GROWTH AND WATER USE OF CONVENTIONAL AND SEMI-LEAFLESS PEAS

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ABSTRACT

An experiment was conducted to test whether a semi-leafless type of pea (Rovar x semi-leafless) uses water more efficiently than a conventional cultivar (Rovar). The growth and water use of the two peas were compared under irrigated and dryland conditions at Lincoln during the 1980-81 season.

The two cultivars performed equally well when irrigated, but the semi-leafless pea made more efficient use of water in dry conditions. Evapotranspiration rates of the cultivars were similar but the total water used in irrigated plots was 28% greater than in dryland plots over the whole measurement period. The growth rate and maximum dry matter production (both total above-ground and seed) of the two cultivars were similar with irrigation but, without irrigation, the semi-leafless pea was superior.

It is suggested that the main reason for the cultivar difference was the photosynthetic contribution from the tendrils of the semi-leafless cultivar which were apparently less sensitive to water deficit than normal leaves and remained healthy after most of the leaves had senesced.

***Additional Key Words:** Water use efficiency, evapotranspiration, dry matter production.*

INTRODUCTION

A leafless pea, with a mutant gene that converts normal leaflets to tendrils (Snoad, 1974), has been used in the field pea breeding programme at Lincoln since 1976, with the objective of incorporating this characteristic into locally-adapted cultivars. The result is a semi-leafless type (SL), which has normal stipules but has tendrils in place of conventional leaflets. These increase inter-plant binding and mutual support so that erect plant stands are produced, reducing lodging and harvesting problems.

The SL type has yielded well in evaluation trials in Canterbury, particularly under dryland conditions where its yields have been significantly better than conventional cultivars (Jermyn, unpublished). The reasons for this have not been identified but they are important to plant breeders and to farmers who will grow SL cultivars because they may use limited water supplies more efficiently than conventional peas.

This possibility has not been examined in field experiments, but seems plausible in view of the results of controlled-environment experiments in the U.K. Growth characteristics of single plants of SL and conventional peas grown in pots were compared (Snoad, 1974, 1981; Harvey and Goodwin, 1978; Harvey, 1980). Conventional peas always produced a much larger total foliage area although there was no difference in stipule area. It could follow that SL uses water less rapidly because of the smaller foliage area but whether there is a correspondingly reduced rate of dry matter production is uncertain. In some of the U.K. studies, total and seed dry matter production by the two types were similar but, in other experiments, SL consistently accumulated less dry matter and produced lower seed yields than conventional plants.

Our objective was to test whether an SL crop uses water more efficiently than a conventional crop, particularly in dry conditions. A field experiment was conducted during the 1980/81 season to compare the growth and water use of an SL line from the Lincoln breeding programme (Rovar x semi-leafless) with a related conventional cultivar (Rovar) under irrigated and dryland conditions. Total dry matter, foliage area production and water use were measured throughout the season from which water use efficiencies were estimated.

MATERIALS AND METHODS

The two cultivars were sown on the Crop Research Division farm at Lincoln on October 1, 1980. Details of the site and procedures were:

Soil Type: Wakanui silt loam — 30 cm of silt loam topsoil overlying mottled silty clay loam subsoil to a depth exceeding 1m. The upper metre of the soil profile was capable of retaining approximately 20% by volume of plant-available water (Volumetric water contents at - 0.3 and -15 bars matric potential were 35% and 15% respectively).

Site history and cultivation: The experiment followed two successive cereal crops. The site was autumn-ploughed and winter-fallowed before final spring cultivation.

Fertiliser: Superphosphate at 250 kg/ha was broadcast and incorporated by cultivation immediately before sowing.

Weed Control: Trifluralin (1 litre a.i./ha) was soil-incorporated 14 days before sowing. No further herbicide applications were required.

Sowing: A Stanhay precision seeder was used to sow plots 10m long and 1.05m (7 rows) wide at an intended planting density of 140 seeds per m^2.

Experimental design: The experiment was a factorial arranged in randomised blocks with four replicates. Each replicate contained irrigated and non-irrigated plots of the two pea cultivars.

Irrigation: Each decision to irrigate the appropriate plots took account both of the degree of soil water depletion and the stage of crop development. Two irrigations were necessary, at early flowering (65mm) and 14 days later at the onset of pod-swell (85mm) respectively, the two stages when irrigation is most likely to improve final seed yield (Salter and Goode, 1967). At both times approximately 50% of the volume of water potentially retained above 15 bars matric potential in the upper 1 m of soil remained. Trickle irrigation was used to saturate the entire soil profile.

