RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

# Condiment Paprika:
## *Breeding, Harvesting & Commercialisation*

**A report for the Rural Industries Research and Development Corporation**

by *Adjunct Professor N.F. DERERA, AM, FAIAST, CPAg*

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# Foreword

The recent increased need for natural spices and colourants expanded the demand for high quality condiment paprika worldwide. Hungary has produced the high quality condiment paprika required in the past, however, exports have declined significantly over the last 10 years. This is the result of contamination caused by air pollution and bad publicity because of some Hungarian companies were selling adulterated paprika. The Hungarians were exporting virtually no condiment paprika to their traditional customers Czechoslovakia, Japan and Germany by 1994. The Hungarian research organisations tried to restore the reputation of their product by producing the famous paprika cultivars in overseas countries such as Israel, South Africa and now in Australia

ASAS Pty. Limited successfully negotiated with the Hungarian Vegetable Crop Research Institute Ltd. to obtain the rights to be the sole licensee of their famous condiment paprika cultivars for the South Pacific region. With the help of the Hungarian cultivars and other genetic material it is hoped to establish a viable condiment paprika industry in Australia.

To achieve these aims an application was made to RIRDC for a grant to assist this program. The reasoning for this grant was 'to introduce and further develop genetic material of condiment paprika to produce cultivars with high initial pigment (> 200 ASTA) and dry matter content suitable for direct seeding and mechanical harvesting. To develop a commercially viable integrated production, harvesting and processing system for identified markets by 2002.' In this Project ASAS Pty Ltd was in cooperation with industrial/commercial partners, The University of Sydney, Plant Breeding Institute- Cobbitty and the Hungarian Condiment Paprika Research-Development Ltd.

This report concentrates on the plant-breeding program that has the major aim to develop cultivars suitable for mechanised production particularly to machine harvesting.

This project was funded from RIRDC Core Funds which are provided by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our New Plant Products R&D sub-program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
- purchases at www.rirdc.gov.au/eshop

**Peter Core**
Managing Director
Rural Industries Research and Development Corporation

## Acknowledgments

Special appreciation is due to Mr Graham Blight, Whitton, NSW, who to great expense to himself, proved that condiment paprika could be grown agronomically successfully in this country.


## About the Author

Professor Nicholas F. DERERA, AM, FAIAST, CPAg arrived with his wife and son in Australia as refugees after the Hungarian uprising, on 19th September 1957. He was process worker, then laboratory assistant in 1957/58. From the end of 1958 till 1961 he was Research Agronomist with the NSW Department of Agriculture. During this period N F Derera had a crucial role in the establishment of the cotton growing industry by proving the suitability of the land, selecting the varieties and inviting American cotton growers to lay the foundations of the cotton industry. In 1957/58 Australia was importing £52,000,000 worth of cotton while recently cotton export is well over one billion dollars. He also discovered and described a hitherto undescribed wild cotton species in the Nandewar ranges, which was named *Gossypium nandewarense* Derera.

In 1961 N F Derera, or Nick Derera as he was known by the farmers, joined The University of Sydney as a Plant Breeder at The North West Wheat Research Institute, Narrabri, later renamed I.A. Watson, Plant Breeding Institute. Here he was Plant Breeder, Senior Plant Breeder and Officer-in-Charge of the Institute. In 1973 he was appointed Director of Wheat Breeding of the University's Plant Breeding Institute and retired in mid 1981. His research results between 1961-1981 included: Breeder and co-breeder of 11 new prime hard wheat cultivars namely Mendos, Gamut, Gamset, Timgalen, Gatcher, Songlen, Shortim, Timson, Sunkota, Suneca and Sunstar. Developed breeding methodologies such as Mechanical Mass Selection system, verification of the advantage of the "Limited Selection" system. Invented screening techniques for drought resistance, flag smut resistance, micro quality tests and sprouting damage resistance. Studied the role of awns and roots, particularly their importance regarding drought tolerance of the wheat plant. Conducted intensive research into the problem of preharvest sprouting damage, consequently it became possible to breed white wheat tolerant to preharvest sprouting damage. Nick Derera established an international cooperation concerning preharvest sprouting research and because of this a series of International Symposia on Preharvest Sprouting in Cereals are in progress. He is a life member of the International Organising Committee of these symposia. Nick Derera is also author/editor of a book published in the USA titled "Preharvest Field Sprouting in Cereals"(1989). He is author and co-author of 88 scientific, semi-popular and major conference papers.

Since retirement established "ASAS" Agricultural Science Advisory Service (ASAS Pty. Ltd.)and in his consultant capacity has a major involvement in the Australian Native Ornamental Plant Improvement program. Resulting from this work, five new Geraldton Wax cultivars are either granted or in progress for Plant Variety Right registration, namely Niribri, Cascade Mist, Cascade Jewel, Cascade Brook and Crystal. In 1998 released three dwarf chilli cultivars, Bantam, Orange Bantam and Thimble. Two of the Cascades were granted USA patents. He is still involved in this program. More recently Nick Derera was invited by The University of Sydney to cooperate with the Department of Crop Science and the University's Plant Breeding Institute to partake in the supervision of postgraduate students and to help in the establishment of horticultural plant breeding programs, particularly paprika breeding in relation to the introduction of the Hungarian condiment paprika production to Australia. In October 1998 he was appointed Adjunct Professor as recognition of his present research and teaching work.

Nick Derera received the following peer recognitions and awards: Fellow of the Australian Institute of Agricultural Science ( 1977) for outstanding contribution to the Agr. Science; Certificate of Appreciation for Services to the Community from the RSL **(**1979)**.** NSW Branch; Farrer Memorial Medal (1981) for achievements in plant breeding; bronze plaque and citation from colleagues in Canada ( 1982) in recognition of research on preharvest sprouting damage in cereals; Rotary Award for Vocational Excellence (1983) for contribution to the wheat and cotton industries. He was appointed as a Member of the Order of Australia (1994) in the Queen's Birthday List.

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# Executive Summary

The market for high quality condiment paprika for the spice and cosmetic industry is rapidly increasing worldwide. Historically, Hungary has produced the high quality condiment paprika required, however, exports have declined significantly over the last 10 years. This is partly the result of heavy metal contamination caused by air pollution and bad publicity because of some Hungarian companies selling adulterated paprika. At the end of 1994 the Hungarian authorities had to destroy approximately 25,000 tons of adulterated paprika. Exports decreased significantly, with the Hungarians exporting virtually no condiment paprika to their traditional customers Czechoslovakia, Japan and Germany by 1994. The Hungarian research organisations tried to restore the reputation of their product by producing the famous paprika cultivars in overseas countries such as Israel, South Africa and now in Australia. ASAS Pty. Limited successfully negotiated with the Hungarian Vegetable Crop Research Institute Ltd. to obtain the rights to be the sole licensee of their famous condiment paprika cultivars for the South Pacific region. With the help of the Hungarian cultivars and other genetic material we hope to establish a viable condiment paprika industry in Australia.

During 1995-96 the total paprika products imported into Australia were valued at $5.3 million ( ABS. Custom Traffic Codes 0904. 20. 00. 16, - 17, - 18, - 19). If we consider the Australian, European, North American, Japanese and South East Asian consumption then we can conservatively estimate these markets at 19,000 t $y^{-1}$ which is a potential market of $55 million. To exploit this opportunity it requires the development of elite adapted varieties and integrated production, harvesting and processing systems.

Capsaicin and oleoresin extracted from condiment paprika for pharmacology and the cosmetic industry must also be considered. Due to the restricted use of artificial colouring agents allowed in cosmetics and canning industries, demand for the resin is increasing rapidly. Demand for the milled paprika product has grown by 42% in the last five years. We estimate the current growth is 20% per annum.

This rapid increase in Australian imports reflects current global demand. European condiment paprika marketing experts estimated 20% growth in condiment paprika consumption in Europe and Asia.

It is interesting to study the world condiment paprika trends. Table I. shows condiment paprika production data of selected countries. These data are based on recent FAO reports and it is suspected that both in China and North America the hot chilli production is included as well. However, if we look at the traditional condiment paprika producing countries we can observe that Morocco, South Africa, Israel, Slovenia and Spain have relatively constant production. Hungary tried to adjust its production to the spice industry's requirements. Zimbabwe focused its paprika production for oleoresin extraction. All their products were exported to Spain and Germany mainly for oleoresin (pigment) extraction and as it can be seen on this table their production has increased year by year according to the market requirements. Unfortunately the recent political developments in Zimbabwe are greatly hindering and they might significantly reduce their paprika production and export.(R. Hemlyn pers. com.)

**TABLE** I.

*Paprika Production (Mt )* ©FAO

| Country | 1997 | 1998 | 1999 |
|---|---|---|---|
| Morocco | 12,000 | 12,000 | 12,000 |
| South Africa | 11,000 | 10,000 | 9,500 |
| Zimbabwe | 10,000 | 22,000 | 23,000 |
| China | 200,000 | 200,000 | 200,000 |
| Israel | 2,600 | 2,600 | 2,600 |
| Hungary | 45,323 | 65,000 | 48,000 |
| Slovenia | 6,100 | 6,100 | 6,100 |
| Spain | 6,000 | 6,000 | 6,000 |
| North America | 56,000 | 50,000 | 50,000 |

Late in 1994 I was privately informed by a wheat breeder colleague of some problems of condiment paprika production in Hungary due to the air pollution and adulteration as explained earlier. My immediate response was to produce the Hungarian Condiment Paprika here in Australia in cooperation with the appropriate Hungarian organisations. Dr Norbert Somogyi contacted me, a research scientist attached to the Hungarian Vegetable Crop Research Institute, Condiment Paprika Research Unit (later Paprika Unit) in Szeged, Hungary. He and his superiors liked the idea and after exchanging many faxes and letters the possibility of a close cooperation was suggested.

On 28th March, 1996, The Hungarian Vegetable Crop Research Institute, Condiment Paprika Unit, authorised me to be their sole representative in Australia and in the South-Pacific region.

The Hungarians provided me with seed of their most popular varieties. These varieties were included in a small-scale variety trial at The University Sydney, Plant Breeding Institute, Cobbitty. This trial, my earlier experiments and the practical experience of many market gardeners demonstrated that *Capsicum*s of Hungarian origin could be successfully grown in this country. The Hungarian condiment paprika varieties are performing satisfactorily even at Cobbitty in spite of the fact that the site is not ideal for paprika production.

It was clear that condiment paprika could not be grown in Australia with the same crop husbandry practice as in Hungary and many other paprika producing countries where the hand labour is relatively cheap. It was decided that a research program should be initiated to find out the best crop husbandry practices and develop cultivars that are suited for mechanised production systems. To achieve these aims an application was made to RIRDC for a grant to assist this program. The reasoning for this grant was to introduce and further develop genetic material of condiment paprika to produce cultivars with high initial pigment (> 200 ASTA) and dry matter content suitable for direct seeding and mechanical harvesting. To develop a commercially viable integrated production, harvesting and processing system for identified markets by 2002. In this Project ASAS Pty Ltd was in cooperation with industrial/commercial partners, The University of Sydney, Plant Breeding Institute- Cobbitty and the Hungarian Condiment Paprika Research-Development Ltd. A three-year research grant was approved. The plant breeding part of the program is proceeding well as will be explained further on. Nevertheless, the commercial production and mechanisation part had major setbacks. It may be said that it was difficult to decide which is needed first. Should the production be established at first then buy the machinery or the reverse. Our industrial partner tried to grow paprika without having specialised harvester and drying facility. After two years they decided that low yield, harvesting by hand and using batch driers are uneconomical and therefore they discontinued their cooperation with us. During the 1999/2000 season on Mr. Graham Blight's property at Whitton two hectares of Szegedi 80 paprika cultivar was successfully direct sown and had a stand of approximately 220,000 plants per hectare. With the help of the NSW Department of Agriculture they identified a pre-emergence weedicide (Devanol®) that can be successfully used with direct seeded paprika. Mr. Blight also found that in the case of direct seeding only furrow or drip-irrigation can be used because overhead watering on clayey loams can be detrimental on emergence. I estimated the yield at 22 tonnes per hectare. Unfortunately due to lack of availability of specialised machinery it was hand-harvested and because of the high labour costs only approx. 10 tonnes were harvested. The drying was done by a tomato batch-drier, which also proved to be very expensive. It was established that agronomically paprika can be grown on a large scale, however, without full mechanisation including specialised driers it is uneconomical. A specialised harvester costs approx. USD130,000.00 and a mobile drier is about the same. Including the machinery, drier and improved research equipment half a million dollars initial investment is needed.

In opposition to the commercial production attempts the plant improvement program progressed according to plan. Thirteen Hungarian condiment paprika cultivars were reselected in 1997. 102 selections were grown at Cobbitty in 1997/98 and 24 outstanding progenies were sown in variety and strain trials on two sites at Merriwa and Cobbitty. The Merriwa trial averaged a converted plot yield of 23.4 t/h while the Cobbitty trial's mean yield was 26.1 t/h. The pigment test at Merriwa averaged 143.7 ASTA and at Cobbitty 204 ASTA. Both the yield and the pigment tests indicate the lower nutrient status and weed competition of the Merriwa site.

