THE EFFECTS OF PLANT SPACING AND WATER ON GREEN PEAS

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CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The processed pea industry has grown rapidly in New Zealand over the last few years and prospects for further growth look reasonably bright. In the 1964-65 season, 16,012 tons of peas were produced for processing from 11,816 acres. In the 1969-70 season 28,999 tons were produced from 21,133 acres. Exports of frozen peas have also increased greatly over the last few years, 2,165 tons being exported to 16 countries in the year ending June 30, 1966, and 7,632 tons (an increase of 250%) being exported to 23 countries in the year ending June 30, 1970 (N.Z.D.A. Hort. Stats. 1971).

In the past the main production area for processed peas has been Hawkes Bay. With the opening of a second processing factory in Christchurch and further expansion of one in Timaru in the 1970-71 season, Canterbury is becoming increasingly important in the production of processed peas, and is likely to become the dominant green pea producing area of New Zealand before long. The climate is favourable and there is a large area of suitable soils (White, 1968).

Despite their increasing importance to New Zealand, very little agronomic research has been carried out on processed peas in New Zealand. Although seasonal fluctuations in yield occur there appears to have been no consistent increase in green pea yields over the last few years. Average green pea yields are not high and more information is required on agronomic factors which may affect yield.

The results of overseas work on the effect of plant density on green peas are variable, and no reliable indication of the optimum plant density for Canterbury could be obtained from them. Good responses to irrigation have been measured overseas, and have also been obtained by some Canterbury farmers. However, most of the overseas work has been done in areas where the soil and climate differ from that in Canterbury and results are unable to be applied directly to Canterbury.

This study was therefore initiated to obtain information on the response of green peas to different plant spacings and moisture levels under Canterbury conditions.

CHAPTER II

LITERATURE REVIEW

I. PLANT DENSITY

(1) Introduction

Efforts by many workers on a wide range of crops and pasture grown in different environmental conditions have shown that plant density can have a considerable effect on total biological and economic plant yield. In order that maximum possible production be obtained it is therefore important that the effects of plant competition and the relationships between plant density and crop yield be established for different crops and conditions.

(2) Factors of Plant Competition Affecting Optimum Plant Densities

Clements (1907) quoted by Donald (1963) stated - "When the immediate supply of a single necessary factor falls below the combined demands of the plants, competition begins". Donald (1963) gives factors for which competition may occur among plants as water, nutrients, light, oxygen and carbon dioxide with agents of pollination and dispersion added in the reproductive stage.

The degree to which competition occurs can have a considerable effect on the optimum plant population. This can clearly be seen in work of Lang *et al*., (1956) who showed that at low nitrogen levels a mean maximum yield of 75 bu/acre was obtained at 12,000 plants/acre. With medium nitrogen levels 92 bu were obtained from 16,000 plants/acre while at high nitrogen levels a peak yield of 118 bu occurred at 20,000 plants/acre.

From results such as these Donald (1963) stated that the more favourable the environment for any reason whatsoever, the higher will be the optimum population. This was an overstatement as shown, by Allison and Eddowes (1968), who in comparative trials with maize in England and Rhodesia showed that greater densities may sometimes be needed where temperatures and radiation are less favourable for vegetative growth.

The effect of water on optimum plant densities will be discussed in a later section.

Holliday (1953) showed the importance of time of harvest on competition at different densities. Using ryegrass sown at seed densities from 5lb to 160lb/acre he showed yield increases to be virtually linear with seeding rate from 5lb to 40lb with a further increase up to 160lb when cut after three months. This yield increase however occurred only in the first year and subsequent production was the same at all sowing densities.

Lang *et al*., (1956) also showed the effect of genotype on optimum plant density. Of nine maize hybrids the lowest yielding gave a mean maximum yield of 89 bu at 12,000 plants per acre. The highest yielding variety however, gave a maximum yield of 112 bu at 20,000 plants per acre.

(3) Plant Density and Relationship to Yield

Engledow (1925) gave an equation for yield against plant density and other factors for wheat. This was

$$y = p \quad e \quad n \quad g$$

where y = yield

p = the average number of plants per unit area

e = the average number of grains/ear

g = the average weight of a single grain

Because of the effects of plant plasticity the number of ears per plant changes markedly with plant population. The number of grains per ear changes less markedly while only a small change occurs in grain weight. This can be well seen in the following data for wheat of Puckridge (1962) quoted by Donald (1963).

Seed Rate (lb/acre)	21	105	552
Ears/plant	18.6	7.2	2.2
Grains/ear	37.8	29.9	21.5
Wt./grain	35.0	33.7	33.2

Hardwick and Milbourne (1967) provided a similar equation to that of Engledow's for vining peas.

$$\text{yield} = \frac{\text{no. of}}{\text{podding nodes}} \times \frac{\text{pods/}}{\text{podding node}} \times \frac{\text{peas/}}{\text{pod}} \times \frac{\text{wt./}}{\text{pea}}$$

This equation however, gives little indication of the within plant variation which can be better described by their equation -

$$\text{yield} = \frac{\text{sum over all}}{\text{podding nodes}} \left\{ \frac{\text{no. of nodes}}{\text{at node n}} \times \frac{\text{pods/node}}{\text{at node n}} \times \frac{\text{peas/node}}{\text{at node n}} \times \frac{\text{wt/pea}}{\text{at node n}} \right\}$$

Holliday (1960) suggested that there were basically two relationships between crop yield and plant density. The first in the parabolic relationship where yield per unit area rises with increasing plant density to a maximum but then declines at high densities. Holliday suggested that reproductuve forms of yield conformed to this relationship and gave examples of Hudson (1941) with wheat and other workers that followed the parabolic pattern of yield with density.

The second relationship suggested was the asymptotic one where yield per unit area increased with plant density but then gradually levelled off to a constant level at higher densities. Holliday suggestedthat total crop dry matter conformed to this relationship and gave among other examples work of his own kale which conformed to this relationship.

However, the parabolic relationship can occur in certain measurements of vegetative yield as shown by Bleasdale and Thompson (1966) with parsnips. Total production followed an asymptotic pattern with plant density but the highest yield of roots with a crown diameter greater than 2 in. occurred at 2 plants/sq. ft. The maximum yield of parsnips of packing size $1\frac{1}{2}$ - $2\frac{1}{2}$ in. diameter occurred at 4-6 plants/sq. ft.

In recent years increasing numbers of workers have attempted to establish quantitative relationships between plant density and yield by the use of yield/density equations. Wiley and Heath (1969) examined the usefulness of different types of mathematical equations and reached the conclusion that reciprocal equations as first proposed by Shinozaki and Kira (1956) generally have a better biological foundation and have proved more satisfactory in practice than other types of equation. They are the only type that realistically describe both the asymptotic and parabolic yield situations. Fery and Janick (1971) found a modified reciprocal equation adequate in describing both part and total top yields for field and sweet corn over wide population ranges.

(4) Plant Rectangularity

Wiley and Heath (1969) considered that the effect of plant rectangularity is largely dependent on the plasticity of the individual plant. Generally as rectangularity increases yield per unit area decreases. Bleasdale et al., (1961) obtained a 25% yield increase in carrots at 6-8 plants/sq. ft. by decreasing row width from 24 in. to 12 in.

The effect of plant rectangularity is generally greater at higher plant populations. This can be seen in the following yield figures of Harvey *et al.*, (1958) for wheat.

Row Width	Seed Rate (lb/acre) 77	144	238
4"	43.9 (cwt)	43.9	43.6
8"	43.0	42.5	41.4
12"	41.6	41.4	38.0

(5) The Response of Peas to Plant Density

The published results of plant density trials with vining peas are very variable. Many workers (Gritton and Eastin, 1968; Ottosson, 1968(a); Meadley and Milbourne, 1970) have reported widely varying yields in different seasons' experiments. Bleasdale and Thompson (1963) in one season found yields still increasing at 8.4 plants/sq. ft and by extrapolation maximum yield would have been recorded at 13.4 plants per sq. ft. The following season they recorded a drop in yield with increasing plant population at only 6.7 plants/sq. ft. However the same workers (1964) reported that 5 plants/sq. ft have always given at least 80% and in most cases 90% of the maximum yield in any experiment.

King (1966) reported on a number of years' trial work, that yield rose to a maximum at approximately 16 plants per sq. ft., and then fell off slightly. However the population at which the greatest net return would be obtained after deducting seed costs was 11 plants/sq. ft.

Meadley and Milbourne (1970) with plant populations of 31, 71 and 126 plants/m^2 (2.9, 6.6, 11.7 plants/sq. ft) obtained no significant yield differences between plant densities over two years.

Ottosson (1968a) obtained a small yield increase over the range of 50 - 90 plants/m^2 (4.6 - 8.4 plants/sq. ft). Younkin *et al*., (1950), Vittum *et al*., (1958) and Gritton and Eastin (1968) all obtained marked yield increases of an asymptotic pattern with plant density. Of these workers Gritton and Eastin used the highest plant densities with a peak of 1,660,000 plants per hectare (15.4 plants/sq. ft). It is somewhat surprising that few workers in plant density studies with peas have taken their highest plant densities even to this level let alone beyond it.

Reynolds (1950) working with dried peas found that highest yields were obtained at about 2 in. seed spacings at all row spacings. There is good evidence that the optimum density for vining and market peas is greater than that for dried and seed peas (Bull. 81, Minist. Agric. Fish. Food, 1969). The optimum seed rate is also lower for free branching varieties.

Factors that may account for the large differences between different plant spacing trials with vining peas include differences in climate and season, soil, variety, experimental technique and management, maturity at harvest, row spacing spacing and date of sowing. Salter and Williams (1967) obtained a very large decrease in yield for peas sown late and suggested that this could differentially affect plants at different densities.

(6) The Effect of Row Spacing on Pea Yields

King (1966) reported that wide row spacings in peas were formerly needed to allow inter-row cultivation. However since the early 1950's with the introduction of suitable herbicides, narrower row spacings have been possible.

Reynolds (1950) with dried peas reported 7-8in. rows as generally giving higher yields than 14-16in. rows. Vincent (1958) working with green peas reported a large increase in yield by decreasing row width from 16in. to 8in. with constant population but little advantage in going to 4in. rows. The same trend was reported by King (1966) who obtained an average yield increase of 22% by reducing row width from 24in. to 16 in. and a further 24% increase by reducing row width to 8in. There was no consistent trend in further reducing row width to 4in.

Gritton and Eastin (1968) however found that 9cm ($3\frac{1}{2}$in.) rows gave higher yields than 18cm. (7 in.) or 27cm (10.5in.) rows. The yield increase in 9cm. rows was greater at higher plant population as can be seen in the following table.

Green Pea Yield Kg/ha

Row Spacing	Plant Population Plants/ha 1,660,000	1,110,000	550,000
9 cm	5,630	4,970	3,080
18 cm	4,050	3,980	2,890
27 cm	3,870	3,600	2,450

Shekhawat *et al.*, (1967) with dried peas of a free branching variety reported that of a range of row spacings 45.72 cm (18in.) was the best yielding.

(7) Conclusion

In view of the variable results obtained in plant density experiments with peas Bleasdale and Thompson (1964) stated that there is no constant mathematical relationship between yield and plant density in peas. They suggested that some at present unknown factors affected the relationship and that these may in turn affect the ability of the roots to take up water.

II. PLANT WATER REQUIREMENT

(1) Introduction

Water deficit is one of the most widespread and important factors limiting crop growth and yield. This section of the review looks at the need for water by plants and the response of crops, particularly peas, to irrigation.

(2) The Need for Water by Plants

Kramer (1963) gave four general functions of water in plants:

(i) It is a major constituent of physiologically active tissue.

(ii) It is a reagent in photosynthesis and in hydrolytic processes such as starch digestion.

(iii) It is the solvent in which salts, sugars and other solutes move from cell to cell and organ to organ.

(iv) It is essential for the maintenance of the turgidity necessary for cell enlargement and plant growth.

Kramer stated that the degree of stress experienced depends on the internal plant water balance. This depends on the relative rates of water absorption and loss which is a combination of soil, plant and atmospheric conditions.

(3) Plant Response to Water

Rawson (1874) quoted by Salter and Goode (1967) was one of the first people to correlate crop yield with moisture when he showed that sugar cane yields were above average following twelve of fifteen wet years, average in two and below average in one. After nine dry years yields were below average in eight years and average in one. Since then the need for water in acheiving high crop yields has been realized and a considerable amount of irrigation development has occurred.

Salter and Goode (1967) stated that irrigation is one of the most important means of raising crop productivity in many parts of the world. These reviewers quote a large number of workers over a wide range of crops who have obtained considerable increases in yield with irrigation.

Wiesner (1964) emphasized that the best results to irrigation can only be obtained in association with all other sound and approved agricultural practices. Water use efficiency is greater in fertile conditions and it often pays to raise fertility conditions before considering irrigation. This is well shown in the following results of Fernāndez and Laird (1957).

Maize Yield Tons of Ear/ha

	N applied	
	0	150 kg./ha.
No drought	2.7	6.2
11 Days' stress at flowering	2.5	4.7

(4) Differential Response of Plants to Water at Different Growth Stages

The response of any crop to irrigation will depend not only on moisture availability and plant water balance but also on the stage of growth or development of the crop.

Salter and Goode (1967) reported that of 114 studies with cereals the most sensitive moisture stage in 101 of these studies occurred during the latter part of shooting, at heading and during flowering. Tomatoes showed the greatest response to water from the start of fruit set on. Generally the differential water response was relative to the pattern of root growth. This is discussed more fully later in work with peas by Salter and Drew (1965). Singh *et al.*, (1966) showed that in cabbage, broccoli, lettuce, radish and onions that yield was reduced most by moisture stress in the head, root or bulb enlargement period. With corn the greatest effect was at silking and ear development. Claason and Shaw (1970) showed the maximum reduction in vegetative yield of corn by moisture stress three weeks before 75% silking. Grain yield however showed a maximum yield reduction of 53% by stress at 75% silking. Stress after silking caused a 30% yield reduction but stress at the vegetative stage gave only a 12-15% reduction in grain yield.