Soil water measurements: Neutron probe access tubes were installed to 1m depth in all plots of two replicates and weekly measurements were made of volumetric soil water content profiles. Soil moisture contents near the surface (0-25cm) were determined gravimetrically. Evapotranspiration (ET) rates for intervals between measurements were estimated using a water balance method:

$$ET = I + R \pm \Delta SM$$

where I = irrigation; R = rainfall; ΔSM = change in volumetric soil moisture. It was assumed that there were no losses by drainage below the 1m profiles and that run-off, if any, was the same for all plots. No attempt was made to separate ET into its two components, evaporation (E) and transpiration (T).

Soil water measurements and ET rate estimations began 17 days after sowing and continued until day 84 (early seed-fill), when technical problems prevented further measurements.

Plant growth measurements: Plant samples were harvested at weekly intervals throughout the growing season. All above-ground plant material was removed from a 0.2m^2 area in each plot and plant population, total dry weight, area of green foliage and leaf area index (LAI) were determined.

Water use efficiency (WUE): The average WUE for each treatment over the ET measurement period was calculated as the ratio of the total weights of dry matter produced to water used in ET.

Seed harvest: When the crops reached maturity, a 3m^2 area of each plot was hand-harvested and the samples machine-threshed. The seed yields obtained were adjusted to 10% moisture content.

RESULTS

Uniform plant establishment was achieved. Although similar seed numbers were sown, plant populations were 103 and 130 per m^2 in Rovar and SL plots respectively. Nearly all the plants survived until maturity. The difference in populations was attributed to different seed viability between the cultivars. The consequences for the comparisons of growth and water use are discussed later.

The two cultivars produced similar seed yields when irrigated but, without irrigation, SL significantly outyielded Rovar (Table 1). This result was consistent with previous observations in Canterbury (Jermyn, unpublished).

TABLE 1: Seed yields at 10% moisture content (kg/ha)

Cultivar	Irrigated	Not Irrigated	Mean	Response to Irrigation (%)
Rovar	5360 Aa	3830 Bc	4595	40
SL	5430 Aa	4640 ABb	5035	17
Mean	5395	4235	4815	27
Cultivar Difference (%)	1	21	10	

C.V. = 8.8%

Total Dry Matter Production

The total dry weight in all treatments followed the classical approximately S-shaped course (Fig. 1). The growth of the two cultivars was similar during the first 40 days after sowing but, in the 25 days from then until the commencement of flowering, SL accumulated dry matter

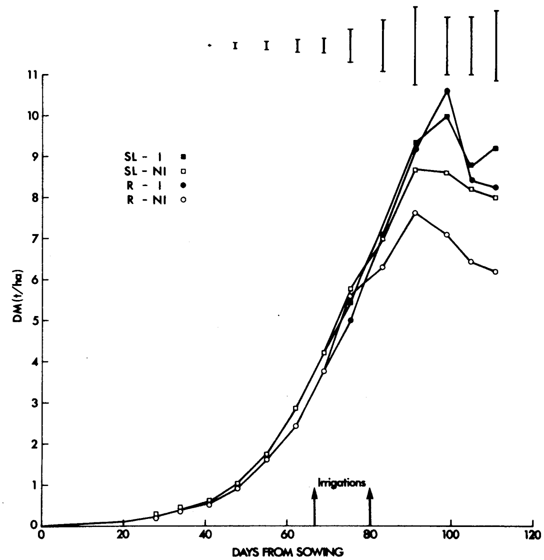

Figure 1: Total above-ground dry matter yield (DM) of Rovar (R) and Semi-leafless (SL), either irrigated (I) or not irrigated (NI). Vertical bars are LSD values (p = 0.05).

TABLE 2: Components of seed yield

Treatment	Plants per m^2	Pods per Plant	Peas per Pod	Peas per m^2	1000-Seed Wt(g)	Calculated Seed Yield (kg/ha)
R-I*	103 Bb	5.1 Aa	3.8 BCbc	2000 ABab	250 Aa	4930 Aa
R-NI	102 Bb	4.0 Bbc	3.6 Cc	1460 Cc	240 ABab	3510 Bc
SL-I	127 Aa	4.1 Bb	4.2 Aa	2200 Aa	227 Bb	5000 Aa
SL-NI	134 Aa	3.5 Bc	4.0 ABab	1860 Bb	230 ABb	4270 ABb
C.V.(%)	6.0	7.3	3.9	6.9	3.4	8.9

*R = Rovar; SL = Semi-leafless; I = Irrigated; NI = Not Irrigated.

more rapidly than Rovar, so that by day 65 it had 18% more dry matter. This was probably a result of SL's higher plant population, with individual plants growing at about the same rate in all plots before complete crop canopy development occurred.

