POTENTIAL OF SOYABEAN YIELD IN WAIKATO AS DETERMINED BY CLIMATE

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ABSTRACT

Sowing date studies with the cultivars Acme, Comet and Amsoy, sown between October 25 and December 19, were conducted in the six years to 1968 to 1973 with irrigation being used in 1973.

Given average seasonal temperatures and adequate moisture yield increased with delay in sowing date and with cultivar maturity viz. Amsoy Comet Acme. Whether the potential yield of a late sowing was achieved in any one year depended on the pattern and extent of a) temperature b) rainfall.

Completion of growth by April 1 was considered desirable because of rapidly declining temperature and increased rainfall thereafter. Amsoy, sown December 1 in 1972 and 1973, ceased bean filling by late March. Yield potential for Amsoy in each of the past 20 seasons was assessed from the degree days available. Yield potentials were 3370 kg/ha (6 seasons), 3030 kg/ha (10 seasons), 2300 kg/ha (3 seasons) and 1500 kg/ha (1 season) with an average of 2950 kg/ha.

Using the 1971-72 season as a base for minimum rainfall requirements, in the past 26 seasons, 8 seasons had sufficient, 8 seasons insufficient and 10 seasons marginal rainfall to realise potential yield.

It was concluded that variation in annual rainfall rather than temperature is the principal factor limiting soyabean potential in the Waikato.

INTRODUCTION

The growing of soyabeans in the Waikato has been investigated for some 15 years. Over this period a range of cultivars has been tested and commercially acceptable yields of up to 3030 kg/ha have been obtained. However, the wide variation in yield from year to year has prevented soyabean production becoming a viable cropping enterprise.

The general belief has arisen that the temperatures in the locality are marginal for satisfactory soyabean production. Sowing date studies conducted over the past six years (unpublished data) have indicated that inadequate rainfall might also be an important factor in causing variation in annual yield.

The object in the present study was to estimate the relative effect of variation in temperature and rainfall on yield from the sowing date studies and to determine, from past weather records, the limits placed on yield potential by local climate.

EXPERIMENTAL METHODS

Sowing date trials were conducted in the six years 1968 to 1973 inclusive with sowing dates spread over the period October 25 to December 19. Three or four cultivars were used in each year with Acme and Comet common to all years and Amsoy sown in the last three. Other cultivars sown were Grant and Lincoln (1968), Lindarin (1969 and 1970) and Wayne (1973). Trials were conducted on Horotiu sandy loam soil in all years except 1972 when an Ohaupo silt loam soil was used. Irrigation was applied by sprinklers in the 1973 trial on December 23 (38 mm), January 28, February 9 and February 20 (51 mm each) to all treatments irrespective of stage or development.

A four replicate, split plot, trial design was used in all years with sowing dates as the main plots and cultivars as sub plots. Sub plots were 6 rows (0.61 m apart) by 8 m with 5 m of each of the two centre rows harvested for yield. Yields of beans were adjusted to 12% moisture content.

Development was followed in the years 1968-1971 inclusive by noting the date of flowering and determining, from regular measurement of bean moisture, the date on which a 20% moisture content was attained. The latter was found to be unsatisfactory as an end point in development as moisture content fluctuated with successive rain showers.

Development was monitored more closely in the 1972 and 1973 sowings, using weekly assessments of vegetative and reproductive stages, as described by Fehr **et al.** (1971).

RESULTS AND DISCUSSIONS

The patterns of yield of Acme, Comet and Amsoy in relation to sowing date in each year could be grouped by seasons in accordance with the prevailing temperatures and rainfall.

1. *1973-74 Above average temperatures and adequate water.
2. 1971-72 Average temperatures and sufficient rainfall.
3. 1968-69 Below average temperatures but adequate rainfall.
4. 1969-70 Average to above average temperatures but inadequate rainfall.
   1970-71
   1972-73
   1973-74

* Irrigation used

Causes of annual yield variation

1. Sowing date.

Given average seasonal temperatures and sufficient rainfall (1971/72) the yields of all three cultivars increased as the date of sowing was delayed, with the yield at a given sowing date being greater in accordance with the longevity of the cultivar viz. Amsoy Comet Acme. (Fig. 1). These results were considered to express the basic yield-sowing date response to th temperature and photoperiod components of local climate although the date of sowing giving maximum yield was not shown. Whether the potential for yield, inherent in late sowing, was realised in other seasons clearly depended on the patterns and extents of temperature and rainfall.

