VG319

Sweetcorn breeding and development to meet the requirements of Australian and export markets

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INDUSTRY SUMMARY

Two highly successful supersweet corn hybrids have been bred and released to the industry. The first of these, H5, has resistance to a virus, Johnson Grass Mosaic Virus , which has the capacity to devastate existing temperate sweetcorn cultivars. Its introduction revolutionised sweetcorn production in south east Queensland by lengthening the harvesting window by 3 months. It also extended the area of sweetcorn growing by enabling production on the Darling Downs , a large potential growing area previously excluded by the JGM virus.

H5 has been a significant contributor in a financial sense not only to the growers but also to Golden Circle Cannery which is now exporting canned kernels to Japan with great success. The product is considered by Japanese marketers to be superior to canned kernels from north America. Production cannot keep up with demand. Exceptionally high yields of 25 tonnes per hectare have been achieved making sweetcorn growing the financial saviour for some farmers who faced bankruptcy in their traditional grain growing enterprises. Further, kernel recovery percentages are running in excess of 40% compared with the 30% of previously-used temperate hybrids. This creates commensurate efficiencies in transportation costs for the cannery.

A final bonus for the processing industry is that in the summer of 1997, it was not necessary to spray insecticide for the control of Heliothis ear worm on H5 crops grown for canning. This must be a very significant selling point in negotiations for export markets, particularly with the Japanese who are renowned for their insistence on low or nil chemical residues in food. The tight husk closure of tropical H5 keep Heliothis infestation to a minimum in contrast to the open temperate varieties.

Pacific Seeds, the joint operator of the breeding project, have been very effective in seed production and marketing, both domestically and overseas. From domestic seed sales one can estimate sweetcorn production value of H5 in the vicinity of $10 million in the 96-97 financial year.

H44 is a hybrid with greater uniformity of maturity and cob size than H5. This makes it ideal for the canning trade which demands evenness of maturity and kernel size and shape.

A third hybrid, H 141, bred during the project, now moving toward release, has improved cosmetic traits over H5 that should make it attractive to the fresh corn trade. It has the bright green husk leaves favoured by supermarket customers and superior resistance to Turcicum leaf blight.

TECHNICAL SUMMARY

Genetic studies indicate that we have isolated a single dominant gene for resistance to the virus disease Johnson Grass Mosaic (JGM). This was resident in 2 sweetcorn populations we had developed from material introduced from Dr James Brewbaker, University of Hawaii in 1969. We have demonstrated that the frequency of resistant progenies can be rapidly increased by recurrent selection for resistance.

These populations have now been converted to supersweet populations by backcrossing them to sources of the 2 supersweet mutants ***shrunken2*** and ***brittle 1***. These populations have been progressively improved for disease resistance, eating quality traits (flavour and pericarp tenderness) and cosmetic traits such as husk leaf colour, kernel colour, cob and kernel shape, and flag leaf.

During the recurrent selection procedure we are able to identify elite inbreds which have then been used to create hybrids for evaluation at 4 trials sites strategically located throughout Queensland.

Future work will concentrate on transferring resistance to disease (JGMV, blight and rust) and insects (Heliothis and thrips) to temperate germplasm.

1. INTRODUCTION.

The main objective of VG 319 (which commenced in January 1994 and ended in June 1996)was to breed supersweet corn hybrids which could handle the particular the particular stresses (diseases, insects and climatic) which afflict sweet corn in tropical and subtropical Australia. Although the emphasis was on resistance there was a clear need to select for eating quality aspects such as flavour and tenderness if the project was to be successful in producing marketable commercial hybrids.

In this report of the project it is worth reiterating the original objectives as a measuring stick of success. They were,

- Johnson grass mosaic virus resistance
- Turcicum leaf blight resistance
- Common rust resistance
- high yields of uniform cobs throughout the summer period in southern Queensland
- heat, rain and storm resistance
- kernel characteristics for processing - such as thin kernel pericarp, crisp kernels, good flavour and aroma, high sucrose and total sugar.
- high kernel recovery
- high seed production capacity
- seedling vigour
- a degree of resistance to Helicoverpa ear worm
- a golden kernel colour

To these we can add the following traits which have become desirable objectives as the project proceeded

- bright green husk leaves
- low husk leaf sheath attachment

The initial reason for commencing breeding work was that sweetcorn growers in Queensland's largest growing region, the Lockyer and Fassifern Valleys, were unable to plant existing temperate-adapted sweetcorn after December because of the depredations of the virus disease Johnson Grass Mosaic .Tropical sweetcorn populations were imported from Professor Jim Brewbaker, University of Hawaii in an attempt to find germplasm with better disease resistance.