Our aim is mechanical harvesting and therefore it is extremely important to have a synchronised ripening. From practical point of view the large portion of the yield should be available at first harvest. In this regard the standard Szegedi 80's performance was acceptable while a selection of Kalocsai 801.2 was the best, 92.5% of the total yield came off with the first harvest (Table b). It was decided in agreement with the Hungarian colleagues that the four outstanding lines be sown for seed increase, to be subjected to further tests during the 2000/2001 season and the best line to be submitted for registration for Plant Variety Protection. It must be noted that a number of our selections have reasonably high pigment (ASTA) content (Table II)

**Table II.**
**Proportion of Yield at First Harvest**

| Cultivars | Origin | % |
|---|---|---|
| Papri Mild | USA | 58.1 |
| Conquistador | USA | 50.0 |
| K.801.2 | PBI | **92.5** |
| K.801.8 | PBI | 71.0 |
| Sz.80 | Hung. | 80.6 |
| K.121 | Hung. | 80.3 |
| K.57-231 | Hung. | 79.0 |
| Sz.20 | Hung. | 74.9 |
| K.50 | Hung. | 72 |
| SzNFD | Hung | 65.2 |

**Table III.**
**Pigment (ASTA) Levels of Selected Cultivars**

| Cultivars | ASTA |
|---|---|
| Papri Mild | 155 |
| Conquistador | 130 |
| K.801.8 | 195 |
| K.801.2 | 185 |
| K.50 | 187 |
| Sz.20 | 180 |
| K.121 | 205 |
| K.57-231 | 210 |
| Sz.80 | 238 |
| SzNFD | 320 |

One of the main aims of our plant improvement work is to develop cultivar or cultivars suitable for mechanised production particularly for mechanised harvesting. We identified the gene in a wild species, *Capsicum chacoense*, which allows the fruit to be detached from the calyx at full maturity, however, in this species the fruit is soft at this stage. Earlier it was believed that the same gene causes both the detachability and the fruit softening at ripening. We successfully separated the detachability from the softening gene. We have now several early generation lines in our backcrossing program where the detachability is combined with the condiment paprika characteristics.

It is important both from hand or machine harvesting point of view that the pedicel should easily snap off the stem. We identified a trait, which allows the very easy separation of the pedicel. We have several $F_4$ condiment paprika lines having the 'snap off' trait.

To be able to produce hybrid seed in a reasonable price bracket we designed a system where the identification of genetic male-sterility in seedling stage is needed and the male-sterile plants are to be propagated with the help of micropropagation. Male sterile plants together with the pollen source are planted out in the field where the fertilisation will take place with the help of bees.

It must be pointed out, that besides import replacement and export possibilities of paprika products we see a number of new avenues that may outweigh the previously mentioned commercial prospects. These are:

- The hybrid seed production scheme that is under investigation is patentable. This will also include a protocol of commercial micropropagation of capsicum and a possible hybrid seed export.
- Both of the genes of detachability from the calyx and 'snap off' trait of pedicel may be patented. Nevertheless, the protected cultivars possessing these genes will open up a seed export.
- We should not neglect that besides the commercial values a great deal of scientific progress will be made serving other crops as well.

Most of the Australian investors look at condiment paprika only as a source of spice. The Zimbabwe farmers realised that the spice is only a side product of the condiment paprika industry the main application is coming from pigment extraction to be used in the cosmetic and food industries.

Some of our companies looking at the potential of the paprika industry examined only the milled spice side of the trade and found it too small considering it solely as an import replacement. Some other representatives of the local spice business stated that India rules the oleoresin industry and we do not have a chance to compete with them. I am quoting from AIC Market Briefs regarding paprika oleoresins dated 3rd August 2000 when they state: "However, the Indian product (paprika oleoresin) is generally regarded as too hot for optimal use as a colorant" If I go further and quote from the Kancor Crop Updates dated 21st July 2000: "Oleoresin Paprika. Indian sources of raw material have almost dried up except for limited availability of cold storage stock. Zimbabwe situation continues to be uncertain. The world supply situation continues to be firm and more buyers are chasing the limited supplies. Oleoresin availability is extremely limited and prices are moving up in response to the raw material situation - this situation is expected to continue"

Further on I may quote a few $s and cents figures: Under our environment and with reasonable crop husbandry we can produce 25 t/ha of raw paprika. Minimum 1/6th of the produce will be milled product and that equals 4166 kg. The store value of this is after milling**:** AUD24,996.00 (@ $6/kg). In general it is estimated that 10 - 14 kg of dried paprika is needed to produce 1 kg of paprika oleoresin depending on the pigment content of the raw material. If we take the average that is 12kg than from the 25 t/ha produce we obtain 347.00 kg oleoresin which has a value of AUD34,022.66 (@ $98/kg) Using the petrochemical (Hexane) extraction method the cost of processing is fairly low cc. $1.50/ kg of the extract.

Mr. Graham Blight did some test marketing as fresh produce on the Melbourne and Sydney markets. He found, particularly in Melbourne, that the public was glad to buy these new 'sweet chillies'.

We found out with every introduced crop eg. wheat, cotton etc. that the introduced cultivars in their original forms do nor perform as well as the locally improved cultivars at a later stage. This syndrome is quite obvious in the case of condiment paprika. For this reason a further plant improvement program is a must. Up-to-date we are extremely grateful to RIRDC for providing us with a research grant during the past three years. We reapplied for further support and further two years has been approved. Unfortunately we received approx half of the monies we applied for. This reduction of research monies means that we have to cut back drastically our research program. The paprika story is very similar to the cotton. The local farmers except one were afraid at the beginning of the cotton growing in NSW. The cotton industry really started when on my encouragement two American cotton farmers moved to the Namoi Valley. Maybe our solution is to encourage a few Zimbabwe paprika farmers to come here.(Derera, 2000)

# 1. Introduction

## 1.1 The Genus *Capsicum*

### 1.1.1 The Name

The condiment paprika is a variant of *Capsicum.* The name of *Capsicum* more likely is coming from the Greek *Kapto***,** which means 'to bite' referring to the pungency of heat of the fruit. The word paprika originates from the Greek or Latin *peperi*-*piper* that means pepper however the word has a Sanskrit origin (Balint 1962). For quite a long while in Europe there was confusion regarding the differentiation between pepper and paprika. The names used all over the world are as follows (Somos 1985, Balint 1962, Becker-Dillinger 1956, Szucs 1975):

German: Spanishe Pepper, Paprika
Spanish: Pimiento
Portugese: Pimento, Pimentao
French: Piment, Poivre
Vallon (Belgian): Piment
English (USA): Red Pepper and recently Paprika and Capsicum is also used
Holland: Peper, Spaansche Pepper, recently Paprika and Capsicum as well
Norvegian: Pepper
Swedish: Spansk Pepper
Danish: Spansk Peber
Italian: Pepperone, Pepperone comune, pepper cornuto
Russian: Perec
Polish: Papryka, pieprz
Czech: Paprika
Bulgarian: Piper
Serbian: Paprika
Romanian: Piparca, ardei
Finnish: Pippuri
Estonian: Pipar
Latvian: Pipari
Turkish: Biber
Armenian: Bibar
Arabic: Filfil, felfel
In Peru: Aji
In Mexico: Chili
In the Indian languages: Kechuan: Uchu
Aimara: Huayha
Atakameno: Sicku
Araukan: Thapi

The widely used word 'chili' is referring usually to the hot variant of capsicum. This word has its origin from the Aztec word of chil. "Bell pepper " or "Bell capsicum" usually means the bell shaped, blocky and non-pungent capsicum types. The condiment or spice paprika refers to the type of capsicum, which when fully ripe, dried and milled is used as spice and colouring agent in cooking. The same paprika type is used for oleoresin (pigment) extraction for use in the food and cosmetic industries (Caselton 1998).

### 1.1.2 Botanical Classification

The botanical name of condiment paprika is *Capsicum annuum* covar. *longum* The genus C*apsicum* belongs to the *Solenaceae* (nightshade) family that includes also *Solanum, Lycopersicon, Jaltomata, Cyphomandra, Cuatresia, Athenaia, Witheringia, Larnax, Capsicum, Physalis, Vassobia, Exodeconus, Dunalia, Acnistus, Saracha, Iochroma* and *Deprea* genera. (Hunziker 1979). To demonstrate the evolution of the *Capsicum* genus see the following:

Division: *Anthophyta*
Class: *Magnoliopsida*
Subclass: *Asteridae*
Order: *Sonales*
Family: *Solenaceae*
Genus: *Capsicum*
Species: *annuum.*

In this program not only the *longum* types are used but quite a number of other capsicum species are involved in the plant breeding program eg. *Capsicum annuum* var. *annuum* , *C. baccatum* var. *baccatum*, *C. baccatum* var. *pendulum, C. chinense, C. frutescens, C. pubescens, C. chacoense, C. tovarii, C. cardenasii* and *C. eximium*. The latter five are wild species having useful traits to improve condiment paprika.

## 1.2 Production Trends of Paprika

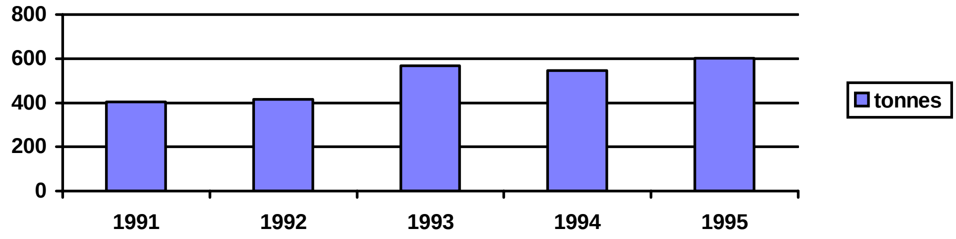
It is interesting to study the world condiment paprika trends. Table 1 shows condiment paprika production data of selected countries. These data are based on recent FAO reports (Appendix 5.1) and it is suspected that in China, India and North America the hot chilli production is included as well. However, if we look at the traditional condiment paprika producing countries we can observe that Morocco, South Africa, Israel, Slovenia and Spain have relatively constant production. Hungary tried to adjust its production to the spice industry's requirements. Zimbabwe focused its paprika production for oleoresin extraction. All their products were exported to Spain and Germany mainly for oleoresin (pigment) extraction. As it can be seen on Table 5. their production has increased year by year as the market demanded it. Unfortunately the recent political developments in Zimbabwe are greatly hindering and might significantly reduce the paprika production and export from this country (R. Hemlyn pers. com.)

**Table 1 Paprika World Production (Mt ) ©FAO**

| Country | 1997 | 1998 | 1999 |
|---|---|---|---|
| Morocco | 12,000 | 12,000 | 12,000 |
| South Africa | 11,000 | 10,000 | 9,500 |
| Zimbabwe | 10,000 | 22,000 | 23,000 |
| China | 200,000 | 200,000 | 200,000 |
| Israel | 2,600 | 2,600 | 2,600 |
| Hungary | 45,323 | 65,000 | 48,000 |
| Slovenia | 6,100 | 6,100 | 6,100 |
| Spain | 6,000 | 6,000 | 6,000 |
| North America | 56,000 | 50,000 | 50,000 |

Australia imported paprika products worth AUD5.3 M in 1995/96 this includes 625 t of milled condiment paprika. Demand for the milled paprika product has grown by 42% in the five years between 1991-1995. We estimate the current growth is 20% per annum (Fig.1.).

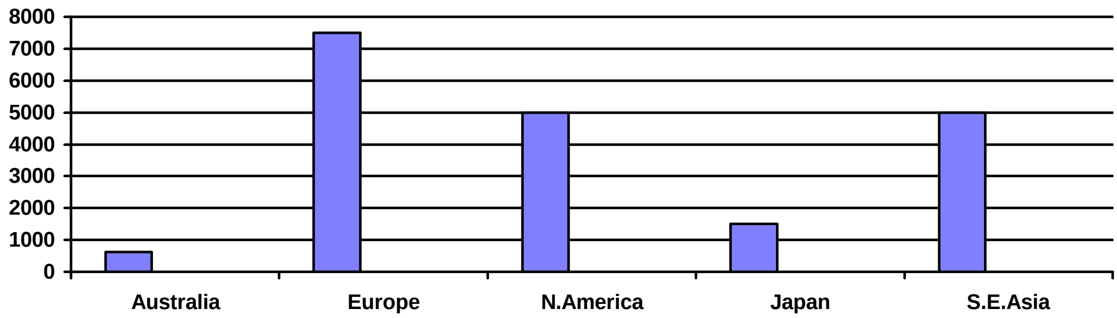
**Fig.1. Australian condiment paprika import**




This rapid increase in Australian imports reflects current global demand. According to European condiment paprika marketing experts estimated also at 20% growth in condiment paprika consumption in Europe and Asia.

Australian growers of condiment paprika would have a potential world market worth AUD55 M per annum. This figure is derived from the 19,000 t of milled condiment paprika conservatively estimated to be consumed by Europe, North America, Japan and South East Asia in a single year (Fig. 2.)

**Fig.2 World milled condiment paprika consumption (tonnes)**




Growing, harvesting and processing condiment paprika in Australia has enormous potential for the economy in terms of garnering new expertise and employment for rural areas, diversification of farming activities and development of new mechanical harvesting technology.