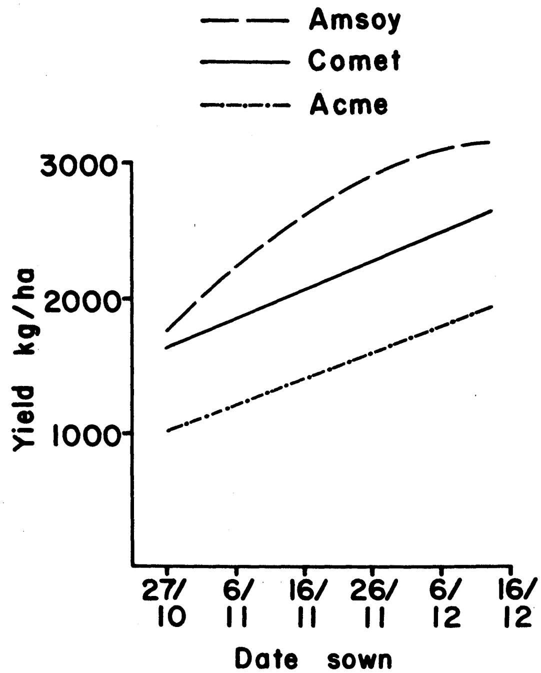

FIGURE 1: Yield in relation to sowing date for three cultivars under average seasonal temperatures and with adequate moisture (1971/72)

2. Temperature

Above average seasonal temperatures (1973-74) would appear to lead to increased yields although this effect could not be separated from irrigation **per se.** The yields of Comet and Amsoy for sowings made after November 16, 1973 were considered to have been limited by inappropriate timing of the irrigation. Fluctuations in plant water supply during the flowering period greatly increase the extent of flower abortion (Fukui and Ojima, 1957). In 1971-72, under a less favourable temperature regime, pod numbers increased with the late sowings but there was no such increase in 1973-74. Had pod numbers increased, it is considered probable that yields would have increased further.

Below average seasonal temperatures (1968-69) led to reduced yields for the mid December sowings. Maximum yields of Acme and Comet were attained with sowings made in late and mid November respectively and by the mid December sowing, yields had declined (Figures 1

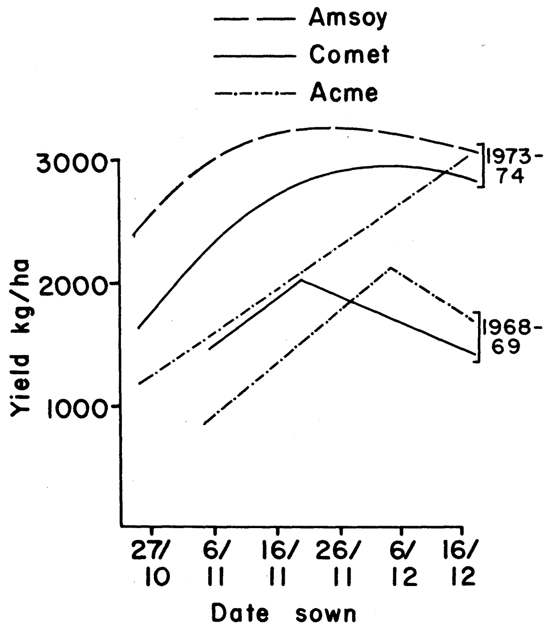

FIGURE 2: Yield in relation to sowing date for three cultivars in a hot season (1973/74) and a cool season (1968/69) with adequate water.

and 2). As the relative differences between cultivars were similar, among years in which plant water supply was adequate, it was assumed that Amsoy would have given maximum yield from an early November sowing, and, for a mid December sowing, have had a yield slightly below Comet.

3. Rainfall

In five out of the six seasons, while temperatures were sufficient to have given a yield sowing date response similar to that in 1971-72, the pattern and/or extent of rainfall was inadequate to allow for expression of the sowing date response. Differences in cultivar response among dry seasons reflected the periods in which rainfall was inadequate. The period in which rainfall was low varied from season to season.

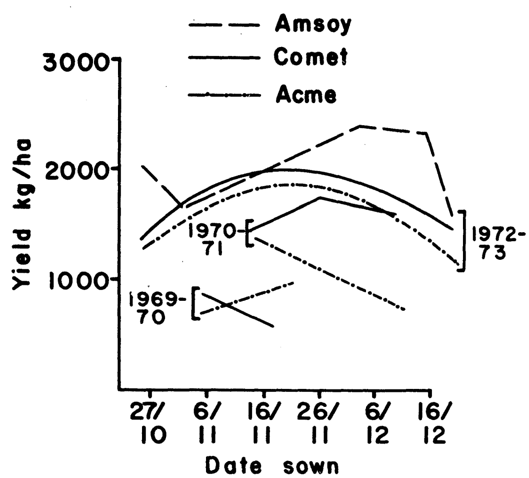

FIGURE 3: Yield in relation to sowing date for three cultivars in average to hot seasons with inadequate water.