Variety can have a considerable effect on the optimum irrigation times. North (1960) showed with King Edward potatoes that irrigation from tuber swelling gave a marked yield increase but irrigation right from emergence gave a very marked yield depression. However varieties with a lower tuber number gave a marked yield increase to irrigation throughout the growing season.

A period of moisture stress may even be desirable at certain stages of growth in some crops. Alvim (1960) showed that a period of moisture stress is necessary to induce flowering in coffee while Doull (1967) reported that highest yields of lucerne seed are obtained when moisture stress is applied from early flowering.

(5) The Response of Peas to Irrigation

Early work by Monson (1942), and Brouwer (1949) quoted by Salter and Goode (1967), showed that generally irrigation of peas before flowering was of no advantage but that irrigation at flowering gave a marked yield increase. Since then Salter (1962) showed that pod swelling is also a critical time for moisture stress in peas.

A number of workers have obtained yield increases in peas by maintaining high soil moisture levels during flowering and pod swelling (Salter 1962, 1963; Behl *et al.*, 1968; Maurer *et al.*, 1968; Strydom 1968). Salter (1963) obtained no response to irrigation at petal fall but Carter (1961) quoted by Salter and Goode (1967) obtained a large yield increase by irrigating at this period. However it is possible that this irrigation may also have raised soil moisture levels during the pod swelling stage.

Fröhlich and Henkel (1961), and workers at Winchmore Irrigation Research Station (Advisory Report 1971) have shown that in dry conditions contrary to the usual trend, irrigation during the vegetative stage can also give yield increases. Frölich and Henkel, surprisingly in view of most other results suggested that optimum soil moisture levels decreased from before flowering to 10 days after its commencement.

Work by Frese <u>et al</u>., (1955) quoted by Salter and Goode (1967) and by Crampton (Pers. comm.) has shown a decline in yield through the application of too much water at flowering. Such a decline may have been due to lack of aeration of the roots and would depend on weather and on soil type and structure.

Monson (1942) considered that timeliness of irrigation of peas to be more important than the amount of water applied at any one irrigation.

Salter and Drew (1965) offered an explanation for the sensitivity of peas to moisture at flowering and pod swelling when they showed that root growth in peas increased rapidly to a peak just after the initiation of the first flower primordia. It then declined sharply and many older roots died before the first flowers opened. There was sometimes a slight resurgence at the start of pod development but little root growth occurred during pod swelling and it stopped as the pods matured. Root growth is an important factor controlling water uptake. Salter and Drew suggested that when growth is reduced water absorption becomes greatly dependent on the flow of water through the soil to the root surface. This irrigation is likely to be most beneficial at periods of reduced root growth.

Brouwer (1959) quoted by Salter and Goode (1967) suggested that the response to irrigation at flowering was due to increased nutrient availability. He suggested that 10% of the total nitrogen, 40% of the phosphate, 40% of the potash and 45% of the calcium was taken up in the three week flowering period.

The increase in yield obtained by irrigation at flowering and pod swelling appears to be largely due to an increase in the number of pods per plant. For instance Salter (1963) increased the number of pods per plant from 2.99 without irrigation to 4.52 by irrigation at flowering and pod swelling.

In conclusion it would appear that flowering and pod swelling are the stages when irrigation is most likely to give the greater increase in yield of green peas. Irrigation at any other stage would be unlikely to increase yield unless soil moisture levels were particularly low.

III. THE COMBINED EFFECT OF PLANT SPACING AND MOISTURE LEVEL ON CROP YIELD

Salter and Goode (1967) stated that the response of crops to soil moisture conditions in the field will be greatly influenced by the plant density, but in general two factor experiments varying water supply and plant spacing are not common.

Donald (1963) stated that it is commonly found that the optimum density is greater with adequate water. This was well shown by Salter (1961) who obtained no irrigation response with cauliflowers at a 34 in. x 34 in. plant spacing but with a 12in. x 12in. plant spacing there was a 70% increase in total yield. The effect of spacing on the irrigation response in the yield of marketable heads was even greater as can be seen in the following table.

Yield - Marketable heads Tons/ac.

Spacing	Irrigated	Non-irrigated
24"x24"	12.2	7.6
17"x17"	14.8	2.8
12"x12"	14.6	1.0

Drew (1966) obtained a similar interaction with cabbages when irrigation gave a 50% total and 120% marketable yield increase at a high plant density (13 in. x 13 in.) but at a lower density (27 in. x 27 in.) the respective increases were only 20% and 18.5%.

This type of response may be at least partially explained by Milthorpe (1961) who considered that the more leaf produced before plants come into contact with each other, the more extensive is the root system and the less likely the plant to suffer from drought. The higher the density, then the smaller is each plant at any time during ontogeny and the lower the soil moisture deficit at which shortage of water is experienced.

Colyer and Kroth (1970) showed that maximum yields of corn were obtained from irrigated plots and at higher input levels for both nitrogen and population. Work with potatoes by Howe and Rhodes (1948) showed that the maximum effects of moisture level and plant spacing were obtained at the highest level of each other.

Massey *et al.*, (1962) doubled edible yields of broccoli and improved quality with irrigation. Increasing density from 1½ ft. to 1 ft. within the row also increased yield. The only interaction however was a wide spacing X irrigation interaction for appearance.

Vittum *et al.*, (1959) obtained considerable yield increases in corn with both irrigation and increased population but there was no interaction between the two. Grimes and Musick (1960) with sorghums obtained no yield effect from plant density in the range 56,000 to 22,400 plants per acre. However a greater response to irrigation was shown in narrow rows than in wide rows.

Dougherty (1969) obtained a slight yield increase with irrigation in soybeans. There was also an increase in yield at higher densities but the largest yield effect was caused by row spacing; 20 in. rows giving an average yield of 19.6 bu/ac. and 40 in. rows giving only 12.2 bu per acre.

Gautam and Lenka (1968) looked at stage of irrigation (pre bloom, bloom and both) and plant density with dried peas. Over two seasons stage of irrigation had no significant yield effect but a yield increase was obtained with increasing seeding rate up to 147 kg/ha. (131 lb./ac.). Reducing row width to 20 cm. (8 in.) also increased yield.

The effect of plant density and irrigation on vining peas was looked at by Salter and Williams (1967). They found that irrigation at flowering and pod swelling generally gave increased yields. The mean increase for 'Dark Skinned Perfection' peas was 40% while that for 'Progress No. 9' was only 10%. There were considerable differences in irrigation response between seasons, the response being greatest in the driest of three seasons. 'Progress No. 9' reached a peak yield at the highest density in both of the years it was grown. However this was only at 8.6 and 6.1 plants per sq. ft. respectively.

With 'Dark Skinned Perfection' the highest densities were 12.0 - 13.5 plants per sq. ft. and in two out of three three years there was a fall off in yield at this density. Generally the effect of irrigation was greatest at highest and least at the lowest plant densities.

Salter and Williams concluded that because of the reduction in yields at about 12 plants/sq. ft. two out of three years with 'Dark Skinned Perfection' and of the cost of seed, that even where irrigation at flowering and pod swelling was available that densities of 5-6 plants/sq. ft. should not be exceeded, at least until more was known about the relationship between plant density and yield.

CHAPTER III

1969-70 ROW WIDTH, SEED SPACING AND PHOSPHATE TRIAL

I. INTRODUCTION

The main purpose of this experiment was to measure the effects of plant spacing on green peas under optimum soil moisture conditions. Thus a range of plant spacings, ranging in density from considerably below that normally used in farm practice to far above it were sown.

It was also decided to look at the effect of applied phosphate on green pea yields, as it was thought that phosphate may become limiting at high plant densities.

II. EXPERIMENTAL TECHNIQUE

(1) Trial Design

The trial had a factorial design, with two replicates. The following factors were chosen:

(i) Three row widths of 4, 8 and 12 in.

(ii) Three seed spacings of 1, 2 and 3 in. within the row.

(iii) Three phosphate levels equivalent to 0, 20 and 60lb of phosphorus per acre. (0, 2 and 6 cwt of superphosphate/ac.)

The trial was confounded into blocks of nine plots with parts of the three factor interaction being confounded giving a total of six blocks. There was a total of 54 plots each 6ft. 6 in. wide and 60 ft. long.

(2) Site of Trial

The trial was sited on the Lincoln College Research Farm on a Wakanui silt loam previously in six year ryegrass-white clover pasture. The soil was well structured and had a high fertility level. Soil samples (0 - 3 in.) taken on July 3, 1969 gave the following Department of Agriculture quick test results:

pH	Ca	K	P (Truog)	P (Bray)
6.2	8	10	14	55

(3) Preparation and Sowing

The trial area was ploughed in mid-July and received one discing in early September. Following an irrigation it was Dutch harrowed 3 times one week before sowing. Gypsum ($CaSO_4.2H_2O$) was then applied as a basal dressing to give 25lb of sulphur/acre. Double superphosphate ($Ca(H_2PO_4)_2$), containing 25% P, was then applied to the required plots. These applications were followed by a further Dutch harrowing.

The 4 in. rows were sown on October 14, 1969 and the 8 in. and 12 in. rows the following day using a 'Stanhay' precision seeder. In the 4 in. row plots ten rows were sown down the centre of the plot with the 'Stanhay' with 2 guard rows sown down each side with a 'Planet Junior'. In the 8in. row and 12 in. row plots nine rows and six rows respectively were sown in each plot with the 'Stanhay'. The settings and calibration for the different seed spacings within the row are shown below.

(i) 1 in. seed spacing - V base - No. 44 hole x 28 holes belt - A pulley - 489 peas in 450 in. run.

(ii) 2 in. seed spacing - V base - No. 32 hole x 36 holes belt - A pulley - 480 peas in 900 in. run.

(iii) 3 in. seed spacing - P base - No. 32 hole x 36 holes belt - A pulley - 300 peas in 900 in. run.

Sowing speed was 1.7 m.p.h. and the shaft speed 50 r.p.m. for all seed spacings.

No herbicidal or mechanical weed control was carried out at any stage as the area was comparatively weed-free after germination.

(4) <u>Seed</u>

The variety chosen was 'Victory Freezer" which is one of the standard varieties used in Canterbury. The seed had been treated with Captan and gave a germination test of 94%. The seed weight was 1570 peas/lb.

(5) Plant Establishment

Plant populations were ascertained on November 10, 1969 by counting the number of plants in one yard lengths of the six centre rows of each plot. These populations are shown in Table 1 along with the sowing rate of each treatment in bu/ac., calculated from the calibration of the precision seeder and the individual seed weight.

TABLE 1

Plant Population (plants/sq. ft) and Sowing Rate (bu/ac.) 1969-70

	Seed Spacing Within Rows 1 in.		2 in.		3 in.	
Row Width	Pop.	bu/ac	Pop.	bu/ac	Pop.	bu/ac
4 in.	34.5	17.7	16.8	8.9	11.0	5.6
8 in.	16.9	8.9	8.7	4.4	5.4	2.8
12 in.	10.7	5.9	5.5	3.0	3.3	1.9

(6) Irrigation

Approximately $1\frac{1}{2}$ in. of water was applied to the trial site with a sprinkler irrigation system prior to sowing. Following a dry month in November (0.89 in.) another $1\frac{1}{2}$ in. of water was applied on December 1 and 2 just prior to flowering. No irrigation was given at pod swelling as 0.58 in. of rain fell on December 24 and 25.

(7) <u>Harvest</u>

As the optimum harvest dates approached periodic maturometer readings were taken on samples from a number of plots. This was to ensure that all peas were harvested as near as possible to a tenderometer reading (TR) (Martin, 1937) of 105. This is the TR around which peas are normally harvested for freezing.

When the plots were ready an area 6 rows x 10 ft. in the 4 in. and 8 in. row plots and 4 rows x 15 ft. in the 12 in. row plots was selected at random from the centre rows of each plot. Care was taken to avoid parts of rows that had been missed at sowing. All plants in this area were pulled and total green weight measured. A 15lb sub-sample was then taken and vined in a mini-viner for five minutes and the weight of shelled peas measured. The peas were then washed and taken to the processing factory of Unilever (N.Z.) Ltd at Papanui where TRs were obtained.

At the time of harvest 25 plants were removed from the ends of the harvested area of each plot and the following measurements made:

(i) Vine length to first pod.

(ii) Total vine length.

(iii) Number of full pods/plant. A full pod was any pod containing at least one developed pea.

(iv) Number of flat pods/plant.

(v) Number of ovule initials/pod and per plant.

(vi) Number of peas/full pod and per plant.

(vii) Percentage sieve size of the peas by weight: The sieves used were 8/32 in., 10/32 in., and 12/32 in.

Harvesting began on December 28, 1969 and was completed on December 31.

(8) <u>Weed Score</u>

At the time of harvest each plot was scored for weeds on 1 - 10 scale. Weed-free plots received a score of 1 and very weedy plots a score of 10. A species list was compiled of weeds present.

III. RESULTS

(1) Phosphate Responses

Analysis of the results showed that the phosphate response was in almost all cases not significant. Because of this no further reference will be made to phosphate in the results and the tables will be restricted to the effects of row width and seed spacing within the row.

(2) Total Green Yield

Table 2 contains the mean total green yields obtained for each plant spacing.

TABLE 2

Total Green Weight lb/ac. 1969-70				
	Seed Spacing Within Row 1 in.	2 in.	3 in.	Mean
Row Width 4in.	42750 a	38900 b	38100 b	39900 a a
8in.	37950 b	35000 c	31150 d	34700 b b
12in.	34000 c	28350 e	23100 f	28500 c c
Mean	38250 aaa	34050 bbb	30800 ccc	34350

The total green yield rose with increasing plant population with a significant increase over the next highest plant population occurring even at the high 4 x 1 in. spacing.

Reducing row width has had a greater effect on total green yield than reducing the seed spacing within the row. This is well shown in the significant yield differences between the 4 x 3 in. and the 12 x 1 in. spacing and between the 8 x 3 in. and the 12 x 2 in. spacings. Although the plant populations are similar in both cases a significantly higher yield has been obtained in the treatment with the narrower row width. There is a significant positive interaction between row width and seed spacing at the 5% level.

