Soybean improvement program

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Abstract

The public Australian breeding program seeks to develop cultivars with adaptation to environments from northern Australia to central Victoria, a north-south range of more than 3000 Km. In addition the grain quality from these cultivars should meet the highest culinary-quality possible within the constraints imposed by the cropping environment, agricultural system in each region and limitations imposed by funding. In northern Australia, the priorities are high yielding dual-purpose grain or green manure cultivars with strong rust tolerance and broad adaptation to sowing date. In southern Queensland and inland NSW, priorities are culinary quality for milk, tofu and natto and early maturity without sacrificing yield or disease resistance. In coastal southern Qld and northern NSW priorities are maintaining grain yield and weathering tolerance but shifting to light hilum and possibly tofu quality if research suggests it can be reliably produced in this region. In southern NSW and Victoria, priorities are high tofu quality, improved phytophthora resistance, early maturity and increasing grain yield. This paper presents an update for each of these regions.

Introduction.

The public Australian breeding program links CSIRO Plant Industry, Qld Department of Primary Industry, NSW Agriculture and Department of Natural Resources and Environment in Victoria and has many links to other agencies and to the private sector. Rather than detail the work of each group, this paper seeks to provide information about the general thrust of the breeding program. Where another speaker from within the program is also presenting at this conference, such as Malcolm Ryley, Ian Rose, Peter Desborough or Luke Gaynor their work will be left largely to them to report. Greatest detail of the program will therefore be given to varietal evaluation work in Queensland and the work to improve culinary quality.

Northern Australian component.

Until recently, northern Australia had only one cultivar with good adaptation. This is an inherently risky proposition given that when this has occurred in other places and in a wide range of crops, the frequent consequence is widespread crop damage when a new disease or other pest occurs to which the widely grown cultivar is susceptible. The cultivar, Leichhardt, for example is highly susceptible to soybean rust (*Phakopsora pachyrhizi*) and whilst rust is only a problem in some years and sites such as the Atherton Tablelands with extended overcast periods and cool temperatures, it highlights the vulnerability of an industry based on a single cultivar.

The latest release from the program cultivar YY, which is a selection from the Thai variety CM60 was released to provide a complimentary cultivar with tropical adaptation, better rust tolerance than Leichhardt and potential for harvest as grain rather than green manure. YY has generally shorter duration but tends to be taller with a more open canopy than Leichhardt making it more suited to control of sucking bugs in-crop than Leichhardt. The shorter duration also permits a shorter window whilst control of insects is required and may fit more easily into some cropping rotations, especially those which aim to manage the crop through to harvest of grain. However, shorter duration does mean that YY does not generally produce as large a bulk of dry matter as Leichhardt (Table 1).

Warm winter conditions in the tropics also permit seed production under irrigation to occur during the dry winter period. If attempting this with Leichhardt it is important to sow the crop before the end of June, but preferably late May or early June. Later sowing runs the risk of the longer duration Leichhardt undergoing vegetative reversion as the longer days of early summer approach. When this occurs, grain yield can be very low and difficulties in harvest occur due to leaf retention and green stems. YY has broader adaptation to sowing date, being well adapted to May though to July sowing and from November through to January in the wet season.

Table 1. Comparison of the performance of the cultivars YY and Leichhardt over the period 2000 to 2002.

	Variety	Days to maturity	Grain Yield (Kg/Ha)	Dry matter yield (Kg/Ha)
December sowing rust free sites	YY	123*	4.1	9.0*
	Leichhardt	155*	4.3	12.4*
January sowing rust free sites	YY	118	2.5*	5.5*
	Leichhardt	121	3.7*	9.4*
Sites affected by rust at flowering	YY	102*	3.1*	6.7*
	Leichhardt	110*	2.0*	3.9*
June sowing frost-free sites	YY	121*	3.4*	7.8*
	Leichhardt	130*	2.1*	6.6*
July sowing frost-free sites	YY	111*	2.6*	5.7
	Leichhardt	151*	1.7*	5.6

* differences are statistically significant (P. 0.05)

Further varietal evaluation work in the north seeks to produce a dual-purpose grain and green manure cultivar. Varieties in advanced trials have been selected for a higher level of rust tolerance than YY, medium duration, high grain and dry matter yields and tall growth habit to give ability to compensate for variable plant populations and be highly competitive against weeds (Table 2). Most also have light hilum and although it is yet to be confirmed, are anticipated to have tolerance to weathering at harvest. They have not been evaluated for tofu making potential, but have one parent which appears to have above-average gelling potential.

