International Specialised Skills Institute

Victoria
The Place To Be

NATURAL AND CULTIVATED TRUFFLE PRODUCTION

Quality Assurance in Italy, France and Spain

Colin Carter
Skills Victoria/ISS Institute TAFE Fellowship

Fellowship funded by Skills Victoria,
Department of Innovation,
Industry and Regional Development,
Victorian Government

ISS Institute Inc
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Cover photo: Colin and Nathan Carter with a truffle vendor at Lalbenque Market

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Executive Summary

This Skills Victoria/ISS Institute TAFE Fellowship was sponsored by Skills Victoria. It provided The Fellow with the opportunity to undertake an overseas study program in trufficulture in the main growing regions throughout Europe. The primary focus of this Fellowship was the issues of quality assurance (QA) and improved production levels.

In addition, the study provided an opportunity for the Fellow to gain first-hand experience in production techniques used in natural truffle forests and cultivated truffières. It also allowed the Fellow to gain an understanding of the evaluation of different QA methods used by the three countries visited. Knowledge was also gained in truffière maintenance and irrigation techniques. The information learnt will be of great benefit to, and shared with the Australian industry.

The truffle industry in Australia is largely made up of small growers, most with primary sources of income from other industries. Whilst the local industry is still young, more and more local truffières are coming into production and it is becoming noticeable that production levels vary between regions and overall are quite low.

Currently, in the Australian truffle industry there is no industry-specific QA scheme for truffle cultivation. This specifically relates to the nursery-produced inoculated truffle trees requiring a high percentage of infected roots of the correct species that are free from competitor contamination. The export of fresh product overseas is crucial; as the demand in local markets becomes saturated, the need to export becomes much greater. The industry has many phenological and seasonal advantages over naturally producing countries in terms of export competition. But, for these advantages to be truly realised and for the assurance of long-term success a quality product is vital.

In Europe there were many species of Tuber and similar genera that were present in natural forests as well as cultivated truffières. For the most part, Australian truffières require the addition of large amounts of lime to bring soil pH levels up to a level that favours the truffle. Whilst this is a costly process it does give favourable advantages: native mycorrhizas, which would be competitors, cannot survive in these heavily ameliorated soils. The desired species can survive and have the potential to be very productive, as they are free from competitors. Also in Europe, Tuber indicum (known as the Chinese truffle) has been introduced but is yet to find it's way to Australian shores. It is, however, important that local growers be able to easily identify different species. Morphological testing of spores and infected roots is the most practical and relatively inexpensive way of identifying different species. It does require a high-powered microscope and expert identification skills, but provides reliable results.

All of the three countries visited had their own internal certification system for nursery-produced trees. Whilst each country works independently from the others, all testing of trees was based on similar criteria. The three main criteria were:

- infection of the plant with the desired species
- high level of infection (the minimum level was set by each country)
- a plant that was free from competitor fungi.

All tree nurseries had strong alliances with the local universities and these universities provided the assessment and certification of the young trees.

Maintenance and irrigation techniques are critical in cultivated truffières. The natural forests in Europe that were not subject to irrigation had production levels that varied greatly from year to year. During the 2008 season production was particularly low due to a hot, dry summer. Ongoing research is being conducted on moisture monitoring; in particular which moisture levels are ideal and determining critical times to irrigate. These results will be beneficial to Australia, though the research will need to be replicated locally to ensure relevance.

Executive Summary

Formative pruning was used consistently throughout the life of the tree. This maintained the tree in a conical shape. The trunk was free from branches to a point approximately two meters up the trunk of the tree. This helped the farmers harvest with ease and maximised sunlight to the soil. Also of importance was controlling the vegetative growth of the tree. Since vegetative growth is proportional to root growth, pruning can be used to control root growth and better match the infection rate with root growth to minimise the number of roots in the soil that are not infected by the desired species and, therefore, prone to contamination from competitor fungi.

The Fellow noted that cultivation techniques were widely used in Europe. Shallow tilling was carried out from the end of the harvest through to summer. The purpose of this was to remove the infected roots at the surface, causing the truffles to form deeper down in the soil in order to ensure they were not exposed to the elements. This eliminated the chance of them drying out and cracking and also limited insect damage; thereby, reducing the onset of secondary bacterial damage and rot. Shallow tilling also aided in controlling weeds and oxygenating the soil.

In Italy and France the businesses visited were operated very professionally. Whilst there was no industry-specific QA scheme in operation, they still operated under their own strict hygiene protocols. Under these certification processes insects and undesirable fungi were not tolerated. All trees were grown on raised benches. Only the strongest plants were chosen for infection and only the best quality inoculum were used. Plant health was intensely monitored and consequently all plants offered for sale were of the highest quality.

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Abbreviations/Acronyms

ACT	Australian Capital Territory
AD	Angle droix
AFP	Air filled porosity
AQIS	Australian Quarantine and Inspection Service
ATGA	Australian Truffle Grower's Association
CTFC	Centre Tecnològic Forestal de Catalunya (Forest Technology Centre of Catalonia), Spain
DPI	Department of Primary Industries
INRA	Institut National de la Recherche Agronomique (French National Institute for Agricultural Research), France
ISS Institute	International specialised Skills Institute, Inc.
kPa	Kilopascal
NPK	Nitrogen (N) Phosphorus (P) and Potassium (K). A Nitrogen, Phosphorus and Potassium fertiliser
pH	A measure of acidity or alkalinity
PCR	Polymerase Chain Reaction
QA	Quality assurance
R&D	Research and development
RIRDC	Rural Industries Research Development Corporation
SWOT	Strengths, Weaknesses, Opportunities, Threats
TAFE	Technical and Further Education
VCAH	Victorian College of Agriculture and Horticulture, Burnley
VET	Vocational Education and Training

Definitions

Angle droix
A competitive mycorrhizal fungi. Roots infected with AD are easily confused with Tuber melanosporum.

Ameliorated
Improved

Brûlé
Area of ground under a truffle tree that appears burnt of vegetation due to the active mycorrhiza.

Calcareous
A soil containing accumulations of calcium and magnesium.

Corylus sp – Hazel
A deciduous tree with a pyramidal crown, 3 to 15 metres in height.

Cystidia
The external hyphae (*mycorrhizal* threads) protruding from a mycorrhized root tip.

Design
Design is problem setting and problem solving.

Design is a fundamental economic and business tool. It is embedded in every aspect of commerce and industry and adds high value to any service or product—in business, government, education and training, and the community in general.

Reference: ‘Sustainable Policies for a Dynamic Future’, Carolynne Bourne AM, ISS Institute 2007.

Gleba
The tissue of the truffle fruit body under the peridium.

Inoculum
The material used in an inoculation.

Interveinal chlorosis
Iron deficiency

kPa
Kilopascals. A measure of soil tension, represented in a pressure rating.

Morphological
A detailed study of the various characteristics of truffles, including, but not limited to, depth of fruit, shape, texture, colour, growth, and anatomical features.

Phenological
Periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate.

Definitions

Peridium

The outer layer of the truffle.

Quercus sp

Genus of oak tree

Skill deficiency

A skill deficiency is where a demand for labour has not been recognised and training is unavailable in Australian education institutions. This arises where skills are acquired on-the-job, gleaned from published material or from working and/or studying overseas.

Reference: 'Directory of Opportunities. Specialised Courses with Italy. Part 1: Veneto Region', ISS Institute, 1991.

There may be individuals or individual firms that have these capabilities. However, individuals in the main do not share their capabilities, but rather keep the intellectual property to themselves. Over time these individuals retire and pass away. Firms likewise come and go.

Sustainability

The ISS Institute follows the United Nations for Non-Governmental Organisations' definition on sustainability: *"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".*

Reference: http://www.unngosustainability.org/CSD_Definitions%20SD.htm

Tuber

Genus of truffle

Tuber indicum

Chinese truffle

Tuber magnatum

Italian white truffle

Tuber melanosporum

French black truffle

Truffière

Truffle farm

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Colin Carter would like to thank the following individuals and organisations who gave generously of their time and their expertise to assist, advise and guide him throughout the Fellowship program.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The Fellow would like to acknowledge the support of the CEO and staff of ISS Institute, particularly Paul Sumner and Ken Greenhill, in developing the study program and preparation of this report.

The International Specialised Skills Institute Inc is an independent, national organisation that for over two decades has worked with Australian governments, industry and education institutions to enable individuals to gain enhanced skills and experience in traditional trades, professions and leading-edge technologies.

At the heart of the ISS Institute are our Fellows. Under the **Overseas Applied Research Fellowship Program** the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

1. Preparing a detailed report for distribution to government departments, industry and educational institutions.
2. Recommending improvements to accredited educational courses.
3. Delivering training activities including workshops, conferences and forums.

Over 180 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 22 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010':

> Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change.
>
> International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills, but also multiple and higher level skills and qualifications. Deepening skills across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills across a range of industries and occupations.[1]

In this context, the ISS Institute works with Fellows, industry and government to identify specific skills in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional practice, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see www.issinstitute.org.au.

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[1] Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010', pp. 1-2 http://www.skillsaustralia.gov.au/PDFs_RTFs/WWF_strategy.pdf

Fellowship Sponsor

The Victorian Government, Skills Victoria is responsible for the administration and coordination of programs for the provision of training and further education, adult community education and employment services in Victoria and is a valued sponsor of the ISS Institute. Carter would like to thank them for providing funding support for this Fellowship.

Supporters

The Fellowship was made possible by the valued support of the following individuals and organisations:

- Arthur Blewitt, Chief Executive Officer, AgriFood Skills Council
- Alan Davey, Senior Research Manager, The Rural Industries Research and Development Corporation
- Wayne Haslam, President, The Australian Truffle Grower's Association
- Louise Palmer, Deputy Vice Chancellor, Swinburne University of Technology (TAFE Division)

Australian Individuals and Organisations Impacted by this Fellowship

- **Five Acre Nursery**

  Contact: Al Blakers, Manjimup, Western Australia

  Description: Grower and supplier of truffle-inoculated trees and truffles

- **Friend and Burrell Pty Ltd**

  Contact: Bryan Burrell, Kew, Victoria

  Description: Wholesaler of truffles (in season)

- **Nursery and Garden Industry Australia**

  Contact: Robert Prince, Epping, NSW

  Description: Australian Nursery Industry Association

- **Nursery and Garden Industry Victoria**

  Contact: Robert Chin, Caulfield East, Victroria

  Description: Victorian Nursery Industry Association

- **Perigord Truffles of Tasmania Pty Ltd**

  Contact: Duncan Garvey, Grove, Tasmania

  Description: Grower and supplier of truffle-inoculated trees

- **Rural Industries Research and Development Corporation**

  Contact: Alan Davey, Kingston, ACT

  Description: Government rural research body

- **Swinburne University of Technology (TAFE)**

  Contact: Fred Hellriegel, Department of Horticulture and Environment, Wantirna, Victoria

  Description: Registered Training Organisation (RTO), providing education and training in all areas of horticulture.

