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Breeding fresh market tomatoes for machine harvest

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Queensland Horticulture Institute

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FINAL REPORT

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BREEDING FRESH MARKET TOMATOES FOR MACHINE HARVEST

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The purpose of this report is to discuss the progress in the development of breeding lines during the life of the project.

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Media summary

- Fresh market tomato production is an intensive operation that requires a high labour input, particularly at harvest. If crops could be harvested by machine, labour input would be reduced and production costs lowered.

- HAL, QFVG, QDPI and SP Exports are partners in this breeding project that aims to develop tomato cultivars suited to machine harvest. A suitable cultivar would have a compact, multiple branched bush habit with concentrated fruit maturity.

- At the end of the project, we have produced 420 breeding lines at various stages of development. The most recent lines require further inbreeding and selection.

- Apart from bush type, we have placed a great deal of emphasis in breeding for multiple disease resistance and root-knot nematode resistance to reduce growers' dependence on chemicals.

- We have also concentrated on improving fruit quality by introducing the gene for crimson internal fruit colour. This attribute will have a huge impact in improving market appeal of fresh market tomatoes.

- While we currently don't have any lines at the commercialisation stage, the lines that have been developed offer a solid foundation on which to develop improved cultivars to satisfy the outcomes of any future project.

- It is important that this project be refunded to take the breeding lines to their final stages. This would then allow us to seek expressions of interest from international seed companies for the commercialisation of the lines.

- We would require the successful seed company to use the lines as parents for commercial F1 hybrid production. We also expect that the seed company will target not only the Australian industry but also the global fresh market tomato industry.

Technical summary

This project was initiated as a result of a request from SP Exports Pty Ltd to develop fresh market tomato cultivars suitable for once-over machine harvest. As the development of tomato cultivars for this purpose had received little attention in the past, a breeding program was commenced. The aim was to develop compact multiple branched bushes with concentrated fruit maturity.

Fresh market tomato production is an intensive operation that requires a high labour input, particularly at harvest. The ability to machine harvest crops would reduce labour input, reduce production costs and allow growers to remain viable.

Once suitable germplasm had been introduced from international collections, a number of genetically heterogenous gene pools were set up. These were allowed to self pollinate and used for selection over a number of generations for the improvement of target traits. At the end of the project, 420 lines ranging from F10 to BC1F2 generations have been developed.

A wide range of bush types has been developed. Bush types range from dwarf to compact multiple branched bushes to medium and large bushes. Many of the lines are root-knot nematode resistant and Fusarium wilt race 3 resistance (*Got*-2 isozyme locus) has been introgressed into the most recent breeding lines. Lines developed from Campbell 28 have good leaf disease resistance, an important issue for the Bundaberg district where foliage can stay wet for long periods during the day after nights when heavy dews fall. A high emphasis was placed on multiple disease resistance in order to reduce dependence on chemicals.

Crimson internal colour has also been introgressed into the most recent breeding lines. This attribute will have a huge impact in improving the market appeal of fresh market tomatoes.

This was a breeding program with a completely new focus and, as such, it has not been possible to develop tomato cultivars to satisfy the required outcomes of the project. However, the lines that have been developed offer a solid foundation on which to develop improved cultivars to satisfy the outcomes of any future project.

As many of the lines are now close to inbred status, it is recommended that major emphasis be placed on producing F1 hybrids to test the combining ability of the parental lines. The most recent selections will need to be taken through further selfing and selection programs to bring them closer to inbred status.

If this project receives new funding, it is also recommended that in the first 12 months expressions of interest be sought from seed companies with international exposure to set up a commercialisation strategy for the use of the inbreds for commercial F1 hybrid production.

Introduction

Cost and availability of labour are major factors in the continuing viability of fresh market tomato production. Tomato production is an intensive operation that requires a high labour input, particularly at harvest. The ability to machine harvest fresh market tomato crops would alleviate this need for a readily available labour force at harvest. This aspect of tomato breeding has received little attention in the past.

