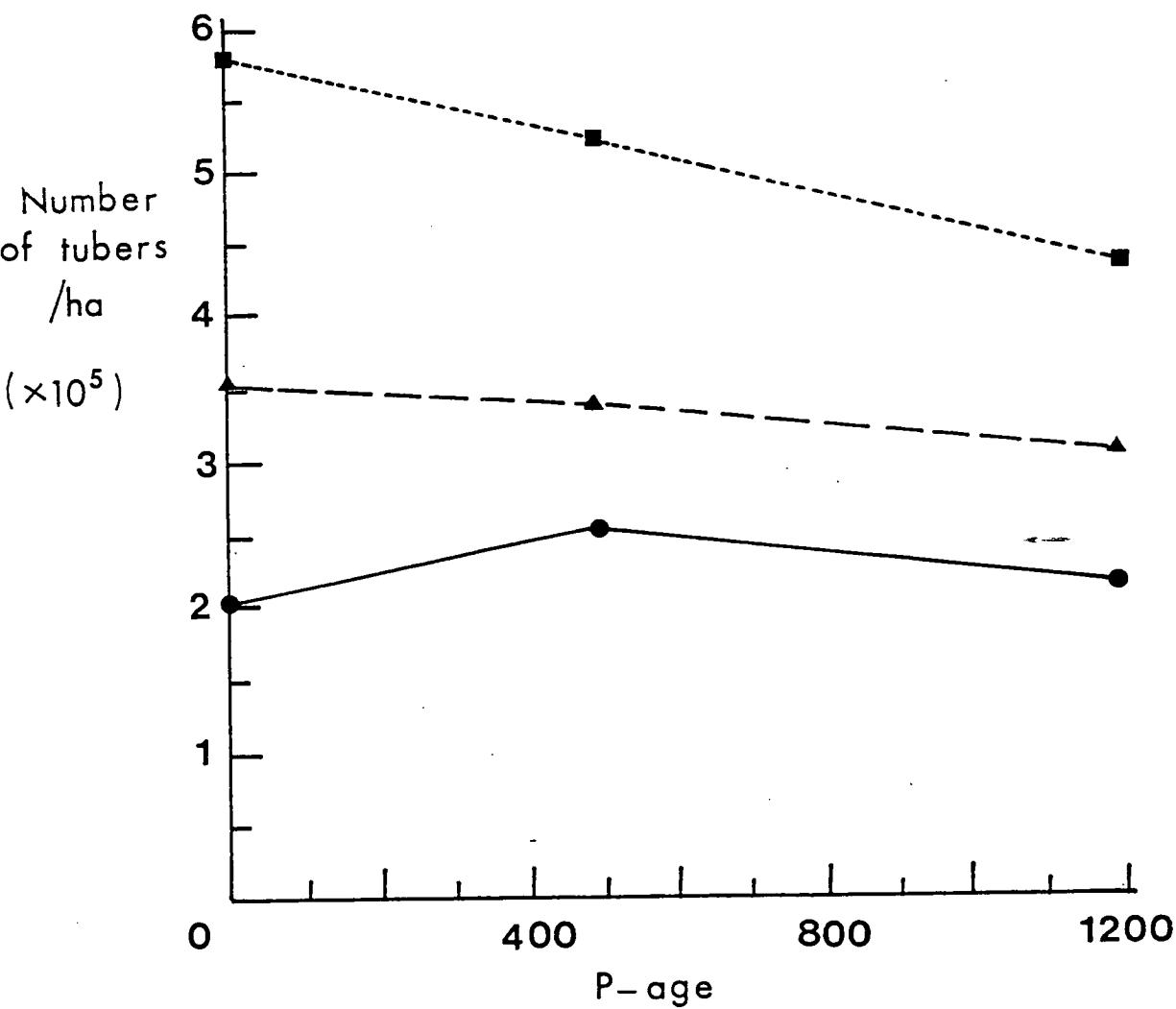
P-age

● ● 3 plants m^{-2} ▲ — — ▲ 6 plants m^{-2} ■---------■ 16 plants m^{-2}

Standard error of treatment means = 7.67 g
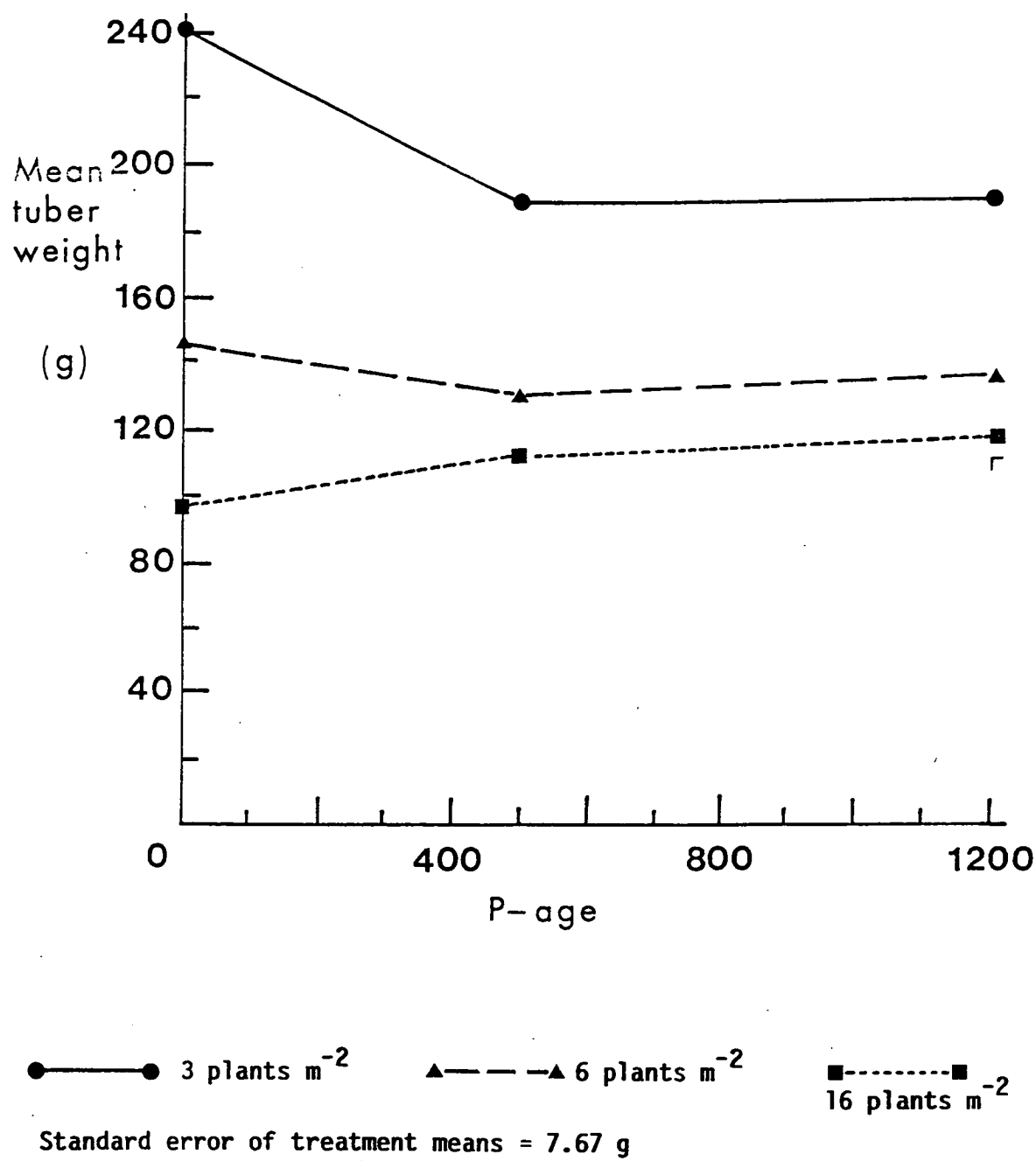
3.4 DISCUSSION

