KEYNOTE ADDRESS: A BRIEF HISTORY OF THE ESTABLISHMENT OF THE AUSTRALIAN SOYBEAN INDUSTRY[1]

R. J. Lawn

School of Tropical Biology, James Cook University, Townsville 4811
CSIRO Sustainable Ecosystems, Davies Laboratory, PMB Aitkenvale 4814

Abstract

Commercial soybean production in Australia began in the subtropics in SE Qld, followed quickly by NW NSW. The first extensive introductions of cultivated varieties were made in the 1930s as part of the search for high protein grains to solve the dry season 'protein gap' in subtropical grazing systems. Further impetus was provided by the perceived need to develop indigenous oil crops in case shipping routes were blockaded during the Second World War. However, initial attempts to grow soybeans using varieties and agronomic practices from the southern USA were unsuccessful. It was not until the late 1960s that better adapted varieties were identified and more reliable agronomic practices were developed, based on an understanding of how photo-thermal conditions affected phenology and yield potential and the implications for seasonal and regional adaptation.

The first significant commercial areas, based on agronomic management to accommodate variety X sowing date X density interactions, were grown in SE Qld in 1969-70. Successful crops were grown rainfed in the sub-coastal West Moreton and Burnett areas, and under irrigation at Brookstead on the Darling Downs. The industry quickly expanded into the irrigated areas of NW NSW and the northern coastal areas of NSW, with smaller areas in central western NSW, northern Victoria, Central Qld, the Ord and the NT. The expansion was stimulated by demand from the fledgling oilseed manufacturing industry and import-parity pricing. Unlike in SE Qld, the initial expansion into the irrigated areas of NW NSW was based in part on wide-row culture of full-season varieties as had proved successful in the USA. It helped that some of the first growers were expatriate cotton growers familiar with USA soybean production. Later, there was greater emphasis on tailoring varieties and agronomy to local needs in most areas, especially in the tropics where it was not possible to rely on imported varieties.

The early research showed that the time to flowering, and thus yield potential per plant, varied depending on varietal maturity and sowing date. In many areas of the eastern subtropics, sowing dates were often later while temperatures were generally warmer than in the southern USA, so that varieties often flowered sooner and yield potentials were lower. Consequently, narrower rows and higher populations were needed to raise yield potentials per area. One of the outcomes of the early soybean work was the recognition that commercial yields were possible using higher density sowings of shorter duration varieties with naturally higher harvest index. This concept ran counter to the prevailing USA orthodoxy based on vegetatively vigorous, full season varieties and wide-row agronomy. It laid the foundation, however, for the later successful use of the long-juvenile trait to develop shorter-duration, photo-insensitive cultivars suited to high density culture.

Introduction

Commercial scale soybean production began in Australia in 1969-70 (Fig. 1), after a long gestation and a number of false starts that saw a paddock or two planted from time to time, but with limited success. The industry started in SE Queensland, concurrently in two different cropping systems: irrigated crops on the Darling Downs around Brookstead and Dalby and rainfed crops in the sub-coastal areas of the West Moreton and Burnett regions. Subsequent expansion into NW NSW was rapid, with significant areas of irrigated soybeans sown in the cotton areas of the Namoi Valley. By 1975, there were nearly 50,000 ha under production, about two-thirds in Qld, and one-third in NSW.

Thereafter, the industry expanded into the north coast of NSW, with smaller areas in central western NSW, northern Victoria, Central Qld, the Ord and the NT. The establishment and rapid initial

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expansion of the industry was stimulated by demand from the fledgling oilseed manufacturing industry and import-parity pricing. It was facilitated by several technical initiatives by universities, state departments and the CSIRO that helped overcome the initial emergent constraints.

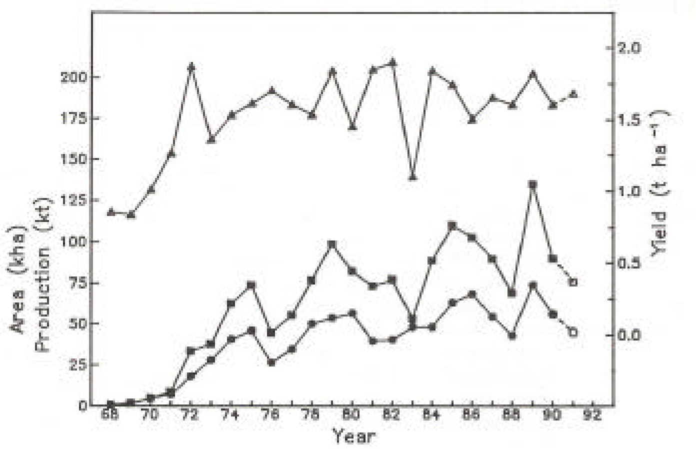

Fig. 1 The area sown to soybeans expanded rapidly following the release in 1970 of grower advisory bulletins on how to grow the crop in Qld. Added impetus was provided by the expansion of commercial production in northern NSW a couple of seasons later (from Lawn & Imrie 1993).