- **The Australian Truffle Grower's Association**

  Contact: Wayne Haslam, Sutton, NSW

  Description: Australian truffle industry association

- **Trufficulture Pty Ltd**

  Contact: Nathan Carter, Gembrook, Victoria

  Description: Grower and supplier of truffle-inoculated trees

- **Truffles Australis Pty Ltd**

  Contact: Tim Terry, Deloraine, Tasmania

  Description: Grower and supplier of truffle-inoculated trees

- **The Wine and Truffle Company**

  Contact: Nick Malajczuk, Manjimup, Western Australia

  Description: Grower and supplier of truffle-inoculated trees and truffles

About the Fellow

Name: Colin Carter

Employment

- Senior Educator, Swinburne University of Technology (TAFE Division).

Qualifications

- Diploma of Sustainability, Swinburne University of TAFE, 2009.
- Diploma of Training and Assessment, Swinburne University of TAFE, 2009.
- Diploma of Victorian Education and Training (VET) practice, Swinburne University of TAFE, 2008.
- Diploma of Horticultural Science, Victorian College of Agriculture and Horticulture (VCAH), Burnley, 1974 (now part of University of Melbourne).

Memberships

- The Australian Truffle Grower's Association (ATGA)
- Victorian Horticultural Training Network

Brief Biography

Over a career of more than thirty years Colin Carter has gained enormous experience in many sectors of horticulture industry. The first 10 years of his career he was in the area of horticultural allied trades supply with Hortico (a supplier of garden products to the retail nursery industry). This was followed by another nine years with Safeway Stores as the Nursery Consultant and Buyer for their 140 stores. Carter then decided to branch into his own business supplying supermarkets with floral products through his company Farm Fresh Flowers Pty Ltd. In 2000 the business was sold and Carter joined the teaching team at Swinburne University of Technology (TAFE) in Wantirna, Victoria, where he is currently employed. During this period Carter has maintained his strong interest in growing plants and working with the family wholesale nursery business at Gembrook.

Several years ago, as part of the teaching curriculum Carter became interested in the fascinating world of subterranean fungi known as *mycorrhiza*. Another teaching colleague was developing a French black truffle (*Tuber melanosporum*) farm or truffière and Carter's interest was sparked. Carter researched as much information as possible on the technical and culture aspects associated with truffle growing and began trial work on the inoculation of the fungus onto oak trees.

The first successfully inoculated trees were grown in 2008 and planting in the truffière at Gembrook has begun. The family nursery business, Trufficulture Pty Ltd, also supplies inoculated trees to the industry.

Carter became an Associate member of the ATGA in 2008 and is passionate about developing the fledgling Australian industry. He has realised that whilst truffle growers have begun harvesting truffles they are experiencing low and inconsistent yields and there is an apparent knowledge deficiency in the trufficulture practices and understanding of the mycology of this specialised and often unseen fungus. Carter saw the need to gather knowledge from truffle experts, researchers and growers around the world and apply this to the Australian industry whilst taking into account the local climatic differences.

The introduction of the inferior Chinese truffle (*Tuber indicum*) into Australian French black truffières could have the potential risk of damaging the 'green image' of the Australian truffle industry. Carter believes a quality assurance (QA) system needs to be introduced along with improved knowledge of the identification of truffle fungi, to prevent the spread of this inferior species. His vision is to make this information available to all growers in order to allow the Australian truffle industry to prosper and grow.

Aims of the Fellowship Program

The purpose of the Fellowship program was to undertake an overseas study program to gain an insight into European trufficulture methods and quality standards of inoculation nurseries and truffières. The aims were as follows:

- Efficiently and accurately identify various species of truffle.
- Design an industry standard audit, accreditation, certification, evaluation and monitoring process for the inoculation of host trees.
- Develop improved techniques for the vegetative propagation of the *Quercus sp* species.
- Determine the variables and evaluate seasonal maintenance and irrigation techniques used in cultivated truffières.
- Develop improved harvest yields through field trials and agricultural practices.
- Develop best business practice in creating, building and sustaining a financially viable inoculation nursery.

The Australian Context

A Brief Description of the Industry

The Australian truffle industry originated in Tasmania with the establishment of the first truffière in 1992 and the harvest of the first Australian French black truffle in 1999. The industry has since grown and reached a new level of maturity over the last 10 years. It now appears to be entering a new phase of industry investment and growth. With limited supply and robust world prices for the prized French black truffle, Australia has an opportunity to establish itself as the largest supplier in the southern hemisphere.[2]

Growers vary from the larger capital-intensive commercial enterprises through to the part-time hobby farmers and professional retirees on small acreage properties. There appears to be considerable interest in the potential of establishing new truffières.

A recent Rural Industries Research Development Corporation (RIRDC) report (Number 124) indicated that the potential export market was insatiable and would not become saturated in the foreseeable future due to the huge unfulfilled demand. Also the Australian winter harvest season is separated by six months from the northern hemisphere and, therefore, poses no threat to the European market.

Truffières are now established in Western Australia, Tasmania, Victoria, New South Wales and the Australian Capital Territory (ACT) and producers have begun harvesting. However, these farms are experiencing low yields with low proportions of trees harvesting truffles. It is well documented that the prized *Tuber melanosporum* has always maintained a mystique allure surrounding its culture methods, harvesting and culinary values. Knowledge has not been easily obtained and quite often locked within commercial agreements. There are many knowledge and skill deficiencies that need to be addressed in the trufficulture requirements and growing practices regarding Australian truffières.

The native Australian *mycorrhizae* does not compete favourably with the introduced *Tuber* species in calcareous soil so we have an opportunity to develop a ‘clean green’ marketing image. Most Australian soils are acidic and need to be ameliorated with lime to a pH of eight to become calcareous. Most native *mycorrhizae* are not adapted to exist in calcareous soil and therefore cannot survive and compete with the introduced *Tuber sp.* Consequently, Australian truffieres should only produce truffles of the same type as that used to inoculate the trees prior to planting. However, this is dependant on not allowing the introduction and spread of the inferior Chinese truffle.

The Fellow believes that an identification process of all the *Tuber* species and other possible contaminants is of paramount importance and there has been some very good work done towards this by Ian Hall in New Zealand, and others in Europe. The industry needs to develop identification tools for inoculation nurseries, growers, wholesalers, Australian Quarantine Inspection Service (AQIS) authorities and Department of Primary Industries (DPI) authorities, restaurants and consumers in order to ensure a clear process of awareness.

For the truffle industry in Australia to reach its full potential it needs to be developed with a collegiate approach. Logically, this should be organised through the industry association, ATGA, with a focus on developing an industry quality and accreditation system and with a centralised marketing approach. The association can offer agronomy support, knowledge sharing, marketing and a co-operative approach that will build industry strength.

Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis

A SWOT analysis provides a useful avenue for exploring the truffle growing industry in Australia. Exploring strengths, weaknesses, opportunities and threats provides an effective means of mapping the current situation and identifying opportunities for future development.

[2] The following website has a brief presentation on trufficulture: http://www.youtube.com/watch?v=e-r33jbMiOc&feature=fvw

Strengths

- Strong demand and huge potential for export to Europe and Asia.
- Reduction in worldwide production levels has caused sustained demand and escalating prices, and this is expected to continue.
- The target market for supply is the top echelon restaurants and, therefore, this is less vulnerable to price cycling or global economic pressure.
- The Australian truffle harvest season is six months apart from that of Europe so there is no direct competition with traditional truffle growers.
- Existing high interest by potential growers to enter the truffle industry.
- RIRDC reports indicate that expected future expansion of truffle production will not cause the saturation of the market in the foreseeable future.
- A truffière only requires small acreage to grow a commercially viable crop.
- An established truffière requires only small maintenance operations with low labour requirements to maintain and harvest the crop annually.
- The ATGA is a strong industry body providing strong network support to growers and good vector for information and promotion.
- The successful truffle growing areas of Europe are climatically similar (Mediterranean) to regions of Australia.

Weaknesses

- Current operating inoculating nurseries resisting change to trufficulture practices or adhering to a quality/accreditation scheme.
- Existing inoculation nurseries and truffières with their own business model and agenda not wanting to communicate or be involved in the ATGA or adopt industry guidelines.
- In Australia there is a lack of research and development (R&D) into trufficulture and a general lack of understanding among truffle growers.
- Many current truffle growers are retiring professionals without any horticultural/agricultural qualifications or experience.
- Much of the overseas private R&D is controlled by corporate organisations and is either not available under commercial agreements or not easily accessible.
- Some published R&D is in the native language and is yet to be translated.
- The amelioration of Australia's low pH soil, eventuating in the soil then becoming calcareous, is expensive to counteract and will require periodic maintenance with lime.
- Some agricultural soils that are high in nutrient levels or contain residual agricultural chemicals will not be suitable for truffle growing.
- There is a low proportion of trees, within truffières, currently producing truffles and low levels of production throughout the Australian industry.

Opportunities

- Potential to access new export markets that are seeking quality assured French black truffles and French black truffle products.
- Develop a 'clean green' reputation for supplying a pure and premium quality of French black truffle.
- Truffles offer a viable alternative to conventional horticultural crops for commercial producers.

- Attractive to small acreage property owners and hobby farmers.
- The mystique, folklore and misunderstandings surrounding trufficulture produce many inconsistencies and knowledge deficiencies that need to be addressed.
- Training for new and existing truffle growers in a range of horticultural skills and trufficulture techniques.
- Development of strong international networks and forums between truffle growers, researchers, government bodies and universities will enhance and bridge the knowledge deficiencies.
- Providing a greater knowledge bank and bridging the skills deficiencies will see improved truffle production levels and ensure the sustainability of the industry.
- Developing a suitable method of vegetative propagation of *Quercus sp* (oak trees) will remove one variable arising from genetic differences in seed grown stock.

Threats

- An outbreak of Chinese truffles and the ultimate spread of these truffles would decimate Australia's 'clean green' reputation for supplying the French black truffle.
- Where Chinese truffles are discovered growers may not want to allow removal and disinfection of the truffière.
- Not all nurseries will want to adopt a new QA system or an accreditation system.
- The periodic auditing of nurseries will be time consuming and costly to industry members.
- Inoculation nurseries that do not comply and growers not following industry standards may cause a split or segregation in the truffle industry.
- Throughout the world, and indeed in Australia, there are many varied theories and misguided opinions regarding truffle requirements and trufficulture practices.
- Being a unique subterranean symbiotic *mycorrhizal* fungus, the traditional agricultural growing and disease control methods can be detrimental to truffles, such as phosphate fertiliser, fungicides and herbicides.
- The depth of a global economic depression would affect the short-term potential of truffle market expansion.

Identifying the Skills Deficiencies

This Fellowship is focussed on bridging the knowledge deficiencies that exist in technical skill development in the cultivation of French black truffles, specifically in the following areas.

1. **Efficiently and accurately identify various species of truffle.**

- To learn the best methods of accurately identifying important truffle species as this is necessary for the industry to control the importation and spread of highly undesirable species.
- To assist in the development of simple and accurate identification field testing tools for growers.