At this early stage of varietal evaluation, there appear to be many new lines with taller growth habit, higher dry matter and grain yields than both YY and Leichhardt. Most of the lines also possess light hilum, which may broaden the use of the harvested grain into some human-consumption markets.

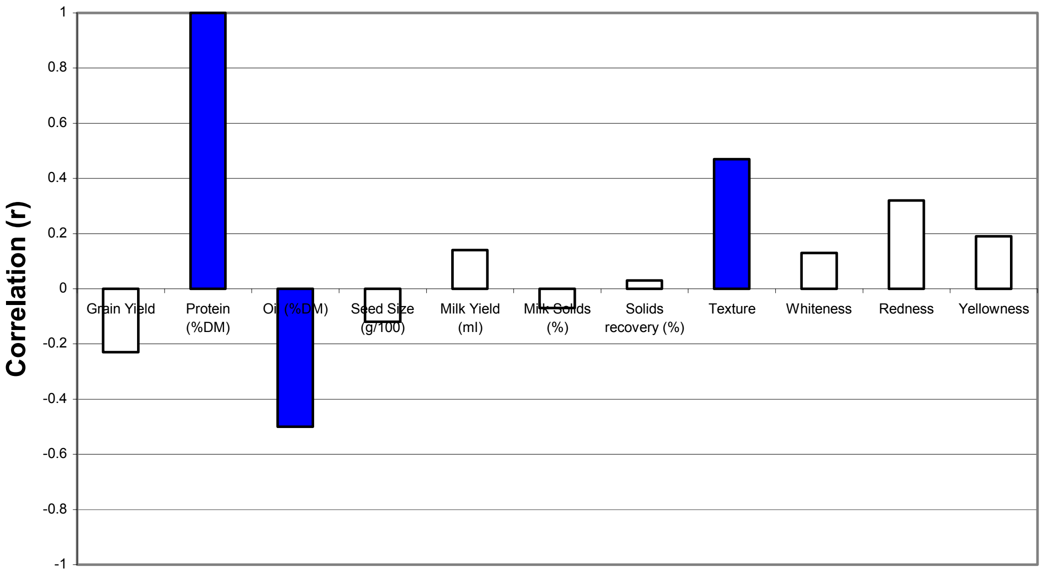
Table 2. Results of preliminary varietal evaluation trials in north Queensland for the year 2002.						
	Days to maturity	Height (cm)	Lodging score	Dry matter (t/Ha	Grain yield (t/Ha)	Hilum colour
99084B - 28	115	83	2.4	8.6*	3.7*	light grey
99084A - 18	117	83	2.2	8.8*	3.7*	clear
99079B - 20	112	86*	1.4	8.1	3.6*	clear
99084A - 27	113	76	1.8	7.9	3.6*	light grey
99084A - 26	106	70	1.5	7.2	3.6*	light grey
99084A - 22	114	87*	1.5	8.0	3.6*	clear
99084B - 33	117	85*	2.9	8.8*	3.6*	light grey
99084B - 4	117	78	2.0	8.6*	3.6*	light grey
99084A - 17	112	80	1.3	7.2	3.5	brown
99079B - 29	114	81	2.4	8.9*	3.5	clear
99084B - 7	115	80	1.7	7.8	3.5	clear
99084A - 11	110	80	1.2	7.8	3.5	clear
99084B - 14	118	83*	2.3	8.3	3.4	light grey
99079C - 14	109	76	1.7	7.3	3.4	buff
99084B - 17	118	91*	1.9	8.4	3.4	light grey
99084A - 34	115	94*	2.1	8.1	3.4	clear
99084A - 10	115	98*	1.2	8.0	3.4	clear
99084B - 30	114	74	1.4	7.2	3.3	light grey
99084B - 35	119	86	2.0	8.6*	3.3	light grey
YY	112	74	2.0	7.7	3.2	brown
99084B - 3	120	91*	2.3	7.7	3.2	light grey
99079C - 15	106	66	0.7	6.7	3.2	buff
99084B - 31	118	86*	1.0	7.6	3.1	light grey
99084B - 6	117	86*	1.2	7.2	3.1	light grey
99084A - 25	113	78	1.4	6.8	3.1	clear
99001 - 25	115	83	1.3	8.3	3.0	clear
Leichhardt	121	73	0.7	7.5	2.8	brown
* differences from better of the two cultivars are statistically significant (P. 0.05)						