Machine harvesting requires a once-over destructive harvest as opposed to the multiple harvest system that is currently used. Current commercial tomato cultivars are not suited to the once-over harvest system. The requirement will be for ground grown bush type cultivars with a concentrated fruit maturation period.

Machine harvesting has been achieved in the processing tomato industry. However, the situation in the processing industry is different to the fresh market tomato industry. In the processing tomato industry the earlier maturing fruit are held (stored) on the bush to allow the later maturing fruit to catch up. A high percentage of the crop can then be harvested at the one time. This can't be done for fresh market tomatoes as the early maturing fruit would be overripe if the same procedure was adopted. For once-over harvest of fresh market tomatoes, the fruit maturation pattern needs to be more concentrated than in the processing tomato industry. It is believed that a radical breeding approach will need to be taken to achieve the desired outcome of fresh market tomato cultivars suited for a once-over machine harvest operation.

The University of Florida had a machine harvest breeding program in the 1970's that resulted in the release of Florida MH-1, the first machine harvest fresh market tomato cultivar. However, crop maturity of Florida MH-1 was found to be not concentrated enough for machine harvest. The program was discontinued. The University of North Carolina currently has a breeding program to produce multiple branched bushes that should produce a uniformly mature crop. However, this material is not being made available to public breeders.

Following a request from the management of SP Exports Pty Ltd to undertake this project, a search for fresh market tomato cultivars suited to machine harvest was commenced. As no suitable cultivars were found, a breeding program was started. The aim was to develop either:

1. Small bush type cultivars that would be grown at high plant populations – each bush producing a small number of fruit, or

2. Compact bush type cultivars grown at normal plant populations – each bush producing a large number of fruit and having a concentrated fruit maturity pattern.

Materials and Methods

The first task in this project was to search worldwide for suitable fresh market tomato cultivars. Seed was obtained from global seed companies and national and international tomato plant breeders. An experimental plot of 79 tomato lines was grown as a ground crop at Bundaberg Research Station. None of the tomato lines were suitable for immediate commercial use.

However, 3 lines obtained from Dr Jay Scott of the University of Florida viz. Florida Petite, Florida Lanai and Florida Basket were of interest for use as parental lines in the breeding program. They are all dwarf, determinate bush types suited for pot and hanging basket culture. Florida Petite and Florida Lanai are upright growing. Florida Basket has a prostrate growth habit. All have short internodes and the bushes have a multiple branching bush habit. This latter trait would be useful in developing bush types suited to once-over machine harvest. Fruit size in all 3 lines is small – between 2 and 3.5 cm diameter.

During the life of the project, inbreds from all populations were genetically recombined to create new breeding cycles with a variety of bush types, improved fruit size, disease resistances, root-knot nematode resistance, 'rin' long shelf-life and good internal fruit colour.

Spring 1996 Crossing Program

The initial crosses were made during the Spring 1996 season and involved the 3 Florida lines mentioned above crossed with inbreds from previous local breeding programs and that carry root-knot nematode resistance, Fusarium wilt race 3 resistance (Delta Tristar source) and rin (non-ripening mutant) in different inbreds. The F1 hybrids were planted out during the Autumn 1997 season and F2 seed selected in order to develop over succeeding generations a number of populations with a range of bush types, fruit sizes and other desirable traits.

Spring 1997 Crossing Program

Eighteen Spring 1996 F1 hybrids were backcrossed to a range of inbreds to produce BC1F1 populations for selection over succeeding generations.

Spring 1998 Crossing Program

To improve the small fruit size of some of the otherwise promising lines that have come through the selection process, a crossing program of F4 and BC1F3 populations was carried out. Forty crosses were made and these were planted out in the Autumn 1999 season. Seed was selected for further inbreeding and selection in succeeding generations.