This review provides a brief overview of the key R&D events of the period that preceded and accompanied the establishment of commercial scale soybean production in SE Qld and its rapid initial expansion into NW NSW. In the interests of brevity, it focusses on the constraints that inhibited the earlier establishment of the industry, the research that identified how to overcome those constraints, and the initiatives that enabled subsequent industry consolidation. It provides an entrée into the relevant literature for the interested reader. Further information is available in Laing & Byth (1972), Lawn & Byth (1979), Lawn (1985) and Lawn & Imrie (1983).

The early years before industry establishment

Serious interest in soybeans in Australia can be traced back to when commercial production started to expand in the USA, some four decades before the local industry was established (Table 1). During those four decades, over 1000 soybean varieties were introduced and evaluated by various state and federal agencies, in a largely *ad hoc* way and unsuccessfully in terms of identifying varieties that could be reliably grown commercially (Byth 1971).

The most extensive introduction program was run by the CSIR, as part of its search for high protein feedstuffs that would help overcome the seasonal protein gap that constrained northern grazing livestock productivity (Paltridge 1942, Miles 1949). Added impetus was given during the war years by the desire to find oilseed crops to reduce the nation's vulnerability to hostile disruption of shipping (Gray 1955). Just after the war, a mission to the USA recommended government action to develop a soybean industry in Australia, given the success of the crop in the USA (Bulcock *et al.* 1947).

In 1958, the CSIRO Division of Plant Industry appointed DE Byth to establish Australia's first soybean breeding program in south east Qld. The initiative reflected recognition that a successful local industry required the tailoring of soybeans to suit local conditions. The program was hosted by CSIRO until 1967, when it was transferred to the University of Qld. At this stage, Byth recruited RJ Lawn as the first of many postgraduate students, to undertake postgraduate research aimed at understanding varietal adaptation. It was mainly from Byth's program that the key information emerged that ultimately enabled the first successful commercial cropping of soybean. Interestingly, however, it was in the form of better understanding of varietal adaptation and the implications for better agronomic management, not improved varieties *per se*, that the main technical contribution was made.

Equally important was the role the program and Byth in particular played in 'championing' soybean as a viable cropping option for the eastern summer rainfall cropping areas. Armed with an understanding of why the early cropping attempts had failed, and with the support of a small number of committed growers (Table 1), the University of Qld breeding program was a key catalyst in ultimately getting commercial soybean production established.

Table 1. Key research and industry people involved in the establishment of the Australian soybean industry in SE Queensland and northern NSW

	Location	**Role(s)**
Queensland		
TB Paltridge	CSIR Canberra/Gatton	Introduction & evaluation 1930-1946 (Paltridge 1942)
JF Miles	CSIRO Fitzroy Vale	Varietal evaluation 1936-1946 (Miles 1949)
SG Gray	CSIRO Gatton	Agronomic and varietal research 1944-51 (Gray 1955)
DE Byth	CSIRO Brisbane / UQ Brisbane	Became Australia's first soybean breeder 1958. Awarded Farrer Memorial Medal for his role as 'product champion' for commercial soybean production (Byth 1986). Characterised photoperiod responses of tropical/subtropical varieties (Byth 1968)
RJ Lawn	UQ Brisbane / CSIRO Brisbane	Conducted the agronomic research (Lawn & Byth 1973, 1974, 1979, Lawn *et al*. 1977) that underpinned initial QGGA farmer recommendations (Lawn 1970, QGGA 1970, 1983); also physiological research that elucidated photo-thermal effects on regional & seasonal adaptation, growth, HI & yield (Lawn *et al.* 1983, Lawn 1988). Promoted commercial production as QGGA consultant.
E Semgreen	Farmer, S Burnett	Released cv. *Semstar*, provenance unknown but possibly a selection from the cross Hernon X Ogden
J Bligh	Farmer, Brookstead	Released cvv. *Wills*, *Bourke* and *Leslie*, derived from southern USA populations
C Flegler	Farmer, Darling Downs	Championed soybeans through the QGGA
F From	Farmer, West Moreton	Championed soybeans through the QGGA
AJP Williamson	QDPI Hermitage	Agronomic studies on southern Downs (Williamson 1974)
JL Rose	QDPI Hermitage	Initiated QDPI's long-term quantitative breeding program at Hermitage Research Station (Rose 1983)
Northern NSW		
HA Eagles	NSW Agriculture, Narrabri	First NSW Agriculture soybean breeder at Narrabri (1969)
DR Laing	University of Sydney	Initiated collaborative soybean varietal evaluation (Laing & Byth 1972, Laing 1974)
OG Carter	University of Sydney	Early agronomic studies for temperate regions (Carter 1974)
K McWhirter	University of Sydney	Initiated breeding research at University of Sydney
IA Rose	NSW Agriculture, Narrabri	Breeding research at University of Sydney, followed by sustained leadership of NSW Agriculture's long-term breeding program at Narrabri targetting specific regional needs (e.g. Rose *et al*. 1983, Rose 1987)
GA Constable	NSW Agriculture, Narrabri	Varietal evaluation and irrigation management in north-western NSW (Constable 1974, Constable 1977)
PJ Desborough	NSW Agriculture, Grafton	Varietal development and agronomic management for north coast (Desborough 1981)

