RAISING SOYBEAN YIELD THROUGH APPLICATION OF CROP PHYSIOLOGY TO AGRONOMY AND BREEDING

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Summary. This paper briefly reviews the impact of advances in physiology on agronomy and breeding of soybean and presents results from an applied improvement program. Agronomic modifications included near equidistant plant spacing, elevated plant population and favourable water supply. Breeding advances included use of semidwarf germplasm and strategic deployment of maturity and long juvenile genes. First results indicate that the yield potential of irrigated soybean can be raised by up to 50% to *c*. 7 t/ha and the optimum planting window broadened to include all planting dates which permit at least 110 days of frost-free growth.

INTRODUCTION

Soybean has an agronomy which is more complex than that of cereals, yet is very responsive to good management. Many researchers have studied one or other of the components of soybean productivity and some have integrated several fields of research. In this paper we consider the contribution of advances in crop management and genetic improvement to soybean adaptation, and report progress in integrating these advances to increase the yield potential of soybean in subtropical Australia.

Water supply. Soybean is quite susceptible to water stress, and ususally responds to frequent watering by substantially increasing vegetative growth. Several studies show that provided other inputs are adequate, yields are highest with the continuous trickle system first developed in Queensland and often referred to as saturated soil culture (9). Indeed, yield can increase linearly with frequency of irrigation to a maximum with saturated soil culture conditions (5).

Phenological adaptation. Recent advances in crop simulation modelling make it possible to predict optimum phenology required in a crop cultivar for a given agro-ecological zone (8). In the case of soybean, excellent quantitative interpretations of genotypic, environmental and genotype x environment interactions for rate of development to flowering are available (7). It is therefore possible to choose which of the so-called maturity (10) or long juvenile (6) genes to deploy to achieve a desired phenology in a given environment.

Plant population and row spacing. The amount of light intercepted by a crop, especially in the early stages of growth, is a simple function of plant population and row spacing (2). Soybean crops sown in narrow rows are able to achieve full light interception sooner and with lower leaf area index than those in wide rows (1) and consequently have a higher yield potential.

Cultivar induced constraints. Genotypic variation for responsiveness to favourable water supply, high plant population and narrow row culture is substantial (3). Some cultivars respond by producing extreme vegetative growth resulting in increased early lodging which causes reduced light interception and death of plant parts underlying the lodged mass. Other cultivars, such as the semidwarf types, have been selected to resist lodging and maximise the yield potential in favourable environments (4).

Integration of advances. We predicted that integrating knowledge of crop genotype and environmental variables outlined above to develop a high-yield production system would produce a substantial increase in maximum yield potential and broad optimum planting window. The results achieved are presented in this paper.

MATERIALS AND METHODS

Initial selections. We hybridised high yield semidwarf germplasm possessing strong lodging resistance with other germplasm sources containing maturity and long juvenile genes. The aim was to produce lines which flower between 40 and 50 days and mature in about 120 days from sowing, at mean temperatures around 25^{o}C in the photoperiods experienced in subtropical Australia. Fourteen genotypes which appeared to possess the desired traits were selected in glasshouse environments over an 18 month period and sufficient seed produced for planting in the field.

First field trial. For evaluation of yield potential, we sought to structure an environment highly conducive to vegetative vigour and high dry matter production. The Gatton experimental site was sown to a cover crop of barley during winter and forage harvested to reduce soil nitrogen reserves and remaining stubble incorporated. Soil was formed into raised beds with 15 cm deep furrows at 1.5 m intervals and a level planting area of 1.1 m. No fertiliser or rhizobium was applied as the soil contained nutrients (except nitrogen), and a rhizobium population sufficient to ensure excellent growth and nodulation. Selected semidwarf lines and the local cultivar Manark were sown at crop densities of 5.5 x 10^{5} /ha in December 1993 in plots of six 20 cm rows, three metres long and replicated twice. Plots were maintained substantially free of insect attack and watered after each 60 mm of cumulative pan evaporation. At maturity 0.5 metre border was removed from plot ends and two metres of the six rows harvested for grain yield determination.

Advanced field trial. The local cultivar Manark and two lines with high yield potential but different growth duration in the 1993 field trial were grown in a serial sowing study at Gatton in six metre long plots with three replications. The trial commenced on 25 August 1994 and sowings were at approximately five week intervals thereafter until the last sowing on 28 February 1995. Agronomy and irrigation frequency were similar to that for the first field trials. Plant populations in this study were reduced to *c*. 4.5 x 10^{5} /ha. The trial was maintained substantially free of insect attack, but some mouse damage occurred near maturity on the February sowing. Dates of major phenological events were noted and five metres of the central six rows were harvested for determination of seed yield at maturity.

RESULTS AND DISCUSSION

First field trial. Twelve of the 14 lines selected in the glasshouse exhibited the predicted phenology of *c*. 45 days to flower in the field evaluation. Eleven of the lines significantly ($P<0.05$) exceeded the yield of Manark (five t/ha), two were not significantly different and one was lower (data not shown). Highest yields were about 7 t/ha.