Culinary quality

There is a long history of food production from soybean, in which grain from certain cultivars was found to be better for specific end uses than grain from others. However, the relative importance of different grain quality traits and sensitivity of processing methodology to this variation is less well known to plant breeders responsible for the improvement of the crop. It is therefore important, in the development of a strategy for soybean improvement, to define optimum quality and consider the effect that modification to processing technology can have in overcoming limitations in the raw material. Variation in grain quality has the greatest impact on ease of manufacture and quality of traditional foods made from soybean such as tofu, natto, vegetable soybeans and soymilk and for that reason, the quality requirements for those foods will be reviewed here. The non-traditional foods made from the whole bean such as soymilk, yoghurt and icecream are also sensitive to the quality of raw beans in a way similar to that found in manufacture of tofu. Elaborately transformed products made from protein isolates such as milk, burgers, hotdogs, soy nuggets and a vast range of other foods in which a soy-fraction is utilised are less sensitive to the quality of the raw material. They are therefore less demanding of a soybean improvement program.

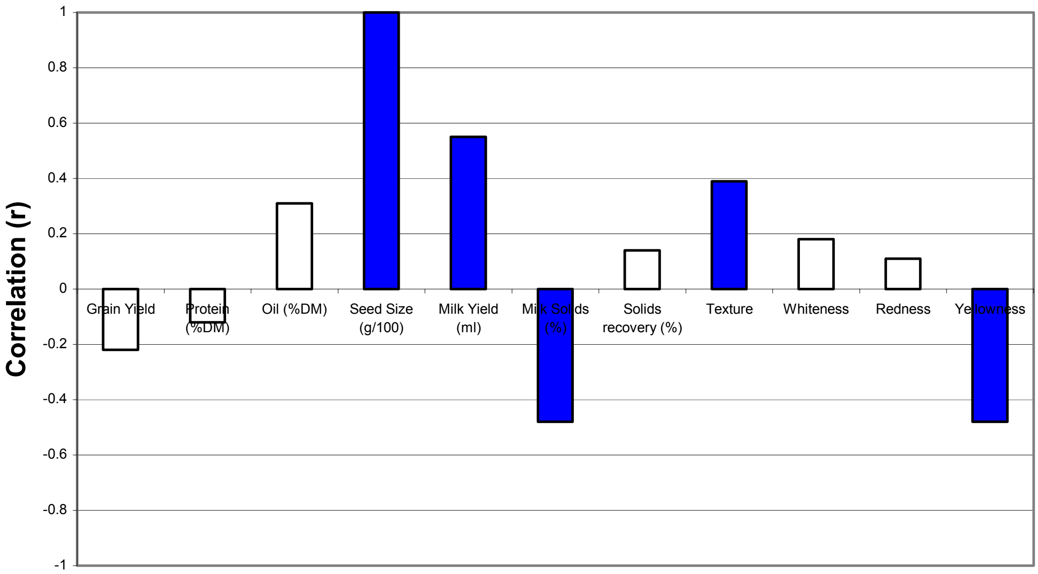
Tofu. There is strong evidence that choice of cultivar influences the quality of tofu. However, small-scale tests have hitherto been unavailable to differentiate between different batches of grain for tofu-making potential. We solved this problem by developing a fast small-scale method of tofu making, that enables many measures of quality to be made. On an 80 gram sample of grain, we can now measure the yield of milk, percentage milk solids, solubility of grain, tofu gelling or texture score, whiteness, redness and yellowness. Grain which produces a high milk yield with high solids and high texture score is preferred for tofu making because it will result in the highest yield of tofu of the best consistency. Generally, yellowness in tofu is undesirable because darkening is associated with longer periods of time in storage. Within the breeding program it is important to understand the interrelations among traits (Figure 1 and Figure 2).