The efforts of the UQ program in the late 1960s in Qld were complemented by several initiatives in NSW (Table 1). The NSW Department of Agriculture appointed it first soybean breeder at Narrabri, HA Eagles, who worked closely with the UQ group until his departure for overseas study in 1970. Meanwhile, DR Laing and colleagues at the University of Sydney set up the cooperative soybean varietal evaluation network (Laing 1974) which enabled results to be compared from selections studies at a range of latitudes across the eastern states. K McWhirter recruited PhD student IA Rose to undertake breeding research on soybean. Rose later became the NSW Agriculture soybean breeder at Narrabri, replacing Eagles.

The University of Sydney / NSW Agriculture group played a lead role championing the development of the soybean industry in various areas of NSW, in a manner analogous to that of Byth's group in Qld. Meanwhile, the QDPI appointed JL Rose, recently returned from the USA, as soybean breeder based at Warwick in SE Qld. At the same time, state departments in all three eastern states appointed district agronomists in key regions to work on emergent problems with the new crop (Table 1). These R&D initiatives collectively facilitated the consolidation of the fledgling industry, and ensured its persistence through the first of the cyclic downturns (Fig. 1) that have since characterised the industry.

It is worth noting that despite the difficulties of directly translating USA experience to Australia, the establishment of the industry here nonetheless drew heavily on USA varieties and experience. Some of the researchers involved in getting the soybean industry going in Australia (Table 1) undertook research or postgraduate research training on soybeans in the USA before during or after the industry's establishment. Byth and Laing did their PhD studies, and OG Carter undertook research at Iowa State University. Lawn and JR Rose undertook PhD studies at the University of Minnesota.

The initial establishment of the industry in SE Qld was achieved using an introduced named variety from the southern USA, cv. *Hill*, and two varieties, *Wills* and *Semstar* that, while they were released by farmers (Table 1), were derived from USA germplasm. Likewise in NW NSW, the industry was established using introduced named varieties from the USA like cvv. *Hill, Lee* and *Bragg*.

The key to the successful use of the existing varieties was in adapting agronomic management, particularly sowing time, row spacing and plant population, to accommodate adaptive responses and maximise yield potential in different environments. It is useful therefore to explore some of the early physiological and agronomic research that led to the understanding of the variety X sowing date X density interactions that needed to be accommodated through agronomic management.

Understanding varietal adaptation to develop successful agronomic management

The early experimental attempts to grow soybean in Australia, using varieties and production practices that had proved successful in the USA, had been characterised by variable vegetative vigour and biomass productivity, generally low seed yields, poor seed quality and large variety X environment interactions (Miles 1949, Gray 1955). Gray recognised there was a relation between varietal maturity and adaptation to latitude, and argued that future breeding emphasis needed to target later maturity varieties than had been the case to that time. He accurately predicted that material from USA maturity groups VII and VIII would be suitable for southern Qld, but noted limitations of the system of USA maturity groupings when applied in Australia.

Byth introduced varieties from tropical regions around the world, with the aim of identifying lines that were later maturing than those available from the southern USA. In most instances, however, these later maturing varieties were poorly suited to mechanised agriculture, and it took several cycles of breeding to combine these new sources of genetic lateness with better agronomic backgrounds. More rapid progress came from recombinations within the USA germplasm.

Byth also undertook a series of controlled environment studies to compare the effect of daylength on flowering in temperate and tropical soybean varieties (Byth 1968). These studies established the differential photoperiod sensitivity of varieties adapted to different latitudes. The question remained, however, how these responses translated into the field and affected adaptation to latitude and sowing date.