Autumn 1999 Crossing Program

Twenty advanced project developed breeding lines (F5, BC1F3 and BC1F4 generations) were crossed with 4 project developed breeding lines (F5, BC1F4 and BC2F3 generations) as well as 6 inbreds collected from Dr Jay Scott of the University of Florida during a visit to the United States. Of the introduced inbreds, Florida 7481 and Florida 7547 were resistant to Fusarium wilt race 3 and had crimson internal colour. Crimson internal colour is controlled by a recessive gene and produces a tomato fruit with very attractive red internal colour. The dominant gene for Fusarium wilt race 3 resistance is linked to the *Got*-2 isozyme. The resistance seems to be stronger than that from the Delta Tristar source. This resistant gene from Delta Tristar is not linked to the *Got*-2 isozyme. Campbell 28 which was also introduced is quite concentrated in fruit set and is the source of heat tolerance used in Florida tomato breeding programs. It has tolerance to 2 races (1 and 3) and probably all 3 races (1, 2 and 3) of bacterial spot, an important leaf disease. The F1 hybrids were planted out in the Spring 1999 season and F2 seed collected. The selected populations were allowed to inbreed for selection in succeeding generations.

A 300 plant F2 population of Tracer (an F1 hybrid ex Asgrow) was planted out. Tracer is a jointed, Fusarium wilt race 3 resistant 'rin' hybrid. The Fusarium wilt resistance comes from Florida 7547 that also carries the crimson gene. This population was allowed to inbreed and selections made for 'rin' parental material carrying genes for both Fusarium wilt race 3 resistance and crimson internal colour.

Autumn 2000 Crossing Program

Twelve advanced project developed breeding lines (F7, BC1F4 and BC1F5 generations) were crossed with 8 project developed advanced breeding lines (F4, F7, BC1F4, BC1F5 and BC1F6 generations) as well as 14 inbreds from previous breeding programs. The aim was to combine root-knot nematode resistance with the 'rin' ripening inhibitor gene. The F1 hybrids were planted out in the Spring 2000 season and F2 seed collected for further inbreeding and selection in succeeding generations.

Spring 2000 Crossing Program

Eight F1 hybrids developed from project developed advanced breeding lines crossed to Florida 7481 and Florida 7547 carrying genes for both Fusarium wilt race 3 resistance and crimson internal colour were backcrossed to the same 2 Florida lines to increase the number of populations carrying the 2 traits. Fifteen project developed advanced breeding lines (F4, F8 and BC1F6 generations) and 1 inbred were crossed with 18 project developed advanced breeding lines (F4, F8 and BC1F6 generations) as well as 5 inbreds. This was to give a further range of populations carrying genes for root-knot nematode resistance, Fusarium wilt race 3 resistance and crimson internal colour. The F1 hybrids and BC1F1 populations were planted out in the Autumn 2001 season and F2 and BC1F2 seed collected for further inbreeding and selection in succeeding generations.

Spring 2001 Crossing Program

As in the Spring 2000 crossing program, a further 6 F1 hybrids developed from project developed advanced breeding lines crossed to Florida 7481 and Florida 7547 were backcrossed to the same 2 Florida lines to further increase the number of populations carrying genes for Fusarium wilt race 3 resistance and crimson internal colour. Seven project developed advanced breeding lines (F4, F5 and F6 generations) were crossed to 8 project developed advanced breeding lines (F4, F5 and F6 generations) as well as 2 inbreds. This was also to increase the range of populations carrying the genes for root-knot nematode resistance, Fusarium wilt race 3 resistance and crimson internal colour together with the highly concentrated fruit set characteristic. The F1 hybrids and BC1F1 populations were planted out in the Autumn 2002 season and F2 and BC1F2 seed collected for further inbreeding and selection in succeeding generations.

Autumn 2002 Crossing Program

Fifteen project developed advanced breeding lines (F5, F6, F7 and BC1F3 generations) and 3 inbreds were crossed to 9 project developed advanced breeding lines (F3, F4, F5 and F6 generations). Twenty-one backcross populations were also produced. This was to continue the development of populations carrying root-knot nematode resistance, Fusarium wilt race 3 resistance, crimson internal colour and 'rin' ripening inhibitor genes in a range of bush types from dwarf to compact multiple branched bushes. The F1 hybrids and resultant segregating populations will be planted out for further inbreeding and selection if a new project proposal is successful.