After day 65, the total dry weight of the two cultivars in irrigated plots was similar until maturity, reaching a maximum about 20 days after seed filling began. However, without irrigation, the growth rate of both cultivars began to decline soon after flowering and, although the data were quite variable, it was evident that the decline was greater for Rovar. The growth rate of SL (calculated from data in Fig. 1) was approximately 60 kg/ha/day greater than that of Rovar for about 14 days during early seed-fill (days 76 to 90); this may explain the 800 kg/ha seed yield difference between cultivars. Although LSDs were high, total dry matter yields of Rovar were significantly greater ($p = 0.05$) than for SL at most harvests after the beginning of seed-fill (Fig. 1).

Yield Components

The cultivars produced similar seed yields with irrigation. Although their plant populations were different, Rovar produced only slightly fewer peas per m^2 than SL, and had a greater 1000-seed weight (Table 2). Without irrigation, Rovar produced significantly fewer peas per m^2 than SL, but their 1000-seed weights were similar. Consequently the seed yield of Rovar was lower. Apparently the formation of seeds by individual Rovar plants was more sensitive to water deficit, despite their lower population. Seed yields calculated from the yield components agreed closely with the measured values (Tables 1 and 2).

Leaf Area

The development of leaf area (including stipules) was the same for both cultivars until maximum LAIs of almost 3.5 were attained during flowering (Fig. 2). By that stage, both cultivars had achieved complete ground cover and SL plants were taller (50cm) than Rovar (35cm).

In irrigated plots, both cultivars maintained maximum LAI for about 20 days, after which senescence began and was completed within 15 days. Without irrigation, senescence began and was completed several days earlier.

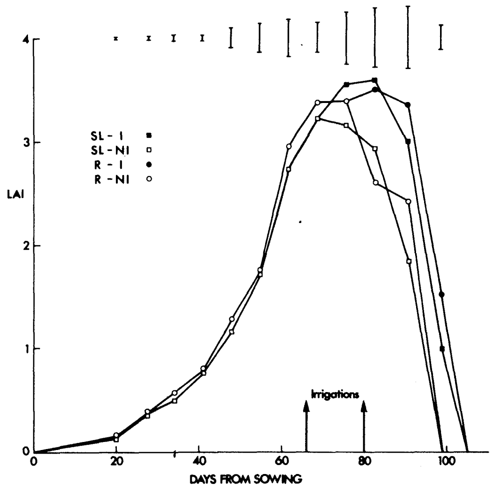

Figure 2: Leaf area indices (LAI) of Rovar (R) and Semi-leafless (SL), either irrigated (I) or not irrigated (NI). Vertical bars are LSD values ($p = 0.05$).

Water Use

The growing season was characterised by a lack of substantial rainfall during the five weeks after sowing (Fig. 3). However, the ET rate was low during this period (Table 3) and soil water content declined only slowly (Fig. 3). The decline continued as the season progressed and crop growth and ET rates increased, despite intermittent rainfall.

The ET rate was similar for the two cultivars throughout the measurement period (Table 3). However, following the first irrigation, the rate was greater from irrigated plots and their total ET over the whole measurement period exceeded that of unirrigated plots by 28% (Table 4).

We assumed that the E component of total ET would be the same for both cultivars, since they had similar LAI throughout the measurement period. Direct E from the soil surface may have been greater in irrigated plots but was probably insuffıcent to account for the 28% ET difference

TABLE 3: Evapotranspiration rates (mm/day)

Days from Sowing	Rovar Irrigated	Rovar Not Irrigated	Semi-leafless Irrigated	Semi-leafless Not Irrigated	C.V. (%)
17					
	—	1.8a*	—	1.6a	42.2
24					
	—	2.6a	—	2.5a	12.3
31					
	—	2.2a	—	2.3a	11.4
43					
	—	4.2a	—	4.3a	17.3
51					
	—	4.6a	—	4.5a	8.3
64					
	5.5a	3.0b	5.6a	2.8b	7.8
72					
	8.3a	6.7b	7.4ab	5.2c	5.7
78					
	5.3ab	2.3b	8.8a	2.9b	23.1
84					

*Values in each row with different letters are significantly different at p = 0.05.