Environmental control of phenology in the field. As part of the initial research to establish the optimal agronomic management for soybeans in SE Queensland, serial sowing date studies were used to explore environmental effects on phenology (Fig. 2). Large effects of sowing date were related, through regression models, to the effects of photoperiod and temperature on the phenology of different varieties at different sowing dates (Lawn and Byth 1973).

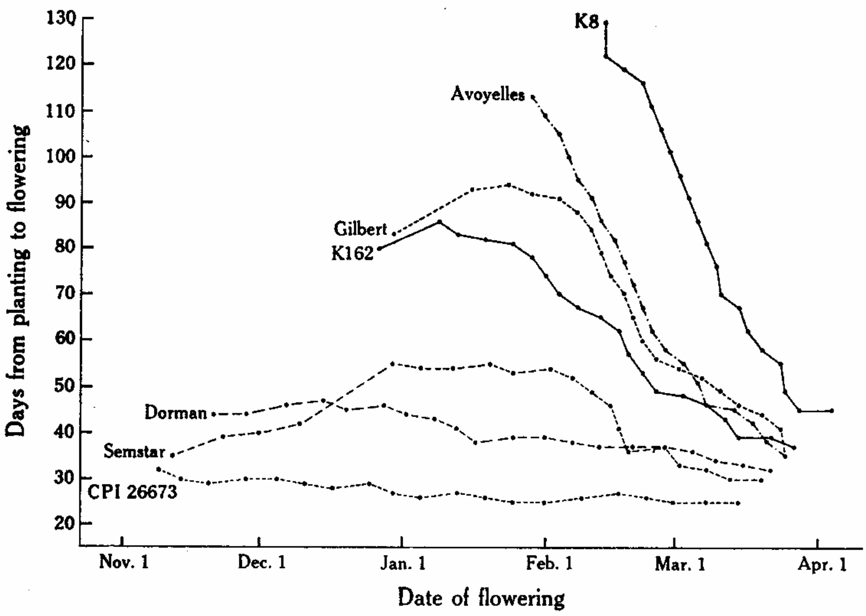

Fig. 2 Differences among soybean varieties in their responses in time to flowering over sowing dates were shown to be a consequence of differential genotypic sensitivity to photoperiod and to a lesser extent, temperature. (From Lawn and Byth 1973)

These studies confirmed that apart from a small number of very early, photoperiod-insensitive genotypes, most varieties were quantitative short day plants with development in both the pre- and post flowering phases delayed by longer days. Differential genotypic sensitivity to longer (mid-summer) photoperiods delayed development to a greater or lesser extent, with the latest maturing varieties being the most photoperiod-sensitive (Fig. 2). While soybean had been long-recognised as a short day plant in terms of flowering (e.g. Garner and Allard 1923), differential the effects of varietal responses were not widely understood, especially during post-flowering.

Based on these relations, it was predicted that culture of the same set of soybean varieties that were grown in south east Qld, in the shorter summer day lengths of the tropics, would result in all lines being relatively earlier in maturity, and less responsive to sowing date. In the short days of the tropics, varieties adapted to a range of higher latitudes would form an early flowering group largely unresponsive to sowing date. Conversely, if grown under longer summer photoperiods at higher latitudes, all varieties would be relatively later in maturity, and even more responsive to sowing date. These predictions proved correct (Fig. 3).

It was also postulated and later confirmed (Mayers *et al.* 1991) that lines would become earlier flowering under the short day lengths in the tropical dry season. However, while the short days stimulated rapid progress toward flowering in the dry season, this could be partially (or in cooler, higher altitudes regions like the Atherton Tableland, wholly) offset by cool night temperatures. At the other extreme, high maximum temperatures (> 30 ^{o}C) were also shown to slow development toward flowering.

In later years, the apparent complexity of these flowering responses in the field was able to be captured using relatively simple empirical models (see Fig. 4).

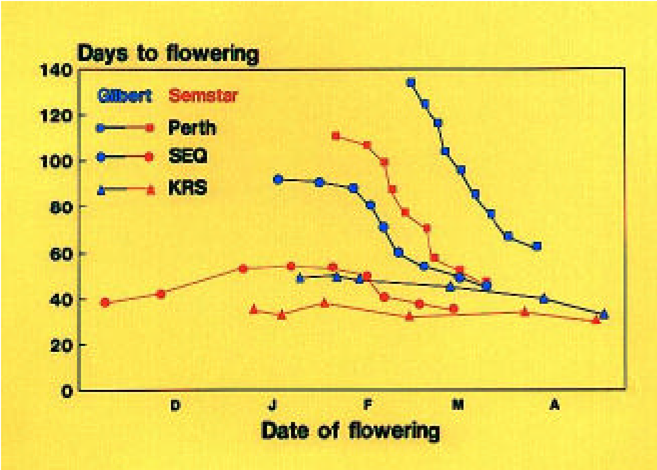

Fig. 3 Flowering response of two soybean varieties (*Gilbert*, tropical, lighter; *Semstar*, subtropical, darker) for a range of sowings at Perth (32°S), South East Queensland (SEQ, 27°S) and the Ord River area (KRS, 15°S). At the two higher latitude sites, flowering of all spring and early summer sowings was delayed until the shorter days of autumn. (From Lawn *et al*. 1985)