Visit to the United States

This 3 week visit was made during October – November 1998 with the aim to:

1. Undertake isozyme electrophoresis training and to study tomato seedling inoculation techniques for resistance testing to root-knot nematode and Fusarium wilt race 3 with Dr Bob Heisey at Asgrow seed company's plant breeding laboratory at San Juan Bautista, California and
2. To study the fresh market tomato breeding program of Dr Jay Scott at the University of Florida. Bradenton and to collect tomato germplasm for incorporation into the machine harvest tomato breeding program at Bundaberg Research Station.

Results

A number of genetically heterogenous gene pools were set up during the life of this project. These were allowed to self pollinate and used for selection over a number of generations for the improvement of target traits. Each series of crosses has reached different stages in the breeding cycle. Some selections are fixed or homozygous while others are still segregating. The result of each series of crosses is given below.

Spring 1996 Crossing Program

Thirty-three F1 hybrids were developed with dwarf determinate bush types viz. Florida Petite, Florida Lanai and Florida Basket used mainly as the pollen parents. The female parents were inbreds which had semi-determinate bushes and required trellising for best results. The resultant F1 hybrids produced highly concentrated fruit maturity with fruit size being intermediate between the parental fruit sizes. However, the fruit were not of a commercial size. This result gave us confidence to pursue the development of dwarf bush types with near commercial fruit size. This material would have potential as pollen parents in crosses with semi-determinate bush types to produce F1 hybrids to satisfy the goals of the project i.e. cultivars with a highly concentrated fruit maturity pattern.

Four F10 inbreds have been selected from these original crosses – 3 have multiple branched medium sized bushes with concentrated fruit set and 1 dwarf bush type with medium sized fruit. One line is root-knot nematode resistant. Some of the lines have been used in further breeding cycles.

Spring 1997 Crossing Program

This backcross program has resulted in 16 BC1F8 lines with a range of bush types from dwarf to multiple branched medium sized bushes. All have a highly concentrated fruit set. However, fruit size is still down being in the range from small-medium to medium. Four lines are root-knot nematode resistant and 3 are 'rin' inbreds. Some of the lines have been used in further breeding cycles.

Spring 1998 Crossing Program

Nine F8 lines have been advanced from this program, 5 being dwarf types and 4 are medium sized multiple branched bushes. Fruit size of all lines is in the medium-large to large range. All of these lines are nematode susceptible. A range of F1 hybrids was developed using these lines as parents. They will be evaluated if a new project is approved. Inbreds from these crosses should result in good hybrid parental material that could be commercialised in partnership with international seed companies.

Autumn 1999 Crossing Program

Fifteen F7 lines and 52 F6 lines have been advanced from this program. Both root-knot nematode resistance and crimson internal colour are important traits that have been introgressed into these advanced lines. Twenty-three lines have root-knot nematode resistance and 14 are fixed for crimson internal colour. Some of the parents used had the *Got-2* isozyme linked Fusarium wilt race 3 resistance gene. The lines are yet to be screened for this resistance.

A wide range of bush types is represented in these lines – from dwarf bushes to compact medium sized multiple branched bushes to medium large bush types. The majority of the lines have a concentrated fruit maturity pattern. Fruit size ranges from medium to large sized fruit.

In the final year of the project, a number of these lines were used to develop experimental F1 hybrids. The hybrids have not yet been field tested.

Of the 8 F7 'rin' inbreds selected from Tracer for the presence of the crimson internal colour gene, 3 were crimson, 2 were not while we could not decide on the final 3. They are still to be screened for Fusarium wilt race 3 resistance. More work will need to be done to determine the crimson status of these lines.