2. **Design an audit, accreditation, certification, evaluation and monitoring industry standard for the inoculation of host trees.**

- To gain a clear understanding of audit and certification standards and systems in use in the selected countries, to assist with the development of the Australian industry standards.

3. **Develop improved techniques for the vegetative propagation of *Quercus sp* species.**

- To learn about and evaluate the appropriate methods and equipment being used in laboratories and nursery operations overseas to carry out vegetative propagation, and to investigate the standards that are also in place.
- Determine the appropriate systems to record, analyse and evaluate the findings.
- To gain a clear understanding of the principles and methods utilised overseas for asexual oak propagation in order to aid in establishing asexual propagation of this species in Australia.

4. **Determine the variables and evaluate seasonal maintenance and irrigation techniques in cultivated truffières.**

- Conduct interviews and record data relating to specific maintenance and irrigation operations and techniques carried out in truffières on a seasonal basis.

5. Develop improved harvest yields through field trials and agricultural practices.

- Evaluate the development of improved methods in agricultural practices through field trials, to improve production yields and consistency of harvest of Australian truffles. Included are issues such as nutrition, water quality and soil amelioration.
- To gain knowledge of the factors that potentially effect (both positively and negatively) low yield of truffles in Australian truffières.
- To determine current best practice maintenance techniques used in the management of cultivated truffières.

6. **Develop best business practice in creating, building and sustaining a financially viable inoculation nursery.**

- Analyse all necessary plans and processes, including financial, infrastructure, humane resources (HR), organisational behaviour, sustainability, water supply/storage, stock control and marketing.
- To gain knowledge of the critical factors of the successful development and operation of an industry-specific inoculation nursery.

Why it Needs to be Addressed

It is of paramount importance that the new, emerging Australian truffle industry maintains its integrity with providing a ‘clean green’ marketing image. To this end the industry must avoid allowing the inferior Chinese truffle (*Tuber indicum*) or other species to be mistakenly grown instead of the true French black truffle. Accurate and simple methods and tools need to be developed to allow growers to determine the correct species.

Development of an accreditation scheme will ensure the truffle industry maintains quality through approved industry standards.

The current industry practice is to propagate all *Quercus sp* by seed and therefore they display genetic variability. Sexual propagation is used because oak trees (*Quercus sp*) cannot be propagated from cuttings. The sparse and often infrequent occurrence of truffles on mature inoculated oaks has led scientific enquiry as to whether the genetic variability between certain oaks is responsible for the lack of consistent production. Sexual propagation of truffle-producing oaks may produce more consistent results with truffle production.

Generally, all growers are experiencing low and inconsistent yields of truffles. This may mean that changes to the trufficulture method should be employed. Incorporating best practice maintenance techniques, improving trufficulture practices, nutritional amelioration and irrigation scheduling will assist in producing consistency of growth, development and yield of truffles in cultivated truffières.

Developing best business practices to industry quality standards will ensure a sustainable and financially secure future for the truffle industry.

The International Experience

Overview

The study tour to the European countries of Italy, France and Spain was conducted in December 2009. The period was chosen to coincide with the commencement of harvest season for the French black truffle. Also in Italy early December is the late part of the harvest period for the famed Italian white truffle (*Tuber magnatum*).

The tour commenced in Italy, visiting the truffle growing areas (both natural truffle forests and cultivated truffières) around Bologna and Cesena.

Natural magnatum *forest on left and cultivated truffiere on right*

Destinations

Italy

- Department of Protection and Food and Agriculture Exploitation, at the University of Bologna
- Appennino Funghi e Tartufi, a truffle marketing company.
- Raggi Vivai, a truffle tree nursery.

France

- Lot region in France
  - A two-day microbiological study of truffle *mycorrhiza* at Agri-ecole Institution in Cahors.
  - Natural truffle forests
  - cultivated truffières in Le Montat
  - truffle market at Lalbenque
  - Pebeyre, a truffle marketing company in the region.
- Agri-truffe, a tree nursery near Bordeaux

Spain

- Catalona region of Spain
- Mycology Department at the University of Centre Tecnològic Forestal de Catalunya, the Forest Technological Center of Catalonia (CTFC), Lleida.
- Truffle hunters and truffière operators in Cabo and Organya, Spain

Harvesting melanosporum *in a cultivated truffiere in Spain*

Efficiently and Accurately Identify Various Species of Truffle

Italy

There were many species of truffles found in the natural forest areas. Typically, on one truffle hunt the following species could be unearthed: *Tuber melanosporum*, *Tuber magnatum*, *Tuber borchii, Tuber maculatum*, *Tuber macrosporum, Tuber excavatum, Tuber brumale, Tuber mesentericum*, and *Genea fragran*s, *Genea verrucosa* and *Balsamea vulgaris*.[3] Some of these were not considered to have any culinary or economic value and therefore needed to be identified and culled. The most important Tuber species that were of the highest value were *Tuber melanosporum*, *Tuber magnatum*, *Tuber uncinatum*, *Tuber aestivum*, and *Tuber borchii*.

Tuber brumale was considered a pest because it out-competes *Tuber melanosporum* (especially under *Corylus sp – Hazel* trees) and it thrives in soils with a pH lower than the 7.8–8.1 range ideal for *Tuber melanosporum*. However, Raggi Vivai grows and supplies this species for certain customers in marginal growth areas. In the European marketplace *Tuber brumale* still had some economic and culinary value.

[3] The following YouTube video shows a truffle hunter and his dog in action hunting truffles. The video runs for about 3 minutes: http://www.youtube.com/watch?v=oNw_oXfvl_g&feature=related

In Bologna there were 10,000 registered truffle hunters who were knowledgeable enough to accurately identify all of these species by physical assessment. To become registered, people needed to study the different species, their culture requirements, the correct method of harvesting and then pass a test before qualifying for registration. It was illegal to hunt for truffles without registration; this was providing some protection for the natural truffle forests.

The truffle tree production nurseries were required to certify each batch of trees with the required *mycorrhiza*. This was done by several universities that were able to provide an independent and inexpensive assessment. The process mainly used morphological methods using high-powered microscopic examination of root tips, the mantel and the associated *cystidia*. Each truffle selected for inoculum had spores removed and was checked under the microscope for accurate identification of *Tuber* species. DNA molecular testing was also conducted by the universities; however, this was expensive and offered to customers at an added cost.

France

A similar certification system, using morphological testing methods, was used by the Institut National de la Recherche Agronomique, the French National Institute for Agricultural Research, (INRA). Agri-truffe is a major tree producer and INRA inspectors frequently visited the nursery. Each batch of plants was sent to INRA for assessment and certification prior to sale. Agri-truffe has an expert mycologist and used high-powered microscopic techniques to ensure plants were infected with the correct species.

Expert mycologist at Agri-truffe identifying truffles

The Lycee Professionnel Agricole Viticole de Cahors-Le Montat, a specialist agricultural truffle school, provides qualified training in all aspects of trufficulture.

In the Lalbenque truffle market the experienced truffle hunters were able to identify the various species, although imported Chinese truffle (*Tuber indicum*) had, in the past, been introduced and sold in baskets with *Tuber melanosporum* without detection by the buyers.

The marketing company Pebeyre used physical assessment methods and had no problems identifying the species after washing. The peridium of *Tuber brumale* peels easily in the washing process and is easily identifiable.

Lalbenque truffle market in France

Truffle washing machine used in France by Pebeyre

Tuber brumale *showing coarse vein structure and peeling skin*

Tuber mesentericum

Tuber mesentericum is also black but typically has a hollow base and the gleba is whitish when cut.

Spain

Similarly, universities such as the CTFC in the Catalonia area conducted the morphologic assessment and certification of truffle species on host trees for production nurseries. Again the truffle hunters and growers relied on their experience and knowledge to identify the truffle species in the field.

Relevance to Australia

In Australia there is no independent and inexpensive system for the certification of truffle-infected plants sold from nurseries. Unlike Europe, Australia does not have the advantage of having a traditional truffle industry; the Australian public is generally unaware of what truffles look like, let alone being able to differentiate between species.

Also, very few truffière operators/farmers in Australia have the knowledge or tools to identify the different *Tuber* species they may harvest. European truffle experts and scientists can supply the information and digital images to help inform our industry. A full colour poster or booklet could be produced to compare the main truffle species and competing *mycorrhiza*, including microscopic images showing the differences in truffle morphology of the roots, mycelia, root tips, cystidia and mantle, as well as the fruiting bodies.

There is a need to develop a trufficulture course in Australia similar to the truffle school in France. A course could be initiated through the ATGA; however, the Australian industry is small, and if there was insufficient interest then this may prove to be unviable.

Design an Industry Standard Audit, Accreditation, Certification, Evaluation and Monitoring Process for the Inoculation of Host Trees

Italy, France and Spain

There were no existing industry-specific QA schemes operating in Europe controlling the production and sale of truffle-infected trees. However, these countries all had independent certification systems generally run by their local universities to certify the trees sold by the truffle production nurseries.

Agri-truffe certification label

In France, the INRA operated a points system based on three criteria:

a) Correct *Tuber* species infected on the roots (mandatory).

b) Percentage of roots that infected (minimum of 33% by count).

c) Presence of competing fungi/*mycorrhiza* species.

Every batch of plants (regardless of the size) was certified and, prior to selling, had a certification label attached.

The roots were examined under a dissecting microscope.

Root analysis under a dissecting microscope

The inoculation nursery used a strict (and commercially secret) methodology. However, the hygiene practices were evident and mandatory. Footbaths were used on every house, with complete sterilisation of the house between crops. No plant residues, pests or diseases were prevalent. The growing-on house at Agri-truffe was environmentally controlled, including the temperature, humidity and light. The floor was concrete and all plants were grown above the floor on benches.

Agri-truffe growing house

Truffles that were selected for inoculum were large in size and every fruiting body had spores that were removed and checked under a high-powered microscope. The only morphologic check done at this stage is shown in the photograph on page 17.

Relevance to Australia

The Australian truffle industry has identified the need for a QA scheme.[4] The system in Europe successfully operated with infected plants being certified as described above. The system was fairly inexpensive and worked independently through several local universities that used similar criteria.

Australian certified plants could carry an ATGA label and provide a financial return to the ATGA for further R&D. The ATGA could endorse institutions, companies or universities to conduct the certification scheme, it could require all registered inoculation nurseries to adopt the scheme and gain certification of all plants prior to sale.

The certifying institution would need access to the nursery production facilities and disclosure of the inoculation method, procedure and timing, would be required. Clearly an accurate, quick turn-around and an inexpensive morphologic process should be adopted. The truffle infection production nursery should comply with a set of minimum standards that will ensure quality, disease-free host plants are infected with the desired truffle *mycorrhiza* at a minimum percentage of root tips.

[4] Reference: Nathan Carter's survey on the ATGA website: http://www.agrifood.info/perspectives/2010/Carter_McSweeney.pdf. Please see Attachment.