Figure 1. Correlations between protein content and other grain traits thought to be important for tofu quality. Shades bars are statistically significant (P <0.05) correlations.



It is possible to make significant changes to the tofu making potential of soybean through selection. Manufacturers prefer cultivars with higher protein content and larger seed size than is usual for varieties selected for oil seed crushing, because this will give higher yields of tofu with firmer texture. However, it is important that protein content not be pushed too high because this will have a negative impact on sugar content and flavour of the tofu. Different market segments appear to prefer different levels of isoflavones and saponins. The level of grassy-beany flavours acceptable to the market also vary with market segment. Yellow hilum is preferred, but buff is accepted in the market. However, the premium end of the market is likely to demand clear hilum. It is necessary to measure gelling and colour of tofu made from beans in order to confirm that cultivars have high gelling and light colour characteristics needed for tofu. Cultivar differences in dry matter solubility appear real but slight after removal of seed size, protein and oil effects. The main traits that the breeder needs to consider are therefore protein and sugar content, seed size, hilum colour and gelling and tofu colour.

Figure 2 Correlations between seed size and other grain traits thought to be important for tofu quality. Shades bars are statistically significant (P <0.05) correlations.



In Australia, some varieties gained a reputation for making good tofu. These varieties generally came from the Riverina region of NSW and varieties adapted to other regions of the country were generally not preferred. We have generally found the same result when making tofu from samples of grain from regional variety trials. In the Qld trials (Figure 3), varieties A6785, Cawana , Centaur, Dragon, Jabiru, Manark, Melrose, Poseidon, Soy 791 and Warrigal all had relatively low gelling as measured by texture score. Many of these same varieties also had relatively long duration, which has come to be considered as unfavourable in times of limited irrigation water supplies (Figure 4). Two lines from the regional variety trials which had high texture score combined with clear hilum, earlier maturity and good yield for their maturity are 96130-2 and 96130-20. The performance of these lines from this summer's trials will be considered before a decision is made for release.

Similar comparisons were made for lines from the regional variety trials in southern NSW and Victoria (Figure 5). The recent privately-released cultivar Empyle has not yet been evaluated for tofu making ability within the program, but is included in this years trials and will be tested later this year. From the Riverina trials, the line 97016-11 is looking particularly promising. See paper of Luke Gaynor this proceedings for more information about this.

Further research in the program is aimed at better understanding the way that environment during pod maturation interacts with grain quality and protein globulins so that varietal improvement for tofu quality can be targeted toward those environments with the greatest potential to maximise quality.

Figure 3. Comparison of tofu texture score from grain harvested from the regional variety trial at Hermitage, Warwick, with that harvested from the trial at Brookstead.