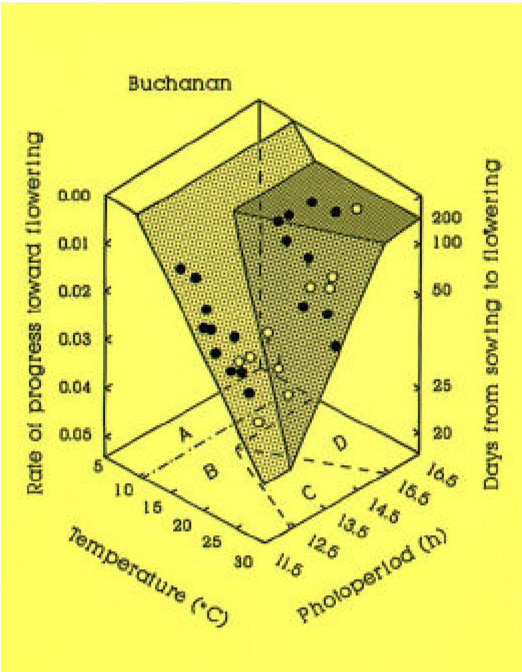

Fig. 4 Photo-thermal model relating rate of progress toward flowering to mean daily photoperiod (P) and temperature (T), prevailing prior to flowering, for the tropical soybean variety *Buchanan*. Annotated points represent data from field sowings at different locations and sowing dates. Segments A, B, C and D are projections onto the horizontal of the four planes comprising the flowering response surface. Segment A represents conditions where T is below the base temperature and no development occurs. Segment B is the thermal plane, where P is less than the critical photoperiod. Segment C represents the photo-thermal plane, where flowering is responsive to both photoperiod and temperature. Segment D represents conditions where P exceeds the ceiling photoperiod, and development proceeds independent of photoperiod, albeit very slowly. (From Summerfield *et al*. 1989)

Interesting the same model worked well not only for other short day crops, like mungbean and cowpea, but also long day crops like chickpea, lentil and barley. In a study of 44 varieties from nine crops grown at locations from Horsham to the Ord, comparison of model outputs with the observed flowering responses across the variety X location X sowing date combinations showed that the model was successful in explaining the observed genotypic and environmental effects on time to flowering across the range of crops (Lawn *et al.* 1995). The model also provided a plausible physiological explanation for the observed variety X environment interaction effects.

Relation between phenology and biomass. The early agronomic trials, using overseas varieties and production practices showed that introduced genotypes from subtropical/warm temperate regions in the USA generally produced low grain yields, especially if sown after mid-December, when adequate sowing rains were more likely to occur in the summer cropping regions (Lawn 1974, Lawn *et al.* 1977). The studies showed that crop duration of USA lines was often too short to allow adequate biomass production to sustain high seed yields.

Analysis of the vegetative growth of a range of variety X sowing date combinations established that, for any particular sowing arrangement, biomass production was largely a function of the duration from sowing to the end of flowering (Fig. 5), which in turn was affected by varietal maturity and date of sowing. The introduced varieties usually flowered sooner under Australian conditions, largely because temperatures were warmer than at similar latitudes in the USA. This was exacerbated because summer rainfall also dictated later sowing dates in Australia, pushing the crop into late summer when days were shortening and temperatures were warmer.

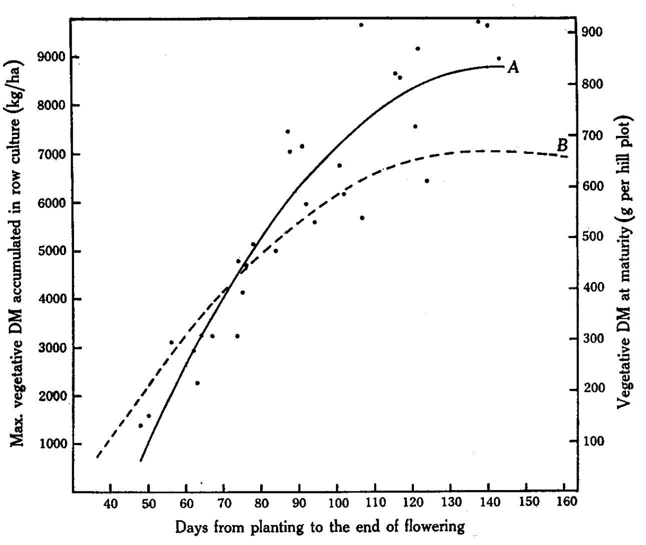

Fig. 5 Dry matter production in diverse soybean variety X sowing date combinations as a function of duration from sowing to the end of flowering (A = row plantings of 6 varieties at 5 sowing dates; B = hill plots of 18 varieties at 20 sowing dates. Individual datum points for line B are not shown). (From Lawn 1974)