Regardless of planting density certain characteristics of the physiological age response documented in Exp. 1, were observed in this experiment. Rates of emergence were slower for P-0 plants, longevity of the crop was greater and so was yield from p-younger treatments.

Of greatest note was the relationship between physiological age and numbers of stems per plant . At each of the three planting densities the greatest number of stems per plant occurred when physiological age was P-500 . At p-ages greater or less than P-500, numbers of stems per plant were reduced.

Total yield was significantly lower at all plant spacings, from P-1200 seed. In Exp. 1 this effect was observed and attributed to a smaller crop canopy which was less able to intercept radiation. Also in Exp. 1 crops from physiologically aged seed were observed to senesce earlier. In this experiment rate of senescence was measured by rating leaf colour. Early senescence was encouraged by increased physiological age and also by increased planting density.

At high plant density the effects of physiological age on the components of yield, mean tuber weight and tuber number, which were observed in Exp. 1 werapparent. They included reduced tuber numbers and increasing mean tuber weight with increasing physiological age.
However, at low plant density these affects did not occur as mean tuber weight was greatest for P-0 at 3 plants m^{-2}, and numbers of tubers were less than the other physiological age treatments at 3 plants m^{-2}.

It appears that the effects of physiological age on mean tuber weight and tuber numbers are related to the degree of competition exerted on the plant.

When little or no interplant competition occurs such as at 3 plants m^{-2}, the main affect of p-age is seen through its influence on the number of stems per plant. At this low density, there were no significant differences between the number of tubers per stem for any p-age. Hence the resulting mean tuber weight is proportional to the total available assimilates divided by the number of stems per plant.

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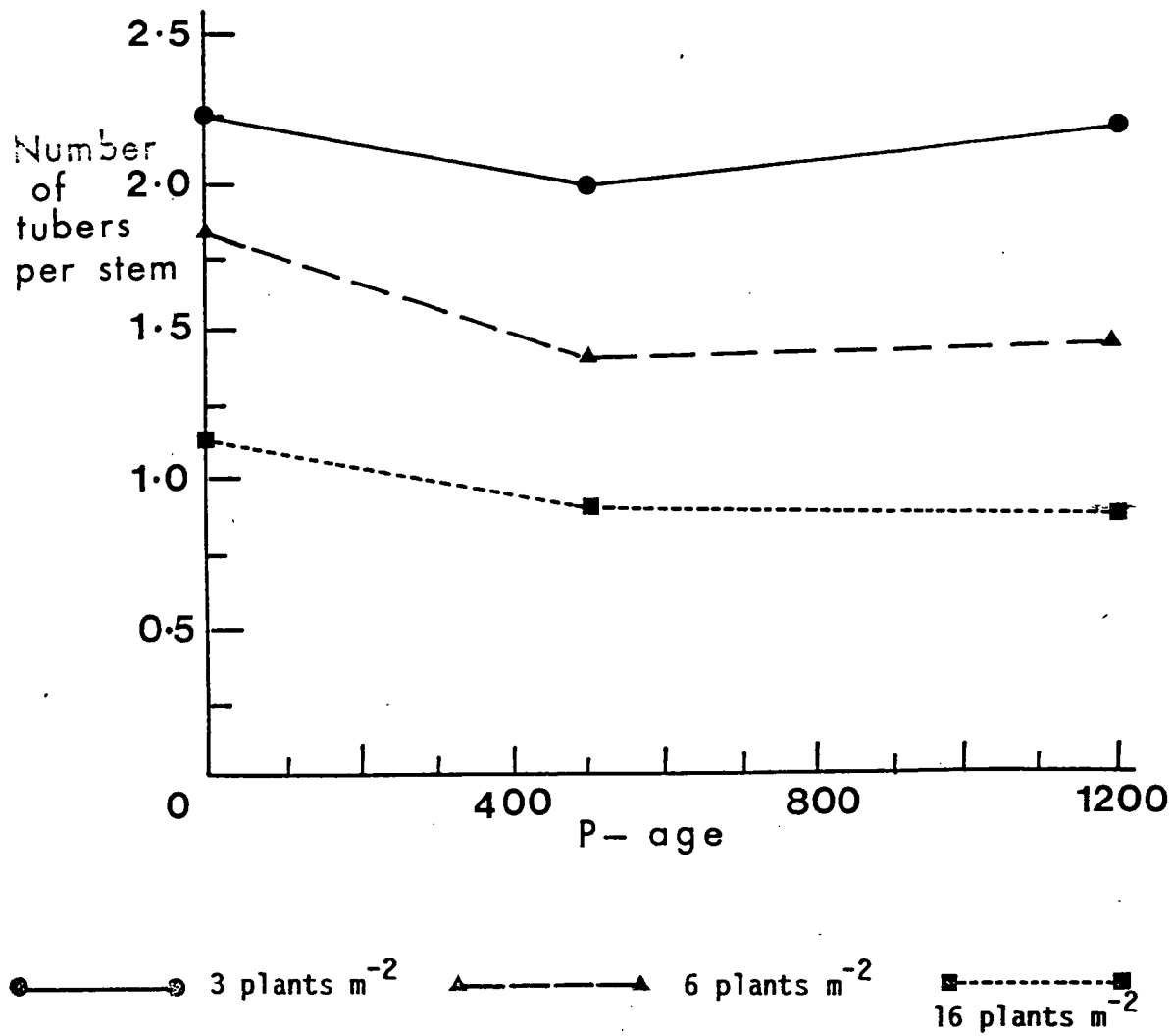
Standard error of treatment means = 0.09 tubers per stem

Plants from P-0 seed had relatively low numbers of stems per plant, high potential yield and so large mean tuber weights.