(3) <u>Green Pea Yield</u>

Although most plots were harvested at a TR between 100 and 110 the range in readings over all plots was 94 to 119. The green pea yield for each plot was therefore corrected to a standard TR of 105 using the yield correction factors derived for irrigated peas in the Yield - TR Relationship Trial described in Chapter 5. The green pea yields are shown in Table 3.

TABLE 3

Green Pea Yield lb/ac (Corrected to TR=105) 1969-70				
	Seed Spacing Within Row			Mean
	1 in.	2 in.	3 in.	
Row Width 4in.	7880 a	7690 a	6870 b	7480 aa
8in.	7280 ab	6570 bc	5330 d	6400 bb
12in.	6080 c	4920 d	3460 e	4820 cc
Mean	7080 aaa	6400 bbb	5220 ccc	6230

SE = 618 CV = 9.9

Green pea yields increased as row width or seed spacing decreased. The highest yield occurred at the highest plant population in the 4 x 1 in. plant spacing. This yield however is not significantly higher than in either of the two plant spacings (4 x 2 in. and 8 x 1 in) with approximately half the plant density. At lower plant densities the increase in yield with increasing plant density is however very considerable. It can be seen from the mean figures for row width and seed spacing that decreasing row width has given a greater increase in yield than decreasing the seed spacing within the rows.

(4) Shelling Percentage

The shelling percentage is the shelled pea weight as a percentage of the total green weight. The shelling percentages shown in Table 4 have been calculated using the green pea yield corrected to a TR of 105.

TABLE 4

Shelling Percentage 1969-70				
	Seed Spacing Within Row 1 in.	2 in.	3 in.	Mean
Row Width 4 in.	18.4 abc	19.8 a	18.1 bc	18.8 aa
8 in.	19.2 ab	19.1 ab	17.2 c	18.5 aa
12 in.	17.9 bc	17.3 c	15.0 d	16.7 bb
Mean	18.5 aaa	18.7 aaa	16.7 bbb	18.0

SE = 1.28 CV = 7.0

The most noticeable feature of this table is the drop is shelling percentage at the lower plant densities.

(5) Vine Length

Both the total vine length and the vine length to the first pod are shown in Table 5.

TABLE 5

TOTAL VINE LENGTH AND VINE LENGTH TO 1ST POD (IN.) 1969-70

	Seed Spacing Within Rows 1 in.		2 in.		3 in.		Mean	
Row Width	Total Length	Length to 1st Pod	Total Length	Length to 1st Pod	Total Length	Length to 1st Pod	Total Length	Length to 1st Pod
4 in.	10.9 f	10.5 z	13.6 e	12.6 y	15.4 d	13.1 xy	13.3 cc	12.1 zz
8 in.	14.0 e	13.0 xy	16.9 c	14.0 x	18.5 b	13.8 xy	16.5 bb	13.6 yy
12 in.	16.2 cd	14.1 x	18.3 b	15.4 w	22.2 u	14.0 x	18.9 aa	14.5 xx
Mean	13.7 ccc	12.5 zzz	16.3 bbb	14.0 xyy	18.7 aaa	13.6 yyy	16.2	13.4

Total Vine Length SE = 1.10 CV = 6.8

Vine Length to first pod SE = 0.96 CV = 7.2

Total vine length increased inverseley with plant population to a maximum of 22.2 in. in the 12 x 3 in. spacing. This trend is less consistent for vine length to the first pod as the 12 x 2 in. spacing figure is significantly greater than that of the 12 x 3 in. spacing.

There is a tendency, for both total vine length and length to the first pod, towards a greater length in the wider row spacings where plant populations are equivalent (4 x 2 in. and 8 x 1 in.; 4 x 3 in. and 12 x 1 in.; 8 x 3 in. and 12 x 2 in.). These is negative interaction between row width and seed spacing at the 5% level for the vine length to the first pod.

(6) Pods per Plant

The number of full and flat pods per plant are shown in Table 6.

TABLE 6

Number of Pods/Plant 1969-70								
	Seed Spacing Within Rows 1 in.		2in.		3 in.		Mean	
Row Width	Full	Flat	Full	Flat	Full	Flat	Full	Flat
4 in.	1.72 f	0.20 z	2.67 e	0.17 z	3.67 d	0.24 yz	2.69 cc	0.20 zz
8 in.	2.55 e	0.14 z	4.23 c	0.27 yz	4.91 b	0.55 yz	3.90 bb	0.32 zz
12 in.	3.27 d	0.14 z	4.66 bc	0.64 y	5.95 a	1.15 x	4.62 aa	0.64 yy
Mean	2.51 ccc	0.16 zzz	3.85 bbb	0.36 zzz	4.84 aaa	0.64 yy	3.74	0.39

Full pods/plant SE = 0.378 CV = 10.1

Flat pods/plant SE = 0.321 CV = 82.3

The number of full pods per plant increased inversely with plant density.

The number of flat pods per plant however did not change noticeably except at low plant densities where there was a sharp increase in number with decreasing density.

This has led to a significant positive interaction at the 5% level between row width and seed spacing for the number of flat pods per plant.

(7) Number of Ovule Initials

Because of obvious and large human errors in recording the number of ovule initials this data was discarded.

(8) Number of Peas

Table 7 contains the mean number of peas per full pod and per plant for each plant spacing.

TABLE 7

Number of Peas/Full Pod and Peas/Plant 1969-70								
	Seed Spacing Within Row 1 in.		2in.		3 in.		Mean	
Row Width	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant
4 in.	3.79 g	6.6 z	4.55 ef	12.2 y	5.22 bc	19.3 w	4.52 bb	12.7 zz
8 in.	4.41 f	11.2 y	5.09 cd	21.5 w	5.63 a	27.7 u	5.04 aa	20.1 yy
12 in.	4.86 ae	16.0 x	5.31 abc	24.7 v	5.47 ab	32.5 x	5.21 ad	24.4 xx
Mean	4.35 ccc	11.2 zzz	4.98 bbb	19.5 yyy	5.44 aaa	26.5 xxx	4.92	19.1

No. of peas/full pod SE = 0.286 CV = 5.8
No. of peas/plant SE = 2.01 CV = 10.6

The number of peas per full pod has tended to follow an inverse relationship with plant density. However the difference between the population extremes is considerably less than for the number of pods per plant. There is a negative interaction between row width and seed spacing significant at 5% for the number of peas per full pod.

The most noticeable feature of the number of peas per plant is its trend with plant density. Almost all spacing treatments were significantly different from each other. The effect of narrower row spacing in increasing the number of peas per plant can be seen clearly. In two of the three plant spacings with similar plant populations (4 x 3 in. and 12 x 1 in.; 8 x 3 in. and 12 x 2 in.) the narrower row spacings had given a significant increase at the 5% level in the number of peas per plant.

(9) <u>Pea Sieve Size</u>

The statistical analysis of the percentage peas of each sieve size was carried out on an active arcsine transformation of the percentage peas of each sieve size. The sizes < 8/32 in. and 8/32 - 10/32 in. were combined for analysis. Of the 3 sieve sizes (<10/32 in.; 10/32 - 12/32 in.; < 12/32 in.) the only significant difference between treatments appeared in the sieve size <10/32 in. at low plant densities, where there was a marked increase in the percentage of smaller peas. This is shown in Table 8.

TABLE 8

Percentage Peas < 10/32" (Transformed % in Parentheses) 1969 - 70				
	Seed Spacing Within Row 1 in.	2 in.	3 in.	Mean
Row Width				
4 in.	5.5 (13.1) bc	5.3 (12.1) c	7.3 (15.5) abc	6.0 (13.6) bb
8 in.	7.6 (15.7) abc	7.8 (15.7) abc	10.3 (18.3) ab	8.6 (16.6) aa bb
12 in.	6.3 (13.7) bc	10.1 (18.1) abc	12.8 (20.8) a	9.7 (17.5) aa
Mean	6.5 (14.2) bbb	7.7 (15.3) aaa bbb	10.1 (18.2) aaa	8.1 (15.9)

SE = 4.48 CV = 28.2

(10) Time to Maturity

Plant density had a marked effect on the time taken for the peas to reach the optimum harvest stage. Plots at the highest plant density (34.5 plants/sq. ft. at the 4 x 1 in. spacing) matured first and were harvested on December 28. On succeeding days further plots became ready, in order of decreasing plant density. The final plots harvested on December 31 were the sparse 12 x 3 in. plots with only 3.3 plants/sq. ft. These had taken four days longer to reach optimum maturity than the most dense plots.

(11) Weed Score

Table 9 contains the mean weed score for each plant spacing. The statistical analysis on the weed score was done using a $\sqrt{(x + 1)}$ transformation.

TABLE 9

Weed Score (Transformed Score in Parenthesis) 1969 - 70

	Seed Spacing Within Row 1 in.	2 in.	3 in.	Mean
Row Width 4 in.	1.0 (1.4) e	1.5 (1.6) de	2.5 (1.8) cd	1.7 (1.6) cc
8 in.	1.7 (1.6) de	2.9 (1.9) c	6.0 (2.6) b	3.5 (2.1) bb
12 in.	3.5 (2.1) c	6.0 (2.6) b	7.7 (2.9) a	5.7 (2.5) aa
Mean	2.1 (1.7)	3.5 (2.0)	5.4 (2.5)	3.6 (2.1)

SE = 0.22 CV = 10.9

It can be seen that as plant density increased the incidence of weeds fell until at the highest plant density there were virtually no weeds. At low plant densities weed incidence was considerable. Decreasing row width had a greater effect on weed score than reducing the spacing within the row. There was a positive interaction at the 5% significance level between row width and seed spacing.

Fathen, wild pansy, spurry, scarlet pimpernel, fumitory and sorrel were the most common weeds with lesser amounts of wireweed, cornbind, catsear, ryegrass and black nightshade.

IV. DISCUSSION

Gane (1963) stated that the general response of peas to applied fertilizer is much less than the majority of farm crops. During (1967) reporting on New Zealand work stated that experiments with phosphate fertilizers on peas had generally given negative results. Bishop <u>et al</u>., (1968) obtained a significant phosphate response in peas at only two of twelve sites. Thus in view of these results and the high soil phosphate level on the trial site before sowing the lack of a phosphate response is not surprising.

The total green yield produced has followed the asymptotic pattern with increasing plant population generally obtained for total crop production (Holliday (1960). Other workers (Younkin <u>et al</u>., 1950; Gritton and Eastin 1968) have shown a similar pattern but recorded considerably lower vine yields. The total green yield produced in peas could be considered of minor economic importance although after vining the residual vine is generally baled for supplementary stock feed.

The green pea yield is of course the most important parameter measured. The relationship between green pea yield and plant density in this trial appears to be asymptotic; and not parabolic which is the more typical pattern for reproductive yield suggested by Holliday (1960). Some workers (Younkin et al., 1950; Vittum et al., 1958; Gritton and Eastin; 1968.) have also obtained yield increases up to the maximum plant population but none of these workers used as high a maximum plant density as in this trial. Other workers however have obtained a parabolic yield pattern with plant population in green peas. These workers include King (1966) who over a series of trials reported a maximum yield at an average of 16 plants/sq. ft. and Bleasdale and Thompson (1963) who in one trial obtained a drop in yield at 6.7 plants/sq. ft.

It should be noted that compared with normal commercial green pea yields in New Zealand and much of the overseas experimental work that the yields acheived in the experiment are very high. The mean yield of 3,460 lb./ac. at the lowest plant density in this experiment is above the average green pea yield of 3,150 ab./ac. obtained in New Zealand over the last six years. The seed rate for the 8 x 2 in. spacing was 4.4 bu/ac., which is close to the usually recommended seed rate in New Zealand of 4 bu./ac. The mean yield of 6,570 lb. obtained at this spacing is more than double the New Zealand average green pea yield.

Reasons for the particularly high green pea yields obtained in this trial could include:

row spacing has given a 800 lb./ac. yield increase although plant densities are similar. This is similar to results of Gritton and Eastin (1968) who obtained an increase in yield by reducing row width to as little as $3\frac{1}{2}$ in.

The shelling percentage gives a measure of the harvest index (Donald,1962), or the total economic yield as a proportion of total crop yield. This is important to processors as it can affect the rate of output of commercial pea viners. If the shelling percentage is low more material must be vined for an equivalent weight of green peas. The general trend in this experiment of increased shelling percentage with plant population is similar to that reported by King (1966) and Gritton and Eastin (1968).

The vine length to the first pod and total vine length can be important considerations in the harvesting of green peas. If vine length to the first pod is too short difficulties may be experienced in setting machinery low enough to harvest all pods while if total vine length is too long harvesting difficulties can occur through the crop lying flat. This can also lead to problems of stem rotting.

It can be seen that at high plant population the difference between the vine length to the first pod and total vine length is small. This indicates that all pods are near the top of the vine whereas at low densities the pods are likely to be spread out over a larger number of nodes. This factor

(i) The use of irrigation at flowering and the occurrence of light rain at pod swelling which appear to be the most moisture sensitive stages for peas. (Salter 1963).

(ii) Lower pea losses at harvest than would normally occur with commercial vines.

(iii) The use of a precision seeder ensuring more even plant population than those normally obtainable under normal farm drilling conditions.

(iv) The high fertility and good structure of a paddock just out of six years' pasture and on a good cropping soil.

It can be seen from Table 3 that in this trial a considerable yield increase has been gained by higher seeding rates than that normally used in farm practise. The 4 x 1 in. spacing has given a yield increase of 1,310 lb./ac. or 20% over the 8 x 2 in. spacing. However in view of high seed costs and the low marginal return on increased plant population commercial seeding rates are not likely to approach this level. The increase of 1,1120 lb./ac. obtained in the 4 x 2 in. over the 8 x 2 in. spacing is only slightly smaller. Even after deducting the cost of seed an increase in yield of this magnitude would give a very good economic return.

The effect of row spacing on yield can be well seen in the 4 x 3 in. and 12 x 1 in. spacings where the narrower may become of some importance if machinery is commercially developed for stripping the pods from the vine in the field (Anon, 1969).

No previous measurements of vine length to the first pod are known. However increased total vine length at lower plant populations has been recorded by Younkin *et al.*, (1950) and King (1966). The slight effect of a longer vine with increasing row width at constant population was also found by Vincent *et al.*, (1958).