## 1.3 History of the Project

Late in 1994 a Hungarian wheat breeder colleague regarding some problems of condiment paprika production in Hungary privately informed the author. One of their concerns was air pollution specifically lead due to excessive use of leaded fuels. They have also grave problems because some irresponsible companies sold adulterated paprika to overseas buyers. The adulterators used flour, sawdust, brick dust, and lead based colouring agents for their product. Due to this activity Hungary lost nearly all of their export market and some of their customers such as Japan stopped importing Hungarian paprika completely. My immediate reaction was to grow Hungarian condiment paprika here in Australia in cooperation with the appropriate Hungarian organisations. Shortly Dr. Norbert Somogyi a research scientist attached to the Hungarian Vegetable Crop Research Institute, Condiment Paprika Research Unit (later Paprika Unit) in Szeged, Hungary, contacted me. He and his superiors liked the idea and the possibility of a close cooperation was suggested. Eventually on 29 December 1995 Dr. J. Bittsanszky, the Director General of the Institute and Dr. F. Markus the Director of the paprika unit, issued an official response:

> "We consider a cooperation on the field of condiment paprika between Australia and Hungary possible and feasible. We could suggest the following steps:

- Setting up of small plot trials in Australia to evaluate varieties and choose the most promising ones
- Setting up of semi-farm trials or production for processing using seed from the Vegetable Crop Research Institute.
- If the results are satisfactory discussions could start about an agreement including seed production rights in Australia, cultivar registration and patenting
- Later, when required breeding of cultivars corresponding with local requirements could also be commenced."

On 28th March 1996 the Hungarian Vegetable Crop Research Institute, Condiment Paprika Unit, authorised ASAS Pty. Limited to be their sole representative in the South Pacific region particularly in Australia. The Hungarians provided seed of their most popular cultivars. These cultivars were included in a small-scale cultivar trial at the University of Sydney Plant Breeding Institute, Cobbitty. This trial, my earlier experience and the practical experience of many market gardeners demonstrated that capsicum could be successfully grown in this country. The Hungarian condiment paprika cultivars were performing satisfactorily in Cobbitty in spite of that the site is not really ideal for paprika production.

It was clear that condiment paprika could not be grown in Australia with the same crop husbandry practice as in Hungary and many other paprika producing countries where the hand labour is relatively cheap. It was decided that a research program should be initiated to find out the best crop husbandry practices and develop cultivars that are suited for mechanised production systems. To achieve these aims an application was made to RIRDC for a grant to assist this program. The reasoning for this grant was to introduce and further develop genetic material of condiment paprika to produce cultivars with high initial pigment (> 200 ASTA) and dry matter content suitable for direct seeding and mechanical harvesting. To develop a commercially viable integrated production, harvesting and processing system for identified markets by 2002. In this project ASAS Pty Ltd was in cooperation with industrial/commercial partner Hunter Valley Herb Farm, The University of Sydney, Plant Breeding Institute- Cobbitty and the Hungarian Condiment Paprika Research-Development Ltd. A three-year research grant was approved.

# 2. Agronomy of Paprika

## 2.1 Trial sites

The condiment paprika experiments were conducted on two sites and three different soil types.The main sites were The University of Sydney, Plant Breeding Institute's property at Cobbitty, NSW (latitude 34°01'S, longitude 150°40'E, elevation 75m) and the Hunter Valley Herb Farm's holdings at Merriwa, NSW (latitude 32°10'S,longitude 150°21', elevation 267m) during the 1997/98 and 1998/99 seasons. The soil type at Cobbitty is clay brown loam while at Merriwa the 'homestead' paddock is light sand and a rented paddock on a nearby farm has heavy chernozem type of soil.

During the 1999/2000 season a farm scale commercial production trial was conducted at Whitton, NSW on Mr Graham Blight's property (latitude 34°30'S, longitude 146°13'E).

Milling experiments and pigment analyses were carried out at the laboratories of BRI Australia at Ryde, NSW.

## 2.2 Crop Husbandry Considerations

The aims of the crop husbandry trials were to investigate the most economically sound production system and. see how the New Mexico and Hungarian agronomy could be utilised in Australia. In Australia mainly bell capsicums were grown and marketed as fresh produce. A limited acreage was sown by chillies for market-garden output. For this reason it was important to turn to countries where paprika and chillies were grown in commercial quantities and to try to use their production systems if possible. The New Mexican paprika and chilli crop husbandry system has a particular interest to us as their soil and climatic conditions are the nearest to our conditions. The trials were kept as simple as possible and it was made sure that any findings could be applied in commercial production directly. The following trials were conducted at the industrial partner's property:

### 2.2.1 Time and depth of sowing trial

The aims of this trial were to determine the most suitable sowing/planting depth and time for the Upper Hunter region. Sowing and planting were conducted in fifteen-day intervals from 1st October till 15th November. In the case of direct sowing the trial was combined with depth of sowing on two sites. The different temperature regimes during different sowing times are expected to influence the optimum sowing depth. Three sowing depths were used eg 15 mm, 30 mm and 45 mm. A 3 x 4 factorial design in randomised blocks were programmed. This type of trial was planned to be conducted for two years and in the third year a simplified trial was planned to be conducted on several farmers' properties. The five sowing times and the three sowing depths would have provided a response curve indicating the range of sowing, planting and time applicable in the particular environment where the trials were conducted.

All field trials were planted/sown according to schedule during 1997/98, nevertheless the trial area was on a paddock that still had significant amount of sorghum stubble on it. Unfortunately sorghum stubble had a detrimental effect on capsicum seed germination. Sorghum stubble besides being a hotbed for several diseases and pests also contains some alkaloids that hinder germination and plant development of *Solenaceae.* The cooperator has been warned previous to sowing, however, no other paddock was available

The trial gave some useful information in spite of the notably uneven establishment. The 15mm sowing depth was significantly better than the 45mm, however was not significantly different from the 30mm depth of sowing. Nevertheless, the 30mm was not significantly different from the 45 mm depth. (Table 2)

**Table 2**

| Depth Mm | Mean | Homog-eneous groups |
|---|---|---|
| 15 | 31.00 | **I** |
| 30 | 22.375 | **I I** |
| 45 | 13.708 | **I** |

Critical value for comparison: 16.914. Rejection level: 0.010

This result confirms the Hungarian and the New Mexican recommendations on depth of sowing, it also emphasises the importance of the soil types and moisture conditions. The extension workers of New Mexico strongly recommend to cover the row with a 7-10 cm 'cap' which is removed with a dragging harrow before the seedlings emerge (crook stage). This method reduces the drying out of the seedbed. The post sowing watering could cause problems and should be avoided.

Four times of sowing were combined with the depth of sowing in 15 days intervals starting on 1st October1997. The crop establishment was poor, the C.V. high, nevertheless, the results were again supporting the overseas advice. The second sowing, mid October, proved to be significantly the most successful sowing time. Obviously the soil temperature was at the most favourable level around 15°C. The third sowing time was significantly lower than the second, but still acceptable. Both first and fourth sowings gave significantly lower yield than the second and third sowings but were not different from each other.(Table 3).

**Table 3**

| Time | Mean | Homogeneous groups |
|---|---|---|
| 2 | 49.389 | I |
| 3 | 30.056 | I |
| 4 | 6.333 | I |
| 1 | 3.6667 | I |

Critical value for comparison: 11.840. Rejection level: 0.010

The most favourable sowing time in average was in the second half of October at Merriwa in 1997 and the sowing depth should be between 15 mm and 30 mm depending on soil type.

### 2.2.2 The Plant Density Trial

This trial has failed, it could not be harvested because it was sown in the paddock with sorghum stubble.

### 2.2.3 Commercial Production Trials

In the 1997/98 season condiment paprika production on both sites at Merriwa could not be called a big success. On the light soils the only acceptable crop was that was planted with pre-grown seedlings, all the others had poor establishment and had constant struggle with weeds. In general on the light soil nutrient levels were not up to standard. On the Farnham's property (black self-mulching soil) the choice of paddock, as noted many times previously, was not a good one. During the last couple of years attempts to grow condiment paprika on the Hunter Valley Herb Farm's property proved that, only transplanted seedlings could really prosper on light sandy soil, if the nutrition is adequate. It must be pointed out that looking at the performance both on light and heavy soils, either the sites or the applied crop husbandry is incorrect and not suited for paprika production. Both the Hungarian and New Mexican experiences clearly indicate that condiment paprika needs a well prepared soil with high nutrient levels and a good pre- and post-sowing weed control. We have to add to this a well-timed irrigation.

During the 1999/2000 season on Mr. Graham Blight's property at Whitton two hectares of Szegedi 80 paprika cultivar was successfully direct sown and had a stand of approximately 220,000 plants per hectare. With the help of the NSW Department of Agriculture they identified a pre-emergence weedicide (Devalon ®) that can be successfully used with direct seeded paprika. Mr. Blight also found that in the case of direct seeding only furrow or drip-irrigation should be used because overhead watering on clayey loams can be detrimental on seed emergence. I estimated the yield at 22 tonnes per hectare. Unfortunately due to lack of availability of specialised machinery it was hand-harvested and because of the high labour costs only approx. 10 tonnes were harvested. The drying was done by a tomato batch-drier, which also proved to be very expensive. It was established that agronomically paprika could be grown on a large scale, however mechanisation is a must.

The three-year experience clearly indicates that the seasonal climatic fluctuation has the most significant influence on the crop husbandry practice applied rather then strict prescriptions. Fundamentally the New Mexican and Hungarian condiment paprika production systems could be applied with a "good farmer" care.

### 2.2.4 Mechanisation

In the industrial partner's workshop a one-row harvester prototype was built for the 1997 harvesting season. In spite of a reasonable fruit handling this prototype No.1 could not harvest the low fruits and also was dropping large number of fruits to the ground. For the 1997/98 season prototype No.2 was designed and built to operate as a towed unit with its own hydraulic power system driving chamber doors, strippers and conveyors. Quoting from the industrial partner's report: '*The stripping chamber was improved by the addition of crop entry rotating doors which prevented fruit from exiting the chamber from the front. Two pick-up and one delivery conveyors were added to elevate the stripped fruit from the chamber to the collection bin. Problems were found with these conveyors in being able to get low enough to collect all low fruit. The prototype was built using belt conveyors as the initial fruit pick-up. In the trials we found that positioning the belts too close to the soil meant that when uneven ground was encountered the conveyors dug into the soil, lowered the stripping head, jammed and the drive chain snapped'*. Two years' work was spent to build a mechanical paprika picker from scratch. The Principal Investigator has recommended the investigation of purchase or adaptation of existing USA machinery. In the USA there are several manufacturers producing paprika pickers, one of them is suitable for multiple picking. As far as I know there is a four-row picker in use in the Bundaberg region.

The Hunter Valley Herb Farm (HVHF) made two attempts to construct a paprika harvester. They used the double helix picking head principle that is used by many of the USA made machinery manufacturers. During the initial tests the head looked promising, nevertheless, due to lack of mechanical engineering knowledge and experience they failed two build a useable paprika picker. I recommended fitting the picking head on a self-propelled cotton picker or on a green bean harvester. I must note that these kinds of applications were demonstrated to the Farm Manager of HVHF when he visited Israel during 1996. Green Bean harvesters were successfully used in Hungary during the early fifties.

# 3. Cultivar Introduction and Improvement

## 3.1 Variety Trials

During 1997/98 and 1998/99 seasons variety trials were conducted with twenty cultivars on two sites to find the most suitable cultivars among the lines introduced from Hungary and other sources. In these trials pre grown seedlings were used. The experimental design is complete randomised blocks. It was expected that in the third year, using eight to ten cultivars, it would be possible to ascertain the most useful four or five cultivars for the region. The data was collected and evaluated by the following criteria: a) Plant height and shape at beginning of ripening, b) Earliness: flowering and ripening time, c) Observations on disease symptoms, d) Yield and its components., e) Quality aspects: pigment and capsaicin content and drying indices.

During the 1997/98 season the cultivar introduction trial at Cobbitty resulted in good yields, however the coefficient of variation (C.V.) was too high. The only significant difference was that the USA hybrid gave the highest yield, however Papri King, Papri Mild, Kalocsai 50, Szegedi 179 and Papri Queen were not significantly different from the US hybrid. While Szegedi 178, Szegedi 80 and Szegedi F-03 gave the lowest yield, they were significantly different from the USA hybrid but not different from the rest of the cultivars (Table 4).

**Table 4 Variety and Strain (VS)Trial 1997/98, Cobbitty**

| CULT # | MEAN | HOMOGENEOUS GROUPS | Cultivar name |
|---|---|---|---|
| --------- | ---Kg/plot----- | | ----------- |
| 13 | 15.600 | I | US Hybrid |
| 14 | 12.800 | I I | Papri King |
| 15 | 11.200 | I I I | Papri Mild |
| 17 | 10.900 | I I I I | Kalocsai 50 |
| 8 | 10.633 | .. I I I | Szegedi 179-97 |
| 16 | 10.333 | .. I I I I | Papri Quin |
| 11 | 8.6333 | .. I I I I | Szegedi 17 |
| 12 | 8.6333 | .. I I I I | Szentesi NFD |
| 19 | 7.7333 | .... I I I | Kalocsai E-15 |
| 10 | 7.5333 | .... I I I | Szegedi 57-13 |
| 9 | 7.2667 | .... I I I | Szegedi 20 |
| 6 | 7.2000 | .... I I I | Szegedi 178-97 |
| 7 | 7.2000 | .... I I I | Szegedi 179-96 |
| 4 | 6.9333 | .... I I I | Kalocsai 90-97 |
| 5 | 6.3333 | ...... I I | Szegedi 178-96 |
| 2 | 6.2667 | ...... I I | Szegedi 80-97 |
| 18 | 5.9000 | ........ I | Szegedi F0-3 |

```
THERE ARE 5 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.

CRITICAL T VALUE                    2.032   REJECTION LEVEL   0.050
CRITICAL VALUE FOR COMPARISON      4.7150
STANDARD ERROR FOR COMPARISON      2.3201
```

In the cultivar trials at Merriwa again the USA hybrid topped the list but this trial also had high C.V. therefore from yield point of view the trial was inconclusive (Table 5).