Develop Improved Techniques for the Vegetative Propagation of *Quercus sp* Species

Italy, France and Spain

In all three countries visited there were no methods of vegetative propagation being adopted. The only method of reproduction of host trees used was seed propagation. Seed was collected from the same region where it was to be planted. The method of selection of the trees to be infected relied on sowing a large quantity of acorns and carefully selecting the strongest, true-to-type seedlings.

In Italy, Raggi Vivai had not yet been successful at inoculating vegetatively grown cuttings of *Populus sp* or *Salix sp* with *Tuber magnatum* in the nursery. However, successful infection has been achieved with seed-grown *Quercus sp*. In the natural forests in Italy both *Populus sp* and *Salix sp* were naturally infected with *Tuber magnatum* and produced white truffles.

No information was obtained on the research/trial studies of the vegetative propagation of *Quercus sp* being undertaken. *Quercus sp* did not propagate readily from cuttings and, at the time, tissue culture had not been successful. Also, there was little interest in pursuing this work because the current traditional methods were successful.

Relevance to Australia

It is not yet clear if there is a genetic connection between trees that readily establish a *mycorrhizal* relationship and those that don't. There is an opportunity for someone to develop a tissue culture method and conduct trial work in this area. Successful development of a reliable vegetative propagation technique would have strong export potential to Europe and around the world.

Determine the Variables and Evaluate Seasonal Maintenance and Irrigation Techniques in Cultivated Truffières

Italy

Irrigation

Cultivated truffières were generally not irrigated because the natural weather provided frequent summer rains. The desire of most truffle growers was to emulate the traditional methods and treat the truffière as the natural forest would. In recent years, however, there have been some areas that have experienced drought conditions, where there was very little summer rain, and the production of truffles was lower. As a result, the relationship between summer rain and truffle production has now been established and new cultivated truffières are established with irrigation.

However, there were no known parameters for ideal soil moisture, application quantities or dry – wet periods established as yet.

Cultivation

Traditional cultivation techniques were followed, where the soil was tilled to a shallow depth from winter to spring. In winter the depth of tilling was about 150 millimetres and later in spring the tilling was no more than 50 millimetres. This tilling operation was never used from mid-summer because the young truffle fruiting bodies were developing then. Tilling was used to introduce oxygen into the soil and as a weed control method. Whilst the shallow tree roots were severed (not ripped), this caused them to produce new root branches in spring that then became naturally re-infected with *mycorrhiza*. The very shallow tilling also killed the *mycorrhiza* near the surface and prevented the problem of having truffles produced too close to the surface. These truffles would have suffered from environmental damage and insect attack, etc.

The soils growing *Tuber melanosporum* were very stony (typically limestone) with excellent drainage capacity and high air filled porosity (AFP).

Typical melanosporum *soil in France showing where a truffle was harvested*

Tilling these soils tended to bring the stones to the surface, which acted as a mulch and also provided insulation and conserved soil moisture.

Nutrition and Soil pH

There were no nutritional amendments applied to soils. The soils chosen for cultivating truffles were naturally formed limestone soils that were low in nutrition but with healthy soil biology. Where the soil pH was too low for *Tuber melanosporum* (approximate pH less than 7.5) *Tuber brumale* was recommended for planting.

Tree Species

Mainly *Quercus pubescens* and *Quercus ilex* were used as host trees for *Tuber melanosporum*. These were found in the native forests along with *Corylus sp – Haze*l. *Quercus pubescens* was also used as a host for *Tuber magnatum*. These were the main tree species used as hosts in cultivated truffières. The tree production nursery attempted to match tree species and truffle inoculant from the same region to where they would be planted.

Quercus cerris and *Quercus coccifera* were also used to host *Tuber melanosporum*; however, this was to be exported to a customer in Greece where these oak species are native. *Pinus pinea* was used as the host tree for *Tuber borchii*.

France

Irrigation

The situation in France was similar to Italy; however, a twenty hectare cultivated truffière at La Montat was irrigated with low-pressure emitters and poly pipe.

Supply was from a 20-megalitre spring-fed dam. No parameters for ideal soil moisture, application quantities or dry – wet periods were available.

Low pressure sprinklers used in France

Mature truffiere showing cultivated soil in France

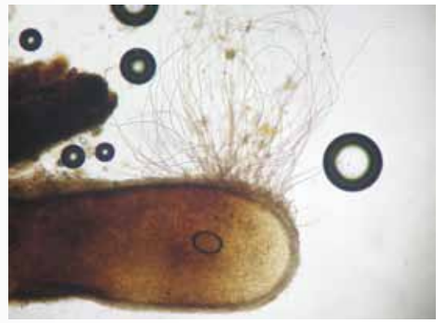
Annual Cultivation

The same traditional tilling methods were used in France as in Italy; however, there is a concern that the using tilling would spread undesirable truffle species and competing fungi like, *Hebeloma*, *Scleroderma* and the *Angle droix (AD)* type fungus.

Cultivation under *Corylus sp – Hazel* is likely to spread *Tuber brumale*, which is highly viable and will out-compete the *Tuber melanosporum*.

Mycorrhizal Life Pattern New Theory

Pierre Sourzat, at Lycee Professionnel Agricole Viticole de Cahors-Le Montat, describes the French black truffle as having two distinct periods of fungal activity:



Tuber aestivum *swollen club root with cystidia*

1) SYMBIOTIC: The germinated spores produce a fungal hyphae that encapsulate the root tip and invade the root by moving around between the root cells to form a harteg net. The resulting new swollen club roots are formed which send hyphae (cystidia) into the surrounding soil.

   They are then able absorb nutrients (especially N & P) and supply these to the plant. In turn they absorb carbohydrates and sugars from the tree for growth. This is a perfect symbiotic relationship where both organisms benefit from each other.

2) PARASTIC: Once the fruiting bodies (truffle ascocarps) are formed (through a sexual process) the *mycorrhiza* requires and absorbs a much greater quantity of nutrients from the tree to feed the developing truffle. However little is returned to the tree so thus it becomes parasitic. Later after the truffles have formed the club roots become dessicated from the old roots. This leaves a scarred appearance on the old roots. New roots are again infected and the process begins again.

Prunning

A 'formulative pruning method' developed by Sourzat was generally used to shape the trees into a reverse cone shape, leaving no branches under about 1.2 metres from the ground. This allowed light to enter the brûlé and assisted truffle growth in late autumn and winter, as well allowing for easier harvesting. Annual pruning was also carried out in cultivated truffières to control excessive foliage growth of trees. This excessive foliage growth may have been due to seasonally wetter conditions, applied fertiliser or nutrients that caused vigorous growth. The vigorous growth was then matched by a larger expansive root system that grew faster than the *mycorrhiza* could infect. This created a zone of root growth outside the expected area of the brûlé that was vulnerable to infection by other undesirable *mycorrhiza*. Pruning back the top growth caused a reduction in the expansiveness of the root system.

Also, if the brûlés of two adjacent trees converged or met, Sourzat believed they would have a negative (parastic) effect on each other. Truffle production could be lost from all trees in a Truffière if the root systems converged. This also had an impact where the spacing distance between trees was too close (less than four metres). Also, controlling the top growth of trees reduced the spread of the roots and of course the brûlé.

Nutrition and Soil pH

There were no nutritional amendments applied to soils. The soils chosen for cultivating truffles were naturally formed limestone soils that were low in nutrition but with healthy soil biology. There was some trial/research work on applied nutrients in the tree production nursery. Different forms of controlled release fertilisers: Osmocote, Plantcote, Nutricote, and Chelated Iron were being trialled to reduce the symptoms of interveinal chlorosis (iron deficiency) due to the high pH media conditions.

Nutrition trial Agri-truffe

Tree Species

Mainly *Quercus pubescens* and *Quercus ilex* are used as host trees for *Tuber melanosporum*. These are found in the native forests.

Truffiere in France showing the most commonly planted species – Q ilex *and* Q pubescens

Spain

Irrigation

Spain has a relatively young history in truffle production compared to France and Italy. It is only in the last 40 years that Spain's natural forests revealed the famous French black truffle, therefore truffles generally are not a traditional part of their cuisine. Spain has found a huge market exporting black truffles to France. Spain has also been very active in planting cultivated truffières and with a drier climate than France and Italy; they are irrigating many of their cultivated truffières.

At CFTC there were several research projects under way. One of these involved studying the effects of applied irrigation on the growth of mycelium. Please see PhD Projects Conducted at CTFC below for details of these projects.

Cultivation

As was seen in Italy and France, the Spanish growers had also adopted the traditional tilling methods used in Europe. In Spain there was less concern with spreading undesirable *mycorrhiza* species because they saw less competing *mycorrhiza*.

Young truffiere in Spain

Pruning

Again, pruning methods were adopted for the purpose of forming shape and controlling excess growth.

Relevance to Australia

Selected Australian truffières use some formative pruning, however, in many cases there is neither annual pruning nor any cultivation techniques applied. As this allows more light to enter the brûlé and assists with truffle growth this would be worth trialling or adopting in Australia.

Currently, some tree nurseries are recommending a tree spacing of three metres. Whilst this has assisted their profitability, it may not be advantageous to growers if trees are planted too close together and truffle production is affected over time. After all, an individual oak tree with little competition will potentially grow to 20 metres in height and width. A minimum of six metres spacing has been suggested as a better alternative.

Most Australian truffières are established with irrigation systems that provide good control over soil moisture levels. However, many truffle operators are applying irrigation water too frequently and, whilst this does help maximise tree growth, it is inappropriate for the truffle culture. Truffle-infected trees should only be irrigated after the trees have had approximately 20 days without a saturating rain (or since the last irrigation). This will be at a soil moisture tension of approximately 100 to 200 kPa (kilopascals). Thus, installing an irrigation system in Australian truffières acts as an insurance policy against long periods (approximately 20 days) of no summer/autumn rain.

Develop Improved Harvest Yields Through Field Trials and Agricultural Practices

Spain

PhD Projects Conducted at CTFC

Several projects were under trial and are due to be concluded in 2012. Field trials were being conducted in order to research agricultural practices, including irrigation and cultivation, as well as determining the most suitable soil texture for truffle mycelium growth. The exact trial design, data and parameters were not made available but the following is a summary of the work being undertaken. The results of this work will be made available through future published scientific literature.

Irrigation

1) Water Requirements of Young Trees

Several watering regimes of high, medium and low irrigation frequencies are required to determine how the primordia are affected. Combinations of different irrigation frequencies (high frequency until primordia is initiated, followed by lower frequencies) are also included in the treatments.

Data of soil and air temperature and moisture as well as tree parameters (growth) are collected. Soil parameters such as texture, bulk density, surface and total stoniness are collected as well as plant growth within the brûlé. Soil core samples are taken and the amount of truffle mycelium at primordia stage is determined at the conclusion of the irrigation trial.

The aim is to correlate all or some of the data with the development of truffle mycelium and the developing trees.