The number of pods per plant can be considered as the product of the number of podding nodes and the number of pods per node which are suggested as components of yield for green peas by Hardwick and Milbourn (1967). They suggest the number of pods per node as an important yield governing factor due to the possibility of the production of only one flower at the node or though the loss of pods by abscission. Meadley and Milbourn (1970) showed abscission losses to be greater at high plant densities. The large increase in the number of full pods per plant obtained with decreasing density would be due largely to the increase in the number of podding nodes per plant possible at lower plant densities. The large increase in the number of flat pods per plant at low densities is also due to an increase in the number of podding nodes per plant. This will be discussed more fully in Chapter 4.

The number of peas per pod was also described by Hardwick and Milbourn (1967) as an important yield governing factor as many ovules do not develop especially at high populations. The increase in the number of peas per pod obtained with decreasing plant density in this experiment is of the same order as Gritton and Eastin (1968) and greater than Younkin et al., (1950) over equivalent density ranges. It is considerably less than the equivalent range of Meadley and Milbourn (1970). They however, obtained no significant yield differences between different plant densities and it would appear that this large difference in the number of peas/pod was a significant compensatory factor in obtaining high green pea yields at lower plant densities.

The large difference between spacing in the number of peas/plant is a combined effect from variations between spacing in the number of pods/plant and peas/pod. The increased number of smaller peas at low plant densities is in agreement with results of Younkin et al., (1950) and Ottosson (1968a). This is likely to be due to an increased number of podding nodes per plant at low densities and will be discussed more fully in Chapter 4.

The time that peas take to mature to the green pea stage is dependent largely on temperature. A heat unit system (Katz 1952) is often used by processors to plan planting schedules. The increase in the rate of maturity at dense plant populations could thus be due partly to a microclimatic effect leading to a higher temperature within the denser plant populations. Another contributing factor could be the presence of less mature peas at the higher nodes of lower plant densities lowering the average TR of the whole sample. Ottosson (1968a) obtained a similar trend of maturity with plant density but Gritton and Eastin (1969) reported no density effect on maturity.

The effect of plant density on weed growth with high plant density and narrow rows having a suppressive effect on weeds is similar to results recorded by Marx and Hagedorn (1961) and Gritton and Eastin (1968).

Plate I - General View - Irrigation x Plant Density Trial - Yield - TR Block in Foreground.

CHAPTER IV

1970-71 IRRIGATION X PLANT DENSITY TRIAL

I. INTRODUCTION

In the previous season's trial a large increase in yield was obtained under virtually optimum soil moisture conditions, by sowing green peas at higher densities than those normally used. In view of the normally dry summer conditions experienced in Canterbury and the responses obtained to irrigating green peas, both by overseas workers and a few Canterbury farmers, it was considered that soil moisture stress was normally one of the major factors limiting green pea yields in Canterbury.

This trial was therefore carried out to obtain an indication of the increase in yield possible with irrigation, and to see if the pattern of green pea yield with plant density established the previous year prevailed under less optimum soil moisture conditons.

II. EXPERIMENTAL TECHNIQUE

(1) Trial Design

The trial was factorial with a completely randomized flock design. The following were the treatments used:

Plant Spacings:

(i) 4 in. rows; 1 in. seed spacing

(ii) 4 in. rows; 2 in. seed spacing

(iii) 4 in. rows; 3 in. seed spacing

(iv) 8 in. rows; 2 in. seed spacing

(v) 8 in. rows; 3 in. seed spacing

Moisture Treatments:

(i) Optimum water at flowering and pod swelling, during which the soil moisture levels were kept close to field capacity.

(ii) Water stress at flowering and pod swelling, during which soil moisture levels were kept around wilting point.

(iii) Natural rainfall throughout the growing period.

There were thus 15 treatments, and with 3 replicates there was a total of 45 plots. Each plot measured 6ft. 6in. x 20ft. An interplot plot area of similar size was planted between each plot to stop lateral water movement between plots.

(2) Methods of Applying Irrigation and Moisture Stress

The irrigated plots were watered with a trickle irrigation system (Dunn, 1970). Two ½in. laterals, 3ft. 4in. apart, ran through each plot. From these, 9 in. microtubes of 0.02in. diameter were spaced at 1ft. intervals with each successive microtube directed to alternate sides. The laterals were fed by a $1\frac{1}{2}$ in. main from a head tank at the edge of the trial area. The water pressure from each microtube was 4.7 - 5.0lb/sq. ft. with each releasing approxmately 0.27 gal. of water/hour. The flow of water to individual plots could be regulated by a clip at the junction of the lateral and main.

Removable rain shelters were erected on the water stress plots. Across the plot a permanent semi-circular framework of $\frac{3}{4}$in. reinforcing rod was erected. Over this a plastic sheet, permanently attached to one side could be unrolled and secured if rain appeared likely. (Plate 2)

(3) Site

The trial site was adjacent to that of the previous year's trial described in Chapter III. The soil was a Wakanui silt loam. The trial was preceded by cabbages which followed a 6 year ryegrass-white clover pasture. Soil samples (0 - 4in.) taken on July 15, 1970 gave the following Department of Agriculture quick test results:

pH	Ca	K	P (Truog)	P (Bray)
6.0	7	6	13	50

(4) Preparation and Sowing

The area was ploughed in early September 1970 and Dutch harrowed twice before 2cwt. of superphosphate were broadcast on October 12. A further Dutch harrowing was given before the application of 2pt. a.i./ac. of Trifluralin, a pre-emergence herbicide. This was incorporated with the

Plate II - Rain Shelters - Close View.

Dutch harrows.

A 'Stanhay' precision seeder was used to sow the seed. Settings and sowing procedure were similar to those used for the previous year's trial. Headlands and interplot areas were sown at the 8 x 2 in. spacing. The 4 in. rows were sown on October 14 and the 8 in. rows the following day.

(5) Seed

The variety chosen was again Victory Freezer. The seed was treated with 'Captan' and gave a box germination percentage of 98%. Seed weight was 1570 seeds/lb, the same as in the previous year's trial.

(6) Establishment

Population counts taken on November 10, 1970 gave the following plant populations.

Plant Spacing	Population Plants/sq. ft.
4 in. x 1 in.	33.3
4 in. x 2 in.	16.9
4 in. x 3 in.	9.8
8 in. x 2 in.	8.4
8 in. x 3 in.	4.8

(7) Moisture Treatment of Plots

Moisture was adequate in the early growth stage. Within 48 hours of sowing 1.37 in. of rain fell followed by 1.76 in. on November 3 and 4. However, with little further rain and high evapotranspiration, soil conditions were dry when the first irrigation treatment was applied just prior to flowering on December 2. Up until December 11 approximately 8½ in. was applied to the irrigated plots. The amount of water available to the plants in each plot would have been much less as there was considerable lateral water movement into the interplot area. A further 4½in. of water was applied to the irrigated plots during the period of pod swelling on December 28 to 30 in the 4 x 1 in. and 4 x 2 in. spacings and on December 30 - 31 on the remaining plant spacings.

The only really effective rain after November 4 occurred after flowering on December 13 and 14 when 0.70 in. fell. Of this 0.50 in. was allowed on to the stress plots as flowering was over and the pod swelling period still some time off. The aim was to induce stress at only the flowering and pod swelling stages. As can be seen in Table 10 it was possible for stress to occur at pod swelling even with this rain having fallen on the plot. Although the covers were used on other occasions when rain threatened or very light rain fell the season was such that the stress treatment and natural rainfall treatment were very similar.

Soil moisture readings as shown in Table 10 were taken at intervals using the thermo-gravimetric method.

TABLE 10

Soil Moisture (0 - 6") as a Percentage of Oven Dry Weight				
Date	Natural Rainfall	Stress	Irrigation	Growth Period
19 Oct.	26.5			After sowing.
17 Nov.	15.5			Vegetative stage.
2 Dec.	10.5			Just prior to flowering and first irrigation.
7 Dec.	9.5		20.5	Full flower.
12 Dec.	8.5		23.5	Flowering over.
21 Dec.	14.0	10.5	24.0	
26 Dec.	9.0	8.5	13.0	Pod swelling in unirrigated treatments. Prior to pod swelling irrigation in irrigated treatments.
Field Capacity 27.2%		Wilting Point 11.5		

(8) Harvest

Harvesting procedure was basically similar to that of the previous trial. The harvested area however was not selected at random but taken from the area 3 ft. to 13 ft from the E end of each plot. In the 8 in. row plots only 4 rows x 10ft. were harvested. Tenderometer readings for this trial were taken at J. Wattie Canneries Ltd processing factory at Hornby.

The following measurements were made on the 25 plant samples pulled from each plot.

(i) Vine length to the first pod bearing node from the basal node.

(ii) Total vine length from the basal node.

(iii) Number of full pods/plant. A full pod was any pod containing at least one pea larger than 7/32 in. diameter.

(iv) Number of flat pods/plant.

(v) Number of ovule initials/pod and per plant.

(vi) Number of peas/full pod and per plant.

(vii) Percentage of pods at each pod bearing node up to the fourth or higher node.

(viii) Percentage of peas at each pod bearing node up to the fourth or higher node.

(ix) Percentage sieve size of each sample by weight of peas less than 10/32 in., 10/32 - 12/32 in., 12/32 - 14/32 in. and greater than 14/32 in.

(x) A colour test using U.S.D.A. colour standards after the samples had been blanched for two minutes. The average colour standard of each sample was assessed and the percentage of peas of U.S.D.A. colour standard 4 - 6 and >6 measured respectively.

(9) Seed Harvest

As each plot became fully mature an area 2 ft. (6 rows) x 3 ft. was taken from the 4 in. row plots and 2 ft. 8 in.

(4 rows) x 3 ft. from the 8 in. row plots. All plants in this area were pulled and the seed threshed out in the mini-viner. After leaving 2 months for any moisture differences to equalise the seed was weighed.

Harvesting was spread over four weeks from January 19. The stress plots matured first as they were protected from rain falling after the green pea harvest. The first irrigated plots were harvested almost 2 weeks after the unirrigated peas had been finished.

III. RESULTS

(1) Total Green Weight

The total green weight harvested for each treatment is shown in Table 11.

TABLE 11

Total Green Weight lb/ac 1970-71				
	Moisture Treatment Irrigated	Stress	Nat. Rainfall	Mean
Plant Spacing				
4 x 1 in.	41750 a	23600 d	23500 d	29600 aa
4 x 2 in.	39150 ab	22000 de	21900 de	27700 aa
4 x 3 in.	37450 b	18100 fgh	20050 def	25200 bb
8 x 2 in.	36850 b	18950 efg	17600 fgh	24450 bb
8 x 3 in.	31300 c	14950 h	16350 gh	20850 cc
Mean	37300 aaa	19500 bbb	19900 bbb	25550

SE = 2000 CV = 7.8

The most striking feature of these results is the large response to irrigation. The mean yield from the irrigated treatments is 90% greater than that from the mean of the other two moisture treatments. The lowest yield under irrigation at the 8 x 3 in. spacing was significantly higher, even at the 1% level than the highest yielding unirrigated treatment.

The total green yield increased asymptotically with plant density. The highest yield, at the 4 x 1 in. spacing was 42% greater than that obtained at the widest 8 x 3 in. spacing.

(2) Green Pea Yield

The green pea yields shown in Table 12 are corrected to a TR of 105.

TABLE 12

Green Pea Yields lb/ac 1970-71

	Moisture Treatment			
	Irrigated	Stress	Nat. Rainfall	Mean
Plant Spacing				
4 x 1 in.	7180 ab	4660 cd	4180 cd	5340 aa bb
4 x 2 in.	7340 a	4910 cd	4960 c	5740 aa
4 x 3 in.	7040 ab	4090 d	4710 cd	5280 bb
8 x 2 in.	6490 b	4080 d	4170 cd	4910 bb
8 x 3 in.	4960 c	3280 e	3200 e	3820 cc
Mean	6600 aaa	4200 bbb	4240 bbb	5020

SE = 440 CV = 8.8

These results show that irrigation has again had a major effect with a highly significant response at all plant densities. The mean green pea yield from the irrigated plots was 56% higher than that of the unirrigated plots.

In all moisture treatments yield increased with plant population up to the 4 x 2 in. plant spacing. Beyond this, although the differences are not significant at the 5% level there was a noticeably fall-off in yield at the 4 x 1 in. spacing. This was most noticeable in the natural rainfall treatment and far less marked in the irrigation treatment. Another noticeable trend was the marked drop in yield at the 8 x 3 in. spacing. The difference between the mean yield at this spacing and the next lowest mean, was greater than the difference between the mean of that and all other plant spacings:

(3) Shelling Percentage

There are two obvious features of Table 13. The first is the effect of irrigation in significantly reducing the shelling percentage. The second is the fall in shelling percentage at the two population extremes. There is a significant negative interaction between moisture treatment and plant spacing at the 5% level.

TABLE 13

Shelling Percentage 1970-71				
	Moisture Treatment Irrigated	Stress	Nat. Rainfall	Mean
Plant Spacing				
4 x 1 in.	17.2 de	19.7 bc	17.7 cde	18.2 bb
4 x 2 in.	18.8 cd	22.3 a	22.6 a	21.2 aa
4 x 3 in.	18.8 cd	22.6 a	23.5 a	21.7 aa
8 x 2 in.	17.7 dce	21.5 ab	23.7 a	21.0 aa
8 x 3 in.	15.8 e	21.9 ab	19.6 bcd	19.1 bb
Mean	17.7 bbb	21.6 aaa	21.4 aaa	20.2

SE = 1.28 CV = 6.3

(4) Vine Length

Table 14 gives the vine length to the first pod bearing node and the total vine length for each treatment.

Irrigation has given a 29% mean increase in the vine length to the first pod bearing node. However, the increase in total vine length with irrigation was much greater, a 62% mean increase being obtained.