Relation between phenology and harvest index (HI). One of the interesting findings was that HI was greater in earlier than later maturing varieties (Lawn and Byth 1974). Further, within a variety, HI increased when time to flowering was shortened by delayed sowing. That is, in general terms, HI was greatest where photo-thermal conditions stimulated plants to flower sooner after sowing. In subsequent research, a strong generalised relation whereby HI declines as crop duration is extended was shown to apply to other short day legumes as well as soybean (Fig. 6).

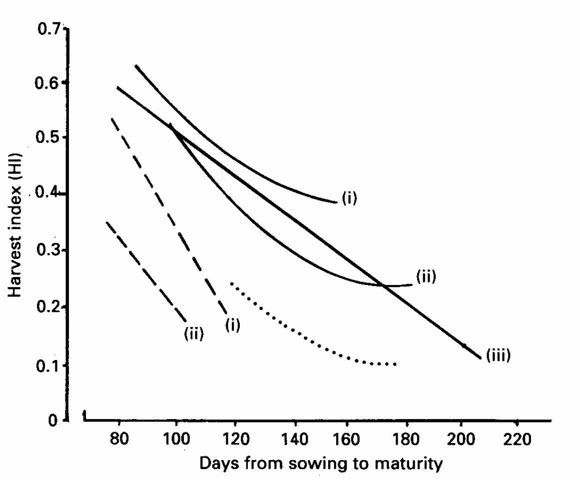

Fig. 6 Generalised negative relations between HI and crop duration for three grain legumes. In each case, variations in phenology had been achieved using a range of variety X sowing date combinations. Solid lines: *soybean* (i) 6 varieties in the USA, (ii) 6 varieties in SE Qld (rows), and (iii) 18 varieties in SE Qld (hill plots). Dashed lines: *mungbean* (i) 15 varieties in SE Qld (rows) and (ii) 6 varieties in SE Qld (hill plots). Dotted line: *pigeon pea* 5 varieties in SE Qld. (From Lawn 1989)

However, consistent with the trends in Fig. 5 biomass is also reduced in these species as crop duration is shortened.

Relations between biomass, seed yield and HI. Analyses of the relations between seed yield, and its components, biomass and HI, from the early agronomic studies illustrated the dynamics of the variety X planting date X density interaction. In these analyses, data from 360 hillplot sowings, comprising 18 varieties X 20 sowing dates, were grouped on the basis of whether closed canopies were formed under the comparatively wide spacings used in the study (Table 2). At densities where biomass production was inadequate to form a closed canopy, and so intercept the available radiation, seed yield was well correlated with biomass (Table 2). However, where biomass was adequate to intercept radiation, seed yield correlated better with HI than biomass.

Table 2. Relations between seed yield in soybean, and its components total biomass and HI, in a hill plot study involving 20 sowings of 18 varieties of differing duration: (i) all 360 entries; (ii) subset of 164 entries where crop duration was too short for closed canopies to be achieved; and (iii) subset of 196 in which closed canopies were achieved. (From Lawn 1988, based on Lawn & Byth 1974)

	Correlation coefficient (r) with seed yield	
	Biomass	HI
i. All variety X sowing date combinations (360 entries)	0.63 ***	0.17 **
ii. Closed canopies not achieved (164 entries)	0.94 ***	0.27 **
iii. Closed canopies achieved (196 entries)	0.10 n.s.	0.81 ***

***, ** = statistical significance at P=0.001, P=0.01 respectively; n.s. = not significant

Implications for agronomic management. The relations outlined in Figs. 5 and 6, and in Table 2, led to what, in agronomic terms, was the key breakthrough in understanding from the early field studies, namely, how variety X planting date X density interactions were caused by photo-thermally induced effects on plant growth, which varied with variety and sowing date (Lawn *et al.* 1974). The corollary was that these effects could be compensated for by adjusting planting arrangement (i.e. row spacing and /or plant population), depending on variety and sowing date.