Advanced field trial. Excellent establishment and early crop growth occurred for all genotypes at all sowing dates, although cool temperatures delayed emergence until ten days after the August sowing. Later sowings emerged in three to six days. Severe lodging of Manark occurred at or before flowering in the September, November and December sowings. Other sowing dates and other genotypes in the same sowing were substantially free of lodging. Semidwarf lines showed a significantly higher yield ($P<0.05$) in all sowing dates except February (Fig. 1).

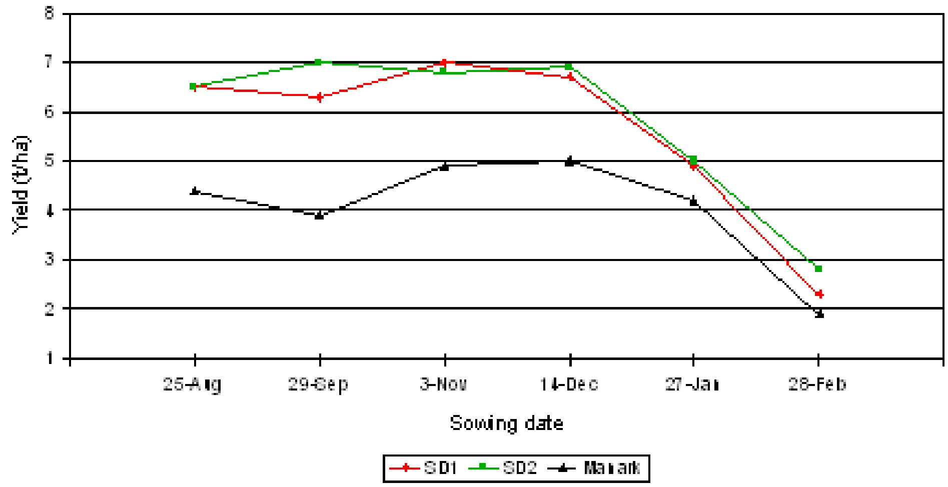

Figure 1. Yield of two semidwarf lines (SD1 and SD2) and the industry standard cultivar Manark for six serial sowings commencing on 25 August 1994 and at five week intervals thereafter.

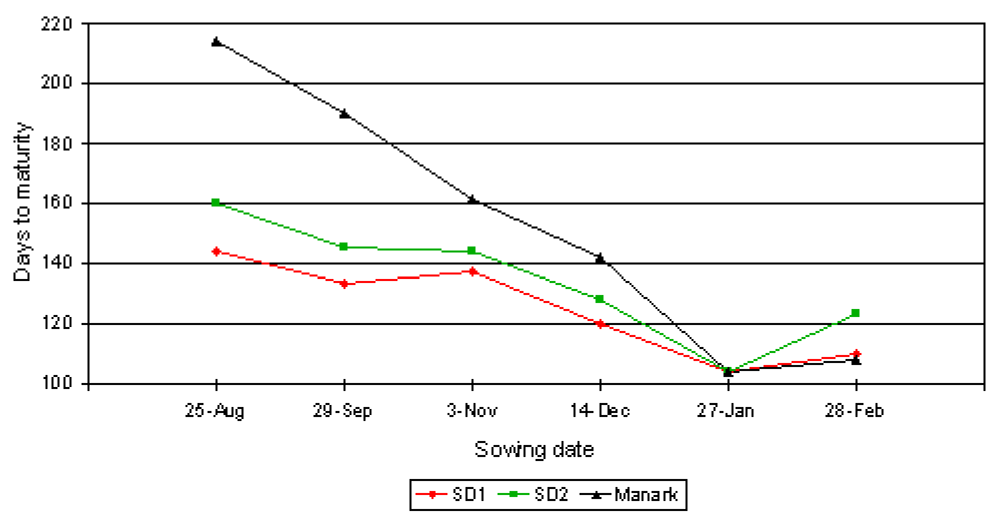

Figure 2. Maturity of two semidwarf lines (SD1 and SD2) and the industry standard cultivar Manark for six serial sowings commencing on 25 August 1994 and at five week intervals thereafter.

The greatest yield advantage for semidwarf lines, of about 50%, was expressed in extremely early sowing dates and when lodging occurred in Manark. Interestingly, a yield advantage of about 20% occurred in the January sowing in which no lodging occurred in Manark and growth duration of the three lines was similar.

Growth duration of the semi-dwarf lines was more stable across planting dates than Manark (Fig 2) and generally within an acceptable duration for a soybean crop. The combination of environmental response genes in the semidwarf lines appears to have substantially broadened the optimum sowing window as predicted

CONCLUSIONS

The use of frequent irrigation, high plant population and narrow row spacing for cultivars with sufficient duration to utilise the environment effectively and lodging resistance, combined with a semi-dwarf habit and high yield potential, has produced substantially higher yeilds than usually achieved with soybean in southern Queensland. An increase in irrigated yield potential of up to 50 percent and extension of the optimum planting window appears possible through the combined use of advances in agronomy and germplasm. The effect of the semi-dwarf plant habit in soybean appears similar to the more well-known effects of the habit in wheat and rice.

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