**Table 5 VS Trial 1997/98, Merriwa**

| VARIETY # | MEAN | HOMOGENEOUS GROUPS | Cultivar's Name |
|---|---|---|---|
| --------- | ----Kg/plot---- | ----------- | |
| 13 | 14.887 | I | US Hybrid |
| 15 | 10.738 | I I | Papri Mild |
| 16 | 9.865 | I I I | Papri Queen |
| 5 | 9.838 | I I I | Szegedi 178-96 |
| 9 | 9.523 | I I I | Szegedi 20 |
| 1 | 9.030 | .. I I | Szegedi 80-96 |
| 14 | 8.535 | .. I I | Papri King |
| 20 | 8.346 | .. I I | Kalocsai 801 |
| 4 | 8.315 | .. I I | Kalocsai 90 |
| 8 | 7.781 | .. I I | Szegedi 179-97 |
| 6 | 7.640 | .. I I | Szegedi 178-97 |
| 12 | 7.395 | .. I I | Szentesi NFD |
| 2 | 7.151 | .. I I | Szegedi 80-96 |
| 19 | 6.541 | .. I I | Kalocsai E-15 |
| 17 | 5.860 | .. I I | Kalocsa 50 |
| 7 | 5.846 | .. I I | Szegedi 179-96 |
| 11 | 5.828 | .. I I | Szegedi 17 |
| 3 | 5.716 | .. I I | Kalocsai 90-96 |
| 10 | 5.260 | .. I I | Szegedi 57-13 |
| 18 | 4.871 | .... I | Szegedi F0-3 |

```
THERE ARE 3 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.

CRITICAL T VALUE                    2.021   REJECTION LEVEL   0.050
CRITICAL VALUE FOR COMPARISON      5.598
STANDARD ERROR FOR COMPARISON      2.770
```

Consequently a weighted-analysis was conducted with yield, together with the characteristics of the milled product eg. ASTA, taste and appearance were considered together (Table 6). The project concerned sweet paprika therefore the capsaicin values were calculated as negative influence. Again a large variation confounded the results. Nevertheless, Szegedi 20, Szegedi 80, Szentesi NFD, Papri Mild, Kalocsai 50 could be considered as the best all round performers, followed by Kalocsai 801, Szegedi 57-13, Kalocsai E-15, Kalocsai 90. A third group Papri King, USA hybrid, Papri Queen, Szegedi F-03, Szegedi 179 and Szegedi 178 had capsaicin content.
The result of the weighted-analysis is shown below:

**Table 6. Weighted Analysis of 1997/98 Paprika Cultivar Trial**

| Code # | Cultivar | Yield _5x | ASTA 1x | Taste 10x | Appearance 10x | Capsaicin -(5x) | Value | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | Szegedi 80 | 104 | 272 | 77 | 85 | | 538 | 2 |
| 3 | Kalocsai 90 | 97 | 166 | 81 | 84 | | 428 | 9 |
| 5 | Szegedi 178 | 108 | 193 | 70 | 88 | 6300 | -5841 | 15 |
| 7 | Szegedi 179 | 110 | 232 | 70 | 88 | 3675 | -3175 | 14 |
| 9 | Szegedi 20 | 120 | 270 | 75 | 90 | | 555 | 1 |
| 10 | Szegedi 57-13 | 89 | 195 | 75 | 95 | | 454 | 7 |
| 11 | Szegedi 17 | 100 | 222 | 67 | 83 | | 472 | 5 |
| 12 | Szentesi NFD | 111 | 210 | 83 | 93 | | 497 | 3 |
| 13 | US Hybrid | 210 | 298 | 70 | 90 | 400 | 268 | 11 |
| 14 | Papri King | 148 | 242 | 70 | 88 | 200 | 350 | 10 |
| 15 | Papri Mild | 152 | 225 | 78 | 92 | 50 | 497 | 3 |
| 16 | Papri Queen | 141 | 232 | 70 | 86 | 300 | 229 | 12 |
| 17 | Kalocsai 50 | 117 | 195 | 76 | 92 | | 480 | 4 |
| 18 | Szegedi F-03 | 75 | 248 | 70 | 88 | 3500 | -3019 | 13 |
| 19 | Kalocsai E-15 | 99 | 178 | 69 | 83 | | 429 | 8 |
| 20 | Kalocsai 801 | 117 | 181 | 83 | 80 | | 461 | 6 |

Due to genotype-environment inter action obvious variations were detected in most of the introduced cultivars particularly those with Hungarian origin. 102 lines selected from 13 Hungarian condiment paprika cultivars were grown at Cobbitty. The selections of the "hot" cultivars were harvested and are in storage. 24 lines of the 'sweet' cultivars were 'eye' selected and their performance were tested during 1998/99 season at Merriwa and Cobbitty. Small samples of these lines also were sown at Cobbitty in a disease nursery to explore their disease tolerance/resistance.

The following selections were tested together with new introductions and Szegedi 80 as the check::

**Table .7**

| **Strain** | **Cultivar** |
|---|---|
| Cap.28.5.b | Szegedi 20 |
| Cap.28.7.b | -"- |
| Cap.28.8.b | -"- |
| Cap.30.2.b | Szegedi 57-13 |
| Cap.30.3.b | -"- |
| Cap.30.4.b | -"- |
| Cap.43.1.b | Kalocsai 90 |
| Cap.34.3.b | Szegedi 17 |
| Cap.34.5.b | -"- |
| Cap.34.9.b | -"- |
| Cap.36.6.b | Kalocsai 57-231 |
| Cap.36.8.b | -"- |
| Cap.36.9.b | -"- |
| Cap.01.b | Conquistador |
| Cap.37.2.b | Kalocsai 801 |
| Cap.37.8.b | -"- |
| Cap.37.9.b | -"- |
| Cap.38.1.b | Kalocsai 50 |
| Cap.38.3.b | -"- |
| Cap.38.6.b | -"- |
| Cap.66.b | Papri Mild |
| Cap.40.1.b | Szentesi NFD |
| Cap.40.3.b | -"- |
| Cap.40.4.b | -"- |
| Cap.35.1.b | Kalocsai E-15 |
| Cap.35.2.b | -"- |

During 1998/99 season the selections listed in Table 7 were also included in the VS trial. Because the numerous entries the VS trial was divided to four sub trials eg. A,B,C and D components. Each of the sub trials had Szegedi 80 cultivar included as control. Intention of this trial was to evaluate the reselections. The Merriwa trials averaged a converted plot yield of 23.4 t/h while the Cobbitty trial's mean yield was 26.1 t/h. The pigment test at Merriwa averaged 143.7 ASTA and at Cobbitty averaged 204 ASTA. Both the yield and the pigment tests indicated the lower nutrient status and weed competition of the Merriwa site. The detailed yield results for these trials are shown in Appendix 5.2.

The combined data of these two trials are shown in Table 8 and 9.

**Table 8. Combined Data VS Trial, Merriwa 1998/99**

| Lines | Yield g/plot | 1st harvest % | Rel. value | ASTA | Sub Trial |
|---|---|---|---|---|---|
| Conquistador (USA) | 10030 | 49 | 179 | 105 | B |
| Kalocsai.E-15.1.b | 7097 | 64 | 133 | 110 | D |
| Szegedi 17.3.b | 7280 | 30 | 130 | 155 | B |
| Szegedi 20.7.b | 7085 | 59 | 125 | 150 | A |
| Papri Mild (USA) | 7950 | 54 | 120 | 115 | C |
| Kalocsai 801.2.b | 7898 | 68 | 119 | 140 | C |
| Szegedi 20.8.b | 6420 | 41 | 113 | 164 | A |
| Kalocsai 90.1.b | 6281 | 58 | 111 | 130 | A |
| Szegedi 57-13.2.b | 6235 | 62 | 110 | 140 | A |
| Kalocsai E-15.2.b | 5763 | 57 | 108 | 105 | D |
| Szegedi 57-13.3.B | 5970 | 63 | 105 | 150 | A |
| Szegedi 20.5.b | 5669 | 43 | 103 | 180 | A |
| Kalocsai 801.8.b | 6831 | 67 | 103 | 140 | C |
| Kalocsa 121 | 5390 | 58 | 101 | 130 | D |
| Szegedi 80 | 5648 | 64 | 100 | 180 | A |
| Szegedi 80 | 5596 | 64 | 100 | 165 | B |
| Szegedi 80 | 6590 | 59 | 100 | 160 | C |
| Szegedi 80 | 5317 | 63 | 100 | 190 | D |
| Kalocsai 50.6.b | 6528 | 85 | 99 | 145 | C |
| Szegedi 57-13.4.b | 5482 | 51 | 97 | 135 | A |
| Kalocsai 101 | 5107 | 60 | 96 | 28 | D |
| Szegedi 17.9.b | 5300 | 50 | 94.7 | 160 | B |
| Kalocsai 57-231.8.b | 5282 | 57 | 94 | 160 | B |
| Kalocsai 57-231.9.b | 5043 | 71 | 90 | 140 | B |
| Kalocsai 57-231,6.b | 4991 | 75 | 89 | 160 | B |
| Szegedi 17.5.b | 4936 | 37 | 88 | 155 | B |
| Szentesi NFD 1.b | 4568 | 77 | 85.9 | 160 | D |
| Szentesi NFD 3.b | 4070 | 66 | 76.5 | 160 | D |
| Kalocsai 50.1.b | 5028 | 81 | 76.3 | 120 | C |
| Szentesi NFD 4.b | 3868 | 77 | 85.9 | 160 | D |
| Kalocsai 50.1.b | 4302 | 82 | 64 | 160 | C |
| KalocsAI 801.9.B | 3678 | 81 | 56 | 135 | C |

This trial's harvest commenced at biological maturity therefore the advantages of line with semi-determinate growth habit did not manifest. If the harvest is delayed then great proportion of the fruit of the semi determinate lines are available for harvest as shown in the Cobbitty trial particularly in the case of Kalocsai 801.2.b.

**Table 9 Combined VS data, Cobbitty 1998/99**

| Lines | Yield-g/plot | Rel V - % | 1st harv. | ASTA | Sub-trial |
|---|---|---|---|---|---|
| Papri Mild | 7166 | 250.3 | 58.1 | 155 | C |
| Kalocsai.50.1.b | 5525 | 193 | 67.7 | 190 | C |
| Conquistador | 7964 | 193.7 | 50 | 130 | B |
| Kalocsai 801.8.b | 4863 | 169.9 | 71 | 195 | C |
| Kalocsai.50.6.b | 4704 | 164.4 | 78.4 | 185 | C |
| Kalocsai 50.3.b | 4628 | 161.7 | 69.8 | 190 | C |
| Kalocsai 801.2.b | 4197 | 146.6 | 92.5 | 185 | C |
| Szegedi 20.8.b | 5707 | 121% | 73.5 | 160 | A |
| Kalocsai 121 | 5543 | 117.7 | 80.3 | 205 | D |
| Szegedi.17.3.b | 4831 | 117.5 | 85 | 195 | B |
| Szegedi 57-13.4.b | 5427 | 115% | 62.6 | 185 | A |
| Kalocsai.90.1.b | 4956 | 105% | 68.5 | 150 | A |
| Szegedi.57-13.3.b | 5382 | 114% | 62.5 | 170 | A |
| Szegedi.17.5.b | 4662 | 113.4 | 82.2 | 225 | B |
| Kalocsai 57-231.6.b | 4653 | 113.2 | 79.3 | 210 | B |
| Szegedi.17.9.b | 4256 | 103.5 | 75.9 | 210 | B |
| Kalocsai.57-231.8.b | 4630 | 112.6 | 87.9 | 220 | B |
| Szentesi.NFD.3.b | 4890 | 103.8 | 74.9 | 260 | D |
| Kalocsai.101 | 4829 | 102.5 | 80.4 | 220 | D |
| SZegedi.80 | 4715 | 100 | 80.4 | 200 | A |
| Szegedi.80 | 4112 | 100 | 84.3 | 240 | B |
| Szegedi 80 | 2863 | 100 | 82.6 | 260 | C |
| Szegedi.80 | 4711 | 100 | 75.1 | 250 | D |
| Kalocsai.57-231.9.b | 4099 | 99.7 | 69.8 | 185 | B |
| Kalocsai.E-15.1.b | 4690 | 99.6 | 75.1 | 200 | D |
| Szegedi.20.7.b | 4457 | 95% | 76.4 | 170 | A |
| Szegedi.57-13.2.b | 4398 | 93% | 63.2 | 125 | A |
| Szegedi.NFD.4.b | 4173 | 88.6 | 51.6 | 320 | D |
| Kalocsai.801.9.b | 2505 | 87.5 | 74.2 | hot | C |
| Szegedi.NFD.1.b | 3959 | 84 | 69.2 | 320 | D |
| Szegedi.20.5.b | 3662 | 78% | 74.9 | 210 | A |
| Kalocsai.E-15.3.b | 3254 | 69.1 | 58.4 | 205 | D |

Our aim is mechanical harvesting and therefore it is extremely important what portion of the yield can be taken off at the first harvest. In this regard the standard Szegedi 80 performed very well while a selection of Kalocsai 801.2 performed the best with 92.5% of the total yield coming off with the first harvest in the Cobbitty trial. It was decided in agreement with the Hungarian colleagues that Szegedi 20.8.b, Kalocsai 801.2.b, Kalocsai 801.8.b and Kalocsai 50.6.b will be subjected to seed increase as these lines are planned to be registered for plant variety protection.