In general terms, optimal sowing arrangement varied with crop duration. With late November – early December planting dates, where pre-flowering duration was longest, high yields were possible from a range of row spacings and plant populations because plants were vegetatively vigorous, especially under irrigation. Likewise with later maturing ('full-season') varieties, for which optimal planting dates were a bit wider. However, where sowing was delayed (Fig. 7a), or with earlier varieties (Fig. 7b), narrower rows and higher plant populations were needed to obtain high yields.

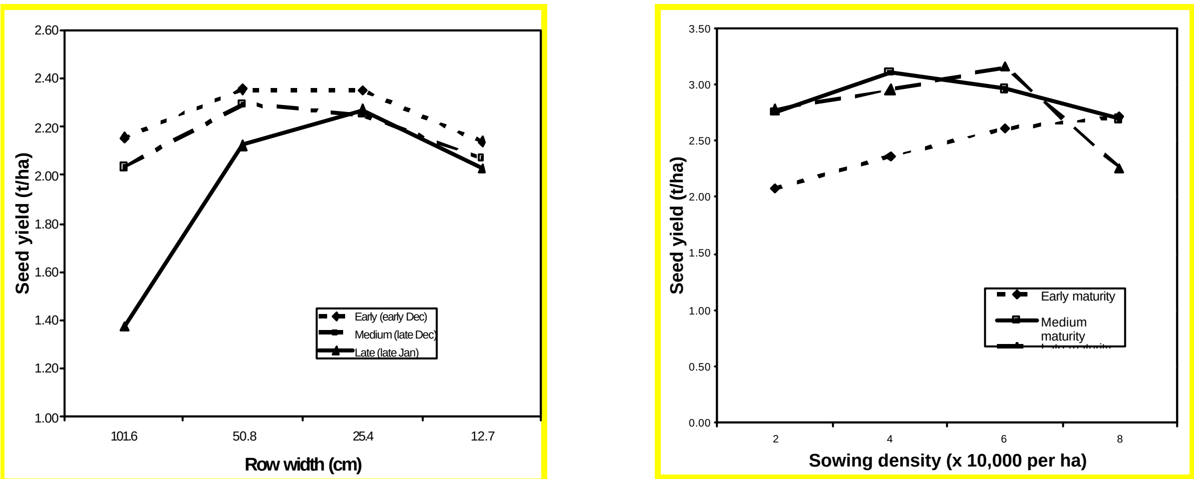

Fig. 7 (a) Narrow rows and higher sowing densities were needed for sowing dates after mid December (After Lawn *et al.* 1977) (b) Narrow rows and higher sowing densities were needed for earlier varieties (After Mayers *et al.* 1991)

In practice, these findings meant that conventional wide-row cropping was feasible using earlier (mid November – mid December) sowing dates, especially with later varieties, but planting patterns closer to solid drilling were needed with early varieties and late sowings. Even so, there came a point if duration was too short (e.g. early varieties sown in mid January) where individual plant size became too small to be offset by further increases in plant density (Lawn *et al.* 1974). Biomass was less a constraint with long duration varieties, even at relatively low densities. However, these often lodged, in which case, HI was the main determinant of seed yield.

Under rainfed conditions, these general relations still applied, but yields were generally maximised at lower densities than under irrigated conditions (Lawn *et al*. 1974).

Importantly, these studies demonstrated that commercially viable yields were possible from the varieties then available in the subtropics, provided flexible management was used to accommodate the variety X planting date X density interactions. The findings were incorporated into some 'rule of thumb' recommendations that were promoted to farmers by the Qld Graingrowers Association (Lawn 1970, QGGA 1970). The first of these was "optimal sowing date is early-mid December". The second was "use narrow rows and higher plant populations with earlier varieties and / or later sowing dates". The third was "plant early varieties early, and late varieties late". The fourth was "use lower densities under rainfed conditions".

These 'rules of thumb' were sufficient to get commercial production underway, using the then-available varieties. However, there were some exceptions to their general application. One was that on the southern Downs close to the mountains, where autumn temperatures were cooler, late varieties sown after mid-December risked exposure to frosts prior to maturity in autumn (Williamson 1974).

In the irrigation areas of the Namoi Valley and further south, there was greater initial success in directly translating the traditional USA production system, based on full-season varieties cultivated in wide rows, into Australia. This was due partly to the fact that flowering of many varieties was later at the higher latitudes than in Qld, so that biomass was less of a constraint. The initial preference for wide row culture was also due in part to the fact that some of the first soybean crops were grown by expatriate USA cotton farmers with first-hand experience of the USA soybean system.

However, it was later shown that even in these areas varietal adaptation and selection needed to take into account sowing date and row spacing (Constable 1977, Constable & Rose 1980, Rose 1987). The main difference was that at higher latitudes, because of cooler spring and autumn temperatures, the range of possible planting dates became narrower, with less overall flexibility in the system.