Although the Hawaiian material had reasonable resistance to many tropical diseases it was susceptible to the JGM virus. In conjunction with Plant Pathologist Denis Persley, a successful recurrent selection program using resistance inherent in the Hawaiian material was conducted to upgrade the frequency and quality of resistance to this disease. This work, which was reported in a conference paper, found that most of the observed resistance could be ascribed to a single dominant gene.

At the same time recurrent selection was under way for resistance to Common rust. Turcicum leaf blight and for improved seedling emergence. (Supersweet corn is notorious for poor germination and emergence mainly because of its lack of seed starches and susceptibility to fungal pathogens.)

However to the quality requirements of a commercial sweetcorn cultivar were not reached in initial cultivars. It was to translate the potential of the disease resistant germplasm into commercial hybrids that HRDC project VG 319 was proposed. It was clear that this would require extensive testing at the main commercial growing sites, close evaluation of cob and kernel quality and attention to seed production and marketing. For these reasons the project was developed as a joint effort involving Queensland Department of Primary Industries and Pacific Seeds . The former organisation had breeding and testing facilities and experience with the lead up research and the latter had breeding, testing and seed production capacity. This report documents progress made by VG 319 over its 2.5 years duration.

2. MATERIALS AND METHODS

The populations received from Hawaii were sweetcorn types (sugary 1 gene), not supersweet. It was necessary firstly to cross them with sources of the supersweet mutant genes **sh2** and **bt1.** Three generations of backcrossing with selection for germinability generated 4 tropical supersweet populations, namely the **shrunken 2** populations **KSH1** and **KSH2** and their **brittle 1** counterparts **KBT1** and **KBT2**. They became the base for our hybrid development work. Singlecross hybrid combinations were generated by crossing F5 inbreds from reciprocal populations. As well quicker maturing hybrids were generated by crossing elite tropical inbreds with temperate inbreds on the basis that tropical inbreds would supply dominant disease resistance and temperate material would contribute superior kernel and cob quality and perhaps some adaptation to the longer daylengths associated with southern environments. This work was undertaken by the Pacific Seeds breeding team led by Errol Corsan at Gatton.

2.1 Yield and quality initial screening trials

The first series consisting of some 27 shrunken-2 tropical hybrids was developed at Kairi in the winter of 1994 and tested by Graham Schull at Gatton in the summer of 94-95 and at Bowen by Ross Wright during the winter months of 1995. In addition a series of hybrids was generated at Pacific Seeds (Gatton) by crossing elite tropical inbreds with temperate inbreds (both yellow kernel and white). These hybrids were tested at Gatton in the autumn of 1995.

A second series of tropical hybrids was generated at Kairi in the winter of 1995 and proceeded to initial screening at Kairi and Gatton in the autumn of 1996. In most trials either 2 or 3 replicates were used. Data was collected on yield, percentage of marketable cobs, flavour, tenderness, cob shape and kernel colour.

2.2 Hybrid adaptation and proving trials

At Bundaberg Jeff Barnes planted a series of 6 trials at 2 monthly intervals commencing in September 1994. They served to establish the adaptation to sequential plantings of 5 commercial hybrids (including 2 emanating from VG319). During the 95-96 season, the trials were repeated but with an altered complement of 8 hybrids.

2.3 Disease and insect resistance

Resistance to Johnson Grass Mosaic Virus is of vital importance in late season (Autumn) planted crops, Denis Persley conducted a trial at Gatton to screen resistance of new hybrids and inbreds in the autumn of 1995.

A poll of team members from major growing areas was conducted to estimate the most important diseases in the respective regions.

At Bundaberg, the percentage of ear worm affected cobs for 5 commercial hybrids was recorded and analysed in a trial conducted by Jeff Barnes.

