VG316

Etch resistance development in butternut pumpkin

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QLD Department of Primary Industries

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VG316

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SUMMARY

The project has allowed the development of butternut lines with a high degree of resistance to etch. This is in combination with other desirable agronomic characteristics, such as large fruit, good plant vigour, compact growth, and apparently some resistance to powdery mildew. This material compares very favourably with the latest developments in butternut breeding.

A small quantity of butternut seed, believed to contain a low percentage with genetic resistance to etch, was increased and selected over two generations of controlled pollination. Some of the families developed were evaluated for etch and virus resistance in field and glasshouse experiments. Several better families were increased and reselected. One was compared in a field experiment with material being developed by other agencies.

Further development of the material to incorporate virus resistance and refine the germplasm was deemed very desirable.

INTRODUCTION

Surface etch of butternut pumpkins has been identified by industry as a major problem (Plate 1).

The main objective of the project was to develop an etch resistant butternut variety for commercial production. Evidence of such resistance was at hand. Likely cultural and chemical control measures appeared impractical.

Surface etch is a common disease of butternut pumpkins (Curcurbita moschata).

Etch is associated with the soil born pathogens Fusarium roseum and Didymella bryonia. The condition appears to be worsened by rainfall and overhead sprinkler irrigation. The incidence of affected fruit varies, but is commonly in the order of 50%. Affected fruit are rendered unsaleable.

Pre and post harvest chemical treatments, curing, washing, and time of harvest have little effect on post harvest rots, including etch (Hawthorne, BT. "Effects of cultural practices on the incidence of storage rots in Curcurbita spp". New Zealand Journal of Crops and Horticultural Science, 1989, 17 (1), pp 49-54.).

The current official recommendation for the prevention/control of etch in butternut is to plant etch tolerant types (Persley, DM; O'Brien, R; and Syme, JR (ed). "Vegetable Crops, a disease management guide". Queensland Department of Primary Industries Information Series Q188019, 1989.).

There is no economical chemical or cultural control measure. Nor is it feasible to replace the butternut type with other pumpkin types which do not succumb to etch, as the value of butternut pumpkin consumption is greater than all other pumpkin types combined.

Genetic resistance to etch would negate the use of chemical control measures and improve the reliability and efficiency of production. In turn, the consumer could be assured of a continuity of attractive product at a lower and more stable price.

The chief investigator's evaluation of a number of QDPI butternut lines identified the presence of etch resistance [Loader,, LR. "Butternut pumpkin etch resistance evaluation". Mimeo, Queensland Department of Primary Industries, 1992]. This work quantified the incidence of etch and revealed the presence of the desirable characteristics such as high yield and good fruit quality. The genetic material evaluated was generated by Mr M Herrington in pursuit of another breeding programme. The details of these findings were reported internally and were fundamental to this project.

MATERIALS AND METHODS

The principle of controlled breeding, in conjunction with selection and scientific evaluation, is well accepted. The development of etch resistance in butternut involved controlled breeding within a population known to contain genetic resistance to etch, the scientific evaluation of this material in replicated trials and the advancement of the most desirable lines.

Year 1 (1993/94)

The small amount of foundation seed remaining from the preliminary evaluation was presoaked and planted in cells. Seedlings were transplanted on a 2m grid in a prepared field at Southedge Research Station.

Most female flowers were hand pollinated (approximately 2000) to produce self and known crosses within lines. Fruit was harvested individually. Pedigree, etch and appearance were recorded. Seed from selected fruits was extracted individually and cleaned by hand. The next generation consisted of fourteen plants, each of thirty-two families. Approximately 3000 controlled pollinations were recorded.

Again, fruit was harvested and recorded individually. Data was combined to provide information on each plant and to generate family means (Table 1). Again seed from selected fruits was extracted individually and cleaned by hand.

Year 2 (1994/95)

Field and glasshouse evaluation of selected families with sufficient seed was conducted. A lattice design with four replications of six plants was used for the field trials. A grid pattern of plots containing the susceptible commercial variety was incorporated to establish the site distribution of etch producing organisms.

Data was collected on an individual plant basis at Southedge, to determine the percentage of etch resistant plants, as well as plant yield, number of fruit, incidence of etch affected fruit and fruit shape. Plant agronomic characteristics were noted.