2) Water Requirements of Productive Trees

A similar trial method is used as with the young trees above. Soil core samples are taken and the amount of truffle mycelium at primordia stage is determined at the conclusion of the irrigation trial. The aim is to correlate all or some of the data with a theoretical initiating of the start of production.

3) Mycelium Growth Throughout the Year

This trial seeks to determine the truffle mycelium growth at several times throughout the year. Soil core samples are taken from producing trees in a range of truffières at about 40-day intervals. The samples are taken from three points inside the brûlé and at a variety of depths.

The amount and species of mycelium in the soil samples is determined by molecular techniques such as Polymerase Chain Reaction (PCR) amplification of a known target of *Tuber melanosporum*.

Data of soil and air temperature and moisture, as well as tree parameters (growth) are collected. Also soil parameters such as texture, bulk density, surface and total stoniness are collected, as well as plant growth within the brûlé.

The aim is to learn about the phenology of black truffles in the local truffières.

4) Mycelium Growth Over a Period of Years and the Evolution of Other Truffle Species

Producing trees of varying ages of three, five, seven, 10, 14 and 20 years are selected for the trial. Test zones from inside the brûlés are created to which inoculum is added. Later, the soil samples are taken and evaluated for all species that exist in the living environment including other fungal species, bacteria and protozoa.

5) Production Response to Tilling

Tilling is a traditional practice used throughout Europe where shallow finger tynes cultivate the soil to a depth of 50 to 100 millimetres. Tilling is used as a weed control method and is carried out from late winter through spring. Tilling provides oxygen into the soil and also cuts shallow roots and removes the *mycorrhiza* from the uppermost soil horizon. Truffles that develop too shallow are suspect to insect attack, damage by freezing (if cold enough) and rotting.

In Europe, where the native oak forests contain many competing truffle *mycorrhiza*, there is now a belief that tilling may be spreading other Tuber species and allowing more dominant species like *Tuber brumale* to out-compete *Tuber melanosporum*, especially under *Corylus sp – Hazel*.

In this trial, producing trees are selected and shallow tilling is applied to the brûlés. Production quantities from the trees prior to the treatments are compared to these trees after the tilling, and then compared to the control trees. All normal soil parameters as well as climate and production levels are monitored.

6) Mycelium response to different soil textures

Soil texture is the measure of the physical properties (amount of sand, silt and clay particles) that make up every soil type.

In this trial the soil texture is artificially altered by the addition of various amounts of sand. Productive trees are selected and soil cores are bored out within the brûlé. Measured amounts of sand are added to the soil and replaced into the core holes. Five different soil textures are created with various percentages of sand ranging from 20%–80%.

Data of soil and air temperature and moisture as well as tree parameters (growth) are collected. Also, soil parameters such as texture, bulk density, surface and total stoniness are collected, as well as plant growth within the brûlé.

The aim is to test if a different sand content can affect the growth of truffle mycelium. The testing of the core samples is carried out at several times throughout the year.

Relevance to Australia

The skills deficiencies identified previously highlighted culturing practices, such as tilling and irrigation, and other methods capable of improving production levels. Spain's truffle industry had some similarities to the Australian industry, such as a relatively young industry of cultivated truffières in a dry Mediterranean climate. The research being conducted in Spain is capable of providing some answers that could be of enormous benefit to Australia. However, the CTFC research should be replicated in Australia to gain a complete understanding in relation to local conditions.

Develop Best Business Practice in Creating, Building and Sustaining a Financially Viable Inoculation Nursery

Inoculation nurseries were visited in both Italy and France.

Italy

The nursery visited, Raggi Vivai, was a small, family-based company with five full time employees. 50% of the company's turnover comes from alternative horticultural crops other than truffle-infected trees. Casual employees were hired for peak times, especially when the process of inoculation was being carried out.

The nursery had strong ties with several universities and consulted with them on trufficulture issues, plant health, morphological root analysis and also DNA testing.

All procedures were well documented with records of inventory kept and updated regularly. However, due to commercial confidentiality the detailed records were not made available.

All floors were sanitised once a fortnight and all greenhouses used were completely cleaned out and disinfected once a year.

Raggi Vivai growing house cleaned out prior to new crop

All greenhouses had a disinfecting footbath that must be used on entry. All plants were grown on benches and generally remain in the greenhouse for up to two years until successfully infected and sold. Any plant that was not properly infected at three years of age was disposed of.

The approximate total stock holding was about 90,000 plants with annual sales of around 30,000 plants. Plant health was intensively monitored and appropriate action taken at an early stage when needed. Care was taken to minimise the application of chemicals (especially fungicides) to plants for the control pests and diseases. Bore water was used for irrigation and is naturally high in Iron. Although the iron leaves a brown residue on the foliage this was not shown to be harmful to the truffle plants.

France

Like Raggi Vivai, the French inoculation nursery visited, Agri-truffe, was very professionally run by a small number of staff. Unlike Raggi Vivia, 100% of Agri-truffe's turnover came from the sale of truffle-infected trees. Trees were sold direct to growers, and also to resellers. This was evident at the fresh truffle market in Lalbenque where trees with Agri-truffe's certification labels were available for sale by small independent sellers. Many trees produced were also destined for export to other countries.

The nursery had a mixture of old-style plastic igloos through to modern climate controlled greenhouses. The older igloos were only used for storage and seed raising activities. The modern greenhouses were used for growing the plants after inoculation.

Prior to any plants being put into a greenhouse, the house was fully sanitised to remove any potential for germination and growth of competing *mycorrhiza*.

Agri-truffe growing house in the process of being sanitised prior to new seasons crop

All greenhouses had a disinfecting footbath that must be used on entry. The inoculation facilities were housed in an air conditioned office suite with a scientific laboratory and workroom. The company's procedures were steeped in tradition and were often under the inspection by Gerard Chevalier (founder of company). Being a world-renowned company helped drive the company to produce good quality, highly *mycorrhized* plants.

Relevance to Australia

Inoculation nurseries need to adhere to more stringent guidelines than is required by current Australian 'Nursery Accreditation' schemes. In Australia modern plant nurseries use pine bark potting media with added high Nitrogen, Phosphorus and Potassium (NPK) controlled release fertiliser. The composted pine bark used in the potting media requires soluble nitrogen fertiliser added to counteract the nitrogen drawdown of bark. This creates a high growth potential that is usually advantageous to plant growth in potted plants.

Luxuriant plant growth produces a leaf cuticle that is softer and more easily penetrated by insect pests and diseases. Also, high-nutrient potting media may not favour good infection of truffle *mycorrhiza*.

The Australian standards for growing plants generally apply to plants growing in a pH of 6–6.5. Australian nurseries have little experience in growing good quality plants in high pH potting media, with a pH of 8.0).

In Europe there was a greater sense of plant culture requirements that provided adequate healthy growth with pest and disease resistance at high pH. More hygienic and better disease preventative measures are also used. In Australian 'accredited' nurseries the approved disease control method is generally application of chemical fungicides. These fungicides may be potentially harmful to truffle *mycorrhizal* fungi.

The aims for a successful Inoculation production nursery are:

1. Growing plants not in contact with the ground or floor.
2. Growing plants under culture conditions that provide adequate, healthy plant growth without excessive stretching (especially *Quercus robur*). This generally means growing plants without using the traditional high Nitrogen or high NPK fertiliser.
3. Growing plants under culture conditions that discourage parasitic fungi, such as powdery mildew, and insect pests such as aphids, mites and thrips.
4. Growing plants under culture conditions so that they do not exhibit nutritional deficiencies such as interveinal chlorosis. This requires a balance of organically chelated trace elements.

The actual inoculation procedure is not covered here, because, although there are several methods used, they are generally under commercial confidentiality agreements and are not in the public domain.

The acceptable percentage of root tips showing truffle infection is still under conjecture because it can vary according to the time of the year and the time of rapid physiological growth, generally in Spring, the root growth can occur more quickly than the *mycorrhizal* infection. In general, in Europe an infected root tip count of 33% was considered acceptable.

Also, the number of plants that are physically checked by morphological methods should be reviewed. Currently, some inoculation nurseries in Australia check less than 5% of plants prior to despatch. This may seem inadequate and a higher percentage of checked plants may be required.

The truffle-infected plants must be inspected and certified by an independent authority. In Italy, France and Spain local universities are able to provide a certification service that is quick and economically viable. It is imperative that Australia also adopts a similar process. The ATGA should make fee-for-service arrangements with universities in the Australian states that have inoculation nurseries. It would seem reasonable that the ATGA would control the process of certification and provide a label for each plant approved. The cost recovery could also provide the ATGA with an income stream.

Knowledge Transfer: Applying the Outcomes

The main aims of this Fellowship were to seek the knowledge and skills developed in Europe in order to provide improved cultivation and growing practices of truffles in Australia; and to investigate introducing a QA system to ensure only quality truffle trees are produced.

Several production techniques were studied and these included irrigation, cultivation, pruning and plant spacing. The outcomes and recommendations for these are documented in Recommendations Section of this report.

The Fellow has been convinced that the European style of certification scheme is the most appropriate system to be developed in Australia. This will ensure that all truffle trees are properly infected with the correct *Tuber* species, and will ultimately improve the potential outcome of producing quality truffles.

Finally, the Fellow has recommended that this knowledge be transferred to the truffle industry through industry driven education programs involving short courses, seminars and workshops.

Recommendations

A series of recommendations have been identified for the following areas:

Industry Association

- Produce an information poster or booklet to compare the main truffle species and competing *mycorrhiza* including microscopic images showing the differences in truffle morphology.
- Develop an independent and inexpensive system for certification of truffle-infected plants sold from nurseries.
- Plants should carry a certification label inaugurated by the ATGA.
- The following field trials need to be conducted by the ATGA with the help of interested growers:
  - Shallow tilling around trees versus no tilling. This may benefit production and quality by oxygenating soil, controlling weeds as well as removing shallow roots and mycelium to prevent surface protruding truffles.
  - Soil moisture monitoring to determine the ideal frequency and timing of irrigations to initiate fruiting and develop the truffles.

Government

- Provide financial assistance with further research funds to assist the ATGA to develop growing trials.

Truffle Growers

- Growers should adopt a wider tree spacing of eight meters between *Quercus sp* and four meters between *Corylus sp – Hazel*.
- Growers should adopt annual tree pruning to maintain an inverted conical shape and control excessive foliage growth.

Truffle Agronomists

- Agronomists charged with making recommendations on the suitability of soils required to grow truffles need to be aware that only soils low in ‘available phosphate’ should be considered for trufficulture.

Community

- Promote degustation truffle dinners to the wider community to develop local knowledge, awareness, acceptance and culinary use of truffles.

Education

- There is an undoubted need to increase the skills and knowledge of truffle growers. However, due to the relatively low numbers of potential truffle students it would not be financially feasible to develop an accredited training course for trufficulture. However, the ATGA could develop a series of workshops and non-accreditated short courses to be delivered through a Registered Training Organisation by teachers with the necessary vocational skills and experience.