2.4 Population improvement and inbred development.

Given the primary objective of improving the eating quality of tropical supersweet germplasm it was decided to base selections of progenies for recombination within the populations on the quality performance of F5 (S4) inbreds in testcross combinations. Previously this criterion was not applied for the reciprocal recurrent selection procedure. This enabled greater emphasis to be placed on quality traits as they are measured in hybrids, the commercial entity genotype.

Likewise inbreds were fixed to the S4 generation before evaluation whereas previously we had found it difficult to get vigorous inbreds beyond the S3 generation presumably because of inbreeding depression.

These innovations had implications for uniformity of hybrids and for seed production. It is significant that recurrent selection was used. In most sweetcorn breeding programs, improved inbreds are generated from F1 hybrids.

3. RESULTS

3.1 Yield and quality screening trials

3.1.1 1994-95 season

Shrunken 2 hybrids

At Gatton , **H67** produced 15% more A Grade cobs than check hybrid **H5** and **H48** produced 22.7 tonnes per hectare of husked green corn compared with 19.9 tha^{-1} for H5. Some of the "tropical x temperate" hybrids were excellent for yield flavour and percentage of A grade cobs but they tended to have tough pericarps.

At Bowen the hybrids were rated on a 1-9 scale for flavour, tenderness, and cob appearance but yield was not measured. Hybrids **H44, H61** and **H67** achieved the best overall summed scores for the 3 quality criteria. **H44** was outstanding, having large, uniform cobs of good cylindrical shape with very deep kernels (10-12 mm) making it a candidate for processing because this trait is associated with high kernel recovery percentage. Flavour was acceptable but the pericarp was a little tough.

Brittle 1 hybrids

Eleven brittle hybrids were tested. As a group they tended to be somewhat tough and they displayed colour mottling on the kernels. However they generally had better cob shape and tip fill than their shrunken counterparts. Two hybrids, **BT8** and **BT28** were considered to warrant further testing.

Summary 94-95 yield and quality trials.

The conclusion from 1994-95 season testing was that H44 had definite potential for the sliced kernel and canning trades and that a group of 6 new hybrids warranted further testing. At this stage the voluntary contributor, Golden Circle Cannery saw potential in the use of H44 as a processing hybrid.

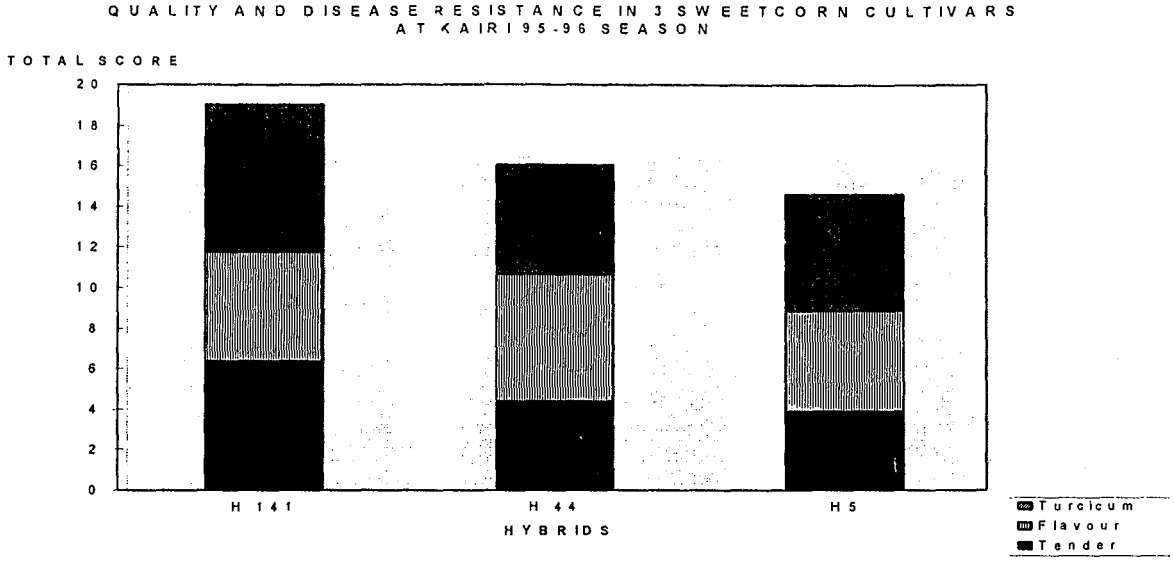
3.1.2 1995-96 season

During the spring of 1995, 91 new tropical hybrids were synthesised utilising 2 tester inbreds which had good resistance to JGMV. These were tested in replicated field trials at 2 sites, Gatton and Kairi, in the autumn of 1996. The best experimental hybrids from the previous cycle as well as commercial checks were included.