Autumn 2000 Crossing Program

Thirty F5 lines have been advanced from this program. Five of the lines carry the 'rin' long shelf life gene and were developed using a 'gourmet' fruit style parental line.

Spring 2000 Crossing Program

Seventy-two BC1F4 populations have been advanced from this program. Forty-nine of these populations are fixed for the crimson internal colour gene. A major goal of this series was to introgress Fusarium wilt race 3 resistance into the populations. Resistance testing is still to be done but it is expected that of the majority of the populations will carry the resistance.

One hundred and six F4 populations are also being advanced. These population were developed to increase the levels of root-knot nematode resistance, Fusarium wilt race 3 resistance and crimson internal colour.

The whole range of bush types is represented in the Spring 2000 crossing series. Bush types vary from dwarf types to small compact bush types to medium sized bush types to large bush types. Fruit size is mainly in the medium large to large range.

Spring 2001 Crossing Program

One hundred and eight BC1F2 populations have been advanced from 12 BC1F1 populations. All of the populations are carrying the Fusarium wilt race 3 resistance gene either in the homozygous or heterozygous state. The populations are also still segregating for the crimson internal colour gene as well as for bush type. Fruit size is mostly in the medium large to large range.

Sixty-five experimental F1 hybrids developed from project developed advanced breeding lines were also produced.

Autumn 2002 Crossing Program

Forty-nine F2 populations were selected from the 65 experimental Spring 2001 F1 hybrids. These will be planted out for selection and inbreeding in a future project. A number of the experimental hybrids showed sufficient promise to be confident that progeny will be available for commercial release in the near future once the material from the later breeding series has reached inbred status.

Ninety-two experimental F1 hybrids from the latest developed advanced breeding lines were produced as well as 21 backcross populations. Further work on this material will be done in any future project.

Result Summary of Breeding Cycles

At the end of the project, 420 lines ranging from F10 to BC1F2 generations have been developed. The break-up of the lines is as follows:

F10	4 lines
BC1F8	16
F8	9
F7	23
F6	52
F5	30
BC1F4	72
F4	106
BC1F2	108

Visit to the United States

<u>California</u>

During my 2 week stay at the Asgrow seed company's plant breeding laboratory at San Juan Bautista, California the following procedures for disease screening of tomato seedlings were studied and carried out:

1. *Aps*-1 isozyme electrophoresis test for root-knot nematode resistance.
2. *Got*-2 isozyme electrophoresis test for Fusarium wilt race 3 resistance.

3. Root-knot nematode (*Meloidogyne incognita*) live test screening.
4. Fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*) races 1, 2 and 3 live test screening.

Electrophoresis tests included preparation of buffers and extraction solutions, sample preparation and running and reading tests. Live tests included inoculum preparation, inoculating seedlings, planting and reading tests. Comparisons were made between live tests and isozyme electrophoresis tests.

Seed from my breeding populations was sent to USA prior to my leaving Australia so that they could be included in the testing program. Lines were found that were either resistant, segregating or susceptible to root-knot nematode indicating that I had been successful in transferring root-knot resistance into some of my breeding populations. A number of my lines developed from the Australian source of Fusarium wilt race 3 resistance had shown resistance to this disease in screening done at Bowen Research Station. However, they did not survive the Asgrow testing procedure whereas the American source of resistance did. There is a difference in the 2 sources in that plants developed from the Australian source did not contain the *Got*-2 isozyme locus. Further investigation into these differences should be carried out.

Florida

I attended the Vegetable Section of the 111th Annual Meeting of the Florida State Horticultural Society at St Petersburg on November 2-3 1998.

The theme of many of the presentations of this section was the use of alternatives to traditional fertilisers and pesticides. The term "bio-rational farm management system" was used in one of the presentations. Presentations were given on IPM and use of soil amendments to build up soil microflora to combat soil borne diseases and as alternatives to inorganic fertilisers. Overall, the quality of the presentations and their content was poor and extremely disappointing. The papers were published in the "Proceedings of the Florida State Horticultural Society".