Data was analysed by a Biometrician at Mareeba using appropriate statistical software.

These experiments compared the generated butternut families with the popular Yates butternut large as control (Tables 2-7).

A glasshouse experiment at Maroochy determined the response of the same butternut lines to mechanical inoculation with the viruses PRSV-W and ZYM-K (Table 8)

Year 3 (1995/96)

Several of the better families identified in the field evaluations were chosen for isolated open pollinated increase with further selection. Each family was progressed over two generations.

An opportunity was grasped for an additional field experiment at Mutchilba (14 May - 16 Sep. '96). It compared one of the generated lines and a range of material being developed by S&G Seeds, a seed company, and Mr Dovesi, a commercial grower, with the commercial variety Yates large butternut. The trial comprised nine treatments, each of ten plants replicated three times. A grid pattern of susceptible plants was established to check the field distribution of etch.

RESULTS

Year 1 (1993/94)

Individual plant data is combined to provide family means in Table 1.

Table 1: Butternut Family Means for Yield per Plant, Percent Etched Fruit, Fruit Weight and Plants with Etched Fruit, Second Generation, Southedge Research Station 1994

Family Number	Yield per Plant (kg)	Etched Fruit (%)	Fruit Weight (kg)	Plants with Etch (%)
1	3.807	16.071	.952	29
2	6.033	56.897	1.248	67
3	5.718	27.397	1.097	36
4	5.107	8.642	.883	14
5	3.954	23.077	.852	29
6	4.946	11.111	1.021	8
7	5.679	32.099	.981	50
8	5.807	32.877	1.114	36
9	4.762	23.667	1.032	38
10	5.669	24.194	1.189	31
11	6.200	63.492	1.181	75
12	5.835	10.448	1.132	8
13	4.892	25.758	.964	36
14	4.977	18.182	.840	23
15	4.417	40.000	1.178	25
16	3.788	9.756	1.109	17
17	4.471	25.000	1.565	29
18	6.038	8.696	1.138	8
19	4.735	13.115	1.009	15
20	3.254	7.407	.884	7
21	4.146	50.877	1.018	64
22	4.171	30.769	1.123	43
24	1.558	6.667	.675	8
25	4.450	79.070	1.138	73
26	4.775	28.356	.916	57
27	5.942	65.079	1.226	85
28	5.210	68.293	1.271	90
29	6.892	86.207	1.426	100
30	5.975	61.250	1.046	71
31	6.061	30.851	.903	50
32	7.065	31.081	1.241	46

The incidence of etch infection was high on susceptible plants. Some families (27, 28 and 29) are fortuitous escapes from rejection in the first generation when disease infection was low. Other families (particularly 6, 12, 18, 20 and 24) now appear to have higher levels of resistance than the original lines. Families 6, 12 and 18 however, have better yields and fruit size than families 20 and 24. Seed from fruit of selected plants within the best families was extracted for evaluation and storage.

Year 2 (1994/95)

Two field trials, one each at Gatton and Southedge Research Stations compared the degree of etch resistance and yield parameters of ten butternut families as treatments with a popular commercial variety of large butternut as control.

Treatments were designated by the family number in the second generation (Table 1) with decimal places identifying the plant within the family which produced the fruit, while "⊗" represents hand pollinated selfing and "-" represents open pollination of the fruit producing the seed.

Table 2 illustrates the practical situation and reflects the combined effects of genetic variability between the families and the commercial variety in etch resistance, fruit size and number. All treatments had a similar or greater marketable yield than the commercial variety.

Table 2 Marketable yield (kg/ha) (Mature etch free fruit > 1kg).

SOUTHEDGE 1995			GATTON 1995		
TREATMENT	MARKETABLE YIELD (KG/HA)		TREATMENT	MARKETABLE YIELD (KG/HA)	
6.06 ⊗	4,765	a	21.01 ⊗	12,541	a
12.05 ⊗	4,468	a b	4.01 ⊗	10,850	a b
21.01 ⊗	4,300	a b c	6.06 ⊗	8,844	a b c
2.10 ⊗	3,483	a b c d	9.03 -	8,492	a b c d
18.02 ⊗	3,133	a b c d	3.11 -	7,545	a b c d e
26.12 ⊗	2,850	b c d	18.02 ⊗	6,076	b c d e
9.03 -	2,821	b c d	17.13 ⊗	5,865	b c d e
4.01 ⊗	2,611	c d e	12.05 ⊗	5,642	c d e
3.11 -	2,238	d e f	2.10 ⊗	4,879	c d e
17.13 ⊗	1,015	e f	26.12 ⊗	3,592	d e
Control	593	f	Control	3,174	e