Attachments

Quality Assurance of the Australian Truffle Industry

Nathan Carter and Peter McSweeney

Nathan Carter, Agronomist, E.E. Muir and Sons

Peter McSweeney, Department of Agriculture and Food Systems, Melbourne School of Land and Environment, The University Of Melbourne

Abstract

Australian truffle growing in Australia is small and at the early stages of development. The industry produced approximately 1,500 kilograms in 2009 with a wholesale price of between $1500 and $2,000 / kilogram. A high proportion of growers operate on a small scale. As well as increasing area being planted, truffle production is increasing approximately 40 percent each year from existing planted areas to meet the growth in local and overseas demand. Commensurate with this growth is the pressure for the industry to develop its supply chain relationships and associated quality assurance (QA). This paper explores the QA assurance approaches suited to the truffle industry and reports industry stakeholder responses toward the implementation of such QA schemes.

110 industry members of the Australian Truffle Growers Association were invited to participate in the survey with 29 responding (26 percent). 20 of these agreed that the overall benefits to their business obtained from introducing a QA scheme would outweigh its costs. It was also generally perceived that QA would ensure continuous improvement and advance the professionalism of the industry. The study involved the design of a user-friendly online questionnaire made accessible to the member group only.

Introduction

The development of supply chain relationships and related quality assurance (QA) programs is seen as an important step in the overall development of emerging industries. The interest in this paper, QA in the Australian truffle industry, grew from an earlier industry study conducted by the Rural Industries Research and Development Corporation (RIRDC) in July 2008 titled 'Taking Stock of the Australian Truffle Industry' (Lee, 2008). The RIRDC study emphasised the need to evaluate an industry specific QA scheme and assess the benefits association with such a scheme. Specifically, the RIRDC report recommended to "review and assess the benefits associated with an audit and certification process for inoculated seedlings, trees and truffles." (Lee, 2008) More recently, QA was central to the 2009 National Truffle Industry conference discussions on industry sustainability and specifically "quality standards, biosecurity and market research" (Australian Truffle Growers Association, 2009).

One driver for industry change is the fact that the domestic demand for truffles is nearly saturated. Haslam, president of the Australian Truffle Growers Association (pers comm., 2009) stated that Australia's current production of fresh truffle is approximately what the domestic market would consume if fully developed. The export of fresh product overseas is the potential area for industry growth and while exporting the native French Black Truffle back to France, will be a challenge, it is off season and the rest of Europe is a significant market. Selling into the Americas and Asia is also of great importance to the Australian industry. Successfully doing so will require market research and development and building Australia's reputation as a quality truffle supplier (Lee, 2008). QA would be seen as one plank in the development of the truffle export market.

The aim of this study was 'to analyse the perceptions of key stakeholders in the Australian truffle industry in response to the introduction of a Quality Assurance scheme for inoculated seedlings, trees and truffles.' The targeted key stakeholders included, but weren't limited to inoculation nurseries, truffle growers, truffle wholesalers and marketers and buyers of fresh truffles. The membership of the Australian Truffle Growers Association (ATGA) was surveyed for the purposes of this study. The survey attempted to establish:

- The tools currently in use to verify and promote product quality.
- The perceived benefits and drawbacks associated with an industry specific quality assurance scheme.
- Support for and likely adoption levels for a quality assurance scheme developed for the industry.

As a member of the Australian truffle industry, the primary author has a personal affiliation with the industry and its future prospects. While there is an apparent pull within the industry for the development of QA, it was important to understand the depth of this interest across the industry membership. It could be argued that the successful development of any QA scheme would be dependent on the support and ultimately high level of uptake from key stakeholders within the industry. The survey of ATGA members was seen as one way of establishing the 'bottom up' perspective on QA.

The Australian Truffle Industry

What is a truffle?

The fresh truffle is the edible fruiting body of a subterranean fungus known as a Mycorrhiza (Renowden, 2005). Mycorrhizae form a symbiotic relationship with a host tree because they cannot synthesize sugars and other carbohydrates on their own. The tree provides the truffle with a source of carbohydrates and nutrients, and in return the fine thread-like filaments (mycelia) of the truffle, coats the tips of the tree roots to form mycorrhiza which assists the tree to absorb soil minerals and nutrients (Lee, 2008). In effect, the mycorrhiza is able to increase the effectiveness of the trees roots and provide phosphorus and trace elements that would normally be unavailable to the tree.

Truffles are one of the most valued and sought after food crops in the world (Lee, 2008). One major source of their high market value stems from their unique, but extremely desirable, aroma and flavour. Their mystique and associated gourmet experience has been described as second to none (Renowden, 2005). Another reason for their high market value is to date only a small percentage of trees in truffières have yielded truffles. Truffière is the French term for a truffle plantation. The conditions under which truffles actually form and fruit are quite variable (Malajcuk and Amaranthus, 2007). The third reason for their high market value is their short supply. Worldwide production has steadily decreased over the last 100 years.

There are many types of truffles found all over the world. The four of most culinary value are the French Black (*Tuber melanosporum*), the Italian White (*Tuber magnatum*), the Bianchetto White (*Tuber borchii*) and the summer truffle (*Tuber aestivum*)(Hall, Bryan and Byars, 2001). Almost all of the Australian truffle industry is focused on growing the French Black and hence it is the most highly cultivated in Australian plantations. According to food wholesalers in Australia the French Black can fetch market prices of over AU$3000 per kilogram (Lee, 2008).

Industry Trends

Truffles are a relatively new crop in Australia (Lee, 2008). The first plantings began in the 1990s in Tasmania and Western Australia with the first truffles being harvested in 1999. Truffières have now been established in Victoria, New South Wales, the ACT, South Australia and southern Queensland.

The industry is entering a new phase of growth and investment (Lee 2008). Australian truffle production could grow by as much as ten times by 2013 (Australian Food News, 2008). Whilst the exact annual production of fresh truffle in Australia is unknown it is estimated to have been approximately 1.5 tonnes for the 2009 harvest season (RIRDC, 2009a). Given that the industry is still relatively young local production is increasing by approximately 40 percent each year.

A high proportion of Australian growers are small-scale growers. In 2010 the total area planted in Australia is estimated to be 550 Ha distributed among an estimated 130 plantation sites nationally (Lee, 2009). Table 1 shows the estimated number of truffières planted in each state and also by type of operation. Approximately 110 of these are members of the ATGA. The highest producing states are Tasmania and Western Australia due to the industry being established in these states first.

Table 1: Types and numbers of truffières planted in the states of Australia

Truffles Growers and Planted Areas in Australia 2009

Grower Type	Description	WA	SA	Tas	Vic	ACT	NSW	Qld	Total Growers	Area Totals
1	Larger scale corporate truffière,	2	0	2	0	0	0	0	4	100
2	Larger scale investment truffière, MIS	1	0	3	0	0	0	0	4	200
3	Smaller scale contracted grower truffière	0	0	>10	>10	1	>20	0	>40	100
4	Smaller scale independent grower truffière	>10	2	>10	>20	1	>40	2	>85	150
	Total	**>13**	**2**	**>25**	**>30**	**2**	**>60**	**2**	**>130**	**>550**
	Total Area Estimate Ha	**>110**	**>5**	**>200**	**>100**	**>7**	**>120**	**>5**	**>550**	**>550**

Data source: (Haslam, 2010 adapted from Lee, 2009)

Traditionally truffles have been harvested out of wild forest areas in France with very rudimentary harvesting techniques. Over the last century the harvest of wild truffles has declined significantly, from over 1000tonnes in the early 1900s to around 100 tonnes per annum during the 1990s (Garvey and Cooper, 2001). The destruction of natural growing areas especially during the world wars, changes in urban land use, pollution, loss of population to the cities and climate change are considered to be the main causes of this decline (Amaranthus, 2007). As a consequence of this truffles are increasingly being produced on cultivated farms planted with inoculated trees (Garvey and Cooper, 2001). Recent data from the Ministry of Agriculture in France shows that in 2007-08 production volumes were around 13 tonnes (Lee, 2008).

At present about half of Australia's truffle supply is sold to the domestic market, especially for the restaurant and fine food wholesale market segments (Lee, 2008). Some of the larger growers within the industry have developed dedicated resources for sales and marketing of truffles, while the majority of smaller growers sell privately or outsource the marketing and distribution to wholesalers. A few of the larger growers have successfully sought stable export markets (RIRDC, 2009b).

The Australian truffle industry is at a natural advantage in that the Australian climate is six months apart from the climate of the northern hemisphere producers. Therefore, Australia's harvest season does not line up with that of these international competitors. The industry in this sense enjoys a significant competitive advantage in the export of fresh truffle, which has a shelf life of only two weeks, to countries in the northern hemisphere during their summer period.

The significant weaknesses of the industry which pose risks for its future development include:

- The limited size of the local market and the underdeveloped supply chain relationships into the overseas markets.
- Contamination of imported inoculum (*Tubers* or *Tuber* mycorrhizae) used for inoculation of tree stock (Lee, 2008).
- Variability of truffle yield and low numbers of producing trees. This threatens guarantee of supply (Hall, Brown and Zambonelli, 2007).
- Variability of quality standards for markets.
- Lack of communication and transfer of technical knowledge along the supply chain. (Nicholas, 2001).

The threat of contamination occurring during the inoculation process is a significant one for the industry. Much of the inoculum used for inoculation of seedlings is imported from overseas (Hall, Brown and Zambonelli, 2007). Hall, Brown and Zambonelli (2007) state that inferior species of black truffle such as the Chinese *Tuber indicum* and *Tuber sinense* have very little market value and can be substituted. Furthermore, there is also the threat of competing mycorrhiza such as Scleroderma taking the place of potential infection sites for the desired fungus. In the field they reproduce prolifically and can out-compete the French Black Truffle fungus – leading to a very low or even absent production. To find out after several years that much of the desired fungus has been displaced would be disastrous for growers. The damage that these contaminants can cause may also ruin the reputation of Australian grown truffles, particularly when marketing the product overseas. QA is one mechanism for controlling contaminants, ensuring they are kept out of the country and most importantly out of inoculation nurseries and truffières.

On farm practices such as nutrition, weed suppression and soil moisture levels have a significant impact on the size, quality and volume of truffles produced. This is still an area of scientific uncertainty and much research on the cultural techniques is still being undertaken (Hall, Brown and Zambonelli, 2007).

Quality Assurance

The Australian truffle industry is not unlike other industries seeking to explore QA as a means of developing customer confidence in the industry. QA can be seen as an important element underlying the credibility and competitiveness of individual firms and industries overall. In the context of truffles, Garvey and Cooper (2004) explain that QA encompasses all planned and systematic actions and programs that are designed to provide confidence that the product (i.e. inoculated trees, fresh truffles or value added products) or service (e.g. agronomic consultancy) will meet customer expectations.

Internationally, there are no truffle industry-specific QA schemes in use; however, standards for grading truffles do exist. The European Union (EU) standard was developed by the United Nations Economic Commission for Europe (UNECE) in 2004 and titled 'Recommendation Standard for Fresh Truffles'.