In comparison, plants from P-1200 seed did not have such yield potential, and so had proportionally smaller mean tuber weights. The physiological age treatment which generated the greatest number of stems per plant P-500, had the correspondingly lowest mean tuber weight.

At 16 plants per square metre, the potential yield of each plant regardless of p-age, could not be achieved due to the extreme interplant competition. In this situation numbers of tubers per stem were significantly influenced by physiological age (Fig 3.6). With increasing physiological age, fewer tubers per stem managed to grow resulting in increasing mean tuber weights in spite of total yield being significantly lower for the P-1200 treatment.

At 6 plants per square metre, there appeared to be effects of interplant competition because numbers of tubers per stem were reduced with increasing physiological age. However, this effect did not follow through to increased mean tuber weights because at the same time total yield was significantly reduced.

Consequently, from the results of this experiment the physiological age response can now be re-described so that regardless of planting density increased physiological age:-

- increases the rate of emergence
- reduces the time until crop senescence
- maximises the number of stems per plant when seed has been physiologically aged to P-500
- results in reduced yields when seed has been physiologically aged to P-1200

If plant density is increased so that individual plants are competing for assimilates and cannot achieve their potential yield, increasing the physiological age will:-

- reduce the numbers of tubers which develop on each stem and hence affect mean tuber weights.

4. EFFECT OF SEED TYPE ON THE PHYSIOLOGICAL AGE RESPONSE OF KENNEBEC

4.1 INTRODUCTION

In Exp. 1, it was found that physiologically aged seed initially grew more rapidly, had fewer stems and developed a relatively smaller canopy which yielded fewer but large sized tubers.

Much of the affects were attributed to the effect of physiological age on numbers of stems. Physiologically aged seed remains apically dominant and tends to set fewer stems. However, seed which has had no chance to sprout and is hence considered physiologically young, also sets few stems.

Apical dominance is believed to contribute to the physiological age response (E.J. Allen, 1985, personal communication).

Apical dominance in potato tubers is the same physiological process which has been thoroughly described for stem structures. The stolon which is structurally a stem, continues to grow diageotropically until it either encounters light or initiates a tuber. In the case of the former, it grows towards the light source, generates chlorophyll and the leaf primordia exposed to light develop fully. All these activities occur in the same manner as they would for a normal stem. In the case of the latter, the apical portion of the stolon comprising the most distal nodes, thickens but continues elongating and differentiating new vegetative meristems (which later become the tuber's eyes) (Artschwager,1924). Repeated cellular division and expansion of this portion of the stolon ultimately form the tuber (Reeve et al,1969).

During the sprouting period the apical portion of a seed tuber contains the most rapidly growing sprout. Growth of the remaining sprouts is suppressed by the plant hormone auxin, originating from the apical sprout.

By planting only the 'heel' portion (stolon end) of a seed tuber, it would be expected that any physiological age response would be subdued if not absent due to the lack of apical dominance exhibited by a heel-end set.

In Tasmania, commercial crops are planted with cut seed because seed tubers are normally too large to use on an economic basis. Unlike the U.K. varieties which respond to close planting by producing a large proportion of small tubers suitable for seed, Tasmanian varieties under the same close planting tend only to produce fewer tubers per plant of relatively large mean tuber weight.

Cut seed comprises split tubers which contain a portion of the apical sprout, heel-end sets, occasional round tubers, mid-section tubers and even "blind" tubers (those without any eyes!)

In this experiment, the physiological age response is examined for each of split, heel and commercially cut seed.

4.1.1 Aim

The aim of Experiment 4, was to quantify the effect of seed type on the physiological age response of Kennebec potatoes.

4.2 MATERIALS AND METHOD

4.2.1 Physiological Aging of Seed

Physiological aging of seed was carried out in an illuminated store maintained at $20^{O}C$ according to the method described in Exp. 1 .

Physiological ages of P-0, P-500 and P-1200 were achieved by placing seed in the $20^{O}C$ store on predetermined dates. Aging of seed for Exp. 4 was carried out simultaneously with aging of seed in Exp. 3 .

4.2.2 Cutting Seed

Seed was removed from storage on the day prior to planting, for sorting, cutting and weighing.

Sets of 80-120 g were halved, by cutting from apical to stem-end (heel-end),

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to create 'splitters' which consequently contain both the apical and heel-end portion in each set. These sets were used in Exp. 1 and termed 'cut sets', and were also used in Exp. 3 .

Commercial cutting was carried out manually by experienced seed cutters. In this procedure the first cut removes the apical portion, and subsequent cuts progressively produce more basipetal sets. Seed tubers were graded to be less than 250 g. Tubers were cut to 45-55 g sets (Fig. 4.1). Heel-end sets were removed from seed tubers of 100 to 250 g. Heel-end sets were 45-55 g. The remaining apical portion of the tuber was discarded.

4.2.3 Field Trial Design and Planting

The field trial was planted at Elliott Research Station on 25/10/82 and managed according to the same procedures outlined for Exp. 1.

The field trial was a randomized block design with three replicates. Three physiological ages, 0, 500 and 1200 day degrees $>4^{\circ}$C, and three seed types were used. The seed types were 'splitters', commercially cut seed and heel-end sets.

Plots were comprised of 10 rows which had the same physiological age treatment and contained three pairs of rows of the three seed type treatments.

The paired rows were separated by single rows of Kennebec, commercially cut buffer plants of that physiological age (Fig. 4.2).

4.2.4 Method of Harvest and Measurement

The emergence rate, stem numbers and colour of the crop were monitored over the season (Table 4.1).

The dates of 50% plant emergence were estimated by interpolation of the emergence results with time.