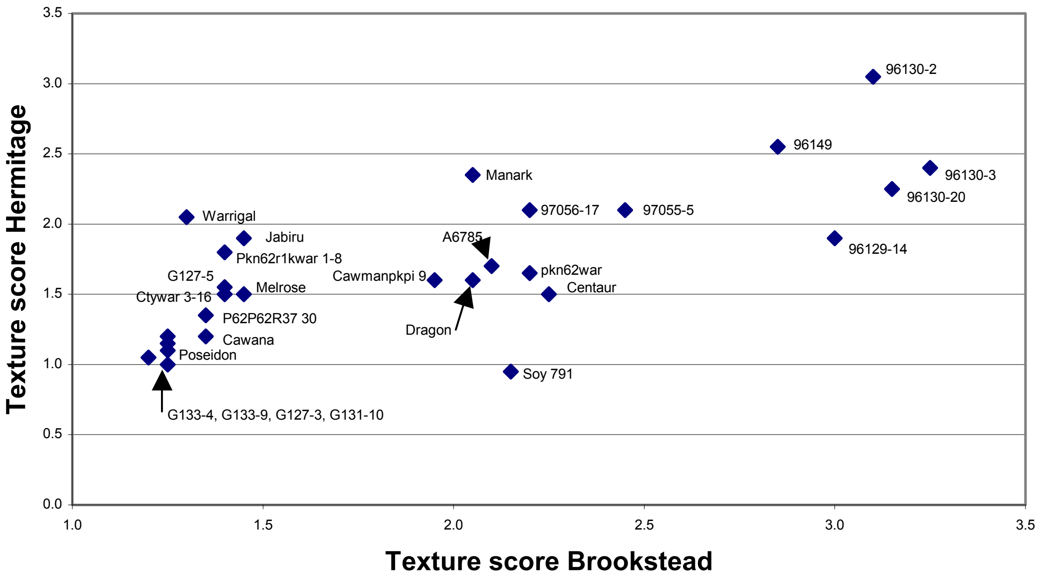


Figure 4. Yield and maturity of varieties included in southern Queensland regional variety trials averaged over all trials.

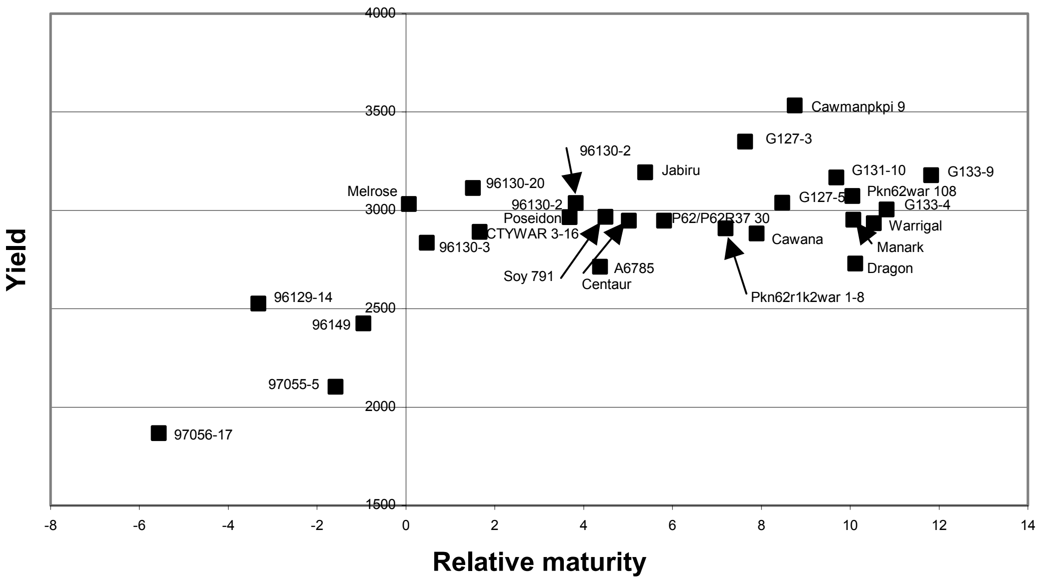
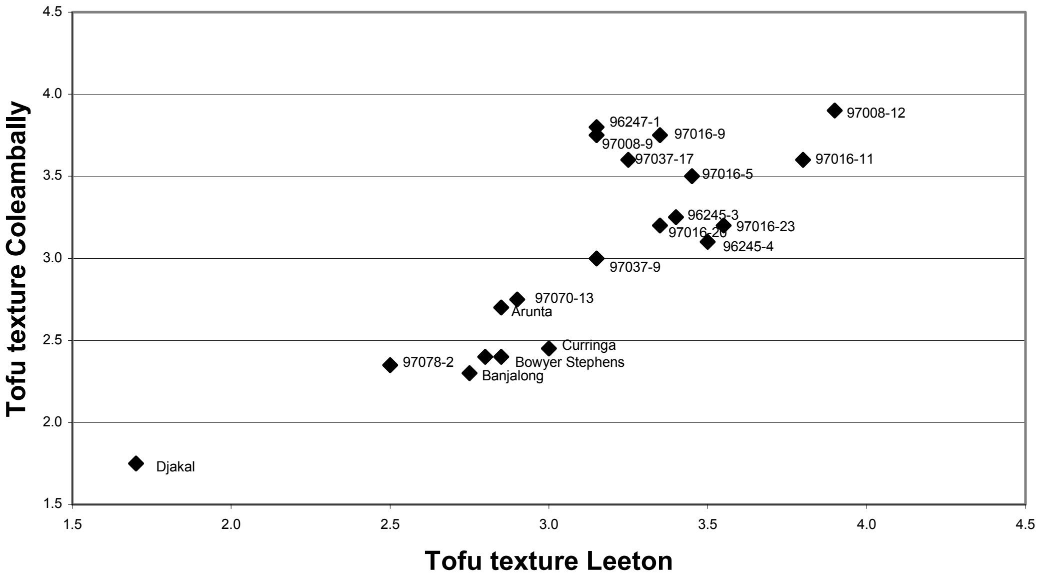