At **Kairi** the hybrids were rated for sweetness, tenderness, tip fill, kernel colour in the quality area, days to flowering and green leaf rating to give a guide to leaf disease resistance. At **Gatton** recordings were made for yield, percentage of marketable cobs, pericarp, flavour, texture, colour, sugar content, tip fill, rows per cob, kernel depth, days to maturity and flag leaf.

The interesting finding was a degree of pericarp tenderness not previously measured in our tropical material. It is exemplified by H141 in the Fig 1.

Figure 1. Comparison of supersweet corn hybrids for eating quality and disease resistance.



N.B. Scoring on a 1-9 scale with higher scores best.

This graph clearly shows the improvement for tenderness achieved with the experimental hybrid H141 and its markedly superior resistance to Turcicum Leaf Blight.

1995-96 Gatton trials

Pacific Seeds evaluated a large number of hybrids, both pure **tropical** and **tropical x temperate** types. Table 1displays some of the more interesting results to indicate the progress that has been made compared with original hybrid release H5.

Table 1. Yield and quality of supersweet hybrids at Gatton, Autumn 1996.

Hybrid	Type	Yield (t/ha)	% A/B Cobs	Tenderness (Penetrometer)	Sweetness (Brix %)	Kernel Depth(mm)	Maturity (days)
H 162	Tropical	26.6	100.0	1.20	17.5	11	90
61418	Trop x Temp	24.2	92.5	1.27	19.3	11	78
H 141	Tropical	22.1	92.5	0.80	16.7	10	86
H5	Tropical	24.0	87.5	1.20	17.8	12	91
Gladiator	Temperate	10.4	42.5	1.12	20.1	n.a.	76

The interesting features of this data are,

- the ability of hybrids of **tropical x temperate** hybrids (eg 61418) to yield as well as the highest yielding full tropical pedigrees (eg H162) while maturing markedly earlier and having higher sugar content.
- the breakthrough to tenderness in full **tropical** hybrids represented by H141 (Note the very low penetrometer reading which brings it into the range of the best temperate hybrids). (This data supports the bite test rating displayed in Table 1.)
- the emergence of H 162 as a very high yielding hybrid which may find application as a processing type cultivar.

1996 Bowen trial (Ross Wright)

Although this trial is outside the duration of the project , it represents the last in a series designed to evaluate a particular set of tropical hybrids. Twenty five tropical hybrids were tested. Yields were not measured as the objectives were mainly qualitative. Significant results are tabled below.

Table 2. Quality characteristics of supersweets at Bowen: 1996

HYBRID	FLAVOUR*	TENDERNESS*	COB APPEARANCE*	KERNEL COLOUR*
H 141	7.5	6.5	6.5	6.0
H 162	6.5	4.0	6.0	5.0
H 5	6.0	4.0	7.0	6.0
H 44	5.5	3.5	8.0	6.0
C.V. (%)	10.3	21.0	16.3	15.9
SIG DIFF (5%)	1.3	2.4	2.0	2.0

*All ratings on a 1-9 basis with 9 being best.

- Once again H 141 has demonstrated its superior tenderness
- H 44 has good cob shape (cylindrical) which makes it suitable for processing.
- H 162 is a high yielder (not shown here) but has kernel colour problems.

3.2 Adaptation trials at Bundaberg

The time of planting trials conducted by Jeff Barnes in 94-95 and 95-96 seasons showed that the tropical hybrids H5 and H44 were more able to maintain marketable yields in the late summer to autumn plantings (January to July) than temperate hybrids such as Challenger, Goldensweet and Krispy King but were slightly inferior in spring plantings (September). Goldensweet had the best recovery of A and B grade cobs. In this respect it was significantly better than the tropical hybrids. The tropicals had poor tip fill compared with Goldensweet.)