More recently, the New Zealand Truffle Association (NZTA) launched its own version of a grading system based on that of the EU (Hall and Nelson, 2009). The system was completed largely by the NZTA with input from committee members of the Australian Truffle Growers Association. The purpose of the standard is to define the quality requirements of truffles at the export control stage, after preparation and packaging and a recommendation for local sales. The document clearly sets out the requirements of the following important provisions:

- Provisions concerning quality: Truffle minimum requirements, maturity requirements and classification (e.g. Grade A, B, C or D)
- Provisions concerning sizing: size is determined by the weight of the truffle
- Provisions concerning packaging: Uniformity and packaging
- Provisions concerning labelling: Identification, nature of the produce, origin of the produce and commercial specifications

The document was developed with the interests of Australian growers in mind also. Both the NZTA and Australian Truffle Growers Association are closely aligned so an Australian version of the grading system is likely to be very similar.

There is considerable literature on growing and cultivating truffles (ATGA 2009; Malajcuk and Amaranthus 2007, UNECE 2004). In addition to Lee's (2008) assessment of the industry, as previously mentioned, RIRDC has also supported several other studies into the industry. These include investigations into "Evaluation of the potential of growing *Tuber melanosporum* as a crop on mainland Australia for export and domestic consumption" (Stahle and Ward 1996), "French Black Truffle. Establishment and production in Tasmania" (Garvey and Cooper, 2001) and "Increasing the productivity of truffières in Tasmania" (Garvey and Cooper 2004). These papers variously highlighted the importance of quality assurance and, specifically:

- The importance of the highest quality truffle produce in maximising the economic benefits for farmers (Stahl and Ward, 1996).
- The protection of the integrity of the industry, and ensuring the production of a certified quality truffle, being dependent upon the inoculation nurseries being able to guarantee the quality of trees distributed to growers (Garvey and Cooper, 2001).
- The marketing potential of the Australian truffles being underwritten by both the best technology available and a quality scheme that certifies the quality and species of the Australian grown French black truffle (Garvey and Cooper, 2004).

More recently, the 'Australian Truffle Industry R&D Strategic Plan 2009-2011' (RIRDC 2009b) set out five major objectives for the industry as part of a set of three year industry priorities. Objectives 3 and 5 in particular focus on industry quality related requirements. The objectives include:

- **Objective 1**
  - Establish an action group to work with AQIS on Import
  - Legislation covering Chinese or other identified truffle varieties
- **Objective 2**
  - Understanding, strengthening and developing market analysis
  - and market drivers for Australian truffles
- **Objective 3**
  - Establishing a Grading Standard for Australian truffles

- **Objective 4**
  - Research into diseases with a focus on affects of rot in truffles
- **Objective 5**
  - Consumer education, industry communication and engagement,
  - and advancement of accreditation standards for Australian truffles

Whilst there is not yet a quality assurance scheme specifically for truffle cultivation in Australia there are several QA systems and standards in use for other horticultural product. One is SQF2000 which is very sophisticated and requires a strong market link (Rudge, pers. comm., 2009). Another is Freshcare which, unlike SQF2000, has relatively low costs of implementation and maintenance, but is primarily focused on food certification rather than the growing processes (Bennett 2005).

The ISO9000 series of standards define minimum requirements for business quality assurance schemes (Handy and Atkinson 1997). Whilst the certification system is internationally recognised it is not industry specific and is most appropriate for the manufacturing industry. It is also too complex for small operations and expensive to implement and maintain.

The Nursery Industry Accreditation Scheme, Australia (NIASA) for production nurseries outlined in the NGIA's Best Management Practice Guidelines manual (Nursery and garden Industry Australia 2003) is adopted by many inoculation nurseries (Blakers per. comm. 2009). Whilst it is cost effective and in the most part applicable, truffles require different cultural and growing practices to a traditional pot plant, in that the focus is more on growing the fungus than the plant. It is clear that conventional practices for things such as pest and disease control will need to be modified and industry guidelines developed specifically for truffles. Another downside of NIASA is that it is strongly business process based and appears to be more of a marketing tool than a practical, quality driving set of procedures (Rudge, pers. comm., 2009).

Some industry sectors have their own specific quality standards. One example of this is Australian Persimmon Export Company (APEC) which was in a similar situation to that of the present Truffle Industry a few years back (Rudge, pers. comm., 2009). APEC consists of about 30 growers so industry penetration is low, but it is entirely grower owned and controlled (Australian Persimmon Export Company 2009). APEC adopts quality standards which must be followed by all members.

Other certification models do exist. For example, the Organic Growers of Australia (OGA) has its own certification system (Organic Growers of Australia 2009). This system is designed to ensure authenticity of an organic product. It is aimed at small operations with reduced certification fees and less complexity than those designed for large scale business (Organic Growers of Australia 2009). One of the concerns with the system relate to control and certification regarding non-organic inputs being used on organic farms.

Industry Survey

As part of the process of developing a model for QA for the Truffle industry, key stakeholders including growers, inoculation nurseries, truffle wholesalers and marketers, were surveyed to establish their likely levels of support for a the concept of an industry based QA model and its associated elements. For any implementation to be successful and gain a high level of uptake from key stakeholders within the industry an analysis of the thoughts of these key stakeholders is critical. The survey was designed to elicit views on any issues and costs, but also the benefits that members feel are important so these can be taken into consideration when a QA scheme is developed.

The survey also presented to the stakeholders a sense of what an industry based QA model might involve for the truffle industry. This was developed after discussions with people within the Australian truffle industry and the wider horticultural industry. This QA 'construct' enabled stakeholders to respond in a more informed way on the elements that would be contained in a system of QA for the industry. The five QA elements included:

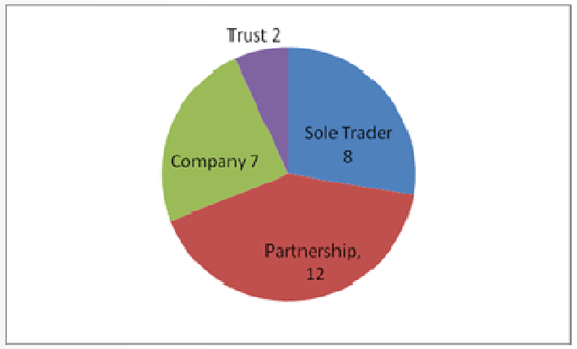
1. A grading system to ensure final product meets specifications
2. Grower and inoculation nursery certification. Whilst the methodology and theory associated with the inoculation of host trees is usually confidential the integrity of the process is crucial for the industry.
3. Environmental certification (e.g. ISO 14000, Freshcare environmental Code)
4. Annual audits - many documents have suggested the need for an audit process. Most have focused on inoculation nurseries, in particular to certify that trees have been successfully infected with *Tuber melanosporum* and free of competing mycorrhizal fungi. Also of importance is DNA analysis for true to type *Tuber melanosporum* and infection is with both mating type loci.
5. Good Agricultural Practice. This appears to form grounding in most industry specific QA schemes (Kingwell, 2003). This would cover the process of benchmarking such as industry best practice techniques. Technical support to growers is also an important issue which would need to be covered under Good Agricultural Practice.

During August 2009, 110 members of the Australian Truffle Industry were invited to complete an online questionnaire. The survey was issued after consultation with industry stakeholders, pilot testing and under the governance and protocols of The University of Melbourne's Human Ethics policy. 29 (26 percent), 25 of which were 25 truffle growers. Other interests included inoculation nurseries / growers, agronomic consultancy business and distributors of fresh truffles.

Business profiles

The dominant legal or ownership structure of the organisations surveyed was the partnership structure (12 or 41 percent) followed by sole traders (28 percent) and companies (24 percent)(Figure 1). All respondents nominated themselves as 'owner / director' within their operations.

Figure 1: Ownership structure of respondents (n = 29)



The largest concentration of respondents (16) was from New South Wales (Table 2). Western Australia and Tasmania had the lowest participation rate with only one from each state. This was not unexpected since while

these are the two states in which the industry was pioneered and are the two highest producing states in Australia, the numbers of growers are small.

The most common size of operation was between 1 and 5 hectares with 15 respondents in this category (Table 2). The high incidence of smaller operations seems consistent with the data presented in 'Taking Stock of the Australian Truffle Industry'. One reason for the high incidence within the industry of smaller scale of operations is that it appears that many growers have planted one hectare on a trial basis. As a new industry requiring much research into the cultural and growing requirements under Australian conditions, the moderate scale of operations may be due to grower conservatism in light of the range of risk factors. Five respondents had a growing area greater than five hectares. The bigger producers were distributed evenly throughout the States.

Table 2: Number of operations by size / State

SIZE/STATE	NSW	VIC	ACT	WA	TAS	TOTAL
< 1ha	4	3	0	0	0	7
1 - 5ha	10	4	1	0	0	15
> 5ha	1	1	1	1	1	5
Other*	1	1	0	0	0	2
TOTAL	16	9	2	1	1	29

Other* includes the two operations which are not growers of fresh truffle but key stakeholders in the industry.

The most common age of operation was between four and ten years with 52 percent in this group (Table 3). 12 operations (41 percents) were in the youngest category (less than four years). The lack of operations greater than ten years is consistent with the view that the industry is still young.

Table 3: Matrix of size and age of the operation

SIZE/AGE	< 4yrs	4-10yrs	> 10yrs	TOTAL
< 1ha	5	2	0	7
1 - 5ha	5	10	0	15
> 5ha	1	3	1	5
Other*	1	0	1	2
TOTAL	12	15	2	29

Quality systems currently in place for the business

Respondents were asked to identify internal production techniques and external production standards or certifications employed by their businesses.

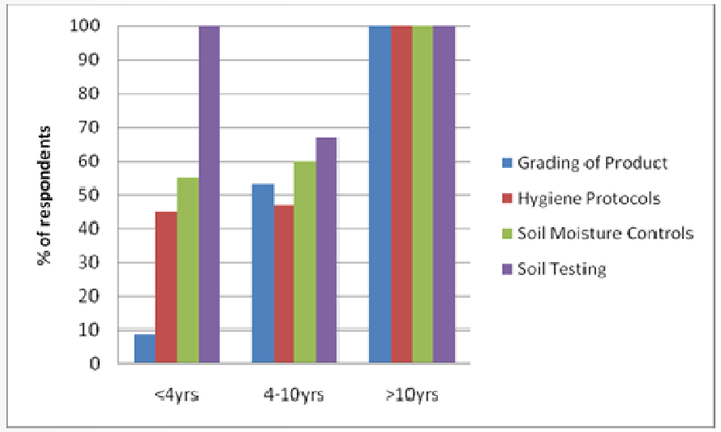
Internal production techniques

Soil testing was the most used internal production technique among the participating growers with 78 percent implementing the technique (Table 4). Business process controls was the least used internal production technique with only five respondents. Of the 27 growers who participated in the survey 37 percent used grading of product as an internal production technique. Only one of the operations less than four years old used this technique, 53 percent in the four to ten year category, and 100 percent of greater than ten year old operations use the technique (Figure 2). This result appears consistent with the earlier assumption that truffles are not usually formed until trees are a minimum of four years of age. The single operation using this technique in the less than four year category was also an inoculation nursery and may use grading of product for use as inoculum. Soil testing was used by all growers in the less than four year and greater than ten year categories with the rate falling away to 67 percent in the intermediate 4-10 year category (Figure 2).