Optimum sowing date

The date of sowing which gave maximum yield of each cultivar in an average temperature season (1971-72), was found not to be the most favourable in respect to date of maturity and subsequent harvesting (Figure 4). Amsoy and Comet, sown December 14, did not reach harvest maturity (stage R8) until April. Soyabeans absorb moisture rapidly after rainfall and consequently a period of dry weather is required, after bean filling is completed, to allow for the crop to mature and be harvested at a reasonable moisture content. Because of the decline in temperature and the increase in rainfall and number of rain days from March onwards, the latest acceptable date for completion of bean filling was considered to be April 1. To meet the requirement Amsoy would need to be sown December 1, Comet December 7 and Acme December 19 or possibly later, depending on the continuation of the yield response with later sowing. Optimum sowing date thus becomes a compromise between obtaining maximum yield and maximum harvestable yield.

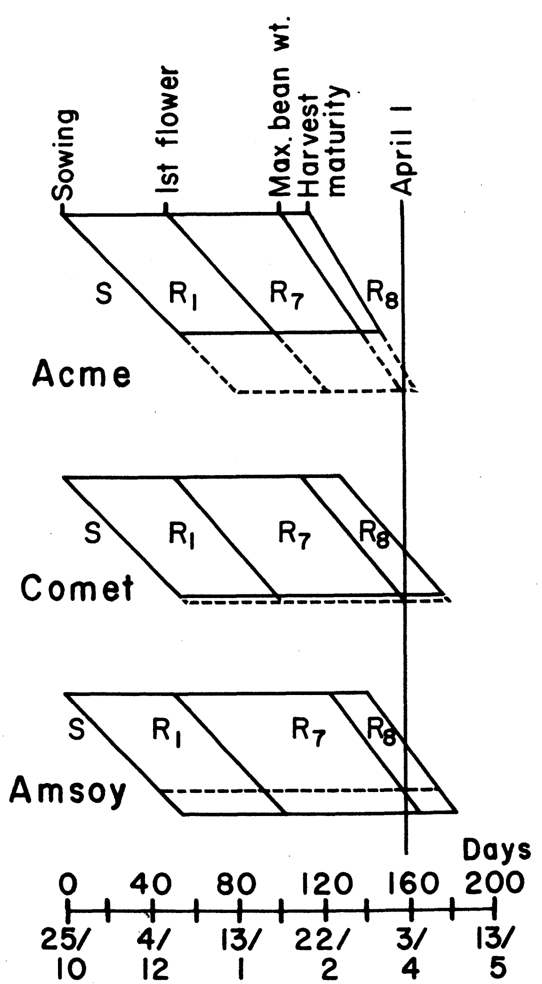

FIGURE 4: Phenology of three cultivars in relation to date of sowing under average seasonal temperatures (1972/73)

Yield potential in relation to climate

Amsoy, the latest maturing in highest yielding of the three cultivars, was selected for analysis. Acme and Comet, earlier maturing cultivars, would both mature within the period allocated to Amsoy.

1. Temperature

Because of the association between seasonal temperature and yield, the period required for the development of Amsoy, December 1 to April 1, was rated in degree days (mean daily temperature less 10 deg. C with minimum temperatures less than 10 deg. C read as 10 deg C). The sum of the degree days over the period is an expression of the average temperature and does not reflect fluctuations in temperature which may affect yield. However, it was considered that growing seasons having degree days sums similar to 1971-72 would give similar yields.

	Degree days			
	700-800	800-900	900-1000	1000-1100
1954 - 55				●
55 - 56				●
56 - 57			●	
57 - 58			●	
58 - 59			●	
59 - 60			●	
60 - 61		●		
61 - 62				●
62 - 63			●	
63 - 64		●		
64 - 65			●	
65 - 66				●
66 - 67		●		
67 - 68			●	
68 - 69	●			
69 - 70				●
70 - 71			●	
71 - 72			●	
72 - 73			●	
73 - 74				●

TABLE 1: Accumulated degree days (sum of mean daily temperature less 10 deg c with temperature less than 10 deg c read as 10 deg c) for period Dec 1 to April 1 for the past 20 years.