3.3 Insect and disease screening

3.3.1 Insect resistance (Bundaberg)

Helicoverpa (Heliothis) ear worms are the biggest insect problem facing sweetcorn growers. At Bowen some growers will not plant sweetcorn this year because of the severity of the problem. Genetic engineering of Bt constructs into sweetcorn is under way in an effort to combat the problem and other biological control methods are being tested. The variety aspect also deserves further examination. Observations by Jeff Barnes at Bundaberg suggest there are large differences amongst cultivars (Table 3).

Table 3. Percentage of Heliothis damaged cobs in supersweet hybrids at various planting times at Bundaberg 95-96 season.

HYBRID	SEPTEMBER	NOVEMBER	JANUARY
Staysweet	11.6	17.0	14.6
Punchline	89.6	23.0	40.6
H 5	17.7	0.7	76.8
Goldensweet	43.4	9.5	20.5

- Florida Staysweet is impressively consistent in resisting Heliothis.
- H 5 was expected to do well because it is a tropical and has good husk cover but it failed in the January planting.
- Punchline lacks good husk closure and is susceptible to attack through the ear tip

3.3.2 Disease resistance

Disease is a serious problem in supersweet corn where crops are planted in close time sequence because of the inoculum buildup factor. The main diseases are **Common rust, Turcicum leaf blight** and **Johnson grass mosaic virus.**

Turcicum leaf blight

The resistance of H141 as displayed in Figure 1 illustrates the type of progress we have been able to make with selection for blight resistance. The regular epidemics at Kairi Research Station make selection relatively straight forward and effective.

Johnson grass mosaic virus

Johnson Grass Mosaic resistance has been assessed in trials conducted by virologist Denis Persley at Gatton Research Station . We are fortunate in having a high frequency of resistance genes in the basic breeding populations. Table 4 shows the effectiveness of resistance in experimental hybrids .

Table 4. Infection levels of Johnson Grass Mosaic virus disease in supersweet hybrids at Gatton, 1995

HYBRID	TYPE	% JGMV INFECTED PLANTS
H5	Tropical	20
H13	Tropical	0
H48	Tropical	16
H51	Tropical	24
H57	Tropical	64
Krispy King	Temperate	98
Golden Sweet	Temperate	100
Jubilee	Temperate	100

Points to note.

- with the exception of H57, the tropical hybrids are clearly superior to temperates for resistance to JGMV
- there is variation for resistance within the tropical hybrids, but from Mendelian studies of resistant x susceptible crosses, we conclude that a single dominant gene for resistance supplies most of the resistance.
- a test of inbred lines showed even greater variability for percentage infected plants. There is an indication that level of vigour has a strong influence on the expression of resistance.

Common rust

This disease is of particular importance at Bundaberg. Jeff Barnes rated commercial hybrids in 95-96 (Table 5)

Table 5. Ratings for Common rust on supersweet cultivars at Bundaberg 1995-96

HYBRID	RUST RATING
H5	2
Punchline	3
Krispy king	5
Gladiator	1
Finale	5
Challenger	5
Staysweet	5
Goldensweet	1

NB: 1=NIL, 5=SEVERE

- the ratings for Gladiator and Goldensweet encourage one to think that effective plant resistance exists
- testing of major genes for resistance in major growing areas is now under way.

4. DISCUSSION

4.1 Adoption by industry.

During the term of VG319 we have released 2 hybrids, H5 and H44, to the industry and developed a third to the pre-release stage.. Because of the seed production and marketing ability of Pacific Seeds (a partner in this project), H5 has been quite widely used both domestically and in Thailand. In south Queensland its resistance to Johnson Grass Mosaic Virus has enabled growers to extend the growing season by some 2 months without the fear of losing crops to the virus. In addition H5 has extended the geographical growing area onto the Darling Downs. Its very high kernel recovery (in the order of 45%) makes it very popular with the canning industry (Golden Circle Pty) because it makes for lower freight costs to the cannery. It has also factored in a surety of supply for the cannery which it didn't have previously which must assist production and marketing planning. Further it presents well in the can as it does not produce a cloudy fluid like the sugary 1 (sweet) cultivars.