TABLE 14

Vine Length to First Pod Bearing Node and Total Vine Length (in.) 1970-71

	Moisture Treatment							
	Irrigated		Stress		Nat. Rainfall		Mean	
Plant Spacing	Length to 1st Pod	Total Length	Length to 1st Pod	Total Length	Length to 1st Pod	Total Length	Length to 1st Pod	Total Length
4 x 1in.	16.3 a	20.0 w	12.3 c	13.0 z	12.9 bc	13.3 yz	13.8 *	15.5 zz
4 x 2in.	16.8 a	21.4 w	13.0 bc	13.9 xyz	12.9 bc	13.7 yz	14.2	16.3 zz
4 x 3in.	17.8 a	25.3 v	12.6 c	13.6 yz	12.5 c	14.3 xyz	14.3	17.7 yy
8 x 2in.	17.0 a	25.1 v	13.3 bc	14.8 xyz	13.0 bc	14.4 xyz	14.5	18.1 yy
8 x 3in.	14.5 b	24.0 v	13.4 bc	16.1 x	12.1 c	15.6 xy	13.4	18.6 yy
Mean	16.5 aa	23.2 yyy	12.9 bb	14.3 222	12.7 bb	14.3 zzz	14.0	17.2

Length to 1st Pod SE = 0.87 CV = 6.2

Total Length SE = 1.23 CV = 7.1

* F test not significant at 5%

Plant spacing had no significant effect on the mean length to the first pod, although the 8 x 3 in. irrigated treatment surprisingly was less than all other irrigated treatments. The total vine length increased graudally with decreasing plant population.

There was a significant positive interaction at the 5% level between plant spacing and moisture treatment for the total vine length and a negative interaction at 5% for vine length to the first pod.

(5) Pods/Plant

The number of full and flat pods/plant for each treatment is given in Table 15.

TABLE 15

Number of Full and Flat Pods/Plant 1970-71

	Moisture Treatment							
	Irrigated		Stress		Nat. Rainfall		Mean	
Plant Spacing	Full	Flat	Full	Flat	Full	Flat	Full	Flat
4 x 1 in.	1.68 fg	0.16 yz	1.46 gh	0.16 yz	1.29 h	0.22 yz	1.47 dd	0.18 zz
4 x 2 in.	2.36 cd	0.10 z	1.86 ef	0.12 z	2.17 de	0.09 z	2.13 cc	0.10 zz
4 x 3 in.	3.38 b	0.09 z	2.36 cd	0.07 z	2.49 cd	0.13 z	2.74 bb	0.09 zz
8 x 2 in.	3.38 b	0.29 yz	2.62 c	0.06 z	2.73 c	0.10 z	2.91 bb	0.15 zz
8 x 3 in.	4.27 a	1.26 x	3.36 b	0.20 yz	3.56 b	0.37 y	3.73 aa	0.61 yy
Mean	3.01 aaa	0.38 yyy	2.33 bbb	0.12 zzz	2.45 bbb	0.18 zzz	2.60	0.23

Full Pods/Plant SE = 0.204 CV = 7.9

Flat Pods/Plant SE = 0.117 CV = 50.4

Irrigation increased the number of full pods/plant by 26% but the effect of varying plant population was considerably greater. At the lowest plant density there was an average of 154% more full pods/plant than at the highest plant density. For the number of full pods/plant there was a significant positive interaction between moisture treatment and plant spacing at the 5% level. More flat pods/plant occurred at the lowest plant density. At the higher plant densities there were no significant differences between the irrigated and non-irrigated treatments, but at the 8 x 3 in. spacing, irrigation caused a large increase in the number of flat pods. Thus there was a strong positive interaction between moisture treatment and plant spacing significant at the 1% level.

(6) Ovule Initials

Table 16 shows the numbers of ovule initials/pod and /plant.

There appears to be no density effect on the number of ovule initials/pod up to the 4 x 3 in. plant spacing. However, above this there is a reduction in the number of ovule initials/pod with increasing plant density. The irrigation treatment gave a small but significant increase in the number of ovule initials/pod.

TABLE 16

Ovule Initials/Pod and /Plant. 1970-71								
Plant Spacing	Moisture Treatment							
	Irrigated		Stress		Nat. Rainfall		Mean	
	/Pod	/Plant	/Pod	/Plant	/Pod	/Plant	/Pod	/Plant
4 x 1in.	6.6 cde	12.2 y	6.1 e	9.8 z	6.4 e	9.7 z	6.4 cc	10.5 zz
4 x 2in.	7.3 ab	18.1 w	7.0 bcd	14. xy	6.5 de	14.5 x	6.9 bb	15.5 yy
4 x 3in.	7.7 a	26.5 v	7.3 ab	17.9 w	7.2 abc	19.0 w	7.4 aa	21.1 xx
8 x 2in.	7.4 ab	27.2 v	7.2 abc	19.7 w	7.0 bcd	19.9 w	7.2 aabb	22.3 xx
8 x 3in.	7.5 ab	41.7 x	7.5 ab	26.9 v	7.1 abc	29.7 u	7.3 aa	32.7 w
Mean	7.3 aaa	25.1 yyy	7.0 bbb	17.6 zzz	6.8 bbb	18.6 zzz	7.1	20.4

Ovule Initials/Pod SE = 0.33 CV = 4.7

Ovule Initials/Plant SE = 1.27 CV = 6.2

For the number of ovule initials/plant these trends are amplified by differences in the number of full and flat pods/plant so that there is a ar greater range between the different treatments.

There is a significant positive interaction at the 1% level for the number of ovule initials/plant.

(7) Number of Peas/Pod and Peas/Plant

The number of peas/pod and peas/plant are presented in Table 17.

TABLE 17

No. of Peas/Pod and Peas/Plant 1970-71								
	Moisture Treatment						Mean	
	Irrigated		Stress		Nat. Rainfall			
Plant Spacing	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant	Peas/ Pod	Peas/ Plant
4 x 1in.	3.27 de	5.5 yz	2.61 f	3.8 z	2.86 ef	3.7 z	2.91 cc	4.3 zz
4 x 2in.	4.63 bc	11.0 w	3.62 d	6.8 xy	3.66 d	8.0 x	3.97 bb	8.6 yy
4 x 3in.	5.01 abc	17.0 v	4.76 abc	11.3 w	4.43 c	11.1 w	4.73 aa	13.1 xx
8 x 2in.	5.16 ab	17.5 v	4.59 bc	12.0 w	4.60 bc	12.5 w	4.78 aa	14.1 xx
8 x 3in.	4.90 abc	21.0 u	5.28 a	17.8 v	5.07 ab	18.1 v	5.08 aa	18.9 ww
Mean	4.59 aaa	14.4 yyy	4.17 bbb	10.3 zzz	4.13 bbb	10.7 zzz	4.30	11.8

Peas/Pod SE = 0.314 CV = 7.3

Peas/Plant SE = 1.23 CV = 10.5

From the means of the moisture treatments it can be seen that irrigation has given a small but significant increase in the number of peas/pod. This effect appears greater at higher populations. At the 8 x 3 in. spacing the number of peas/pod in the irrigated treatment is actually slightly lower than the other 2 moisture levels. The number of peas/pod increased with decreasing plant density, but at the lower densities this trend was only slight. The effect of plant density appeared greater without irrigation.

Irrigation increased the mean number of peas/plant by 37% while decreasing the plant density also caused a large increase.

There was a significant negative interaction between moisture treatment and plant spacing at the 5% level for the number of peas/pod but no interaction for the number of peas/plant.

(8) Percentage of Pods and Peas at Each Node

The percentage of pods and peas at each pod bearing node can be seen in Figure 1. As there was little difference between them, the water stress and natural rainfall data was combined.

It can be seen that with irrigation and decreasing plant density the percentage of pods at the higher pod bearing nodes increased. At the 4 x 1 in. spacing without irrigation almost all pods occurred at the first pod bearing node while in the 8 x 3 in. spacing over 30% of the pods

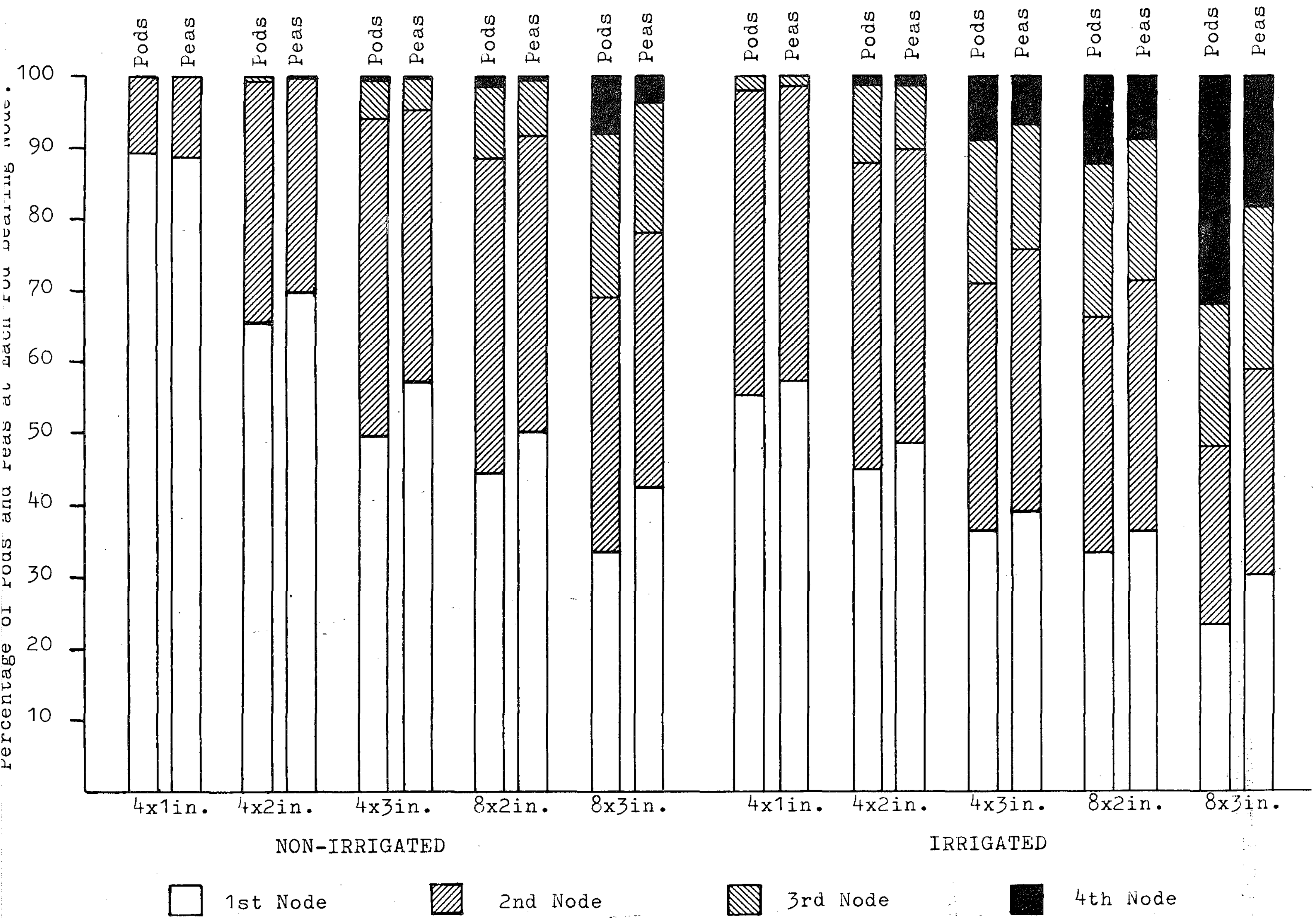

FIG. 1 The Percentage of Pods and Peas at Each Pod Bearing Node

occurred at the fourth or higher pod bearing nodes.

The percentage of peas at each node followed the same trend as the percentage of pods at each node. However there was a tendency, especially where a large percentage of the pods were at higher nodes for a greater proportion of the peas than pods to occur at the lower nodes.

(9) <u>Pea Sieve Size</u>

The only marked differences in pea sieve size between the different treatments occurred at the two extremes in sieve size, $<10/32$ in. and $>14/32$ in. Between these sieve sizes there was little significant difference between the treatments. Table 18 contains the percentage of peas by weight $<10/32$ in. and $>14/32$ in. for each treatment. Statistical analysis was done on an arcsine transformation of the percentage of peas at each sieve size.

TABLE 18

Percentage of Peas 10/32 in. and 14/32 in. Sieve Sice (Arcsine Transformations in Parentheses) 1970-71

Plant Spacing	Moisture Treatment: Irrigated		Stress		Nat. Rainfall		Mean	
	<10/32	>14/32	<10/32	>14/32	<10/32	>14/32	<10/32	>14/32
4 x 1in.	4.9 (11.9) abcd	2.5 (5.3) z	2.6 (9.1) cde	5.9 (14.0) vwxyz	1.6 (7.0) de	8.3 (15.4) vwxyz	3.0 (9.3) cc	5.6 (11.6) zz
4 x 2in.	2.2 (8.3) cde	14.7 (22.1) uv	0.9 (5.0) e	15.3 (22.0) uv	3.4 (9.7) cde	8.8 (16.7) vwxy	2.2 (7.7) cc	12.9 (20.3) yy
4 x 3in.	2.8 (9.1) cde	11.5 (19.8) uvwx	2.3 (8.1) cde	3.5 (8.8) yz	5.7 (13.1) abcd	4.3 (9.2) xyz	3.6 (10.1) bbcc	6.4 (12.6) zz
8 x 2in.	5.6 (13.6) abc	23.1 (28.6) u	4.1 (11.6) bcd	2.8 (7.9) yz	5.9 (13.8) abc	1.5 (5.7) z	5.2 (13.0) aabb	9.1 (14.1) zz
8 x 3in.	9.9 (18.3) a	14.4 (21.4) uvw	4.2 (11.8) bcd	3.7 (11.1) wxyz	8.0 (16.3) ab	6.0 (14.1) vwxyz	7.4 (15.5) aa	8.0 (15.5) yyzz
Mean	5.1 (12.2) aaa	13.2 (19.4) yyy	2.8 (9.1) bbb	6.2 (12.7) zzz	4.9 (12.0) aaa	5.8 (12.2) zzz	4.3 (11.1)	8.4 (14.8)

<10/32 in. SE = 3.39 CV = 30.5

>14/32 in. SE = 5.62 CV = 38.0

It can be seen that the number of peas <10/32 in. tends to increase with decreasing plant density. The water stress treatment had significantly less peas <10/32 in. than the other two moisture treatments.