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

At Southedge, where the incidence of etch was high, all treatments except the open pollinated 3.11- and 17.13⊗ which suffered badly from virus, had a greater marketable yield than the commercial variety at both sites. Treatments 21.01 ⊗, 4.01 ⊗, 6.06 ⊗, and 9.03 - had greater marketable yields than control at both sites despite the low incidence of etch at Gatton.
An etch resistant butternut pumpkin is the main objective of this project.

Table 3 Percentage of etched mature fruit (%)

SOUTHEDGE 1995 TREATMENT	ETCHED FRUIT (%)	GATTON 1995 TREATMENT	ETCHED FRUIT (%)
17.13 ⊗	0.0 a	18.02 ⊗	0.0 a
6.06 ⊗	2.5 a b	3.11 -	0.0 a
12.05 ⊗	11.3 a b	26.12 ⊗	0.0 a
26.12 ⊗	14.7 a b	12.05 ⊗	0.0 a
2.10 ⊗	14.8 a b c	2.10 ⊗	0.0 a
18.02 ⊗	22.1 a b c d	4.01 ⊗	1.7 a
21.01 ⊗	27.0 b c d	9.03 -	2.3 a
9.03 -	39.0 c d	6.06 ⊗	2.5 a
4.01 ⊗	43.8 d	21.01 ⊗	4.8 a b
3.11 -	46.4 d	17.13 ⊗	13.3 b c
Control	73.7 e	Control	18.3 c

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

All treatments, except 17.13 ⊗ at Gatton, had less etch than the commercial variety at both sites.

At Southedge the relatively high percentage of etched fruit in the treatments which were open pollinated in the second generation demonstrates less rapid progress than with hand pollination.

Potential yield of the generated butternut families appears at least as good as the commercial variety.

Table 4: Total Yield of Fruit (kg/ha)

SOUTHEDGE 1995

Treatment	Total Yield (kg)
12.05 ⊗	10021 a
6.06 ⊗	9090 a b
21.01 ⊗	7340 b c
9.03 -	7003 b c
3.11 -	6455 c
4.01 ⊗	6385 c
Control	6161 c
26.12 ⊗	6119 c
2.01 ⊗	5925 c
18.02 ⊗	5172 c
17.13 ⊗	2148 d

GATTON 1995

Treatment	Total Yield (kg)
21.01 ⊗	17341 a
6.06 ⊗	17115 a
26.12 ⊗	17102 a
9.03 -	17007 a
12.05 ⊗	16322 a
4.01 ⊗	15513 a
18.02 ⊗	14581 a
17.13 ⊗	14039 a
3.11 -	13715 a
Control	11736 a
2.10 ⊗	8591 a

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

Total yield of fruit was low at both sites due to unfavourable weather conditions and low populations due to plant spatial arrangement. Despite a considerable range in yield significant differences were few, with two treatments (12.05⊗ and 6.06⊗) being better than control at Southedge. Treatment 17.13⊗ was badly affected by mosaic at Southedge and had a lower yield at that site.

Treatments generally produced a similar number of fruit per ha to control.

Table 5: Average Number of Mature Fruit per ha

SOUTHEDGE 1995

Treatment	Fruit Number/ha				
12.05 ⊗	9792	a			
6.06 ⊗	8333	a	b		
26.12 ⊗	6250		b	c	
9.03 -	6250		b	c	
Control	6250		b	c	
3.11 -	6042		b	c	
2.10 ⊗	5833		b	c	
21.01 ⊗	5611			c	
4.01 ⊗	5417			c	
18.02 ⊗	4583			c	d
17.13 ⊗	2083				d

GATTON 1995

Treatment	Fruit Number/ha			
9.03 -	15000	a		
12.05 ⊗	11875	a	b	
26.12 ⊗	11667	a	b	
21.01 ⊗	11090	a	b	
Control	9583		b	c
3.11 -	9167		b	c
6.06 ⊗	8958		b	c
18.02 ⊗	7917		b	c
4.01	7708		b	c
2.10 ⊗	7292		b	c
17.13 ⊗	6458			c

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

At Southedge 12.05⊗ and 6.06⊗ produced more than control and 17.13⊗ less due to mosaic. At Gatton 9.03- provided more fruit than control.