To utilise the full potential of the condiment paprika the fruit's pigment content (ASTA) is an important consideration. The pigment is extracted and used both in the cosmetic and food industries. In general all the introductions and the selected lines have higher pigment levels here then in their country of origin. The 'Szentesi NFD' selections' ASTA levels are extremely high (320 ASTA), however, their yielding ability is low, nevertheless, they will be useful parent material in our breeding program

## 3.2 Plant improvement program

This program seeks to produce cultivars suited to the Australian conditions, particularly to mechanised production system. In Hungary and the other condiment paprika producing countries this industry is highly labour intensive. Planting and harvesting is done by hand. For these reasons their cultivars are not very well adapted for more economic mechanised production. Besides the general breeding objectives that are needed in condiment paprika breeding, it is imperative to develop cultivars with initial high pigment content (>200 ASTA**),** the pedicel has to be easily detachable from the stem and the fruit from the calyx. Disease resistance aspects also have to be considered as it was found in preliminary experiments that varieties and cultivars are inclined to be resistant to certain viruses in the USA or in Europe but are showing full susceptibility or segregation here.

**a.)** It seems that some of the introduced cultivars need to be reselected, particularly from disease point of view. Two systems are being used at the reselection process: i) Positive mass selection where the desired plants are selected and bulked together, ii) Single plants selected, selfed and progenies tested.
The first method actually recreates the cultivar while the latter is creating a new cultivar. This selection program was conducted at the industrial partner's property, Merriwa..

**b.)** To produce cultivars with the required traits suited for a mechanical production system a complex approach is required. Besides high initial pigment and detachable fruit the appropriate disease resistance properties must also be considered. Genes for most of these attributes can be found in wild species and exotic varieties eg. *Capsicum chacoense, Capsicum frutescens, Capsicum baccatum* covar. *pendulum, Capsicum annuum* covar. *fasciculatum,* Derera's 'O', 'P', 'R' and 'T' lines. **-** The latter four lines besides being dwarfs and semi-dwarfs are highly resistant to several diseases particularly tobacco mosaic virus and *Xanthomonas campestris.*

**c.)** Besides the normal cross breeding back cross, convergent and accumulative crosses were planned and pedigree methods are being used to select the new cultivars. When exotic species and varieties are used as parents embryo rescue and in vitro fertilisation will be applied if necessary. Haploid technology will be also used to shorten the time needed to produce a new cultivar. In many cases as it was expected exotic crosses created male sterile progenies which we overcame by back crossing with the *C. annuum* parent.

The species used in this condiment paprika breeding program with their short description are enumerated below:

*Capsicum annuum* covar. *longum.*
40-100 cm tall herbaceous plants with white flowers. The fruits are either erect or pendulous, are 10-16 cm long, straight tapering towards a pointed tip. The surface is smooth and deep red colour when fully ripe. Usually the fruits have high pigment content and could be either sweet of pungent.
Nearly all the condiment paprika cultivars belong to this sub-species exceptions are the Spanish pimento which are *C. annuum* covar. *annuum* or actually they are closer to covar *grossum*. The pimento types have the disadvantage that they have lower dry matter content than the *longum* types. The cultivars used in this program were listed in the previous chapter (3.1) together with the reselected lines.

*Capsicum baccatum*
Closely related to *C.annuum* and *C. chinense*. The flowers are white or creamy white with a distinguished yellow corolla. The var. *baccatum* has small leaves and flowers and has one or two erect flowers or fruits per node. Some variants are pubescent and some of the varieties could have soft fruits at full ripeness. The var. *pendulum* has one erect flower per node, which becomes

pendulous after fruit setting. The fruit shape and size are variable and have sometimes 15-20 cm long fruits. Its seed could germinate under lower temperature conditions then the other capsicum species. This characteristic is very important when direct seeding is considered. When used as female parent it can be crossed freely with *C. annuum* (Eshbaugh 1970).

*Capsicum chinense*
Closely related to *C. annuum*. The plants' height are variable from dwarf to very tall, the leaves can be glabrous or pubescent could be early or late maturing the unripe fruit could range from white to deep-green and the fully ripe fruit may be red, yellow or brown and the shape is also very variable.. It could be crossed easily with *C. annuum*, however some sterility could occur among the $F_1$ plants. It is debatable whether *C. chinense* is a separate species or a sub-species of *C. frutescens* (Eshbaugh 1975, Pickersgill 1971).

*Capssicum frutescens*
Relatively closely related to *C. annuum*, however, not as variable as the previously described species. The flowers and fruits are always erect, the flowers are either greenish white or pale green, and the number of fruits per node is ranging from 2-6. It is difficult to cross with *C. annuum* and among the $F_1$ and$F_2$ hybrids there are many sterile plants. One of the best known variety which derived from this species is 'Tabasco' (Pickersgill 1971).

*Capsicum pubescens*
The leaf and stem of this species are strongly pubescent, the plant is perennial could develop to a tree of 2-3 metres having also 1-2 metre branches. The flowers are purple with white or yellow corolla and producing a large quantity of nectar therefore attracting bees. The fruits are oval-shaped 3-4cm long and 2-3cm wide with a long pedicel. Unripe fruit is deep green, the fully ripe fruits could be red, yellow or brown. It tolerates cold weather very well as it originates from the high mountains of South America. The author has several plants in his garden and during this winter they set large number of fruits, which are ripening slowly in spite of the cold temperature conditions. This species will have an important role in the establishment of the economically sound hybrid seed production also its cold tolerance could be an important trait in this project. According to the literature using classical techniques it cannot be crossed with *C. annuum* (Somos 1985. Eshbaugh 1979).

*Capsicum chacoense*
This is distinct from any other species. Slender tall plants branching out only after 15-25 nodes but from then on many branches appear. The flowers are erect, white and the anthers are distinctly yellow and producing profuse amount of nectar. Fruits are small and when fully matured are red and soft and easily detachable from the calyx (Somos 1985). The fruit detachability is the characteristic, which is being utilised to develop a cultivar that lends itself easily to mechanical harvesting. Somos (1985) indicated that the detachability and softness are caused by a pleutropic effect of one gene. Some other authors, among others Greenleaf (1986) suspected that the easy separation of mature fruit from the calyx and the soft flesh are caused by two separate genes. Daskalov and Poulos (1994) listing the detachability as an incomplete dominant gene, which easily can be modified by genes that control the fruit form, calyx and placenta and allocated the symbol of *Ps*. The gene that is causing soft flesh is distinct from *Ps,* is a dominant gene and the allocated symbol is *S*.

*Capsicum tovartii* (Acquired in 2000)
Similarly to the previous species it is a slender plant and branching only after the 15$^{th}$ or 20$^{th}$ nodes. The stem itself is weak and lodges very easily. The 3-5 flowers per node are crimson-white. The fruits are small and easily detachable from the calyx when fully ripe (Eshbaugh et al. 1983).

*Capsicum cardenasii* (Acquired in 2000)
Similarly to the previous species has very thin main stem, which branches out only after 15-20 nodes and creates a very loose bush. The whole plant has a typical fragrance, the flowers are erect, bell shaped, the colour is mauve with yellow corolla. This is the only capsicum species that is self-incompatible (Yaqub-Smith 1971). Has very small fruits which are red and soft when fully ripe and are easily detachable from the calyx. As it is originating from the high mountains (1500-2000 m of Bolivia) its cold tolerance is a very important trait.

*Capsicum eximium* (Acquired in 2000)
The growth habit is very similar to *C. cardenasii*, however its flowers are not bell shaped but flat and plate like. The crimson red petals are knit halfway together and have a yellow corolla. The fully ripe fruits are soft and easily detachable. It can be easily crossed with *C. cardensii* and *C. pubescens* (Somos 1985).

The Hungarian condiment paprika varieties have very high quality attributes. The ground paprika derived from these varieties has an excellent taste and aroma and in addition a superior red pigment content. Besides being a favoured spice it is used in the canning industry, in food colouring concentrates and in cosmetics as well. In the Australian program apart from creating varieties which can be economically produced here the maintenance of the quality traits are imperative. The Australian condiment paprika improvement program should follow the ensuing stratagem:

Besides of improving the yielding ability ad pigment content the most important consideration is to produce cultivars suitable for mechanised crop husbandry system.
To improve yield we are using partly the USA origin cultivars such as Conquistador, Papri King, Papri Mild, Papri Queen and NM Sweet. These cultivars are high yielding but their pigment and dry matter contents are relatively low and most of them are pungent as they contain capsaicin.
The breeding objectives are:

| | |
|---|---|
| Growth habit | |
| | Indeterminate<br>Semi-determinate<br>Height: semi-dwarfs |
| High productivity | Number of fruits per plant<br>Size of fruit |
| Earliness | Synchronous flowering and ripening<br>Early ripening |
| Fruiting type | Hanging (pendulous)<br>Fruit shape |
| Disease resistance | CMV - Cucumber mosaic virus<br>TMV - Tobacco mosaic virus<br>AMV - Alfalfa mosaic virus<br>*Xanthomonas vesicatoria* |
| Pest resistance | Fruit fly - *Dacus tryoni, Ceratis capitata*<br>*Heliothis sp* |
| Climatic resistance | Frost<br>Heat -sun burn |
| Mechanisation | For direct sowing: high inherent germination energy |

| | |
|---|---|
| | For mechanical harvesting: appropriate abscission zone for pedicel and/or calyx |
| Quality | Skin and seed ratio<br>Dry matter content<br>Colour - deep red or vivid red, 200 - 300 ASTA<br>Pigment content - high ratio of *capsanthin, cryptocapsin* and *capsorubin.*<br>Stable pigment content<br>High colouring capacity<br>Capsaicin content - absent or low<br>Low sugar content<br>Flavour, taste and aroma |

The species, varieties and cultivars provided by the Hungarian partner and/or brought in the program by ASAS Pty Ltd are listed in Appendix 5.3..

In a classical plant breeding program three years means only the beginning. First year is usually spent on literature search, setting up a variety collection and selection of parents for the basic crosses. In the second year the establishment of variability. We were doing a number of interspecific hybridisations where the $F_1$ hybrids were mainly male sterile and sometimes both male and female sterile. For this reason special care has to be taken in the subsequent generations. In many combinations the sterile $F_1$ can be fertilised only with certain cultivars or varieties. This could be an expensive exercise to find the right $F_1$ plant and the potential pollen source. *C. chacoense* and *C. pubescens* having copious amount of nectar and the latter one has purple flowers that both attracts bees. Normally bees do not attend the cultivated capsicums, nevertheless when the bees frequented the wild species they will go on to collect nectar and pollen from the hybrids and the *C. annuum* cultivars. Experiencing this we planted our interspecific $F_1$ crossing nursery in a way to encourage the bees to do the pollination on our behalf. From all practical points of view we let the sterile hybrids to open pollinate. Admittedly the pollen source was unknown, however, the planting was done so that the preferred and potential parents were planted close to the sterile hybrids. The following seasons from the open pollinated progenies we had to select the genotypes that were, at least in appearance, near to the required type and then further backcrossing was implemented. Some samples of the 2000 year crossing program indicate the direction of the whole condiment paprika plant improvement program. (op = open pollinated)

C2000.12.= Bantam/*C.chacoense*// op/3/Szegedi 20*2
C2000.28= Centennial/*C.chacoense*// op/3/Szegedi 20*2
C2000.33= Centennial/ *C.chacoense*//op/3/Szegedi 80*2
C2000.68= Bantam/*C.chacoense*//op/3/Jalopino/4/Conquistador*2
C2000.72= Szegedi 80/Spanish Spice
C2000.82= Szegedi 20/C.*chacoense*//op/3/Szegedi 80/4/Kalocsai 801.2

To enumerate all the crosses at this stage would be too numerous, as all crosses were aiming to achieve the paramount goal to make condiment paprika suitable for mechanised production. To achieve this objective we have to introduce genes that are causing the pedicel to "snap off" from the stem easily and the fruit to detach from the calix freely. The "snap off" trait exists in a number of USA cultivars we used cultivar Jalapeno that not only has the "snap off" characteristic but also has a good colour when ripe. The trait of detachability from the calix can be found in a few wild *Capsicum* species eg. *C. chacoense, C. cardenacii, C. tovarii* and *C. eximium*. Up to date *C. chacoense* was used as the source of the fruit detachability trait. Recently with the help of New Mexico State University we obtained the three other above mentioned wild species from the United States Department of Agriculture collection. As mentioned earlier many authors regarded the fruit detachability gene and softness of the fruit at maturity as pleutropic. It seems that we successfully separated these two characteristics and now we have several early generation lines in our backcrossing program where the detachability is present, the fruits are relatively firm and have the condiment paprika characteristics. This part of the program has still a long way to go as besides the detachability we have to have firm stems and early fruits should be well above ground level so that the mechanical harvester can take off the fruits without damage.

The snap off characteristic is important both from hand or machine harvesting point of view. The introduction of this trait in the condiment paprika cultivars started before this project was initiated. Nearly all the advanced condiment paprika lines particularly the $F_4$ lines are having the "snap off" trait.

To be able to sow earlier and develop cultivars with cold tolerance we were considering *C. pubescens* as a potential parent. This species is endemic in South America's high mountains. Even under our conditions is setting fruit in late autumn and maturing during August. According to the literature it cannot be crossed with *C. annuum*. We have now three interspecific hybrid plants two of them are completely sterile, however, one plant is only male sterile and we obtained some seed of this plant that will be tested during 2000/2001 season.