Over the past 20 seasons (Table 1) it was found that 10 had a similar degree day sum (900-1000) to 1971-72, six similar (1000-1100) to 1973-74 and one similar (700-800) to 1968-69 while the remaining three were intermediate (800-900) between 1968-69 and 1971-72.

On the basis of the trial work discussed, yields of 3030 kg/ha and 3360 kg/ha were assigned to the seasons having degree day sums of 900-1000 and 1000-1100 respectively. A yield of 1500 kg/ha was assigned to seasons having 700-800 accumulated degree days, as in 1968-69, on the basis of the estimated performance of Amsoy relative to Comet. In the absence of data on seasons having a degree day sum of 800-900, an intermediate yield of 2300 kg/ha was assigned.

In 16 out of the 20 seasons, therefore, there would appear to be a yield potential of 3030-3360 kg/ha in respect to temperature and an average yield over the 20 seasons of 2950 kg/ha.

2. Rainfall

Soil water storage and the variations in the extent and in the pattern of rainfall, in relation to stage of development, made the assessment used for rainfall more complex. The season 1971-72 was used as the basis for the analysis because while the soybeans gave high yields, the fact that they were visibly under water stress in the second half of February, suggested that rainfall in the preceding 4-6 week period was marginal.

The required period for development, December 1 to April 1, was considered in three parts.

1. December - vegetative growth
2. January and February — flowering and early pod fill
3. March — bean filling

Minimum requirements for rainfall were assigned to each period for the following reasons:

Period 1 An accumulated deficit of evaporation (open water) over rainfall on January 1 not greater than 40 mm. Near maximum soil water storage is desirable prior to flowering (Thompson, 1970).

Period 2 Rainfall in January and February not less than 100 mm as in the 1971-72 season.

Period 3 Rainfall in March not less than 100 mm. Though both Runge and Odell (1960) and Thompson (1970) showed the importance of rainfall in the bean filling period, the 235 mm which fell in March 1972 was considered excessive to requirements. As evaporation from the crop during March, in any of the past 26 seasons, would have rarely exceeded 80 mm (80% of open water evaporation), the rainfall requirement for March was set at a minimum of 100 mm.

In certain seasons, because of higher rainfall and/or lower evaporation, the excess of evaporation (open water) over rainfall on March 1 was less than 100 mm. Allowing for reduced evaporation from the crop, it was considered that in such seasons, stored soil water would allow near full development of yield with only a low rainfall in March.

	Period 1 Dec.	Period 2 Jan.&Feb.	Period 3 Mar.
1948 - 49	●	●	●
49 - 50		●	
50 - 51		●	
51 - 52	●	●	
52 - 53	●	●	▲
53 - 54			●
54 - 55			
55 - 56		●	
56 - 57	●		●
57 - 58		●	▲
58 - 59	●	●	▲
59 - 60		●	●
60 - 61		●	
61 - 62		●	
62 - 63	●	●	▲
63 - 64		●	●
64 - 65		●	▲
65 - 66	●	●	●
66 - 67	●	●	●
67 - 68			
68 - 69	●	●	▲
69 - 70	●		●
70 - 71		●	
71 - 72	●	●	●
72 - 73	●		
73 - 74			

TABLE 2: Periods during crop life, in past 26 years considered to have had adequate fainfall for full crop development.

PERIOD 1● Accumulated deficit, open water evaporation over rainfall, on January 1 not more than 40mm

Period 2● Rainfall January and Febuary not more than 100mm

Period 3● Rainfall March not less than 40mm.

▲Accumulated deficit, open water evaporation over rainfall, on March 1 not more than 100mm.

CONCLUSIONS

The pattern and extent of rainfall rather than temperature is the major of the two climatic factors limiting the yield of soyabeans grown in the Waikato. On the basis of temperature alone, the potential for yield is estimated to be 2950 kg/ha.

The introduction of commercial planting should be limited initially to areas where soils have a good water holding capacity or where the pattern and extent of rainfall can meet the demands of the crop.

The use of irrigation, applied at the preflowering and

In the past 26 seasons (Table 2) only four met the requirements laid down for each of the periods. The additional provision made, for seasons where soil moisture on March 1 was high, brought the total number of seasons in which plant water was estimated to be adequate to eight.

While the basis used for deciding the extent of rainfall required in each of the three periods can be disputed, it is considered that the decision made tended to favour seasons in which water supply may have been inadequate rather than adequate. Yet in the 26 seasons considered, only eight met the requirements for rainfall laid down.

the bean filling stages, may be necessary if the yield potential, in respect to temperature at a locality, is to be realised.

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