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Fig. 4.1   Seed Types and Methods of Cutting

SPLITTERS

100 g tuber

COMMERCIALS

tubers
150 - 250 g

HEELS

tubers
100 -
    250 g

Fig. 4.2   Exp. 4   Field Plan
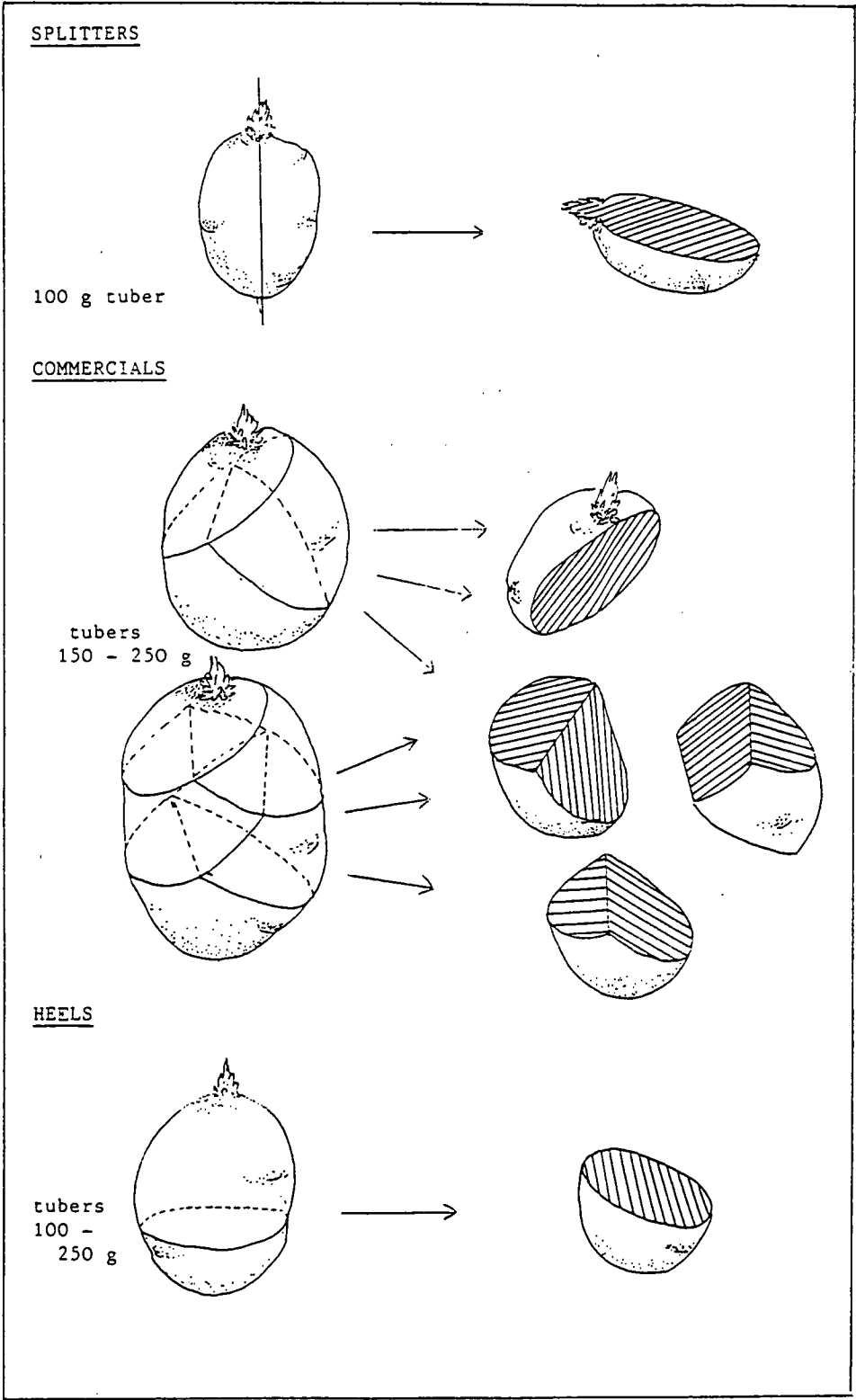
Fig. 4.2   Exp. 4   Field Plan
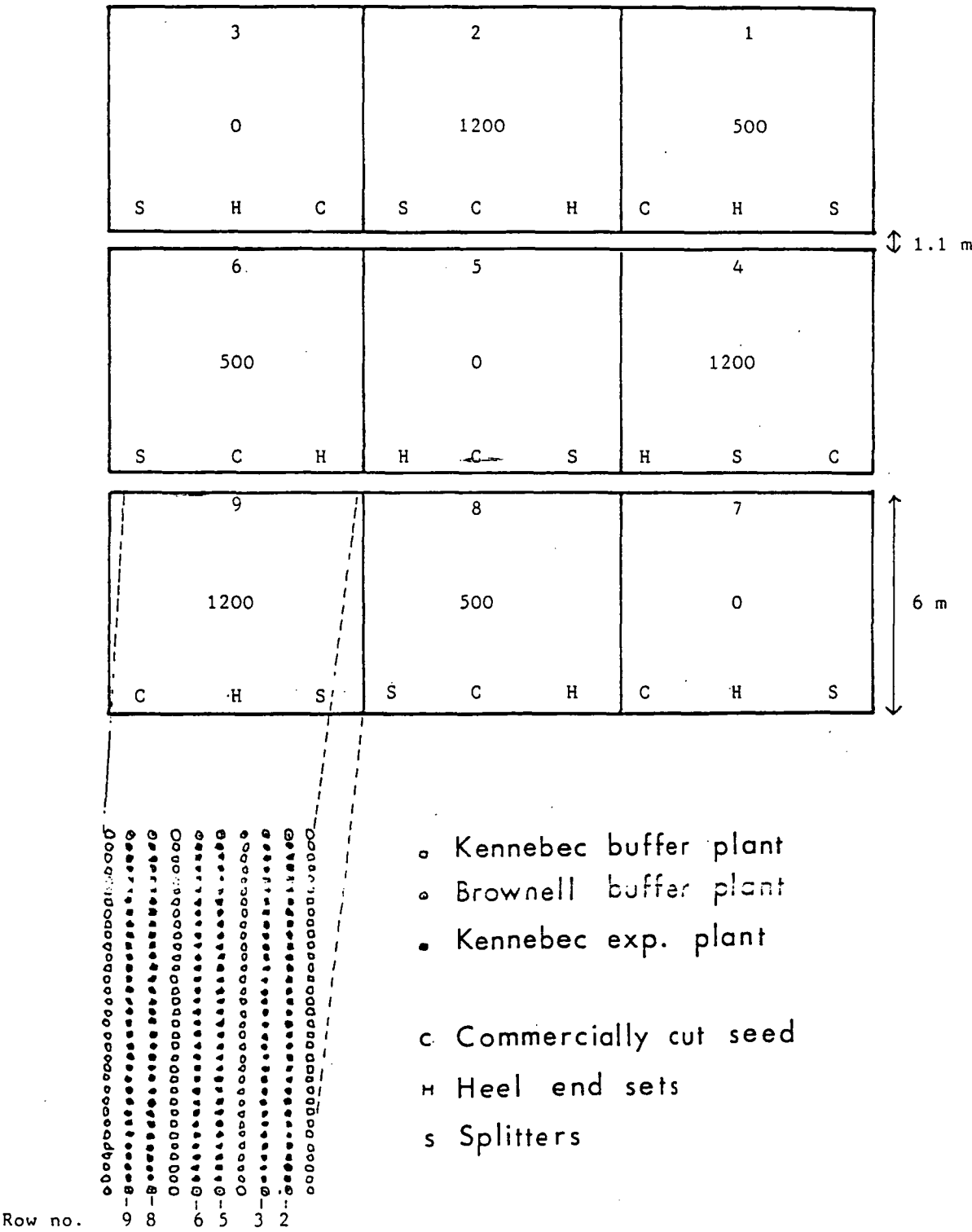
Table 4.1   Dates of Crop Assessment