From a growers viewpoint it has better resistance than existing cultivars to some leaf diseases as well as virus resistance and it produces a higher yield than other commercial hybrids. From a fresh market viewpoint it has good husk cover which helps resist Heliothis ear worms and keeps the cob moist for longer shelf life. Its deficiencies are that it has a tougher pericarp than most cultivars; its cob shape is tapering with less than optimal tip fill and it is not adapted to higher latitudes. It is a good processing variety but lacks some of the eating and cosmetic traits which would make it a top fresh market hybrid.

H44 is an advance on H5 in that it is more uniform in cob shape and should enable more efficient use of the mechanical kernel slicers. It should also produce a more uniform kernel shape in the can. However it is similar in most other respects to H5.

4.2. Directions for future research.

Transfer of disease and insect resistance into temperate-adapted sweetcorn.

There is a need to introgress disease and insect resistance into temperate supersweet hybrids. Temperate hybrids generally have good sweetness and tenderness quality and adaptation to daylength conditions in subtropical and temperate Australia but they lack the ability to cope with the pathogens and insects in many Australian sweetcorn growing environments. Having established good levels of resistance to the important fungal and viral diseases there is now a need to transfer these resistances along with resistance to Helicoverpa, the principal insect pest of sweetcorn , to elite temperate germplasm using backcrossing as the method of transfer. This will open the way to expand the industry in the higher latitude regions of Australia. Some may dispute whether effective genetic resistance to Helicoverpa exists, but we cling to the hope that a combination of genetic resistance (not necessarily Bt constructs) and biological agents such as the virus that occurs naturally and affects Helicoverpa will produce a low incidence of ear worm infestation.

Improvement of eating quality in tropical sweetcorn cultivars

A case could be made for attempting to put sweetness and tenderness from temperate sources into tropical supersweet germplasm. However the hybrid H 141 shows that genetic variation for pericarp tenderness exists in the tropical populations. Continuing selection will increase the frequency of these tenderness allelles. The process could be accelerated by crossing to elite temperate material and selecting for cob and kernel quality then backcrossing to tropical populations.

Attractiveness of fresh market sweetcorn

For the fresh market we need to improve the cosmetic traits in tropical hybrids. A bright green husk colour with husks that stay fresh looking (don't desiccate) well into the marketing phase, and a modicum of attractive flag leaf are attributes which we see as vital to the successful expansion of the fresh corn market. Bright golden kernel colour is also very desirable. Our tropical hybrid H5 has excellent kernel colour but suffers with pale green husk colour and rapid drying out of the husk leaves. Other prominent temperate hybrids do not develop good golden kernel colour by harvest time but have attractive external appearance. Tip fill and husk greenness appear amenable to selection. Desirable flag leaf traits are at a low frequency and may require external sourcing.

Seed production and quality
Parental inbreds must have good disease resistance and yielding ability to enable efficient seed production. Through our efforts to infuse resistance genes into temperate hybrids we should be able to overcome this problem and make seed production of hybrids much more reliable and viable. These are important considerations.

White sweetcorn

There are conflicting opinions over whether white sweetcorn will appeal to the Australian consumer. Nevertheless it is very popular in the eastern states of USA both on the cob as pure white and as bicolours and in canned mixes with yellow kernels. This latter product makes an attractive component in salads.

4.3 Financial/ Commercial Benefits

Export sales of canned kernels from Golden Circle Cannery
A precise quantification of financial benefits accruing from the release of virus-resistant hybrid H5 is not possible because of data insufficiency but it was widely used for fresh and processing (Golden Circle Cannery) in the Gatton, Laidley and Darling Downs districts over the last 2 seasons . The general manager of Golden Circle Cannery was reported in the Australian Financial Review to the effect that H5 was very pleasing to the Asian palate. Anecdotal evidence is that the factory was unable to keep up with demand from Japan and that it is considered superior to any similar product from north America.

Expansion of production into new growing areas.
On the Darling Downs it made supersweet corn production economically feasible rescuing some farmers from bankruptcy. Estimating from domestic seed sales an area of 1,200 hectares with a value of $10,000 per hectare it is feasible to arrive at a value of $12 million dollars annually as income from the introduction of this hybrid. The imminent new release, H 141, a product of this project, will expand the market because of its superior tenderness and markedly better resistance to Turcicum leaf blight.

As well, Pacific Seeds have exported substantial quantities of seed of H5 into Thailand with success. This trade is likely to expand into other tropical Asian countries where quality supersweet hybrids tend to be lacking.