Irrigation has more than doubled the mean percentage of peas >14/32 in. sieve size although at the highest plant density no increase was measured. There are significant differences between the density means but unfortunately there appeared to be no pattern to these differences.

There was an interaction between moisture treatment and spacing significant at the 1% level for peas > 14/32 in. sieve size but no significant interaction for those < 10/32 in.

(10) Pea Colour

The mean pea colour was paler with irrigation but plant density had no effect. The mean U.S.D.A. colour standards for the different moisture treatments is shown in Table 19.

TABLE 19

Mean U.S.D.A. Colour Standard for Moisture Treatments 1970-71		
Irrigated	Stress	Nat. Rainfall
2.8	2.1	2.1
S.E. (Mean) = 0.09	C.V. = 15.5	

The percentages of peas of U.S.D.A. colour standard 4 - 6 is shown in Table 20. An arcsine transformation has also been used for statistical analysis.

At a U.S.D.A. colour standard of 4, peas are a pale green colour and at a U.S.D.A. colour standard of 6 they are virtually yellow.

TABLE 20

Percentage of Peas U.S.D.A. Colour Standard 4 - 6 Arcsine Transformation in Parentheses 1970 - 71

Plant Spacing	Moisture Treatment Irrigated	Stress	Nat. Rainfall	Mean
4 x 1 in.	18.6 (24.4) a	2.3 (6.6) bc	6.8 (15.1) b	9.2 (15.4) aa
4 x 2 in.	3.9 (10.0) bc	3.8 (9.9) bc	3.2 (9.6) bc	3.6 (9.8) bb
4 x 3 in.	3.7 (10.3) bc	0.5 (2.3) c	1.9 (7.2) bc	2.0 (6.6) bbcc
8 x 2 in.	3.0 (9.8) bc	2.0 (7.9) bc	0.5 (4.1) c	1.8 (7.3) bbcc
8 x 3 in.	1.9 (7.2) bc	0.1 (0.9) c	0.2 (1.4) c	0.7 (3.1) cc
Mean	6.2 (12.3) aaa	1.7 (5.5) bbb	2.5 (7.5) bbb	3.5 (8.4)

SE = 5.05 CV = 59.8

Irrigation has more than doubled the percentage of peas of U.S.D.A. colour standard 4 - 6. Increasing plant density also had a large effect especially where the peas were irrigated.

No peas of U.S.D.A. colour standard 6 or greater were recorded in many treatments. There were no significant differences between any treatments except for the 4 x 1 in. irrigated treatment which had significantly more peas of U.S.D.A. colour standard 6 or greater than any other treatment.

(11) Time to Maturity

Both irrigation and plant density had a marked effect on time of maturity. The unirrigated 4 x 1 in. spacing plots were ready for harvest on December 29, 1970. The other unirrigated plots were harvested over the next two days in order of decreasing plant density. The densest irrigated plots were not ready for harvest until January 3, 1971, five days after the equivalent unirrigated plots. The least dense irrigated plots were not ready for harvest until January 7, seven days after the unirrigated plots of equivalent plant density.

(12) Seed Yield

The mature seed pea yields are shown in Table 21. Irrigation has given a 53% increase in the mean seed yield. The effect of plant population on seed yield is a parabolic one with the yield reaching a peak at the 4 x 3 in. spacing and falling away on either side. The lowest mean yield occurred at the highest plant density in the 4 x 1 in. spacing, but there was less yield difference over the whole density range than with green peas.

TABLE 21

Seed Pea Yield lb/acre 1970-71				
Plant Spacing	Moisture Treatment Irrigated	Stress	Nat. Rainfall	Mean
4 x 1 in.	2740 bcd	2160 cde	2010 de	2300 cc
4 x 2 in.	3750 a	2320 cde	2080 cde	2720 aabb
4 x 3 in.	3640 a	2770 bc	2380 cde	2930 aa
8 x 2 in.	3360 ab	2190 cde	2300 cde	2620 aabbcc
8 x 3 in.	3420 ab	1890 e	2000 de	2440 bbcc
Mean	3380 aaa	2270 bbb	2150 bbb	2600

SE = 393 CV = 15.1

IV DISCUSSION

Probably the most notable feature in the results of this trial was the very pronounced effect of irrigation not only on green pea yields but on all other parameters measured. The other feature most apparent about the moisture treatments was the almost complete lack of any significant difference between the stress and the natural rainfall treatments. It is perhaps unfortunate that as the season turned out these two treatments were in fact virtually the same.

The total green yields obtained for the irrigated treatment in this trial were very similar to those of equivalent plant spacings in the 1969-70 trial. The increase in total green yield with both irrigation and increasing plant density could have been expected from the results of other workers (Salter, 1962, 1963; Maurer et al., 1968; Gritton and Easting, 1968).

In view of the dry growing season the 56% increase in green pea yield could also have been expected. Many workers (Salter, 1962, 1963; Smittle and Bradley, 1966; Salter and Williams, 1967) have recorded lesser yield increases of up to about 30% by irrigating at flowering and pod swelling. Maurer et al (1968) using lysimeters, recorded a yield increase almost equal to that in this trial by maintaining a high moisture status from the 10th node stage on. Even larger yield increases with irrigation exceeding 100% have been obtained at Lincoln by Crampton (pers. comm.) and at Winchmore (Advisory Report 1971). The trend of increasing green pea yield with density of the previous year's trial was obtained again except at the highest population where there was evidence of a slight decline in yield. This is more akin to the parabolic pattern of yield with increasing plant density that is usual for reproductive forms of yield (Holliday, 1960).

The increase in both vine length to the first pod and total vine length could have been expected considering the great increase in total green yield achieved with irrigation. Maurer et al., (1968) and Crampton (pers. comm.) both obtained considerable increases in vine length with irrigation. Maurer et al., however obtained only a small increase in length by maintaining a high moisture status from the 10th node stage on which was their closest approximation to the irrigation treatment in this experiment. The effect of plant population on total vine length was similar to the 1969-70 trial but less marked. At the 4 x 1 in. spacing even the unirrigated treatments had a considerably longer vine than the equivalent spacing of the previous year's trial, probably due to the heavy rain in early November. At the lower plant densities the difference between the two years' results was less. The absence of any marked trend with plant spacing in the vine length to the first pod is somewhat surprising, when one considers the regular pattern of increasing vine length to the first pod that emerged from the previous year's trial.

As in the previous year's trial, plant spacing has again had a considerable effect on the number of full pods/plant. The 26% increase in the number of pods/plant with irrigation was of the same order as that of Smittle and Bradley (1966) who reported their yield increase with irrigation as being largely due to a 23% increase in the number of pods produced. Salter (1962) obtained an even bigger increase of 50% with irrigation.

The large number of flat pods in the 8 x 3 in. irrigated treatment compared to all other treatments could be correlated with the very large percentage of pods in this treatment at the fourth pod bearing node or higher. This would have led to a wide range of maturity between pods on the same plant with many of these at the upper nodes still being flat at the optimum stage of harvest.

The number of ovule initials appears to have been rarely measured. This does however, give some idea of the maximum productive potential of any pod. The small increase in the number of ovule initials/pod with irrigation could have been expected although there is no previous evidence of the effect of irrigation on this. The small drop in the number of ovule initials/pod at the two highest densities is confirmed by Gritton and Eastin (1968) who obtained a noticeable although insignificant decrease in the number of ovule initials/pod with increasing density.

The increase of 11% in the number of peas/pod with irrigation is similar to that obtained by Salter (1962) when he irrigated from the start of flowering onwards. However, it is much less than that obtained by Crampton (pers. comm.). The trend with density was basically similar to that of the previous year.

The number of peas/plant as shown in Table 17 is one of the main indications of the yield at any plant density. In this trial there is a large range of variation in the number of peas /plant from below 4 in the unirrigated 4 x 1 in. treatment to 21 in the 8 x 3 in. irrigated treatment.

The number of podding nodes and pods/podding node are important yield components. Hardwick and Milbourn (1967) recognized this when they gave their yield equation of peas that described the variation in yield betwen different nodes.

$$\text{Yield} = \text{Sum over all podding nodes} \left\{ \begin{array}{l}\text{No. of nodes}\\ \text{at node n}\end{array} \times \begin{array}{l}\text{pods/node}\\ \text{at node n}\end{array} \times \begin{array}{l}\text{peas/pod}\\ \text{at node n}\end{array} \times \begin{array}{c}\text{wt/pea}\\ \text{at}\\ \text{node n}\end{array} \right\}$$

They also stated that the number of flowering nodes is generally far less than the number of primoidia as some abort due to competition within the plant. This can be clearly seen in the 4 x 1 in. spacing treatments without irrigation where in nearly all cases only one podding node developed on each plant. Both irrigation and decreasing plant population decrease the level of intraplant competition and more pod bearing nodes form on each plant as irrigation is applied and plant density is reduced. Maurer *et al* (1968) also found that irrigation increased the proportion of pods occurring at higher nodes. Without irrigation they found a maximum of four podding nodes/plant but with irrigation up to six podding nodes/plant were obtained.

The percentage of peas obtained at each node shows that the pods at the higher nodes generally contain fewer peas than those at lower nodes. Maurer *et al*., (1968) obtained a similar pattern. This could be explained partly by intraplant competition becoming more intense as more pods formed. Thus the later developing pods would have a competitive disadvantage and would form fewer peas. Also these later pods on the higher nodes are more immature at the optimum green pea harvest stage, and it is possible that more peas could form in these pods beyond this stage.

As in the previous year's trial there is a tendency towards a larger percentage of peas below sieve size 10/32 in. at low plant densities. This is most likely due to more immature peas occurring on the higher pod bearing nodes. The water stress treatment had a significantly smaller percentage of peas below 10/32 in. than the other two water treatments. Ottosson (1968b) stated pea sieve size increases with TR. The mean TR of the stress treatment was 109 against mean TRs of 105 and 103 respectively for the irrigated and natural rainfall treatments, so that is is likely that the drop in the percentage of small peas in the stress treatment was due to the higher TR.

The significant increase in the number of peas greater than 14/32 in. sieve size, despite the inexplicably low percentage in the 4 x 1 in. irrigated treatment, is in agreement with work of Maurer et al., (1968). Salter (1962) also reported an increase in sieve size by irrigating at petal fall and pod swelling but earlier irrigation tended to reduce the sieve size.

Pea colour depends largely on the chlorophyll content of the pea. Bengtsson and Hylmo (1969) showed that green peas had a chlorophyll content of 101.8 ug/g while for blond peas the figure was 3.85. The effect of irrigation on the mean pea colour, the percentage peas of U.S.D.A. colour standard 4-6 and of U.S.D.A. colour standard greater than 6 was similar to Smittle and Bradley (1966) who reported lower colour along with a lower chlorophyll content in green peas with irrigation.

The lack of any significant effect of plant density on mean pea colour was surprising considering its marked effect on the percentage of peas of U.S.D.A. colour standard 4-6 and greater than 6. It would appear that with irrigation and close planting the vine production is so dense that some lower pods receive very little light and are thus likely to produce more blond peas.

The delay in maturity at lower plant densities and with irrigation was expected in view of the delay with low densities in the previous year's trial, the experience with irrigation of the processing companies and the results of Salter (1962) and Salter and Williams (1967). Processors must consider this delay in maturity with irrigation when planning harvesting schedules.

The mature seed pea yields obtained showed a very similar irrigation response to that of the green pea yields. However, plant spacing has had a very different effect on the seed yield. The pattern of yield with plant density is far more parabolic with the mean yield of the densest 4 x 1 in. spacing being over 20% lower than the highest yield mean in the 4 x 3 in. spacing. There was far less difference between the plant spacing mean yields than occurred for the green pea yields. It would thus appear that if peas are harvested for seed that plant density is a less important yield consideration and that optimum sowing rates would be considerably lower. This agrees with the Ministr. Agric. Fish.Food. Bull. 81 (1969) which states that there is good evidence that the optimum density for vining peas is greater than that for dried peas. This would most likely be due to further development of pods at higher nodes at lower plant densities, after the optimum green pea harvest stage. A larger response to irrigation by harvesting at the seed stage than that obtained might also have been expected, due to a larger number of pods at higher nodes.

CHAPTER V

YIELD-TENDEROMETER READING TRIAL
1970-71

I. INTRODUCTION

The purpose of this trial was to establish a relationship between green pea yield and tenderometer reading under both irrigated and non-irrigated conditions. The main object was to derive satisfactory correction factors that could be used to correct the yield figures of each plot in the other two experiments in this series to a comparable stage of maturity.

II. EXPERIMENTAL TECHNIQUES

(1) Trial Layout

The trial was situated adjacent to the 'Irrigation x Plant Density' trial on the Lincoln College Research Farm. The area, previously in summer cabbages out of pasture had been rotary hoed in early March 1970. Volunteer grass had come away and the area had been grazed with sheep over the winter. Pre-sowing preparation was similar to that of the 'Irrigation x Plant Density' trial.

The trial was laid out in two blocks 60 ft. x 25 ft. which were sown in 25 ft. rows, 4 in. apart with a 3 in. seed spacing within the rows using a 'Stanhay' precision seeder. Each block was then divided into plots 3 ft. 4 in. (10 rows) x 12 ft. Trickle irrigation laterals similar to those in the 'Irrigation x Plant Density' trial were laid 3 ft. 4 in. apart in the irrigation block before flowering.

The peas were sown on October 14, 1970. Watering of the irrigated block was begun on December 2 just prior to flowering. Eight and a half inches of water was applied over the flowering period. At the pod swelling stage on December 30 and 31 a further 4 in. of water was applied.

(2) Harvesting

Harvesting began as soon as the peas were considered large enough to shell mechanically, and continued daily until an advanced stage of maturity was reached. In the unirrigated block harvesting commenced on December 23, 1970 and continued until January 5, 1971. The irrigated block was harvested from December 29, 1970 until January 12, 1971.