Emergence Rating	Colour Rating	Stem Counts	Harvest
10/11/82	18/1/83	28/3/83	14/4/83
12/11/82	21/1/83		
18/11/82	3/3/83		
26/11/82			

Crop colour and stem numbers were recorded using the same methods as described in Exp.2.

On 14/4/83 the trial was harvested. A single row digger was employed and tubers were bagged manually. Yield from individual rows was separately bagged and labelled.

Weights of individual tubers were recorded as in Exp 1.

4.3 RESULTS

4.3.1 Emergence

Rate of emergence is shown in Fig. 4.3, as well as the estimated dates when fifty percent of plants had emerged. Table 4.2 presents the number of days from planting until 50% emergence.

For each physiological age, splitters tended to emerge earlier than commercials, whilst heel-end sets were significantly retarded.

Of the split sets emergence was consistent with Exp. 1, in which physiologically aged seed emerged more rapidly than p-younger seed. Seed

from P-1200 treatment, emerged 16 days after planting while seed from P-0 emerged after 21 days.

Table 4.2   Number of days from planting until 50% emergence

Physiological Age (day degrees >4°C)	Splitters	Commercial	Heels
0	21	22	24
500	17	17	21
1200	16	18	23

Heel-end sets were slow to emerge and were not consistent with this trend as P-500 seed emerged well before the other physiological age treatments. P-1200 heel-end sets only achieved a final plant emergence of 65%.

Commercial seed followed an emergence pattern which was between that of splitters and heels. P-500 seed emerged within 17 days of planting and P-1200 within 18 days.   The P-0 treatment was the slowest to emerge at 22 days after planting.

Since commercially cut seed comprises a selection of heel-end sets, and splitters and some mid-section pieces, it was expected that the behaviour of

Fig. 4.3 Effect of Physiological Age and Seed Type on Rate of Emergence

Physiological Age = 0

O,S = 15/11/82
O,C = 16/11/82
O,H = 18/11/82

Physiological Age = 500

500,S = 11/11/82
500,C = 11/11/82
500,H = 15/11/82

Physiological Age = 1200

1200,S = 10/11/82
1200,C = 12/.11/82
1200,H = 17/11/82

Splitters
Commercials
Heels
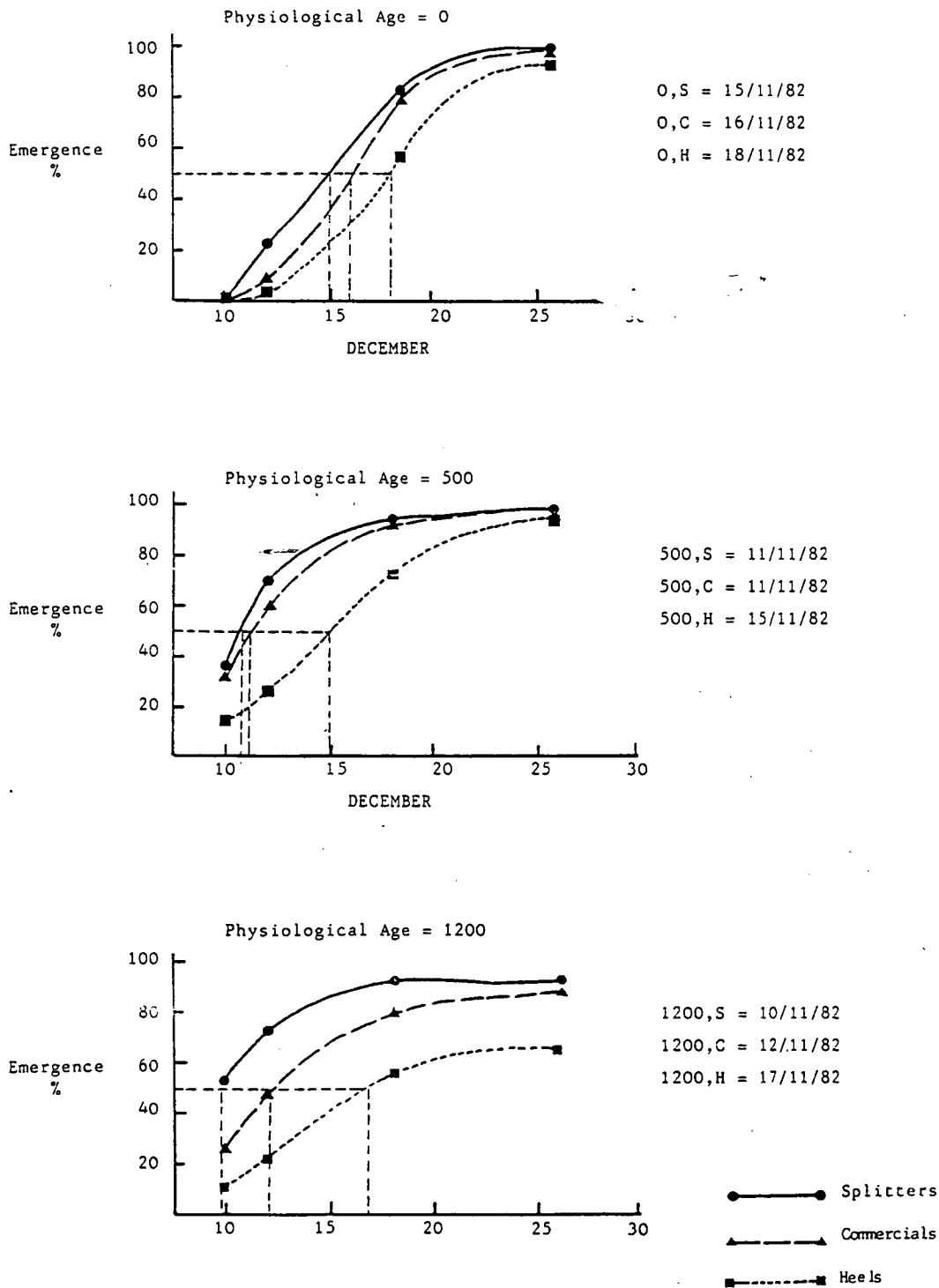
the commercial seed would fall somewhere between that of the splitters and the heel-end sets, depending on the ratio of splitters to heels.