Fruit size is important as larger fruit is preferred on the market place, while smaller fruit is often lost to the field.

Table 6: Average Mature Fruit Weight (kg)

SOUTHEDGE 1995

Treatment	Fruit Weight (kg)	
21.01 ⊗	1.254	a
4.01 ⊗	1.208	a
18.02 ⊗	1.117	a
9.03 -	1.100	a
3.11 -	1.087	a
2.10 ⊗	1.048	a
6.06 ⊗	1.027	a
Control	.989	a
17.13 ⊗	.989	a
26.12 ⊗	.985	a
12.05 ⊗	.984	a

GATTON 1995

Treatment	Fruit Number/ha						
4.01 ⊗	1.586	a					
21.01 ⊗	1.397	a	b				
17.13 ⊗	1.202		b	c			
6.06 ⊗	1.175			c			
3.11 -	1.154			c	d		
18.02 ⊗	1.088			c	d	e	
2.10 ⊗	1.008			c	d	e	f
9.03 -	1.006			c	d	e	f
12.05 ⊗	.958				d	e	f
Control	.915					e	f
26.12 ⊗	.850						f

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

Average mature fruit weight of treatments was at least similar to control at both sites with 4.01⊗, 21.01⊗, 17.13⊗, 6.06⊗, 3.11- and 18.02⊗ being heavier than the commercial variety at the Gatton site.

To be readily accepted commercially a new etch resistant butternut variety will need to be similar in appearance to the current commercial varieties with an increase in size and length being preferable.

Table 7: Average Rating of Mature Fruit Shape (1-5)

SOUTHEDGE 1995

Treatment	Shape Rating (0-5)			
2.10 ⊗	3.212	a		
9.03 -	3.012	a		
26.12 ⊗	2.952	a		
3.11 -	2.771	a		
21.01 ⊗	2.308		b	
12.05 ⊗	2.264		b	
6.06 ⊗	2.103		b	
Control	2.027		b	
4.01 ⊗	2.000		b	
18.02 ⊗	1.958		b	
17.13 ⊗	1.521			c

GATTON 1995

Treatment	Shape Rating (0-5)				
2.10 ⊗	3.668	a			
3.11 -	3.380	a	b		
9.03 -	3.347	a	b		
26.12 ⊗	3.132		b		
12.05 ⊗	2.285			c	
4.01 ⊗	2.227			c	d
6.06 ⊗	2.174			c	d
Control	2.118			c	d
21.01 ⊗	1.981			c	d
18.02 ⊗	1.897			c	d
17.13 ⊗	1.846				d

Treatments at each site with a letter in common do not differ when tested at the 5% level of confidence.

Despite variability within families, Table 7 illustrates the average shape of fruit of treatments compared to control.

All treatments had a fruit shape fairly typical of butternut, however 2.10⊗, 9.03⊗, 26.12⊗ and 3.11- had a more elongated shape than the commercial variety.

The glasshouse trial conducted at Maroochy to evaluate resistance to mosaic revealed that the level of resistance to mosaic in the population was variable, but generally low.

Table 8: Response of Butternut Germplasm Three Weeks After Mechanical Inoculation of Cotyledons with PRSV-W or ZYM-K as Percentage of Leaf Area Chloric

1728-41 is bulk open pollinated seed of F_1 (1748) grown amongst lines 1728-41 in field. Line 1749 is self pollinated seed of a virus resistant selection from Nigeria. Line 1721AOP is open pollinate seed of virus tolerant small butternut. Line 1748 (F_1) is Butternut X Nigerian.