Figure 5. Comparison of tofu texture score from grain harvested from the regional variety trial at Yanco, with that harvested from the trial at Coleambally both in the Riverina region of southern NSW.



Natto. When developing a selection strategy for natto cultivar development, it is important to consider both the effect that variation in seed quality might have on the final product and the effect that variation in processing technology can have to alleviate variation in grain quality. The needs of manufacturers are, thus, paramount. Manufacturers are likely to prefer small spherical grain with a high sugar content because these traits should result in the shortest manufacturing time, highest yield of natto, greatest mucilage production, and lowest ammonia content in natto. There is genotypic variation for sugar content, but cultivars developed outside Japan and China appear to have generally lower sugar content. Sugar content may be negatively correlated with seed protein content. Small-seeded North American varieties also tend to produce a 'less soft' natto than traditional Japanese varieties. The basis for this has not been determined at present, but may be related to sugar content as well as other factors. Genotypic differences in colour are likely to be relatively consistent over time, leading to preferences by manufacturers for specific cultivars.

Research conducted within the program seeks to understand the effects of water stress on natto soybean quality and in particular on the content of sugars and seed size. Drier environments in Australia may have a natural advantage in production of natto, but more research is needed to better understand the best environments to maximise quality.

Vegetable soybean, Edamame or Maodou. Seed pods should have sparse gray pubescence and contain three seeds per pod, though two seeded pods are acceptable in the market. There should be an absolute minimum of one seeded pods because they are disliked by the consumer, requiring greater effort to shell them. Four seeds in a pod are not preferred as the number four is considered unlucky in some cultures. Desirable varieties should have very large seed, high sugar levels, and a smooth texture. It is thought that the genetic removal of lipoxygenases will result in a bean with less beany flavor and greater acceptability to the market. For the fresh-frozen market, uniformity of maturity, a thicker pod wall to reduce freezing damage and plant habit to permit mechanized harvest is required in addition to the quality traits required in the fresh product. In addition, varietal development for edamame for the fresh market should focus on breeding for production in multiple sequential planting dates so that the harvest period can be maximized.

Soymilk. There are two kinds of soymilk produced for the market. The more traditional type is manufactured from whole beans in the same way that soymilk is made in the first few steps of tofu manufacture. This milk contains nutrients, isoflavones, saponins and other soluble components of the soybean from which the milk is made. The non-traditional type of soymilk is manufactured from soy protein isolate, to which fats, sugars and carbohydrates are added to improve flavour and generate a nutritional profile similar to that of cow's milk. Some manufacturers add isoflavones back in to the soymilk in order to make health claims about the product. Although globulin proteins which coagulate well are preferred for tofu, cultivars with globulin proteins which paste rather than gell are preferred for soymilk. Such proteins more likely to remain in solution without gelling.

Conclusions

The program has made substantial progress in understanding quality requirements for high quality high-value human consumption markets. This understanding is being used to target the breeding program toward release of cultivars which can achieve maximum culinary quality which can be supported by the environment.