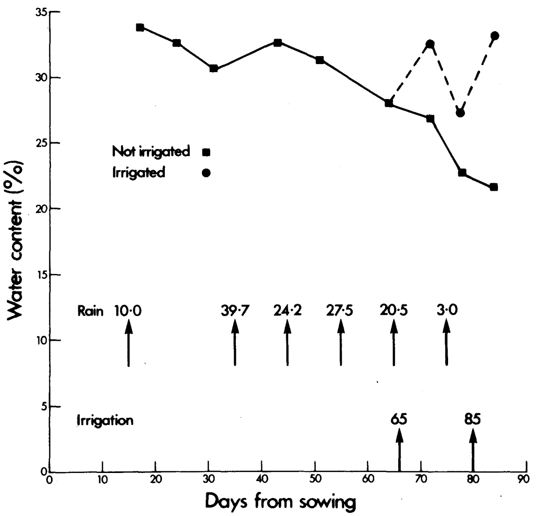

Figure 3: Mean volumetric soil water contents to 1m depth in irrigated and non-irrigated plots of both cultivars. Values across the bottom are 10-day rainfall totals and irrigation applications (mm).

between irrigation treatments. Irrigations did not commence until complete ground cover was attained (LAI > 3; Fig 2).

Water Use Efficiency

Over the ET measurement period, the WUE of the two cultivars was the same with irrigation (Table 4). Without irrigation, both cultivars used water more efficiently, SL being slighty better than Rovar.

The difference between irrigation treatments could be partially attributed to the differing E components of ET but it is possible that yield per unit T (T - efficiency) was higher in unirrigated plots.

Within each irrigation treatment, comparisons between cultivars indicate relative T-efficiency differences, assuming that E was the same for both cultivars. T-efficiency is regarded as a better measure of plant performance than WUE (Tanner, 1981).

TABLE 4: Water use efficiencies (WUE)

Treatment	Total Dry Matter Production (kg/ha)	Cumulative Water Use (mm)	WUE ($x10^{-3}$)
R-I*	7040 Aa	281.6 Aa	2.50 Ab
R-NI	6300 Ab	222.2 Bb	2.84 Aab
SL-I	7280 Aa	287.6 Aa	2.53 Ab
SL-NI	7000 Aa	222.2 Bb	3.15 Aa
C.V.(%)	11.5	0.9	11.7

*As in Table 2

DISCUSSION

The results support the original proposition that SL peas could use water more efficiently in dry conditions. The difference between cultivars cannot be attributed to different water use, because the ET rates and total water use during the period of measurement were about the same (Tables 3 and 4). Rather the different WUEs resulted from the greater accumulation of dry matter by SL (Table 4), particularly after flowering (Fig. 1).

It was not surprising that ET rates were the same because the cultivars were exposed to the same environmental conditions and had similar leaf areas. Inspection of soil moisture profiles showed that the two cultivars extracted water to the same depth throughout the measurement period. It was unfortunate that ET data were not available for the final growth period because differences between the cultivars may have developed as water deficits became more severe in unirrigated plots.

The similarity of total foliage area of the cultivars during the season contrasted with U.K. observations (Harvey and Goodwin, 1978; Snoad, 1981). This was partly a result of the higher population of SL plants but mainly occurred because of the very large stipules of the SL line used in this experiment.

It is possible to speculate about the reasons for the superior dry matter accumulation, and therefore WUE, of SL in dry conditions. Clearly, the difference in plant population between cultivars was a potential cause. Although SL accumulated more dry matter before flowering there was little difference between cultivars in irrigated plots after flowering. This probably occurred because complete canopy cover (LAI$<$3) was achieved about the time flowering began, and the subsequent accumulation of dry matter per unit area was independent of the growth of individual plants in both crops. The significance of the different plant populations in unirrigated plots cannot be assessed. However, in general, water deficient conditions favour crops with lower plant numbers (Stoker, 1975), but in this experiment, the SL, with the higher plant population, performed better. We conclude that the plant population difference in this experiment was of little consequence for total dry matter production.

The consequences were possibly more significant for seed yield and it components, although they did not affect the WUE estimations. Considerable compensation among yield components can occur in crops of differing densities, and the populations of both crops in this experiment were within the accepted optimum range for peas. There was evidence that the number of seeds set per plant was more sensitive to water deficit in Rovar than in SL.

A likely cause of the more rapid growth of SL before flowering and for about two weeks longer than Rovar in unirrigated plots, despite equally rapid leaf senescence, was photosynthetic activity in the tendrils, which remained healthy after most leaves had senesced. We made no attempt to measure the surface area of tendrils. However, it can be a substantial proportion of total foliage area, and the tendrils are photosynthetically competent (Harvey, 1972, 1974; Harvey and Goodwin, 1978). If this explanation is valid, the tendrils must contribute to the higher WUE of SL plants by having a higher photosynthesis:transpiration ratio than normal leaflets. They must also be less sensitive or susceptible to water deficit in order to continue accumulating dry matter after leaf senescence.

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