I visited with Dr Jay Scott, tomato plant breeder, inspected and assisted in rating his tomato Gemini virus breeding plots. Dr Scott appeared to be making good progress in developing resistance to Gemini viruses. In conjunction with a Ph.D. student, he was developing molecular markers to determine Gemini virus resistant germplasm and breeding lines.

Another major tomato disease in Florida is bacterial spot. There are 3 races of bacterial spot. Races 1 (resistance source Hawaii 7998) and 3 (resistance source Hawaii 7981) are found in Florida. Race 2 is prevalent in temperate climates. Campbell 28 has probable tolerance to all 3 races. Campbell 28 is the source of heat tolerance used in Florida breeding programs. Dr Scott has developed good combined resistance to races 1 and 3. However, at the time of my visit, fruit size in his breeding lines was small.

The breeding program for fresh market machine harvest varieties is based in Homestead (S.E. Florida). Unfortunately, I was unable to visit the research centre because of tropical storm "Mitch" (the hurricane that devastated Nicaragua and Guatemala). For ethical reasons, Dr Scott was unable to provide seed of Dr Randy Gardner's brachytic lines. Despite a number of attempts, I have been unable to establish contact with Dr Gardiner. However, I have been able to obtain suitable germplasm from Dr Scott.

Germplasm collected in both Florida and California is as follows:

Breeding Line	Source	Special Characteristics
La716	University of Florida	Fusarium race 3 resistance
Fla. MH-1	University of Florida	Machine harvest
Horizon	University of Florida	Small bush
Campbell 28	University of Florida	Heat tolerance, concentrated harvest
Ohio 89-1	University of Florida	Crimson gene
Suncoast	University of Florida	Large fruit
Fla. 7481	University of Florida	Fusarium race 3 resistance, crimson
Fla. 7547	University of Florida	Fusarium race 3 resistance, crimson
Micro-Tom	University of Florida	Small bush
Micro-Gold	University of Florida	Small bush
Floragold Basket	University of Florida	Small bush
Equinox	University of Florida	F1 hybrid – heat tolerant
Solar Set	Asgrow	F1 hybrid – heat tolerant
Tracer	Asgrow	F1 hybrid – Fusarium 3 resistant
Tracer	Asgrow	F2 seed
Ex 12286	Asgrow	F1 hybrid – Fusarium 3 resistant
Geneva 80	Asgrow	Source plant – nematode inoculum

Discussion

In the 5 years that the project has been running, it has not been possible to develop tomato cultivars to satisfy the required outcomes of the project. Because the development of tomato cultivars for machine harvest had received little attention in the past, it was necessary to start a completely new breeding program with a new aspect to consider. We first searched tomato germplasm banks for material that could be used to start the breeding program.

An important attribute of tomato cultivars suitable for machine harvest is to have a very concentrated fruit maturation period. We believed that this could be achieved by either:

1. Small bush type cultivars that would be grown at high plant populations with each bush producing a small number of fruit, or
2. Compact bush type multiple branched cultivars grown at normal plant populations with each bush producing a large number of fruit and having a concentrated fruit maturity pattern.

Considering that the policy of seed companies in order to protect their germplasm is to release only F1 hybrids for commercial use, and considering that the cost of F1 hybrid seed is escalating, the first option of small bush types grown at high plant populations would prove too costly for growers. The second option is the more likely to succeed.

We found that when we first crossed the small bush types with larger bush types, the spread of fruit maturity in the F1 hybrid was quite concentrated. For this reason, we have continued to develop small bush types and to increase their fruit size. We believe that these small bush types could be used as pollen parents to develop F1 hybrid cultivars for commercial use.

Multiple branched bush habit was also considered to be a necessary attribute for a successful commercial tomato cultivar. We were unable to obtain germplasm from Dr Randy Gardner of the University of North Carolina who is developing tomato cultivars with this trait. However, some of the small bush types from the University of Florida had this trait and were used in the initial crosses.