4.3.2 Stems

The effect of physiological age on the number of stems per plant across the three seed types is shown in Table 4.4 assuming that plant emergence across all treatments was 100%.

The behaviour of splitters to physiological age in terms of number of stems per plant was consistent with results of Exp.1, with P-500 plants producing the greatest number of stems per plant.Commercially cut sets followed a similar trend with P-500 producing the most sets, but P-1200 produced significantly fewer stems per plant than did P-0 treatment.For heel-end sets, both the treatments P-0 and P-500 had 2.8 stems per plant, whilst the P-1200 had only half this number. The lower stem production of the P-1200's reflected the poor plant emergence of this treatment.

Table 4.4 Effect of Physiological Age and Seed Type on the Number of Stems Per Plant

Physiological Age (day degrees >4°C)	Seed Type		
	Splitters	Commercials	Heels
0	3.021	2.414	2.860
500	3.290	2.957	2.806
1200	2.930	2.091	1.435

Standard error of treatment mean = 0.12 stems per plant

4.3.3 Crop Colour

Although there was a tendency for P-0 treatments of all seed types to maintain a higher colour ranking, this effect was not statistically significant (Table 4.5). In fact, P-1200 heel-end sets consistently had the highest colour rating on each of the three dates when colour was recorded. In Exp.3 lower plant densities encouraged later crop senescence consequently the high colour rating of the P-1200 heel-end sets could be attributed to their poor emergence resulting in a lower plant density.

Table 4.5 Effect of Physiological Age and Seed Type on Crop Colour

Date	Physiological Age (day degrees $>4^{o}C$)	Splitters	Commercials	Heels
18/1/83	0	8.7	8.5	8.5
	500	8.0	8.0	8.2
	1200	8.3	8.2	8.8
	Standard error of 18/1/83 treatment mean = 0.18			
21/1/83	0	8.2	8.0	8.2
	500	7.7	7.8	7.8
	1200	8.0	7.7	8.5
3/3/83	0	1.7	0.8	1.5
	500	1.3	1.3	1.5
	1200	1.8	1.3	1.8

4.3.4 Yield

Across all the p-age treatments heel-end tubers produced significantly lower yields than commercials or splitters (Table 4.6). Splitters consistently outyielded commercials but this difference was not significant at pr = .05.

The greatest yield achieved was 51 tonnes per ha from P-500 splitters, and the smallest yield was only 38 tonnes per ha from P-1200 heels.

Although there was a trend towards maximum yield from P-500 and minimum yields from P-1200 treatments of splitters and commercials, there were no significant differences at pr = .05. In heel-end sets yield was inversely proportional to p-age.

Across the various physiological age treatments splitters tended to produce the most numbers of tubers, and heels the least (Table 4.7).

For splitters and commercially cut seed, both P-0 and P-500 treatments produced more tubers, and P-1200's significantly less. Of the heels, P-0 produced more tubers than the P-500 plants which in turn produced more than the P-1200's.

P-0 plants tended to produce the most tubers and P-1200 treatments from each seed type had significantly fewer tubers per ha.

In comparison to tubers per ha, an inverse relationship existed with the number of tubers per stem (Table 4.8). For the various p-age treatments splitters tended to produce fewer tubers per stem than commercials, and commercials produced fewer tubers per stem than heels. However, this trend was only significant for the P-1200 treatment.

For any one seed type, P-500 tended to produce fewer tubers per stem than the other two treatments. Heels of P-1200 had the most tubers per stem of any treatment, but with very low stem numbers per plant.

Mean tuber weights for each seed type increased with p-age, following the same trend as seen in Exp.1 (Table 4.9). These increases were significant for P-1200 of commercial and heel-end sets, averaging 183 and 189 g/tuber

respectively. The smallest mean tuber weight occurred for P-0 heels at 135 g/set.

An analysis of variance of the coefficient of variation (for definition see Exp. 1), showed that any variations around the mean tuber weight, for each seed type and p-age, were not significant for pr = .05 (Table 4.10).

Table 4.6   Effect of Physiological Age and Seed Type
on Yield t/ha

Physiological Age (day degrees >4°C)	Seed Type		
	Splitters	Commercial	Heels
0	48.8	47.1	44.2
500	51.0	49.4	42.8
1200	46.2	43.3	38.1

Standard error of treatment mean = 1.9 t/ha

Table 4.7   Effect of Physiological Age and Seed Type
             on the Number of Tubers Per Hectare   (x 1 000)

Physiological Age	Seed Type		
(day degrees >4°C)	Splitters	Commercials	Heels
0	320.5	304.2	328.3
500	321.9	306.3	289.7
1200	280.5	237.3	201.9

Standard error of treatment mean = 10.9 (x 1000) tubers/ha

Table 4.8   Effect of Physiological Age and Seed Type
             on Numbers of Tubers Per Stem

Physiological Age	Seed Type		
(day degrees >4°C)	Splitters	Commercial	Heels
0	1.616	1.916	1.751
500	1.491	1.571	1.614
1200	1.462	1.757	2.212

Standard error of treatment mean = 0.10 tubers/stem

Table 4.9   Effect of Physiological Age and Seed Type
             on Mean Tuber Weight (g)

Physiological Age	Seed Type		
(day degrees >4°C)	Splitters	Commercials	Heels
0	152.8	154.7	134.8
500	158.8	162.3	147.8
1200	166.5	183.2	188.7

Standard error of treatment mean = 6.6 g

Table 4.10   Effect of Physiological Age and
          Seed Type on the Coefficient of Variation
          of the Tuber Size Frequency Distribution - %

Physiological Age	Seed Type		
(day degrees >4°C)	Splitters	Commercials	Heels
0	28.1	26.4	30.6
500	27.9	28.1	28.8
1200	28.7	31.8	31.6

Standard error of treatment mean = 1.5 %

4.4 DISCUSSION

In Experiment 1 the physiological age response was described for Kennebec grown under similar conditions as for Exp. 4 (soil type, fertilizer, spacing, irrigation and climate) using both round sets and splitters as the seed source. It was found that there were no significant differences between these two seed types in their response to physiological age.