In our crossing program and in the selections we are carefully monitoring the important quality traits. As at the present our main aim is to produce 'sweet paprika' therefore we must make sure that the lines we are selecting are free of capsaicin. The quantitative assessment of capsaicin is usually done by High Pressure Liquid Chromatography (HPLC). For plant breeding purposes this method is too slow and as our aim is the absence of capsaicin therefore a qualitative method is sufficient. At the present we are using an old modified qualitative method, which can indicate the presence of capsaicin. My assistant, Ms Fran Ebb, further developed the method and with a scoring system we can even have an indication of the quantity as well. The test is:

> The reagent is 100ml of ammonium-vanadate + 15ml concentrated hydrochloride acid (HCl). The test: 15ml of the reagent added into a test tube and a 1 - 2 cm paprika rib (the septum that is an extension of the placenta) is inserted. After gentle shaking it is advisable to let it stand overnight, the glands containing capsaicin will be visible as brownish spots.

The frequency of the brownish spots could indicate the amount of capsaicin present. Nevertheless, we are mostly interested in the negative aspects of this test. Other very important trait, which we have to follow, is the pigment content. This is determined with a spectrophotometry method where we are determining the extractable colour in paprika and their oleoresins by measuring the absorbency of an acetone extract by a spectrophotometer capable of accurately measuring absorbency at 460nm. To test according to the ASTA (American Spice Trade Association) analytical method a special glass filter must be used. The extractable pigment content is eventually expressed in ASTA figures. The special filters are fairly expensive and only BRI Australia has the appropriate filters, however, each test costs AUD25.00 therefore we had to find a cheaper solution as we have to do several hundred tests and the cost of it does not fit in with our budget. We established a simpler method, which we can do easily in the Plant Breeding Institute with a slight modification on the existing spectrophotometer. Our results are extremely good and the correlation between the BRI Australia results and our tests gave a correlation coefficient $r = 0.8489$.

## 3.3 Hybrid seed scheme

Some American seed firms produce capsicum hybrid seed by hand pollination. In spite of their program conducted in South American states where the hand labour is cheap, the hybrid seed produced is extremely expensive. Usually the seed is sold by numbers and not by weight. One kg paprika seed could cost over USD8,000.00. We are convinced that with our planned system we could produce paprika hybrid seed in a reasonable price bracket. We designed a system where the identification of genetic male sterility should be determined in the seedling stage and then the male sterile plants are propagated with the help of micropropagation. The so produced male sterile plants are planted together with the pollen source and the fertilisation will take place with the help of bees. There are a few basic problems, which have to be investigated as we are entering into an unknown field. The following themes should be further studied:

- Molecular markers must be found that indicate genetic male sterility at seedling stage.
- Micropropagation system should be developed as up-to-date no such system exists where condiment paprika can be micropropagated on a commercial scale.
- The field fertilisation with the help of bees should be further developed.

Unfortunately, due to lack of funds, this program is now shelved

# 4. Conclusions and Recommendations

## 4.1 Crop husbandry

Considering our own, the Hungarian and the New Mexican experiences a reasonable crop husbandry recommendation could be drawn up. Here we can strongly rely on the New Mexican practices as our climatic and soil conditions are similar.
Capsicum is successfully grown in several parts of Australia eg. South Australia, New South Wales particularly in Sydney market gardens, on broad acres in the Narromine region and in Queensland in the Bundaberg area. All of these productions are based more or less on horticultural practices, eg. transplanting seedlings, hand harvesting etc. Recently in New Mexico, Spain, France and Hungary the direction is to produce high dry matter capsicums (paprika) as broad acre row crops. The aim is full mechanisation so reducing the cost of production.

### 4.1.1Cultivars
There are several types of high dry matter capsicums in production. One of the groups of cultivars has sweet taste and no capsaicin content. The major cultivars in this group are:

Pimento types, mainly grown in Spain.
Hungarian Condiment Paprika cultivars with very high dry matter content (>18%), are used for production of spice and extraction of pigment eg.: Szegedi 80, Szegedi 20, Kalocsai 90 etc.
NM Conquistador with a pod-length of 15-18 cm and about 5cm width, has a relatively thick wall and lower dry matter content than the Hungarian cultivars.

When choosing capsicum cultivars for production we must consider yield, disease resistance, adaptability and market acceptance.

### 4.1.2 Preparing the Land
Rotate capsicum with wheat, barley, oats, lucerne, and maybe cotton to help prevent disease and to provide high production levels. Do not plant capsicum in the same field more than once every three to four years. Also never use a paddock which had sorghum as the previous crop.

A deep, well drained, medium textured sandy loam is best with a pH range of 6.5 to 8.0 for producing capsicum. Overhead irrigation should be avoided, furrow or drip irrigation is preferred. Level the field at the grade of 0.01 to 0.03% in one or both directions. A good drainage is essential to get rid of the extra water, reducing the risk of root diseases.

Preparing soil involves ploughing, deep chiselling, discing, smoothing, and listing. Form listed beds by scalping the top of the ridge with a drag harrow. Irrigate the field weeks before planting. Plant capsicum seed before the soil dries.

It is recommended to convert two normal-width beds into one wide planting bed with a bed shaper. Plant seed on each side of the bed about 10-15cm from the water furrow.

### 4.1.3 Climatic Requirements
Capsicum is a warm season crop that requires about the same growing conditions as tomatoes. Capsicum is very susceptible to spring frosts and grows poorly in the temperature range of 5-15 °C. If seeds are sown too early in the spring, germination rate is slow. Low soil temperatures in September and early October could delay emergence and growth. The soil temperature must be over 15°C to achieve a good emergence to ensure a good stand and yield. Higher yields result when the daily air temperature ranges between 18 and 32°C during fruit set. High temperature during summer does not affect fruit set if adequate moisture is supplied. In Australian experience we found that the

direct sown crop catches up with the transplanted crop at the main flowering stage. As a matter of fact the direct sown crop produced denser population and higher yields.

### 4.1.4 Nutrition

It is strongly recommended that a soil test be conducted to determine the nitrogen, phosphorus, potash and micro nutrient needs.

Broadcast the first nitrogen application and all the phosphorus before discing or listing. The New Mexican experience recommends adding 60-120kg of $P_2O_5$ per hectare before discing if levels are low. Alternatively, band Phosphorus (35kg of $P_2O_5$ /hectare) 7-10cm below the seed. Pre-plant nitrogen also generates vigorous seedling growth, which ensures a well branched plant by the first fruit set. Pre-plant nitrogen is not needed if a soil test shows that the soil has 20 ppm nitrate or more. Broadcast 25-35kg of actual nitrogen/hectare before discing if nitrogen is needed. Otherwise, band nitrogen 2.5-6kg/hectare approximately 10cm below the seed.

The Hungarian recommendation is higher. They recommend that on medium nutrient level soil the following nutrient application is needed. 6 - 7 months before sowing they apply

- 40 tonnes/hectare organic manure
- 120kg/hectare $P_2O_5$
- 120kg/hectare potash
- 50kg/hectare nitrogen certainly in the latter two we are talking about active ingredients.

During spring additional 120kg/hectare nitrogen is applied. Further on they strongly recommend liquid fertiliser application during the growing season. From the stage of ten true leaves till bulk flowering in seven to ten day intervals foliar application of liquid fertiliser is recommended. Foliar fertilising is also recommended between flowering and fruit setting. As stable-manure application in Australia is not customary the application of NPK should be increased instead.

The main point is to apply a steady supply of nitrogen to the plant during fruit set to produce greater yield. Liquid fertiliser solution could also be added to irrigation water.
High yielding or early setting crops may benefit from a third nitrogen application. Nevertheless, too much nitrogen can overstimulate growth producing large plants with only a few early fruits. During high rainfall and humidity, extra nitrogen delays maturity, results in succulent late maturing fruit and increase the risk of serious plant or fruit rot.

A guide is given in the following tables regarding nutrients used by European capsicum producers when growing cultivars with high dry matter content. Table 10. indicates the various soil types and their nutrient levels where capsicum can be grown. Table 11. shows a guide of the nutrition recommended to be used on various soil types

**Table 10. Nutrient status of various soil-types**

| | Medium | good | Very good |
|---|---|---|---|
| **Self mulching black soils** | | | |
| Humus % | 2.41-3.0 | 3.01-4.00 | 4.0- |
| $P_2O_5$ ppm | 81.00-130.00 | 131.00-200 | 201-400 |
| $K_2O$ ppm | 161.00-240 | 241-350 | 351-559 |
| **Lighter black soils Red-brown earth** | | | |
| Humus % | 2.51-3.30 | 3.41-4.50 | 4.51- |
| $P_2O_5$ ppm | 61-100 | 101-150 | 151-350 |
| $K_2O$ ppm | 201-330 | 331-450 | 451-650 |
| **Sandy loams** | | | |
| Humus % | 1.01-1.50 | 1.51-2.50 | 2.51- |
| $P_2O_5$ ppm | 61-100 | 101-200 | 201-400 |
| $K_2O$ | 81-120 | 121-180 | 181-380 |

**Table 11. Nutrient requirement in kg to produce 1 t of capsicum of a cultivar with 18% dry matter content.**

| Nutrient | Soil type | Where the soil's original nutrient status is: | | |
|---|---|---|---|---|
| | | Medium | Good | Very good |
| **Nitrogen N** | Self mulching Black soils | 14 | 13 | 10 |
| | Lighter Black & Red Brown earth | 15 | 14 | 12.5 |
| | Sandy loam | 15 | 14 | 12 |
| **Phosphorus $P_2O_5$** | Self mulching black soils | 12 | 11 | 8.8 |
| | Lighter Black & Red brown earth | 13 | 11 | 8.8 |
| | Sandy loam | 12 | 11 | 8.8 |
| **Potash $K_2O$** | Self mulching black soils | 17 | 16 | 15 |
| | Lighter black & Red-brown earth | 18 | 17 | 16 |
| | Sandy loam | 17 | 16 | 15 |

### 4.1.5 Sowing

In Australia most of the capsicums are grown by transplanting seedlings. This is an outdated old-fashioned methodology established by northern European migrants where capsicum and tomato can be grown only by transplanting seedlings. Admittedly transplanting is justified in areas where the growing season is limited. In Australia, with the exemption of Tasmania and some southern regions of Victoria there is sufficiently long growing season to exercise direct seeding.

As mentioned before paprika is a warm season crop that requires a long frost-free season to produce good quality, and high yields. In the northern areas sowing can take place from the beginning of October to late October. In Central New South Wales sowing can start at mid October when the probability of late frost is minimal. As a warning late sowing in November or December could be detrimental as the young emerging seedlings could be burnt.

In a persistently cold spring, delay planting because seedling growth is slow in cold soils. Slow growth can prolong seedling exposure to insects, diseases, salt or soil crusting, which can all kill seedlings.

Plant high quality seed. Sowing rate varies according to the aim of the crop. Western European growers aim for minimum 25,000 plants/hectare with their pimento type cultivars. We are aiming for high density stand similarly to the Central European (Hungarian) growers. With direct seeding we are aiming for 200,000-400,000 plants/hectare with non-determinate growth habit plants. With semi and fully determinate cultivars we should increase the plant density, depending on the cultivar, up to 600,000/hectare. We are recommending 4 - 6 kg seeding rate/hectare depending on seed size and cultivar. However, some of the more advanced overseas growers are sowing 5-9kg seed/hectare because the extra seed compensates for plant losses particularly from the curly top virus.
Use a harrow to loosen the soil and sow the seed 1.5-2.5 cm deep. The sowing depth, particularly in heavier soils is critical. Never sow deeper than 3 cm. The New Mexican farmers cover the row with a cap: a firm, protective soil layer, 7-10cm high, to reduce water evaporation. Remove the cap with a dragging harrow before seedlings emerge (the crook stage). Carefully adjust soil removal equipment so that a loose 1-1.5cm layer of soil covers the seedlings after dragging. This methodology helps to avoid seedling damage and at the same time encourages a rapid uniform seedling emergence.

When using beds where the furrows are 120cm or wider then sow on both edges of the bed.

As mentioned before, and cannot be over emphasised, capsicum seed is sensitive to low temperatures (below 15°C). Seeds will not germinate until the soil temperature increases above the critical level, or they will germinate sporadically over a period of several weeks. The ability of the seed to germinate at low temperatures varies with the variety and some varieties take 3 weeks or more to germinate in 15°C soils.

It is strongly advised to treat the seed with either Captan® or Thiram® as preventive measure against soil-borne diseases.

### 4.1.6 Cultivating

Shallow inter-row cultivation may control weeds and increases soil aeration. The application of pre emergence herbicides to control weeds is an economic solution. It cannot be over emphasised that before applying any weedicide consult the extension weed specialist either of the Department of Agriculture or the appropriate chemical company.

### 4.1.7.Fruit Set

The first flowers on paprika are expected to appear by mid to end of November in the northern districts with a single flower at the first branching node. Plants may flower later in the central west and southern areas. Flower numbers will double with each extra node. Fruits from early flowers are usually large and have higher pigment content at maturity.

Fruits do not set when the daily mean temperatures are below 15°C or above 33°C. Nevertheless, flowers will drop when the average night temperatures are above 24°C. Fruit set may be hindered if temperatures rise above 33°C after several flowers have set and fruits are developing.

### 4.1.8 Pest and Disease Control

Thrips, leafhoppers, and aphids can infest the emerging seedlings. During the growing season fruit fly and heliothis could affect the fruits. Against fruit fly systemic insecticides give good protection while against heliothis BT sprays give good results. Always has to be made sure that the labels are carefully read before using any pesticides, do not use any chemicals, whether it is a herbicide, insecticide, nematocide, or fungicide, if it is not labelled and licensed for capsicums.

Common diseases that may infect capsicum include *Phytophthora* root rot, *Verticillium* wilt, *Rhizoctonia* root rot, various viruses, and bacterial leaf spot.