The procedure that we adopted for this project was modelled on discussions early in my career with Professor Raphael Frankel during a visit to Bundaberg. Professor Frankel was head of the genetics department at the Volcani Centre, Israel. He was leading a project to develop machine harvesting of fresh market tomatoes for the Israeli tomato industry. His advice was that in developing any breeding program, it was important to have numerous inbreds with different ranges of traits at your disposal. This allows the breeder to change direction quickly to meet industry requirements without having long lag times.

Unfortunately, when we commenced this project, we did not have the luxury of having large numbers of inbreds. Therefore, the first stage of this project has been to increase the number of inbreds and breeding lines at our disposal. These inbreds and breeding lines have different combinations of the desirable traits. At the end of this project, 420 lines ranging from F10 to BC1F2 generations have been developed. The break-up of the lines has been given previously in the **Results** section.

While this is a large number of lines to be carrying through the breeding cycles, the break-up shows that more than half of the lines are still in the early selection stages and are still segregating for the desired attributes. Many of these lines will be eliminated as the process continues. However, given that there is limited suitable germplasm available on the world scene, we believed that it was necessary to develop large numbers of lines to produce a successful outcome for the project.

The most advanced breeding lines display a range of bush habits from dwarf bush types to multiple branched bush types with a high concentration of fruit maturity. However, fruit size is too small for commercial use. These early breeding lines have now been crossed a number of times with larger fruited material. Most of the more recent breeding lines have fruit ranging from medium to large size.

Overall, the lines which we have developed during the course of this project show a wide range of bush habits from dwarf bush types to compact multiple branched bush types to medium sized and also large sized bush types. Many of the lines are root-knot nematode resistant and Fusarium wilt race 3 resistance (*Got*-2 isozyme locus) has been introgressed into the most recent breeding lines. Lines developed from Campbell 28 have good leaf disease resistance, an important issue for the Bundaberg district where foliage can stay wet for long periods during the day after nights when heavy dews fall. A number of the lines are fixed for the 'rin' long shelf life gene.

Many of the recent breeding lines are now fixed for crimson internal colour. This characteristic is controlled by a single recessive gene and imparts a very appealing internal colour to the tomato fruit. It is believed that this attribute will have a huge impact in improving the market appeal of fresh market tomatoes. Being a recessive gene, both parents for F1 hybrid production will need to carry this gene.

These lines which we have developed during the life of this project now offer a solid foundation on which to develop improved tomato cultivars to satisfy the outcomes of any future project.

Technology Transfer

1. Farm walk at Bundaberg Research Station for local growers and industry officials to view advanced breeding lines.

2. Annual meeting of Australian tomato breeders at Bundaberg. Field trip to breeding plot to see progress of project. Also attended by management personnel of HAL and QDPI and a Victorian tomato grower.

3.Regular inspections of breeding plots with SP Exports staff to discuss progress in the project.

4. Milestone reports to HAL were sent by the due date.

5. Regular progress reports have been uploaded into PROMIS – a computer based system. Reports are available to scientists throughout Australia.

Recommendations

Because of the nature of the project and the fact that very little breeding work had been done previously either in Australia or overseas on this subject, it has not been possible in such a short time, from the point of view of breeding programs, that a satisfactory outcome for the release of new tomato cultivars could be achieved.

However, the lines that have been developed during the life of this project now offer a solid foundation on which to develop improved tomato cultivars to satisfy the outcomes of any future project.

It is, therefore, recommended that the project be continued for a further funding period of 3 years.

As many of the breeding lines are close to achieving inbred status, it is recommended that in any new project a major emphasis be placed on F1 hybrid development in order to characterise the combining ability of the respective parental lines.

If this project is continued, it is recommended that in the first 12 months expressions of interest be sought from seed companies with exposure to the global tomato industry to set up a commercialisation strategy for the use of the inbreds for commercial F1 hybrid production.

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