The physiological age response observed in Exp. 1 is tabulated below.

Table 4.11   Physiological Age Response in Exp 1.

Growth Response:	Resulting from Increased Physiological Age
Emergence:	more rapid
Number of stems per plant:	maximum at P-250 - P-500
Senescence of crop:	occurs earlier
Yield:	tendency to maximum at p-ages 250-500
Number of tubers per stem:	decreases
Mean tuber weight:	increases

In this experiment, whilst splitters again produced the same responses to physiological age, heel-end sets differed.

For heel-end sets, tubers of P-500 treatment were the first to emerge, then followed by P-1200 and finally P-0. This difference in emergence may be related to the degree of sprouting on the heel-end sets at the time of

planting.

In Exp. 1, sprouted seed of young physiological age, tended to have some significant sprout growth from not only the apical sprout, but also from eyes nearest the heel-end (plate 1.2).

In comparison, the same eyes on physiologically old seed, were maintained in a state of dormancy by the dominance of the strongly growing apical sprout. Consequently, physiologically younger heel-end sets in Experiment 4 had the largest sprouts.

These observations are supported by Allen et al (1980) who noted that the rate of emergence is proportional to length of sprouts at planting.

The effects of physiological age on the number of stems per plant also differed for heel-end sets.

In Exp. 1 and Exp. 3, there was a significant optimum around P-250 - P-500. However, heel-end sets produced as many stems from P-0 as they did from P-500.

Heel-end sets of P-1200 produced only 50% of the stems of the other two treatments. This effect may be related to the manner in which seed potatoes utilise their starch reserves.

Starch is broken down initially in the heel-end portion of the tuber to supply assimilates to the rapidly growing sprouts (Sacher and Iritani, 1982). If, after a period of p-aging the set is cut, the heel-end portion would contain a disproportionately low concentration of starch reserves, and consequently it would be less able to supply its own growing sprouts and hence bear fewer stems.

The effect of physiological age on crop colour was not as well defined as in Exp. 3 in which it was shown that there was an interaction between physiological age and planting density on colour or rate of crop senscence.

While crop senescence is normally hastened with increasing physiological age, it was significantly delayed for heel-end sets of P-1200. However,

rather than being a direct p-age response, this effect was more likely to be due to the effectively reduced plant density of the P-1200 treatment owing to its low number of stems per plant.

In Exp. 3, increasing physiological age was shown to significantly reduce yields at P-1200 . A similar response was seen in all seed types in this experiment. However, when the two components of yield, numbers of tubers per stem and mean tuber weight are considered, the effects of physiological age on heel-end sets are not consistent. In previous experiments increasing physiological age resulted in decreasing numbers of tubers per stem and simultaneous increases in mean tuber weights. For heel-end sets, increasing physiological age up to P-1200, resulted in an increase in both the mean tuber weight and the number of tubers per stem.

It is likely that the increase in number of tubers per stem resulted from compensation for the very low stem density of this treatment.

In summary, the 'physiological age response' was observed for splitters and to some degree for heel-end sets. Variation in the response of heel-end sets could be explained by the effect of physiological age on stem numbers.

It is interesting to note that the physiological age response was apparent in commercially cut seed and its degree was between that of splitters and heel-end sets. This was to be expected since commercially cut seed comprises a range from the apically dominant 'rose' end sets to the apically dominated heel-end sets.

4.5 REFERENCES

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5. CONCLUSION

5.1 GENERAL DISCUSSION

In Tasmania the target for potato research has been to increase production on the uniform Kraznozem soils of the northern part of the state. The research has been practical and applied, and has identified the agronomic factors which control yield i.e. time of planting, amount of irrigation, cultivar, fertilizer requirements, disease control, seed size, row width, and planting density. In conjunction with each other, these factors have been manipulated for maximum yield production and recommendations for optimum management of potato crops are available from the Department of Agriculture. Growers have adopted this knowledge and benefited through increased yields and by reduced costs of production.

However, individual growers have various limiting resources including constraints on either their land, or water for irrigation and they usually have limited capital for fertilizer, labour or new equipment. Consequently, to optimize returns for individual situations it is increasingly more important that growers are not only familiar with the Departmental recommendations but are aware of the implications of their own management decisions as to how they affect the growth of the potato crop.

In the U.K., research has indicated that there, the most limiting resource controlling potato yield in most situations is the ability of the crop to intercept light (Allen and Scott, 1980). Having a relatively short growing season and total potential solar radiation which is generally significantly lower than that of Tasmania's potato growing area, attempts have been made to manage crops so that maximum radiation is intercepted. The success of plants to intercept light was found to increase with an increase in the leaf area index up to an L value of 3 (Allen and Scott, 1980). Consequently, until the growing crop achieves this peak value, there are significant losses of potential intercepted radiation. Managerial techniques which increase the rate of early crop development were examined. The most obvious means of rapidly attaining a leaf area index of 3, was to reduce the time taken to achieve ground cover. This was done by increasing stem density.It was found that successive increases in density produced progressively smaller effects on the time taken for the canopy to reach L of 3. A density

was reached beyond which there were no further improvements in the rate of development of ground cover (Allen and Scott, 1980). Although at these high planting densities greater early interception of light was achieved, total intercepted radiation was not significantly increased due to the resulting earlier senescence of the crop. Furthermore owing to the high planting density, the final yields were of low mean tuber weight and hence fewer tubers were saleable as ware grade.

Other managerial techniques have been studied in relation to increasing the total intercepted radiation including time of planting, nitrogen application, and choice of varieties. In all cases, gains in light interception at one end of the season were offset by losses at the other, or gains in light interception by using these methods were already being implemented by the present farming practices.