Line	PRSV-W	ZYMV
F21-01	92.8	95.0
Butternut (094)	83.8	93.9
F09-03	77.8	76.7
F26-12	77.2	76.7
1748 (F_1)	77.0	0.4
F03-11	72.2	60.0
F04-01*	68.9	47.8
F10-09	65.5	70.6
F06-06	63.3	48.3
F12-05	63.3	45.6
F18-02	62.2	75.0
F04-01	61.1	31.7
1728-41 (bulk open pollinated F_1 1748)	60.6	11.8
1721AOP	56.7	56.1
F02-10	54.4	65.0
F17-13	49.4	90.6
Nigerian 1749	1.0	0.4
lsd (P=0.05)	13.5	16.6

Most lines showed some tolerance to PRSV-W and ZYMV as suspected, but higher levels of resistance were confirmed in the resistant Nigerian 1749 and a hybrid (1749-41) with this line. While this line is not suitable commercially it should be a useful parent in backcrossing, which has commenced.

Table 9: Yield and Etch Characteristics of Nine Butternut Pumpkin Lines Planted at Dovesi's in 1996

Variety	Marketable yield (kg) per plant		Total yield (kg) per plant		Total number of fruit per plant	Average fruit weight (kg) - based on all fruit	Proportion of etched fruit (%) - based on all fruit
Dovesi F1	9.95 a	(76.5)	11.95 a	(92.0)	4.00 b	3.00 a	0.8 a
Selected Y	7.43 b	(57.2)	9.07 b	(69.8)	3.90 b	2.36 b	5.3 ab
Selected L	6.76 bc	(52.0)	8.66 b	(66.6)	3.70 b	2.35 b	8.6 b
DPI F6.06	5.41 cd	(41.6)	6.03 c	(46.4)	4.60 ab	1.31 d	5.2 ab
Dovesi F2	5.23 cd	(40.3)	6.77 cd	(52.1)	3.60 b	1.90 c	2.4 a
Parent Y	4.25 de	(32.7)	4.97 d	(38.2)	1.80 c	2.69 ab	0.0 a
SG PN 172	3.53 e	(27.2)	4.54 d	(34.9)	4.10 b	1.11 d	2.5 a
SG PN 171	3.52 e	(27.1)	4.74 d	(36.5)	4.50 ab	1.05 d	8.9 b
Butternut	2.88 e	(22.2)	4.92 d	(37.8)	5.20 a	0.94 d	10.2 b
LSD (5%)	1.63		1.61		.98	0.42	5.7

Number in parentheses are equivalent means in t/ha. Means within a column not followed by a common letter are significantly different (P<0.05).

The F1 hybrid (Plate 4) had the highest marketable yield. It produced fewer fruit than commercial butternut but had a heavier fruit weight (3 kg) than all other entries except one parent. The F1 hybrid appears to be resistant to etch, as is one parent, being statistically similar to the commercial seed company S&G Seeds line PN172, the consortiums newly developed butternut family F 6.06, the F2 population and the line selection Y.

The butternut family F 6.06 (Plate 3) had a higher marketable yield than commercial butternut and both lines being developed by S&G Seeds. Statistically it had a similar number of fruit of similar weight. However, the heavier fruit weight of F 6.06 is a great practical advantage. No difference was measured in etch resistance between F 6.06 and other entries.

Commercial butternut (Plate 2) had the lowest marketable yield, being similar to the two seed companies lines PN 171 and PN 172, and parent Y. Commercial butternut however had the largest number of fruit per plant, although was similar to PN 171 and F 6.06. Although butternut had the smallest fruit, it was not statistically different from other typical butternut lines. Commercial butternut had the highest proportion of etched fruit but was not detectably different from PN 171, F 6.06 or selection Y.

S&G Seeds PN 172 (Plate 5) had fewer fruit and a degree of resistance to etch.PN171 was not measurably different from commercial butternut.

A comparison of latest developments in butternut breeding.
(Field trial, Mutchilba, 17/9/96).

Plate 2. Control, Yates butternut large

Plate 3. Consortiums F6.06

Plate 4. Dovesis F1 hybrid butternut

Plate 5. S & G seeds PN172

DISCUSSION

(i) **Results.** The effort of approximately 5,000 controlled pollinations with documentation in the first two generations coupled with heavy selection pressure set the foundation for a fruitful project.

Seed of selected fruit from selected plants within the families, whose means appear in Table 1, was evaluated in district trials. Field conditions have influenced the incidence of etch and adversely affected yield parameters at both sites. The Gatton site was conducted under drought conditions and received irrigation for establishment and only one watering during the growth of the crop. At Southedge, transplanting of seedlings to the field was delayed due to excessively wet conditions. Ample good quality water at Southedge enabled the encouragement of etch producing organisms necessary for identifying resistance to etch in the generated butternut families.