Two plots were selected at random from both blocks each morning and an area 2 ft. (6 rows) x 10 ft. taken. No 25 plant samples were taken but otherwise harvest and post-harvest procedures were the same as those in the 'Irrigation x Plant Density' trial.

From the green pea yields obtained an attempt was made to find a suitable relationship between yield per plot and the log of the TR using a polynomial regression programme in the computer.

III. RESULTS

The green pea yields and corresponding average TRs obtained are shown in Table 22.

TABLE 22

Date	Green Pea Yields and Average Tenderometer Reading			
	Non-irrigated		Irrigated	
	Yield (lb/plot)	TR	Yield (lb/plot)	TR
23-12	0.53	79		
	0.47	80		
24-12	0.85	78		
	0.71	78		
25-12	1.25	85		
	1.25	83		
26-12	1.48	86		
	1.47	83		
27-12	1.81	89		
	1.72	87		
28-12	1.95	90		
	2.03	91		
29-12	2.28	101	1.31	81
	2.42	97	1.70	84
30-12	2.59	113	2.35	85
	2.51	111	3.06	87
31-12	2.45	127	3.02	88
	2.73	123	3.06	89

(Continued)

TABLE 22 (Continued)

Date	Non-irrigated		Irrigated	
	Yield (lb/plot)	TR	Yield (lb/plot)	TR
1 - 1	3.02	128	3.37	88
	2.91	128	3.69	86
2 - 1	3.06	141	4.02	96
	2.70	139	3.92	94
3 - 1	3.16	162	4.67	106
	3.03	160	4.10	101
4 - 1	3.23	173	4.48	108
	2.97	171	4.66	112
5 - 1	3.45	181	4.06	124
	3.14	197	4.45	113
6 - 1			5.04	132
			5.21	128
7 - 1			5.37	129
			5.19	134
8 - 1			6.33	137
			5.66	134
9 - 1			5.66	156
			5.86	153
10 - 1			5.99	157
			5.66	156
11 - 1			5.72	164
			5.97	172
12 - 1			5.76	186
			6.09	175

From this data the yields obtained for each plot were plotted against the log of the TR and the line of best fit between the two obtained. For the unirrigated peas the line of best fit was $y = -22.25\ x^2 + 98.56x - 105.96$ where y = yield of green peas/plot and x = log of the TR.

For the irrigated peas the line of best fit was $y = -35.46\ x^2 + 158.29\ x - 170.76$

However in both cases although the line fitted well at each end, in the area TR 90 - 120 where the best fit to actual yield figures was wanted, the fit was poor. The line was above the points at a TR of 120 and dropped sharply to be well below the points towards a TR of 90. This was due partly to the very large increase obtained in yield with little increase in TR at the low end of the TR scale.

In order to overcome this deficiency the regressions were re-run in the computer using only those yield figures where the TR was between 85 and 140. This removed the very low yields at the bottom end of the TR scale and the long tail of almost constant yield at the high end. These two readings would also normally form the extreme upper and lower limits at which peas would be likely to be harvested for processing. Another factor favouring the choice of these limits is that sufficient TR measurements were made within these limits to obtain a valid regression.

From this data the line of best fit for the unirrigated and irrigated peas became respectively -

$$y = -44.61\ x^2 + 187.26\ x - 193.74$$

and

$$y = -11.29\ x^2 + 58.07\ x - 66.99$$

These equations gave lines with a far better fit to the actual points obtained over the range of TR = 90 to TR = 120 than the previous pair. Thus it was these equations that were used in deriving the correction factors for TR in the other trials of this series. The relationship obtained between yield and TR for irrigated and non-irrigated peas can be seen in Table 23 and Figure 2.

TABLE 23

Relationship Between Yield and TR

TR	Unirrigated		Irrigated	
	Expected yield (lb/plot)	% Yield of Yield at TR = 105	Expected Yield (lb/plot)	% Yield of Yield at TR = 105
85	1.490	59.6	3.015	70.9
90	1.835	73.4	3.370	79.2
95	2.110	84.4	3.685	86.7
100	2.335	93.4	3.975	93.5
105	2.500	100.0	4.250	100.0
110	2.620	104.8	4.500	105.9
115	2.705	108.2	4.725	111.1
120	2.750	110.0	4.930	116.0
125	2.770	110.8	5.125	120.5
130	2.760	110.4	5.305	124.8
135	2.725	109.0	5.470	128.7
140	2.670	106.8	5.615	132.1

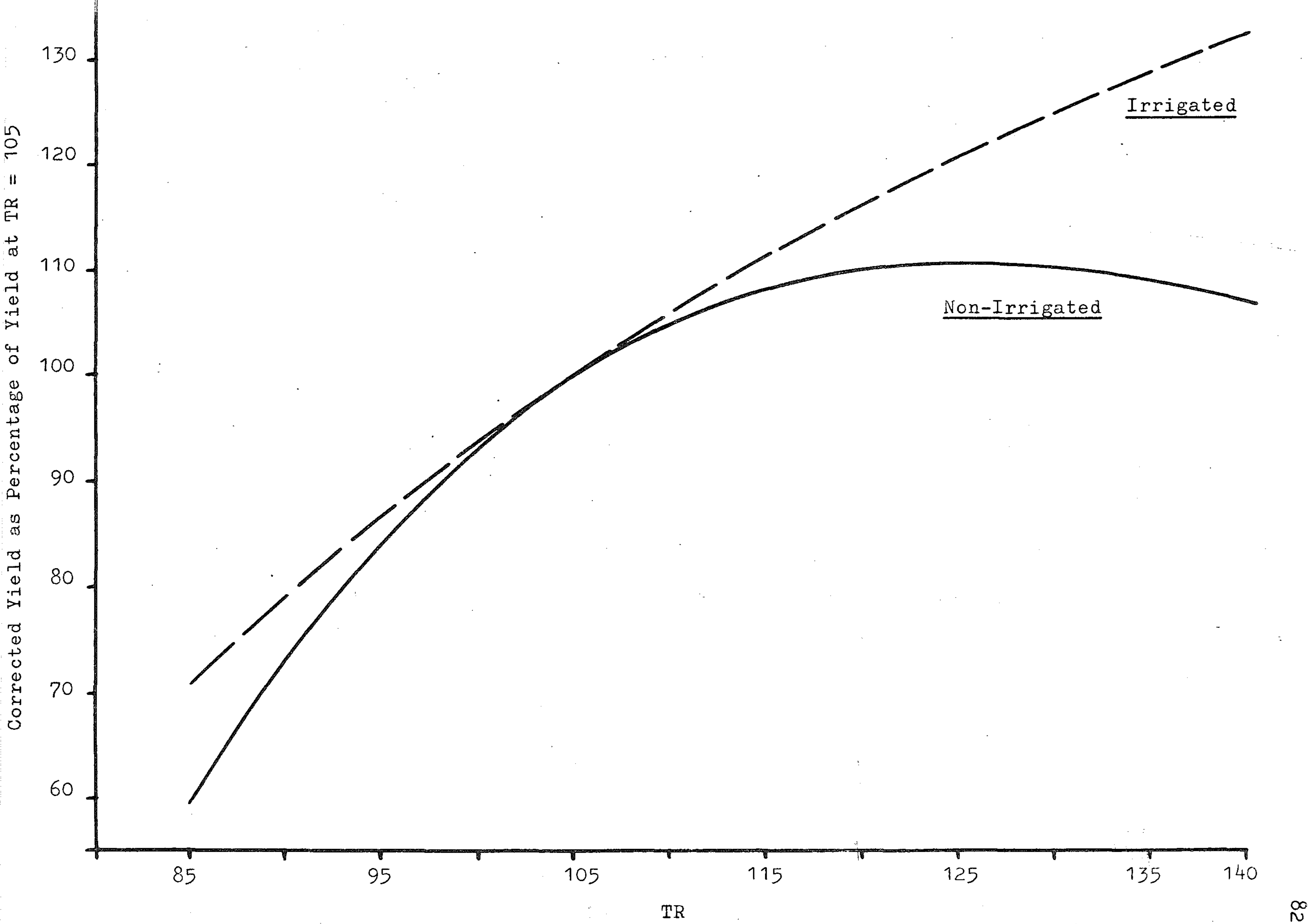

Fig. II - Corrected Yield as a Percentage of Yield at TR = 105.

IV. DISCUSSION

There is not a great deal of published information on the relationship between yield and tenderometer reading in green peas. It is likely however that much unpublished data has been gathered on the subject, mainly by the pea processing companies. The processors base their payments to pea growers on TR, using a sliding scale, with peas of a low TR receiving a higher price.

Hagedorn *et al.*, (1955) developed relationships between yield and TR after four years' experiments for two varieties. For Alaska peas the mean relationship was -

$$y = -1438 + 29.6x$$

where y = yield of green peas in lb/ac and x = TR.

For Wisconsin Perfection peas the relationship derived was -

$$y = -1277 + 27.9x$$

Nelder (1963) suggested a linear relationship between the log of yield (log y) and the log of the TR minus a constant value (log $Tr-TR_o$).

Berry (1963) quoted by Berry (1966) produced a curvilinear model of the yield - TR relationship which he considered to be more accurate than a linear interpolation of results. This was

$$\left(\frac{T-To}{W}\right)^{\theta} = A + B\,(T - To)$$

where θ, To, A and B are constants.

W = yield of shelled peas/plant

T = TR

When used on trial results at Wellsbourne over a number of years Berry obtained the best fit of this equation with To = 70 and $\theta = 1$.

Salter (1962) used Nelder's model when he plotted the log of the weight of shelled peas against log (TR - 75) and obtained four straight lines for his four different water treatments. Salter (1963) however, used the transformation -

$$y = \left(\frac{T - To}{W}\right)^{\theta}$$

where T = TR

W = fresh weight (gm) of peas from 25 plants

To and θ are constants of 64 and 1.25 respectively.

This gave a curvilinear relationship between y and T.

An interesting point to emerge from the trial is the very large increase in yield with time at the early stages of pea maturity with only a small increase in TR. In both the irrigated and unirrigated blocks the yield trebled with an increase of only 10 TR units up to about a TR of 90, after which the rate of increase in yield with TR declined. This is substantiated by Ottosson (1968b) who reported yield - TR curves to be steeper at low TRs and very steep below a TR of 90. Pollard _et al_., (1947) stated that the rate of increase in yield per unit TR decreased after a TR of 102.

Pollard _et al_., also found that the rate of average increase in TR per day increased with maturity. This finding was substantiated by Hagedorn _et al_., (1955) and the results from this trial.

The large difference obtained between the irrigated and non-irrigated blocks in the yield - TR relationship was not unexpected. Salter (1962, 1963) obtained differences between different water treatments but somewhat surprisingly, from his graphs the effect of watering at flowering appeared to increase the ratio between yield and TR as much if not more than watering at pod swelling. This could possibly be due to the increased number of pods obtained with irrigation at flowering with a greater range of maturity between pods.

The relationships obtained between yield and TR in this trial cannot be universally applied. Hagedorn _et al._, (1955) showed in trials over four years that although the average increase in yield of green peas per unit TR over two varieties was 28.8lb/acre the range was 14.7 - 47.1 lb/acre. Pollard _et al._, (1947) showed the effect of variety when they measured a yield increase of 0.068 and 0.053 tons/ac/TR unit for Early Perfection and Perfection peas respectively up to a TR of 102. These yield increases are higher than the increases obtained in this trial and substantially higher than even the greatest increase achieved by Hagedorn _et al._, (1955). However, Pollard _et al._, obtained considerably higher yields than Hagedorn _et al._ Ottosson (1968b) stated that factors affecting the yield curve in relation to maturation are plant density, soil humidity, soil physical conditions and nutrition level, variety and sowing time.

It is worth noting that in the 1970-71 'Irrigation x Plant Density' trial the CV of the actual pea yields was 11.7. This was reduced to 8.8 when the pea yields were corrected. For the 1969-70 'Row Spacing x Seed Spacing x Phosphate' trial the same correction factor as used for the irrigation treatment made no difference in CV. Thus it appears that the correction curves obtained in this trial were less suitable when applied to trial results in a different season. However, the relationships obtained fit well for peas grown at the same time and under similar circumstances.

These relationships could provide a base to which subsequent data might well be added, to perhaps develop a more equitable system of payout for green peas in Canterbury.

This trial would also suggest that dryland peas should preferably be harvested at a TR of 100-110 as beyond this little yield increase occurs with TR. Peas harvested beyond these limits should preferably be irrigated as the increase in yield with TR is considerably greater at high TRs with irrigation.

CHAPTER VI

GENERAL DISCUSSION

The fact that green pea yields from irrigated plots in the Irrigation x Plant Density trial were similar to those obtained at equivalent plant spacings in the previous year's trial, strongly reinforces the conclusions that under favourable growing conditions, higher plant densities than those at present used are likely to result in increased yields. Even without irrigation it would appear that a worthwhile yield increase is obtainable by raising the plant density beyond that generally used.

In the 1969-70 trial reducing row width from 12 in. to 8 in. and again to 4 in. increased green pea yields. Most farm seed drills however, have coulters 6-7 in. apart. Further work to measure the effect of reducing row width below this level should therefore be done. No critical work on the effect of regularity of spacing of peas within the row is known to the author, but it is possible that irregular spacing has a detrimental yield effect, and this is a field warranting further study. Most farm seed drills are far less accurate in spacing within the row than the 'Stanhay' precision seeder used in these trials.

More work on plant spacing with vining peas should be done in Canterbury in order that the optimum plant spacings can be more closely defined.

The second year's work showed the marked effect of irrigation at flowering and pod swelling in increasing green pea yields. The importance of adequate moisture for green peas is also illustrated by green pea yields on the Lincoln College mixed cropping farm, which over the last five seasons have shown a close correlation with November rainfall (White, pers. comm.).

In the 1970-71 season 20% of the crops grown for J. Wattie Canneries Ltd. processing factory at Hornby were irrigated and these gave an average return only 12.5% higher than unirrigated crops (Cawood, pers. comm.). However the highest yielding crops were all irrigated so it would appear that the average farmer needs to become more familiar with the techniques of irrigation and optimum time of application.