Virus diseases could cause also serious problems. Curly top virus, tomato spotted wilt virus, lucerne mosaic virus and capsicum mottle virus also can be found. Aphids and leafhoppers are carriers of viruses.

### 4.1.9 Harvesting

The European growers harvest paprika by hand. Farmers in northern Queensland built a four-row capsicum picker. In the USA three firms are successfully manufacturing capsicum harvesters, one of them is capable of multiple harvests.

When capsicum is produced for drying or industrial purposes the fruit shape and size are less important, however, they need at least 120 ASTA colour units. It was found that both the American and Hungarian cultivars grown in Australia (at Cobbitty and Merriwa) the ASTA values were much higher than that experienced in the countries they originated from. If harvest is too early, some fruits will be immature, and the maximum colour will not have developed.

To avid high drying costs it is advisable to leave the fruits on the plants until their moisture content is below 50% and most of the leaves dropped.

Ethephon® as a ripening enhancer may defoliate, as well as hasten maturity. This chemical will also increase colour of paprika harvested before frosts. Application rates of 1200 - 2000 parts per million stops flowering and enhances fruit maturity.

### 4.1.10 Mechanisation

It is obvious that without full mechanisation condiment paprika production in Australia is uneconomical. Being a fledgling industry in this country cannot be expected from the small farmers to invest large amounts that are needed for a harvester and mobile continuous driers. Our recommendation is that similarly to the cotton industry in the Namoi Valley a condiment paprika co-operative be established. It is envisaged the government (State and/or Federal) provide interest free loan for the purchasing of one mechanical harvester, a mobile drier and an oleoresin extractor. Until the industry is fully established all members of the cooperative should use the equipment.

## 4.2 Research and Development

We believe that the research program, particularly the plant improvement that was initiated is imaginative and could have far reaching effect on the local and international condiment paprika production. Plant breeding is a long-term research commitment and it cannot be completed from start to finish within 4-5 years time. As was mentioned before the paprika industry in this country is in its infancy stage therefore the growers could not be committed to provide a research levy. For the before mentioned reasons a continuous Federal Government assistance is required. It would also be desirable that the State Agricultural Department, particularly NSW, should take a more intensive interest in this crop.

As was explained earlier this R&D project already achieved a number of 'world first'-s such as detachability of paprika fruit, interspecific hybridisation etc. We expect to solve a number of problems eg. hybrid paprika seed production, the value of which could be much greater than simply to grow condiment paprika for spice or oleoresin extraction.

# 5. Appendices

## 5.1 Appendix. World Paprika Production

| *Pimento, Allspice Production (Mt)* | Year | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1997** | **1998** | **1999** |
| **Africa** | 388,710 | 395,304 | 394,987 | 405,990 | 408,767 |
| **Algeria** | 7,000 | 7,000 | 7,000 | 7,000 | 7,000 |
| **Benin** | 21,723 | 18,337 | 16,000 | 15,000 | 15,000 |
| **Cameroon** | 18,500 | 19,000 | 19,000 | 19,000 | 19,000 |
| **Cape Verde** | 750 | 1,170 | 1,200 | 1,200 | 1,200 |
| **Central African Republic** | 97 | 97 | 97 | 97 | 97 |
| **Congo, Dem. Republic of** | 34,000 | 35,000 | 32,000 | 30,000 | 31,000 |
| **Côte d'Ivoire** | 14,000 | 14,000 | 14,000 | 14,000 | 14,000 |
| **Djibouti** | 190 | 190 | 190 | 190 | 190 |
| **Egypt** | 44,000 | 44,500 | 45,000 | 45,500 | 45,500 |
| **Ethiopia** | 105,000 | 110,000 | 110,000 | 112,000 | 113,000 |
| **Ghana** | 22,000 | 22,000 | 22,000 | 22,000 | 22,000 |
| **Kenya** | 5,000 | 5,100 | 5,100 | 5,200 | 5,100 |
| **Madagascar** | 3,600 | 3,600 | 3,400 | 3,400 | 3,500 |
| **Malawi** | 1,000 | 1,600 | 1,800 | 1,823 | 1,900 |
| **Mali** | 2,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| **Morocco** | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| **Niger** | 370 | 400 | 400 | 400 | 400 |
| **Nigeria** | 47,000 | 47,500 | 47,500 | 47,500 | 47,500 |
| **Réunion** | 430 | 430 | 430 | 430 | 430 |
| **Senegal** | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| **Sierra Leone** | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 |
| **South Africa** | 11,000 | 11,000 | 11,000 | 10,000 | 9,500 |
| **Sudan** | 7,200 | 7,300 | 7,200 | 7,350 | 7,400 |
| **Tanzania, United Rep of** | 6,100 | 6,200 | 6,100 | 6,200 | 6,300 |
| **Togo** | 2,200 | 2,200 | 2,200 | 2,200 | 2,200 |
| **Tunisia** | 7,000 | 7,000 | 7,000 | 7,000 | 7,000 |
| **Uganda** | 3,800 | 3,400 | 3,500 | 3,600 | 3,600 |
| **Zambia** | 350 | 380 | 370 | 400 | 450 |
| **Zimbabwe** | 4,900 | 5,400 | 10,000 | 22,000 | 23,000 |

| *Pimento, Allspice Production (Mt)* | Year | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1997** | **1998** | **1999** |
| **Asia** | 1,364,315 | 1,631,516 | 1,411,398 | 1,404,066 | 1,405,481 |
| **Bangladesh** | 52,670 | 52,550 | 53,000 | 53,000 | 53,000 |
| **Bhutan** | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| **Cambodia** | 8,500 | 8,500 | 9,000 | 9,000 | 9,000 |
| **China** | 175,000 | 180,000 | 200,000 | 200,000 | 200,000 |
| **India** | 810,000 | 1,066,000 | 822,000 | 810,000 | 810,000 |
| **Indonesia** | 500 | 500 | 500 | 500 | 500 |

| | | | | | |
|---|---|---|---|---|---|
| **Iran, Islamic Rep of** | 2,600 | 2,600 | 2,600 | 2,600 | 2,600 |
| **Israel** | 360 | 360 | 360 | 360 | 360 |
| **Laos** | 4,500 | 4,400 | 4,400 | 4,400 | 4,400 |
| **Malaysia** | 1,800 | 1,800 | 1,800 | 1,800 | 1,800 |
| **Maldives** | 6 | 6 | 6 | 6 | 6 |
| **Myanmar** | 31,500 | 32,300 | 35,000 | 38,000 | 39,915 |
| **Nepal** | 12,500 | 12,500 | 12,500 | 13,000 | 12,500 |
| **Pakistan** | 135,879 | 140,000 | 140,232 | 140,400 | 140,400 |
| **Thailand** | 32,000 | 33,000 | 33,000 | 33,000 | 33,000 |
| **Turkey** | 21,000 | 21,000 | 21,000 | 21,000 | 21,000 |
| **Viet Nam** | 73,500 | 74,000 | 74,000 | 75,000 | 75,000 |

| ***Pimento, Allspice Production (Mt)*** | **Year** | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1997** | **1998** | **1999** |
| **Europe** | 90,023 | 104,136 | 95,820 | 111,700 | 96,700 |
| **Bulgaria** | 700 | 700 | 700 | 700 | 700 |
| **Czech Republic** | 3,700 | 7,300 | 5,700 | 2,000 | 2,000 |
| **Greece** | 300 | 300 | 300 | 300 | 300 |
| **Hungary** | 40,793 | 52,105 | 45,323 | 65,000 | 48,000 |
| **Romania** | 28,000 | 27,000 | 26,000 | 26,000 | 28,000 |
| **Slovenia** | 4,459 | 6,138 | 6,100 | 6,100 | 6,100 |
| **Spain** | 6,883 | 5,993 | 6,000 | 6,000 | 6,000 |
| **Yugoslavia, Fed Rep of** | 5,188 | 4,600 | 5,697 | 5,600 | 5,600 |

| ***Pimento, Allspice Production (Mt)*** | **Year** | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1997** | **1998** | **1999** |
| **North & Central America** | 123,504 | 111,265 | 143,936 | 95,470 | 95,470 |
| **Grenada** | 77 | 70 | 70 | 70 | 70 |
| **Jamaica** | 9,630 | 10,370 | 10,400 | 10,400 | 10,400 |
| **Mexico** | 53,797 | 44,825 | 77,466 | 35,000 | 35,000 |
| **United States of America** | 60,000 | 56,000 | 56,000 | 50,000 | 50,000 |

| ***Pimento, Allspice Production (Mt)*** | **Year** | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1997** | **1998** | **1999** |
| **South America** | 3,100 | 3,100 | 3,100 | 3,100 | 3,200 |
| **Argentina** | 3,100 | 3,100 | 3,100 | 3,100 | 3,200 |

## 5.2 Appendix. Statistics of Variety Trials

**Selections and their codes.**

| Strain | Cultivar | Sub-trial | Code |
|---|---|---|---|
| Cap.28.5.b | Szegedi 20 | A | 2 |
| Cap.28.7.b | -"- | A | 3 |
| Cap.28.8.b | -"- | A | 4 |
| Cap.30.2.b | Szegedi 57-13 | A | 5 |
| Cap.30.3.b | -"- | A | 6 |
| Cap.30.4.b | -"- | A | 7 |
| Cap.43.1.b | Kalocsai 90 | A | 8 |
| Cap.39.b | Szegedi 80 | A | 1 |
| Cap.34.3.b | Szegedi 17 | B | 9 |
| Cap.34.5.b | -"- | B | 10 |
| Cap.34.9.b | -"- | B | 11 |
| Cap.36.6.b | Kalocsai 57-231 | B | 12 |
| Cap.36.8.b | -"- | B | 13 |
| Cap.36.9.b | -"- | B | 14 |
| Cap.01.b | Conquistador | B | 15 |
| Cap.39.b | Szegedi 80 | B | 1 |
| Cap.37.2.b | Kalocsai 801 | C | 16 |
| Cap.37.8.b | -"- | C | 17 |
| Cap.37.9.b | -"- | C | 18 |
| Cap.38.1.b | Kalocsai 50 | C | 19 |
| Cap.38.3.b | -"- | C | 20 |
| Cap.38.6.b | -"- | C | 21 |
| Cap.66.b | Papri Mild | C | 22 |
| Cap.39.b. | Szegedi 80 | C | 1 |
| Cap.40.1.b | Szentesi NFD | D | 23 |
| Cap.40.3.b | -"- | D | 24 |
| Cap.40.4.b | -"- | D | 25 |
| Cap.35.1.b | Kalocsai E-15 | D | 26 |
| Cap.35.2.b | -"- | D | 27 |
| Cap.177 | Kalocsai 101 | D | 28 |
| Cap. 179 | Kalocsai 121 | D | 29 |
| Cap.39.b | Szegedi 80 | D | 1 |

**VS Trial A. Cobbitty 1998/99**

```
                       HOMOGENEOUS
 CULTIVAR       MEAN    GROUPS
---------  ---Kg/plot-----  -----------
     7        5.427    I
     6        5.382    I
     4        5.010    I
     8        4.956    I I
     1        4.715    I I
     3        4.457    I I
     5        4.398    I I
     2        3.662   .. I

THERE ARE 2 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.
CRITICAL T VALUE                    2.064   REJECTION LEVEL    0.050
CRITICAL VALUE FOR COMPARISON      1.311
```

```
STANDARD ERROR FOR COMPARISON      6.35
```

**VS Trial B. Cobbitty 1998/99**

```
LSD (T) COMPARISON OF MEANS OF YIELD BY CULTIVARS
                       HOMOGENEOUS
CULTIVARS      MEAN    GROUPS
---------  ----------  -----------
    15       7964.8     I
    11       5256.8    .. I
     9       4831.8    .. I
    10       4662.0    .. I
    12       4653.3    .. I
    13       4630.3    .. I
     1       4112.8    .. I
    14       4099.8    .. I

THERE ARE 2 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.
CRITICAL T VALUE                    2.064   REJECTION LEVEL    0.050
CRITICAL VALUE FOR COMPARISON      1288.3
STANDARD ERROR FOR COMPARISON      624.18
```

**VS Trial C. Cobbitty 1998/99**

```
LSD (T) COMPARISON OF MEANS OF YIELD BY CULTIVAR
                       HOMOGENEOUS
 CULTIVAR      MEAN    GROUPS
---------  ----------  -----------
    22       7166.5     I
    19       5525.8     I I
    17       4863.5    .. I
    21       4704.8    .. I
    20       4678.3    .. I
    16       4197.5    .. I I
     1       2863.5    .... I
    18       2552.0    .... I

THERE ARE 3 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.
CRITICAL T VALUE                    2.064   REJECTION LEVEL    0.050
CRITICAL VALUE FOR COMPARISON      1741.9
STANDARD ERROR FOR COMPARISON      844.00
```

**VS Trial D. Cobbitty 1998/99**

```
LSD (T) COMPARISON OF MEANS OF YIELD BY CULTIVAR
                       HOMOGENEOUS
 CULTIVAR      MEAN    GROUPS
---------  ----------  -----------
    29       5543.3     I
    24       4890.5     I I
    28       4829.8     I I
     1       4711.8     I I
    26       4690.5     I I
    25       4173.8    .. I I
    23       3959.8    .. I I
    27       3254.3    .... I

THERE ARE 3 GROUPS IN WHICH THE MEANS ARE
NOT SIGNIFICANTLY DIFFERENT FROM ONE ANOTHER.
CRITICAL T VALUE                    2.064   REJECTION LEVEL    0.050
CRITICAL VALUE FOR COMPARISON      1107.6
STANDARD ERROR FOR COMPARISON      536.66
```