Implications for soybean breeding objectives. The finding that HI was greater when varieties were grown in photo-thermal regimes that stimulated earlier flowering provided the basis for the proposal that soybean yields might be maximised by breeding early-flowering, photoperiod-insensitive lines suited to solid seeding or high density culture (Byth & Lawn 1971).

The idea was that reduced biomass per plant would be offset high plant density and high HI. Apart from higher yield potential, advantages proposed for such an approach included (i) wider adaptation of individual varieties across latitudes and sowing dates and (ii) complex variety X sowing date X density interactions would be avoided, and the same agronomy could be used in a wide range of situations. Conversely, it was acknowledged that short duration crops would be vulnerable to any setbacks during growth and a higher level of management would be required than with vegetatively vigorous, full-season varieties that are more 'forgiving' of poor crop husbandry.

The concept of using narrow row-high density sowings of shorter duration soybean varieties was a significant departure from the conventional 'full season' soybean production system in the USA. It had many analogies, however, with the high density-narrow row system then being proposed by RL Cooper in the mid West of the USA, as a means of avoiding the adverse effects of lodging in vegetatively vigorous, full-season varieties (Cooper 1977).

As noted previously, however, follow-up research showed that existing varieties flowered too soon when grown in photoperiods where they were insensitive (Lawn and Byth 1974). Under these conditions, the reductions in plant size were too large to be offset by higher density and higher HI. The concept of using photoperiod insensitivity was therefore put aside and selection for improved phenological adaptation remained for many years the main focus for soybean varietal improvement in Australia (Lawn & Imrie 1991), reflecting the importance of sensitivity to photo-thermal regime in conditioning regional and seasonal adaptation. This inevitably slowed the rate of genetic advance because quantitative breeding methods were needed to change photo-thermal adaptation.

Epilogue

Several developments in later years enabled elements of Cooper's work to be combined with elements of the early Australian work to develop a novel breeding approach that has since been used in the CSIRO breeding program (James *et al*. 1996). For his part, Cooper tackled the lodging problem in full-season soybeans by developing earlier-maturing, semi-dwarf varieties like *Sprite 87* and *Hobbit*. While not photoperiod-insensitive, these varieties have higher HI, are lodging resistant and are suited to high-density culture (Cooper 1989).

Meanwhile, in Australia, the flowering model provided useful insights into the environmental responses of lines known to possess the long-juvenile (LJ) trait. This trait delays flowering and maturity (Hartwig and Kiihl 1979), and had been used widely in the USA and Brazil, in conjunction with strong photoperiod sensitivity, to develop late maturing varieties suited to wide-row mechanised agriculture at low latitudes (Hinson 1989).

Comparative sowings of isolines pairs with and without the LJ trait in Australia and Thailand in ACIAR Project 9040 showed that while the isolines were sensitive to summer photoperiods at higher latitudes, they were insensitive to the shorter days of the tropics (James *et al.* 1992). Meanwhile, the flowering of the LJ isoline was delayed by ~ 10 days under normally inductive conditions (James *et al.*1997). In effect, the LJ trait provided a genetic 'switch' that delayed flowering and increased the yield potential per plant of short duration varieties, without introducing sensitivity to photoperiod.

These observations opened up the novel strategy for 'converting' elite varieties from temperate to tropical adaptation by simply back-crossing the LJ trait into the elite germplasm. The strategy enables breeding advances in temperate regions to be rapidly 'captured' in the subtropics and tropics, with the added advantage that, being insensitive to photoperiod, the 'converted' germplasm is adapted to a relatively wide range of latitudes and sowing dates (James *et al.* 1996).

This new strategy was used to 'convert' Cooper's elite, high yielding, semi-dwarf variety *Sprite 87*, adapted to the mid-west of the USA, to subtropical adaptation. Cv. *Sprite* had shown the potential to produce high seed yields in the subtropics when flowering was delayed by 10 days using artificial day length extension (James *et al.* 1992). The approach culminated in the release of cv. *Melrose*, the first commercial semi-dwarf soybean variety with tropical/subtropical adaptation (A T James, personal communication, 1999).

Given its short stature and early maturity, *Melrose* required higher sowing densities and narrow rows to maximise seed yields. Because it was photoperiod insensitive at lower latitudes, it had broader adaptation with respect to sowing date and latitude in these regions. Likewise, because of its comparative short duration and photoperiod insensitivity, it had naturally high HI. In effect, the use of the LJ gene in combination with temperate adaptation enabled the key elements of the model proposed by Byth and Lawn (1971) to be achieved.

Acknowledgements

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