Even allowing for lateral water movement out of the plots the amount of water applied to the 1970-71 trials at flowering would be greater than most farmers could consider applying at one irrigation. Further work is therefore needed to measure the effect of varying the amount of water applied to peas, and the rate at which it is applied, particularly in relation to soils which have a low infiltration rate.

Because the natural rainfall and moisture stress treatments gave similar results in the Irrigation x Plant Density trial no information was obtained on the effect of moisture stress at different stages of growth. Further research is needed here, especially on the effect of water stress at pod swelling as many farmers are reluctant to shift irrigation pipes on peas at this stage of growth.

Another feature to emerge from these trials is the particularly high yields obtained in the Yield-TR trial. The calculated yields at a TR of 105 were equivalent to 9,260 and 5,450 lbs/acre for irrigated and non-irrigated peas respectively, which is considerably above the mean yield figures of the equivalent 4 x 3 in. spacing of the adjacent Irrigation x Plant Density trial of 7040 and 4400 lbs/acre respectively. Both trial areas had previously been in cabbages but those in the Yield-TR area had been utilized earlier and rotary hoed in early March, 1970. Volunteer grass had established and the area was grazed for some months before ploughing. The other area was left fallow before ploughing. Unfortunately no comparative measurements on soil structure or any other soil condition were made, but it appears likely that an improvement in the soil conditions due to the rotary hoeing and/or the period in grass, may well have contributed to the higher yield in the Yield-TR trial.

The irrigated plots of the Yield-TR trial received the same amount of water at flowering as the irrigated plots in the adjacent trial, but as they were all in one block there was little lateral water movement. Soil moisture readings taken three days after irrigation ceased, showed a soil moisture percentage of 28.5% which was above field capacity.

However, there was certainly no indication of a yield depression through waterlogging, as was obtained by Crampton (pers. comm.) on a more heavily cropped area of the same soil type. Thus it appears that good soil condition may well minimize the risk of overwatering peas.

This series of trials has shown that in Canterbury, with higher sowing rates than those normally used, and with irrigation, substantial increases in green pea yields are possible. However, the results of this work would also indicate that there are other factors which may contribute to the yield of green peas and that more information is required about these before high yields of green peas can be consistently guaranteed.

SUMMARY

In the 1969-70 trial green peas were grown in all combinations of 4, 8 and 12 in. row widths; 1, 2 and 3 in. seed spacings within the row, and 0, 20 and 60lb. of phosphorus per acre. No yield responses to phosphate were obtained but decreasing both row width and seed spacing within the row gave large increases in green pea yield. Yield was asymptotically related to plant density, the highest yield at the 4 x 1 in. spacing being 7880lb/acre. Narrower row widths increased yield more than decreased spacing within the row.

The total vine length, vine length to the first pod, pods/plant and peas/pod all increased gradually with lower plant densities. This trend was more marked at lower densities for the percentage of peas $<$ 10/32 in. sieve size and the incidence of weeds. The number of flat pods/plant only increased at very low plant densities.

In the 1970-71 trial five plant spacings from the previous year's trial (4 x 1 in., 4 x 2 in., 4 x 3 in. 8 x 2 in., 8 x 3 in.), were grown in combination with three levels of soil moisture (adequate water at flowering and pod swelling, water stress at flowering and pod swelling, natural rainfall). The pattern of green pea yield obtained with plant density was basically similar to that of the previous year's

trial although there was a slight drop in yield at the highest plant density. Yields in the irrigated plots however, were close to those obtained at equivalent plant spacings in the previous year's trial. Most other parameters measured also showed similar trends with plant density to those of the previous year's trial.

Irrigation resulted in an increase of 56% in green pea yield. Large increases were also obtained with irrigation in the number of flat pods/plant, percentage of peas > 14/32 in. sieve size, total green yield, total vine length, vine length to the first pod, number of full pods/plant and peas/pod. Irrigation and lower plant density both increased the percentage of peas and pods at higher nodes and the percentage of pale peas.

Because of the season there was almost no difference between the water stress and natural rainfall treatments and results.

The mature seed yield had a similar response to irrigation as the green pea yield. The yield pattern with plant density was different with the peak yield being obtained in the 4 x 3 in. spacing. The drop in yield at the highest density was more marked, the 4 x 1 in. spacing having a lower mean yield than all others.

In the Yield-TR trial peas from both a non-irrigated block and a block irrigated at flowering and pod swelling were harvested progressively from a very low to a very high TR. A relationship between yield and TR was computed for both irrigated and non-irrigated peas to derive correction factors for yield in the other two experiments. Without irrigation yield rose more rapidly with TR at low TRs than with irrigation but at higher TRs the increase in yield with TR fell off much earlier without irrigation.

The main conclusion from these trials is that with irrigation at flowering and pod swelling and with higher plant densities than those at present used, considerable increases in green pea yields could be obtained in Canterbury.

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APPENDIX I

1969-70 ROW WIDTH, SEED SPACING, PHOSPHATE TRIAL

TRs AND ACTUAL AND CORRECTED GREEN PEA YIELDS

Plot No.	Plot Treatment			Green Pea Yield (lb/acre)		
	Row Width (in.)	Seed Spacing (in.)	P (lb/ acre)	TR	Actual	Corrected
1	12	2	20	108	4430	4280
2	4	2	60	116	9000	8020
3	8	2	0	103	6490	6660
4	8	1	20	101	6070	6390
5	12	3	0	99	2810	3050
6	4	1	0	105	7060	7060
7	8	3	60	105	4470	4470
8	4	3	20	113	6560	6010
9	12	1	60	103	5750	5900
10	4	3	0	103	6270	6430
11	8	1	0	102	7170	7450
12	4	2	20	95	6510	7510
13	4	1	60	101	7340	7730
14	8	2	60	105	5650	5650
15	12	1	20	103	5740	5880
16	12	2	0	110	4600	4340
17	12	3	60	106	3800	3760
18	8	3	20	106	5470	5400
19	4	1	20	97	8320	9300
20	12	2	60	105	4950	4950

APPENDIX I (Cont'd)

Plot No.	Plot Treatment			Green Pea Yield (lb/acre)		
	Row Width (in.)	Seed Spacing (in.)	P (lb/ acre)	TR	Actual	Corrected
21	4	2	0	109	8410	8030
22	8	3	0	100	5860	6270
23	8	2	20	100	6020	6440
24	4	3	60	109	7820	7470
25	12	3	20	99	2660	2880
26	12	1	0	107	6440	6290
27	8	1	60	100	6640	7110
28	4	1	0	99	7820	8480
29	12	3	0	104	4040	4090
30	4	3	60	104	6530	6620
31	4	2	20	106	8840	8740
32	8	2	0	105	7050	7050
33	8	1	60	108	7730	7470
34	12	1	20	106	6660	6580
35	8	3	20	108	4900	4740
36	12	2	60	108	4720	4560
37	4	3	0	109	7800	7450
38	12	1	60	109	6370	6080
39	8	2	20	105	5890	5890
40	12	3	20	98	3090	3400
41	8	1	0	100	7140	7640
42	8	3	60	103	5590	5730

APPENDIX I (Cont'd)

Plot No.	Plot Treatment			Green Pea Yield (lb/acre)		
	Row Width (in.)	Seed Spacing (in.)	P (lb/ acre)	TR	Actual	Corrected
43	4	1	20	109	7380	7050
44	12	2	0	107	5450	5320
45	4	2	60	112	7800	7220
46	12	2	20	101	5790	6100
47	4	1	60	99	7080	7680
48	8	2	60	100	7240	7750
49	12	1	0	107	5870	5730
50	8	3	0	105	5400	5400
51	4	2	0	119	7650	6650
52	4	3	20	111	7750	7250
53	8	1	20	104	7530	7620
54	12	3	60	105	3580	3580

APPENDIX II

1970-71 IRRIGATION x PLANT DENSITY TRIAL

TRs and ACTUAL AND CORRECTED GREEN PEA YIELDS

Plot Treatment				Green Pea Yield (lb/ac.)	
Plot No.	Plant Spacing	Water	TR	Actual	Corrected
1	8 x 3in.	Stress	109	3330	3200
2	8 x 3in.	Nat. Rf.	96	3070	3550
3	4 x 2in.	Nat. Rf.	105	4840	4840
4	4 x 3in.	Nat. Rf.	94	4230	5130
5	4 x 1in.	Stress	110	4421	4220
6	4 x 2in.	Stress	113	5380	5030
7	4 x 3in.	Irrig.	97	6120	6840
8	8 x 2in.	Nat. Rf.	99	4250	4640
9	8 x 3in.	Irrig.	104	5460	5530
10	8 x 2in.	Stress	106	4820	4760
11	4 x 2in.	Irrig.	114	8690	7890
12	4 x 1in.	Irrig.	103	6400	6570
13	4 x 3in.	Stress	109	3920	3770
14	4 x 1in.	Nat. Rf.	103	3860	3950
15	8 x 2in.	Irrig.	108	7370	7120
16	8 x 2in.	Nat. Rf.	109	4040	3880
17	8 x 2in.	Irrig.	105	6240	6240
18	4 x 3in.	Nat. Rf.	99	4230	4610
19	4 x 2in.	Irrig.	98	6560	7210
20	4 x 3in.	Stress	106	4470	4410
21	4 x 2in.	Nat. Rf.	109	5450	5240

APPENDIX II (Cont'd)

Plot Treatment				Green Pea Yield (lb/ac.)	
Plot No.	Plant Spacing	Water	TR	Actual	Corrected
22	8 x 3in.	Nat. Rf.	103	2910	2980
23	4 x 1in.	Irrig.	113	8650	7930
24	8 x 3in.	Stress	111	3410	3230
25	8 x 3in.	Irrig.	111	5520	5170
26	4 x 2in.	Stress	107	4640	4540
27	8 x 2in.	Stress	110	4120	3930
28	4 x 3in.	Irrig.	104	7080	7170
29	4 x 1in.	Stress	109	4660	4480
30	4 x 1in.	Nat. Rf.	104	4310	4360
31	4 x 1in.	Stress	106	5380	5260
32	8 x 2in.	Stress	114	3820	3550
33	8 x 3in.	Irrig.	109	4390	4200
34	4 x 2in.	Irrig.	108	7170	6920
35	8 x 2in.	Irrig.	109	6390	6100
36	4 x 1in.	Irrig.	104	6950	7040
37	4 x 2in.	Stress	110	5400	5150
38	4 x 1in.	Nat. Rf.	103	4120	4220
39	8 x 3in.	Nat. Rf.	104	3040	3080
40	4 x 2in.	Nat. Rf.	99	4400	4800
41	4 x 3in.	Stress	108	4200	4070
42	4 x 3in.	Nat. Rf.	103	4290	4400
43	8 x 3in.	Stress	106	3450	3410
44	8 x 2in.	Nat. Rf.	109	4170	4010
45	4 x 3in.	Irrig.	109	7450	7120

APPENDIX III

YIELDS AS PERCENTAGE OF YIELD AT TR = 105

TR	Yield-TR-Unirrigated % of yield at TR 105	Yield-TR-Irrigated % of yield at TR 105
85	59.6	70.9
86	62.6	72.5
87	65.6	74.3
88	68.2	76.0
89	71.0	77.6
90	73.4	79.2
91	76.0	80.5
92	78.2	82.3
93	80.2	83.7
94	82.4	85.3
95	84.4	86.7
96	86.4	88.2
97	88.4	89.5
98	90.2	90.9
99	91.6	92.2
100	93.4	93.5
101	94.8	94.9
102	96.2	96.2
103	97.6	97.5
104	98.8	98.7
105	100.0	100.0
106	101.2	101.2
107	102.2	102.4
108	103.2	103.5
109	104.0	104.7
110	104.8	105.9
111	105.6	106.9

APPENDIX III (Cont'd)

TR	Yield-TR-Unirrigated % of yield at TR 105	Yield-TR-Irrigated % of yield at TR 105
112	106.4	108.0
113	107.0	109.1
114	107.6	110.1
115	108.2	111.1
116	108.6	112.2
117	109.0	113.1
118	109.4	114.1
119	109.6	115.0
120	110.0	116.0
121	110.2	117.0
122	110.4	118.0
123	110.6	118 8
124	110.6	119.6
125	110.8	120.5
126	110.8	121.4
127	110.8	122.2
128	110.6	123.1
129	110.6	124.0
130	110.4	124.8
131	110.2	125.6
132	110.0	126.3
133	109.6	127.1
134	109.2	127.8
135	109.0	128.7
136	108.8	129.4
137	108.4	130.1
138	107.8	130.8
139	107.2	131.5
140	106.8	132.1

APPENDIX IV

CLIMATIC DATA OVER GROWING PERIOD

I 1969	Rainfall	Evaporation	Mean Daily Max Temp. (°F)	Mean Daily Min. Temp. (°F)
October	1.39"	1.75"	63.1 (from 15th)	40.7 (from 15th)
November	0.89"	7.38"	68.0	47.9
December	2.70"	6.65"	72.8	53.7

Daily Maximum and Minimum Temperatures Over Harvest Period

	Max. (°F)	Min. (°F)
December 27	70.5	47.5
28	76.4	47.8
29	69.0	50.6
30	77.0	52.8
31	74.7	48.2

II 1970/71	Rainfall	Evaporation	Mean Daily Max Temp (°F)	Mean Daily Min. Temp. (°F)
October	1.76"	4.91"	63.2 (from 15th)	43.4 (from 15th)
November	2.22"	6.29"	66.8	46.0
December	0.96"	8.59"	71.1	50.1
January (up to 12th)	0.86"	1.92"	66.9	53.2

Daily Maximum and Minimum Temperatures Over Harvest Period

		Max. °F	Min. °F.
December	22	83.4	52.7
	23	73.6	47.2
	24	83.9	57.6
	25	72.3	66.0
	26	68.1	45.0
	27	78.4	45.9
	28	72.0	55.0
	29	70.2	49.9
	30	73.7	52.0
	31	73.4	55.2
January	1	60.2	55.3
	2	67.0	55.5
	3	76.9	56.0
	4	56.9	56.5
	5	62.4	47.8
	6	60.8	50.2
	7	62.0	51.5
	8	69.8	52.9
	9	71.1	55.0
	10	89.8	56.9
	11	59.8	53.5
	12	65.5	47.5