Like early planting, the use of P-aged seed was found to hasten emergence and early leaf growth, then lead to an earlier onset of senescence (Madec and Perennec, 1955). However, if used in combination, P-aged early-planted crops were able to utilize the early part of the growing season to produce a higher yielding early crop. Unlike using high density, the final size grade of P-aged seed was not adversely affected (Allen and O'Brien, 1980).So as to improve light interception later in the season, P-young seed was planted, and when total radiation was greater later in the season, benefits in yield were obtained by the use of P-young seed.

Allen and O'Brien (1980) summarized that for each environment, it was likely that there is a correct P-age at planting for any variety and planned harvest date, which would lead to senescence when the maximum possible yield within the available growing season had been achieved.

In the U.S.A., particularly Idaho, Washington and Oregon where 80% of potato production is processed, research has concentrated on maximizing yields in their processing grades (French fries require tubers of 224 - 336 g), rather than gaining marginal increases in total yields. To encourage greater tuber size, stem density has been the major factor under study. For Russet Burbank a stem density of 91000 to 137000 stems per hectare has been recommended (Cho and Iritani, 1983). Furthermore, as the management of numbers of stems per plant also affects the numbers of tubers which are set, and hence

affects the graded yield, 2 to 3 stems per set, and a tuber population of 8 to 14 tubers per plant have been recommended as producing maximum economic returns (Cho and Iritani, 1983).

Soil temperatures at the time of planting, seed size and storage temperature of seed have all been found to influence the number of stems per set (Iritani,1963; Iritani,1978). The effect of storage temperatures were studied in relation to stem number, tuber set and yield for Russet Burbank by Iritani et al (1983). As the initial onset of the sprouting period was not defined, it is difficult to assign P-age units to their storage treatments. However, even estimating P-age conservatively, the most radical storage treatment would probably not have exceeded P-750. In their study, they found that the treatments which produced increasing P-ages, produced more stems per set, and simultaneously reduced yields. This occurred through a corresponding increase in numbers of tubers but decrease in mean tuber weight. In Exp. 2 of this series, increasing P-age up to P-750 also tended to increase the number of stems per hectare but it was accompanied by an increase in mean tuber weight. A number of factors probably contribute to the P-age response such as planting density, emergence temperatures and temperatures during crop growth, and would need further study before a full understanding of the P-age response is achieved.

5.2 APPLICATION OF RESULTS

The results of this study already indicate that P-age can be implemented to manipulate potato crops in Tasmania to achieve better yields, particularly in the case of Kennebec in which the effects of P-age were more pronounced.

Owing to our long growing season, with relatively constant monthly radiation receipts, their is little advantage in using P-age to optimize intercepted radiation for the processor or seed growers. However, results from Exp. 1 indicate that by P-aging seed prior to planting, greater early yields can be achieved when crops are harvested prior to maturity. In Tasmania a premium is paid for early potatoes which arrive on the fresh market in October and November. Although this represents a very small proportion of the total

potato production and is mainly dependent on the cvars. Pinkeye and Bismark,
for the growers involved, the gains from P-aging seed would be significant.

The capacity for Tasmanian processor and seed growers to exploit P-age would
not be through any substantial effect of P-age on total yield but through
its effect on mean tuber weight and consequently graded yields.

Table 5.1 presents the theoretical yields for seed and processing grades
calculated for Kennebec in Exp. 1 under the five different P-age treatments,
using the values of tuber number, square root mean and variance.

Table 5.1 Effect of P-age on graded yields of Kennebec from cut seed -
t/ha.

P-age	Seed Grade	Processing Grade	Total Yield
	0 - 250 g	>250 g	
0	44.2	16.9	61.8
250	42.5	23.0	64.2
500	31.7	30.4	65.0
750	32.1	29.8	62.1
1200	23.6	39.8	61.0

For processor growers the graded yields of Exp. 1 show that P-aging
Kennebec seed could be advantageous when a premium is received for larger
sized tubers. However, direct extrapolation from Exp.1 to a commercial
situation must be cautiously considered since the seed used in Exp.1 was not

commercial, and in Exp.4, seed type was shown to affect the P-age response.

For seed growers, there appears to be significant gains from using P-young seed, particularly P-0 seed, because of its ability to produce a large number of small sized tubers. At present seed growers use high planting densities of atleast 6 plants m^{-2} to produce tubers in the small size grades. In Exp.3 the P-age response appeared to be enhanced by high planting densities. The plant spacing of Kennebec in Exp.1 was 6 plants m^{-2}. Combining a high density and planting unsprouted (P-0) seed, should maximize the number of tubers in the seed grade.

The ability of growers to correctly p-age their seed is dependent on their access to cool storage for the dormancy period, to monitor temperatures during the sprouting period, and to maintain a constant storage temperature during the sprouting period. In these experiments for one treatment, seed was stored in ambient conditions from the time of harvest until planting. Although the calculated P-age of this seed was approximately P-400, its growth was not consistent with its calculated P-age, possibly owing to the fluctuating temperatures during the dormancy period.

In order to effectively exploit P-age in commercial situations further research needs to be undertaken on the P-age response and how it is affected by :

1) ambient heat accumulation during both the dormancy period and sprouting period

2) cultivars and their classification according to 'earliness'

3) degree of sprouting on various seed types.

5.3 REFERENCES

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APPENDIX 1. Meterological Data for November - February, 1981/82 and 1982/82,

Elliott Research Station.

Month	Year	Average daily temperature °C		Average soil temperature °C		Rainfall mm/day	Evaporation mm/day	Solar Radiation MJ/m^2/day
		Min	Max	10 cm	20 cm			
November	'81	9.2	16.9	13.8	14.9	2.2	4.5	23.1
December	'81	10.2	20.1	16.7	17.6	1.1	5.4	22.7
January	'82	11.7	22.5	18.8	20.0	1.1	6.4	22.2
February	'82	11.8	21.8	19.1	20.5	1.2	5.7	21.5
March	'82	11.6	19.7	16.6	18.0	3.2	3.5	n/a
November	'82	8.2	18.6	n/a	n/a	1.6	5.3	23.4
December	'82	9.5	19.1	n/a	n/a	2.2	5.5	22.6
January	'83	9.3	19.7	16.0	17.5	1.5	6.0	21.3
February	'83	12.7	23.3	20.0	21.0	0.5	6.1	17.9
March	'83	11.4	19.0	16.0	17.0	2.6	3.6	n/a