Despite variability within families, field evaluations in year 2 confirmed resistance to etch in the generated families. These experiments also show similar or superior yield and fruit characteristics to commercial butternut reflecting considerable advancement in just one year and two generations of controlled pollination and selection. Some late set fruit exhibited a symptom described as stem adhesion. This was thought to be associated with virus infection but testing for virus proved negative.

The need for, and desire to improve butternut pumpkin size, disease resistance and uniformity is reflected in the efforts of commercial seed companies and private growers attempts to produce improved varieties.

The F1 hybrid observed in the field experiment in 1996 was impressive (Table 9, Plate 4). It was ribbed and much larger than typical butternut which may restrict its acceptance in the butternut market. It appears to have resistance to etch as does one parent. It resulted from professional advise provided by the project chief investigator as part of his advisory roll. The grower had attempted to select within generations subsequent to an accidentally created F1 hybrid. The F2 and selections in this trial demonstrated the immense variability and the futility of selection within open pollinated generations of segregating hetrozygons germplasm.

Of the typical butternut types, the consortiums F6.06 performed best overall (Table 9, Plate 3). The low incidence of etch at this site was disappointing however the grid of susceptible checks indicated uniform if low pressure from the organism. The lack of measurable difference between F6.06 and commercial butternut is probably a reflection of low disease pressure and variability within entries in the trial and is different from earlier field experiments (Table 3). Larger fruit size of F 6.06 contributed to a greater proportion of saleable fruit. This is of great practical importance as small fruit is different to sell even at much reduced price. Good plant vigour combined with compact growth and apparently some resistance to powdery mildew are additional characteristics of practical value.

Expansion of the project to screen families for virus resistance in 1995, as a desirable additional selection criteria, identified only low levels of resistance in most lines. As the Department has a good source of resistance to virus, a backcrossing program to incorporate virus resistance was deemed more suitable than selection within the population as a means of developing a butternut variety with resistance to both etch and virus.

(ii) **Extension/Adoption.** Because of the demand for the product developed by this project the extension effort required for its acceptance will be small.

Progress was reported biannually to the funding bodies, industry leaders and QDPI. Growers were kept informed through industry consultative meetings, district FVG meetings, field days, a radio interview and two Horticulture Expos.

Growers viewing the material have commented very favourably.

Reports prepared for funding bodies have not been published in their annual research reports however listing of the project in these reports has resulted in inquiries, some from private seed companies.

A successful outcome will be reported in the publication QFV News. QDPI advisory leaflets such as "Farm Note" would recommend to growers the planting of etch resistant butternut seed as a method of etch prevention.

A technical article for publication in "Australasian Plant Pathology" is also planned.

(iii) **Future research.** Development of a butternut variety with resistance to both etch and mosaic was considered very desirable.

The DPI has a good source of resistance to both PRSV-W & ZYMV in Nigerian 1749 (Table 8). Backcrossing the families with etch resistance developed in this project with Nigerian 1749 and reselecting for both etch and virus resistance while retaining desirable agronomic characteristics and fruit quality will provide industry with a much sought after product, a butternut variety with resistance to both etch and mosiac.

A research project proposal to this end has been prepared and is supported by industry. This project is recommended.

The backcrossing program has commenced.

(iv) **Financial and Commercial benefits.** Queensland pumpkin growers would be the main beneficiaries through savings in growing cost and increased reliability of production. Consumers would benefit by having improved continuity of attractive product at modest prices.

Etch has been a major and long time problem in butternut pumpkin production. Butternut pumpkins receive strong and increasing demand unlike most other pumpkin types. In the absence of effective and economical control of etch, butternut production will remain an inefficient and unreliable enterprise.

Genetic resistance to etch is an economical, convenient and environmentally responsible means of preventing a major problem in an important industry.

Increased production and consumption are likely to accrue. Current production could be achieved more reliably from a fraction of the present production area with proportional savings on fuel, fertiliser, chemicals and water, and some savings in time and labour cost. Growing costs are approximately $1,855/ha. At a fruit infection rate of 50%, current production could be achieved on one half the area thus savings $927/ha in growing costs. Queensland currently grows approximately 860 ha of butternut pumpkins annually. The savings in growing costs would be approximately $800,000 annually.

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