## 5.3 Appendix. *CAPSICUM* ACCESSION LIST

**1996 -**

| **Accs. No: C.** | **Name:** | **Origin:** | **Pedigree:** | **Code:** | **Seed g** |
|---|---|---|---|---|---|
| 0001 | Conquistador | New Mexico | | NMCQ | |
| 0002 | Jalapeno TM Mild | NM | | NMJLP | |
| 0003 | Csipos Alma [Tangy Aple] | Hungary | | CSAL | |
| 0004 | Edes Alma [Sweet Aple] | Hungary | | EAL | |
| 0005 | Feherozon | Hungary | | FHO | |
| 0006 | Elefantormany | Hungary | | ELF | |
| 0007 | Macska Narancs | Hungary | | MNAR | |
| 0008 | Macska Piros | Hungary | | MPIR | |
| 0009 | Macska Sarga | Hungary | | MSAR | |
| 0010 | Rapires | Hungary | | RAP | |
| 0011 | Syn. Cecei | Hungary | | SCEC | |
| 0012 | Chery Hot Red | New Mexico | | CHR | |
| 0013 | Jigsaw (Ornm) | N. M. | | JIGS | |
| 0014 | Centennial (Ornm) | NM | | CENT | |
| 0015 | Twilight (Ornm) | NM | | TWL | |
| 0016 | Sunglo (Ornm) | NM | | SGLO | |
| 0017 | Sunburst (Ornm) | NM | | SBRST | |
| 0019 | Eclipse (Ornm) | NM | | ECLP | |
| 0020 | Aji Amarilo | NM | *C. baccatum* | AJIA | |
| 0021 | Aji Brown | NM | *C. chinense* | AJIB | |
| 0022 | Guajilo | NM | | GUJ | |
| 0023 | Habanero Red | NM | | HABR | |
| 0024 | Habanero | NM | | HAB | |
| 0025 | Tabasco | NM | *C. frutescens* | TAB | |
| 0026 | Roccoto Yellow | NM | *C. pubescens* | ROCY | |
| 0027 | Roccoto Red | NM | *C. pubescens* | ROCR | |
| 0028 | Szeged 20 | Hungary (H) | *C. annuum var. longum* | SZ20 | |
| 0029 | Szeged FO3 | H | | SZFO3 | |
| 0030 | Szeged 57-13 | H | | SZ57-13 | |
| 0031 | Szeged 179 | H | | SZ179 | |
| 0032 | Szeged 178 | H | | SZ178 | |
| 0033 | Cap 96411 | H | | SZ411 | |
| 034 | Cap 96017 (Sweet) | H | | SZ017 | |
| 035 | Kalocsa E-15 | H | | KE15 | |
| 0036 | Kalocsa 57-231 | H | | K57231 | |
| 0037 | Kalocsa 801 | H | | K801 | |
| 0038 | Kalocsa 50 | H | | K50 | |
| 0039 | Szeged 80 | H | | SZ80 | |
| 0040 | Szentesi NFD | H | | SZNFD | |
| 0041 | Campana | ? | | CAMP | |
| 0042 | Hungarian Yellow Wax | Queensland | | QL616 | |
| 0043 | Kalocsa 90 | H | | K90 | |
| 0044 | Tizenegyes | H | | 11 | |

| | | | | | |
|---|---|---|---|---|---|
| 0045 | Suptol | H | | SPTL | |
| 0046 | Hosszu Taltos | H | | HTLTS | |
| 0047 | B-420 | H | $F_1$ | B420 | |
| 0048 | B-56 | H | | B56 | |
| 0049 | Korona | H | | KRNA | |
| 0050 | *C. chacoense* | NM | | Chc | |
| 0051 | ASAS-O1A | ASAS | Marketer/Ornam | O1A | |
| 0052 | ASAS-O1B | ASAS | Mark/Ornam | O1B | |
| 0053 | ASAS-O3A | ASAS | Mark/Ornam | O3A | |
| 0054 | ASAS- P3A | ASAS | Mark/Ornam | P3A | |
| 0055 | ASAS-P3B | ASAS | Mark/Ornam | P3B | |
| 0056 | ASAS-P3C | ASAS | Mark/Ornam | P3C | |
| 0057 | ASAS-T6A | ASAS | Ornam/Festival | T6A | |
| 0058 | ASAS-T6B | ASAS | Ornam/Festival | T6B | |
| 0059 | ASAS-FA | ASAS | Mamma/Bovet | FA | |
| 0060 | ASAS-FB | ASAS | Mamma/Bovet | FB | |
| 0061 | ASAS- H3A | ASAS | Tomato Y/Bovet | H3A | |
| 0062 | ASAS- H3B | ASAS | Tomato Y/Bovet | H3B | |
| 0063 | Ps72285 | USA | | 72285 | |
| 0064 | Papri King | USA | | PPKG | |
| 0065 | Papri Queen | USA | | PPQN | |
| 0066 | Papri Mild | USA | | PPM | |
| 0067 | Top Girl | USA | | TGRL | |
| 0068 | Liebes Apfel | | | Lapf | |
| 0069 | Caysan | USA | | CAY | |
| 0070 | Firefly | USA | | FFY | |
| 0071 | Cluster | USA | | CLST | |
| 0072 | SPS 770 | USA | | 770 | |
| 0073 | NM 64 | USA | | NM64 | |
| 0074 | NM Joe Parker | USA | | NMJP | |
| 0075 | NM Big Jim | USA | | NMBJ | |
| 0076 | NM Sweet | USA- NM | | NMSWT | |
| 0077 | Look 'N' Eat - Bantam | ASAS | R10 | BTM | |
| 0078 | Look 'N' Eat -'Thimble' | ASAS | T6 | GNMC | |
| 0079 | R10, R3 | ASAS | Festival/Ornamental | R!0 | |
| 0080 | NM. Santa Fe Granda | USA | | SfeG | |
| 0081 | Kalocsai E-15 | Hungary | | KE15 | |
| 082 | Jumbo Jalapeno | USA | | JJP | |
| 083 | Espanola impv. | USA | | ESPIMP | |
| 084 | Coloro | USA | | COL | |
| 085 | Bona Paprika | Hungary | Eco-type, Szeged | | |
| 086 | Bullhorn Red | | | BHR | |
| 087 | Long Red Cayenne | | | LRC | |
| 088 | C88.146.b.1.1.1.1.b.3.5 | ASAS | O1C | O1C | |
| 089 | Ancho Mulato | USA | NM State Uni. | ANM | |
| 090 | Barkers Hot | USA | " | BARKH | |
| 091 | Budai Csipos Hajtatasi | Hungary" | | BUDCS | |
| 092 | Fecske | " | | FCSK | |
| 093 | Kecskeszarv | " | | KCSKSZ | |
| 094 | Cayenne Long Red Thick | USA | | LDCYN | |
| 095 | Mirasol | " | | MRS | |

| | | | | | |
|---|---|---|---|---|---|
| 096 | Numex 6-4 | " | | NM64 | |
| 97 | Passila | " | | PSLA | |
| 98 | Pasilla de Oxaca | " | | PSLAO | |
| 99 | Peter Pepper | " | | PP | |
| 100 | Santa Fe Grande | " | | SFEG | |
| 101 | Sobor | Hungary | | SBR | |
| 102 | Taltos | Hungary | | TLTS | |
| 103 | T52 $F_1$ | Hungary | | T52 | |
| 104 | CHI-1/1000 | Hungary | *C. chinese* | CHI1 | |
| 105 | CHI-25/1039 | Hungary | *C. chinense* | CHI25 | |
| 106 | CHI-2/101 | Hungary | *C. chinense* | CHI2 | |
| 107 | CHI-10/1011 | Hungary | *C. chinense* | CHI10 | |
| 108 | Rapires $F_1$ (New) | Hungary | | RAP | |
| 109 | Brill $F_1$ | Hungary | | BRL | |
| 110 | Dabora $F_1$ | Hungary | | DBR | |
| 111 | HM-2 $ms_1$ TMU $L^1$ 1992 | Hungary | Pale green, pointed, sweet, Γ sterile | HM2 | |
| 112 | HM-3 $ms_1$ TMU $L^3$ 1996 | Hungary | Pale green, pointed ,hot<br>Γ sterile | HM3 | |
| 113 | HM-5 $ms_1$ TMU $L^3$ 1997 | Hungary | Pale green, pointed, sweet, Γ sterile | HM5 | |
| 114 | Omnicolor | USA, NM | *C. baccatum* | OMN | |
| 115 | NM Twilight Res.CMV sgr | USA, NM | New | TWI2 | |
| 116 | Joe E. Parker Res TMV (0) | USA, NM | New | NMJP2 | |
| 117 | Carolina Cayenne Res. *M. incognita* rac.1,2,3 & 4 | USA, NM | | CRCYN | |
| 118 | Crillio De Moral's NMCA10467 (CM-334) Res.*Phytophttora* | USA, NM | | CRMRL | |
| 119 | PI.215699 Selection of res.:*Verticillium* wilt | USA, NM | | ResVert. | |
| 120 | Ornamental-3 | Flagrant Garden | | ORN3 | 1 pct |
| 121 | Purple Delight | Flagrant Garden | | PRPDEL | |
| 122 | Purple Tiger | Flagrant Garden | | PRPTGR | |
| 123 | Purple Prince Chilli | Flagrant G. | | PRPPRNC | |
| 124 | Sweet Chocolate | Flagrant G | | SWCHC | |
| 125 | Thai | Flagrant G. | | THI | |
| 126 | Fiesta | Flagrant G | | FSTA | |
| 127 | Cubanelle | Flagrant G | | CBNLL | |
| 128 | Red Missile | Kaydees, NZ | | RDMIS | |
| 129 | Hungarian Yellow Wax-2 | Eden, Seeds | | HYWX2 | |
| 130 | Purple Tiger-2 | Eden, Seeds | | PRPTGR2 | |
| 131 | Jaranda | France (Norbert) | | JAR | |
| 132 | Jariza | France (Norb.) | | J7A | |
| 133 | PM 1256 | Antilles | | PM1256 | |

| | | | | | |
|---|---|---|---|---|---|
| 134 | PM 807 H3 | Ethiopia | | PM807 | |
| 135 | PM 815 Erfutu | China | | PM815 | |
| 136 | PM 1231 (R: Phyto) Chourbadjiiiski | Bulgaria | | PM1231 | |
| 137 | PM 1234 Cochin | India | | PM1234 | |
| 138 | PM 1241 Jaipur | China | | PM1241 | |
| 139 | PM 1258 Emeishanz | China | | PM1258 | |
| 140 | PM 1335 | Reunion | *C. baccatum* | PM1335 | |
| 141 | Aji Panca | Pepper Gal | *C. chinense* | APCA | |
| 142 | Baby Fire | Pepper Gal (PG) | | BFRE | |
| 143 | Bahamian Chile | PG | | BHCH | |
| 144 | Tepin (Birds Eye) | PG | | TPN | |
| 145 | Bouquet | PG | | BQT | |
| 146 | Cherry (Hot) | PG | | CHRY | |
| 147 | Cherry Bomb | PG | | CHRYBB | |
| 148 | Fiesta | PG | | FST | |
| 149 | Fips | PG | | FPS | |
| 150 | Firecracker | PG | | FRECR | |
| 151 | Fireworks | PG | | FREW | |
| 152 | Hero ($F_1$) | PG | | HRO | |
| 153 | Holiday Time | PG (Honduras) | | HDYT | |
| 154 | Marbles | PG | | MRBL | |
| 155 | Mexican Red Hot | PG | | MRH | |
| 156 | Poinsettia | PG | | PSTT | |
| 157 | Sport | PG | *C. frutescens (?)* | SPRT | |
| 158 | Varingata | PG | | VRNG | |
| 159 | White Fire | PG | | WFRE | |
| 160 | White Fire -2 | PG | | WFRE2 | |
| 161 | Yatsafusa | PG (Japan) | | YFSA | |
| 162 | Boldog (Hungarian Spice) | PG (Hungary) | *C. A. covar. Longum* | BLDG | |
| 163 | Canada Cheese | PG | | CCHS | |
| 164 | Cetinel | PG | | CTNL | |
| 165 | Cherry -Sweet | PG | | CHRYSW | |
| 166 | Cherry, Super Sweet | PG | | CHRYSSW | |
| 167 | Corno di Toro, Red | PG (Italy) | | CRTRO | |
| 168 | Cubanelle-2 | PG | | CBNLL2 | |
| 169 | Friariello | PG (Italy) | | FRRLL | |
| 170 | Fushimi | PG (Japan) | | FSHM | |
| 171 | Italian Sweet | PG | | ITALSW | |
| 172 | Lilac ($F_1$) TMV resist. | PG | | LLC | |
| 173 | Pimento | PG (Spain) | | PMNT | |
| 174 | Spanish Spice | PG (Spain) | | SPSPC | |
| 175 | Super Shepherd | PG (Italy) | | SUPSHP | |
| 176 | Kalocsai 100 | Hungary | | K100 | |
| 177 | Kalocsai 101 | Hungary | | K101 | |
| 178 | Kalocsai m 121 | Hungary | | K121 | |
| 179 | Heirloom Mix | Fothergills | | HEIR | |
| 180 | Hung. Yellow Wax -3 | Eden | | HYWX3 | |

| | | | | | |
|---|---|---|---|---|---|
| 181 | Purple Tiger 3 | Eden | | PRPTGR3 | |
| 182 | Szegedi 57-13 | Hungary | | Sz57-13 | |

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