Table 4: Number of respondents using various internal production techniques (n = 29)

Internal production techniques	Count	%
Grading of Product	✓✓✓✓✓✓✓✓✓✓	37
Hygiene Protocols	✓✓✓✓✓✓✓✓✓✓✓✓✓	48
Root sampling/analysis for contamination	✓✓✓✓✓✓✓✓	30
Soil moisture controls	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	59
Soil tests	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	78
Business process controls	✓✓✓✓✓	19

Figure 2: Respondents using various internal production techniques by age of operation (n = 29)



External production standards or certification systems employed

The level of uptake of external production standards or certification systems is considerably lower than internal production techniques (Table 5). Three respondents who are not using any external production standards expressed opinions that the external production standards are not yet applicable to them.

Whilst the number of respondents employing organic certification was low (only 2) several people indicated an interest in participating in an organic certification scheme. One person indicated they will be seeking organic certification once their trees come into production and another stated that they are about to begin starting out preparing for organic certification. The operations of the two respondents who do employ organic certification are both less than four years old (Table 5). The particular organic certification program specified by the two growers was Organic Growers of Australia.

Table 5: Respondents employing various production standards by age of operation (n = 29)

	All		< 4yrs		4-10yrs		> 10yrs	
External production standards	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Industry accreditation	2	7	0	0	1	6.7	1	50
Organic certification	2	7	2	18	0	0	0	0
Customer quality system	5	19	1	9.1	3	20	1	50
Food safety certification	3	11	0	0	2	13	1	50
Environmental certification	0	0	0	0	0	0	0	0

Five (19 percent) respondents used a customer quality system (Table 5). All respondents adopting food safety certification come from the four to ten and greater than ten years of operation categories. This seems reasonable given the assumption that truffles are not usually formed until trees are four years old. With no fruit to sell there is no need for food safety certification.

Industry support for QA

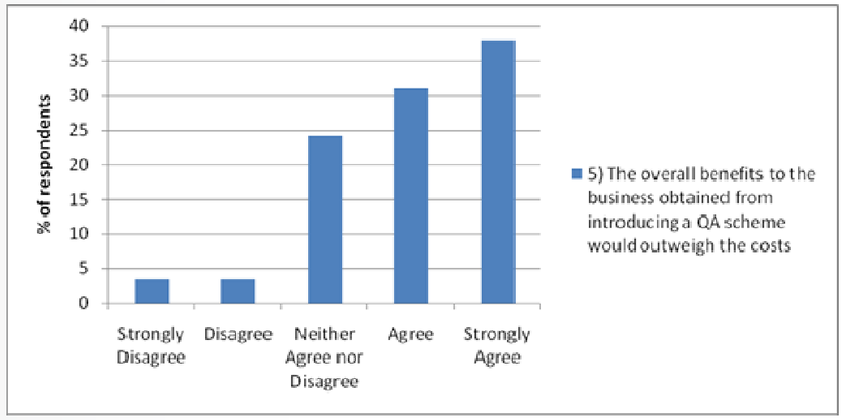
Industry members were asked to indicate their overall level of support for a quality assurance system in response to the following statement:

> "The overall benefits to the business obtained from introducing a QA scheme would outweigh the costs"

Using a 5 point likert scale, response choices ranged from strongly agree (5 rating) to strongly disagree (1 rating) with a neutral rating (3 rating). Participants were generally in favour of the statement with 11 respondents strongly agreeing with 20 of the 29 respondents agreeing overall (Figure 3). The mean response was 3.97, median 4 (agree) and standard deviation of 1.05.

Only two respondents disagreed with the statement. One respondent's reason was that they believed that a QA scheme would take all of "the mystery and magic away from the product and thus lower the value". The other respondent is not a supporter of regulation in private enterprise and feels it is just an impediment and a cost to production. This respondent believes that producers are individually responsible for quality control at the production end and this will build their standing in the marketplace. Whilst this respondent felt the costs outweighed the benefits they did indicate that they will participate in such a scheme and follow common procedure if required.

Figure 3: Frequency (%) of respondents selecting different levels of agreement towards question 5(a) (n = 29)

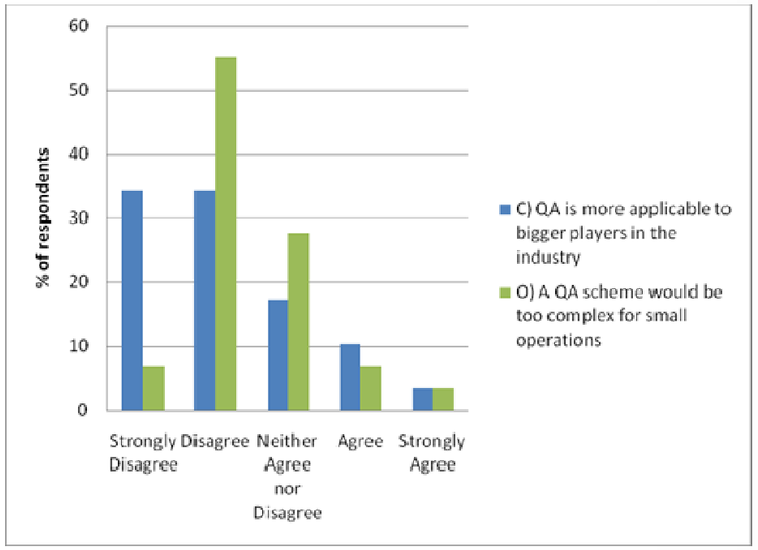


The results were also analysed in terms of whether there were significant differences in the responses of the different groups surveyed. One analysis compared two groups by age of operation. Using the Wilcoxon Rank Sum Test to the ordinal data, there was no significant difference between the growers with operations less than four years old and older operations.

Complexity in administering QA

Industry participants were asked to respond to the notion that QA was more relevant to the bigger industry players. The implication being that QA would be more difficult for the smaller growers to implement and maintain given the likely resources required.

Figure 4: Frequency of respondents selecting different levels of agreement towards questions 4(c) and 4(o) expressed as a percentage (n= 29)



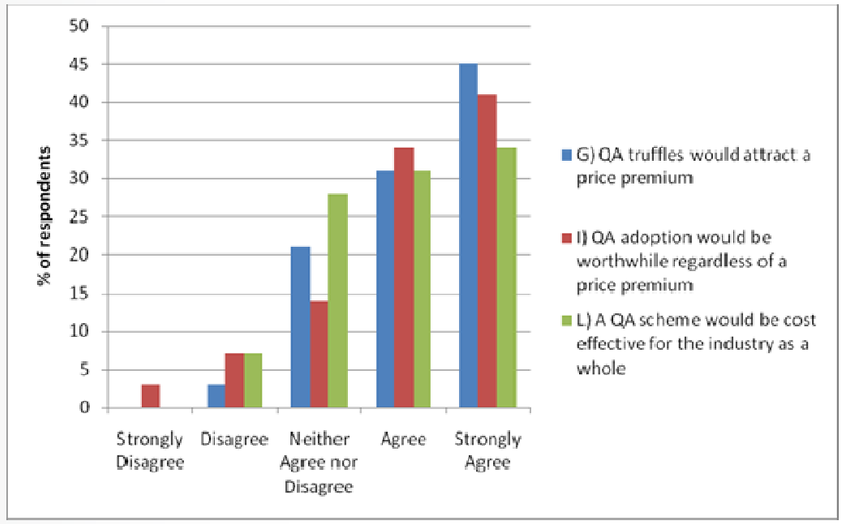
69 percent of respondents disagreed with the statement that QA is more applicable to bigger players in the industry (Figure 4). Likewise, 62 percent disagreed that a QA scheme would be too complex for smaller operators. Only three respondents agreed. It is noticeable that there is stronger disagreement towards statement 4(c) with 34 percent strongly disagreeing compared with 7 percent statement 4(o).

Cost effectiveness in implementing QA

Statements in this group together form a picture about the perceived benefits obtained from the development and implementation of a QA scheme at both an individual business level and the industry as a whole considered in light of the additional resources and costs required.

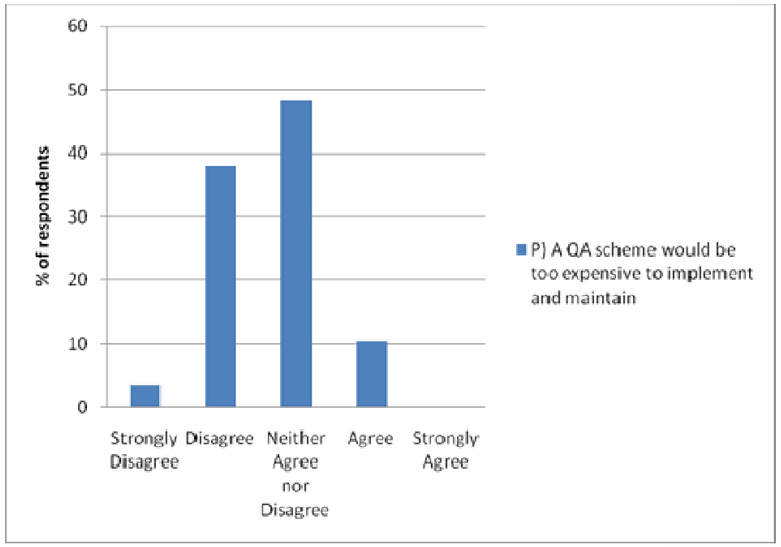
Figure 5 indicates a high level of agreement among respondents towards statements 4(g), 4(i) and 4(l). Not only will a desired price premium be attracted by quality assured truffles this is not the sole reason for adopting a QA scheme. From these results it appears that respondents believe there are other major benefits to be gained by individual operations and the industry, aside from a price premium.

Figure 5: Frequency of respondents selecting different levels of agreement towards questions 4(g), 4(i) and 4(l) expressed (n = 29)



The fourth statement in this group 4(p): A QA scheme would be too expensive to implement and maintain, was included in the survey to ensure a level of consistency with the other elements. High levels of agreement with the first three statements should correspond with disagreement with the fourth. Although there does appear to be general consistency, the strength of agreement / disagreement does differ. For example, 66 percent agreed / strongly agreed with 4(l) (Figure 5), yet fewer respondents (44 percent) disagreed / strongly disagreed with 4(p)(Figure 6). There was more ambivalence among the respondents to 4(p), likely because of a lack of knowledge among members as to the cost involved.

Figure 6: Frequency of respondents selecting different levels of agreement towards question 4(p) (n = 29)



Rationale for International Competitiveness

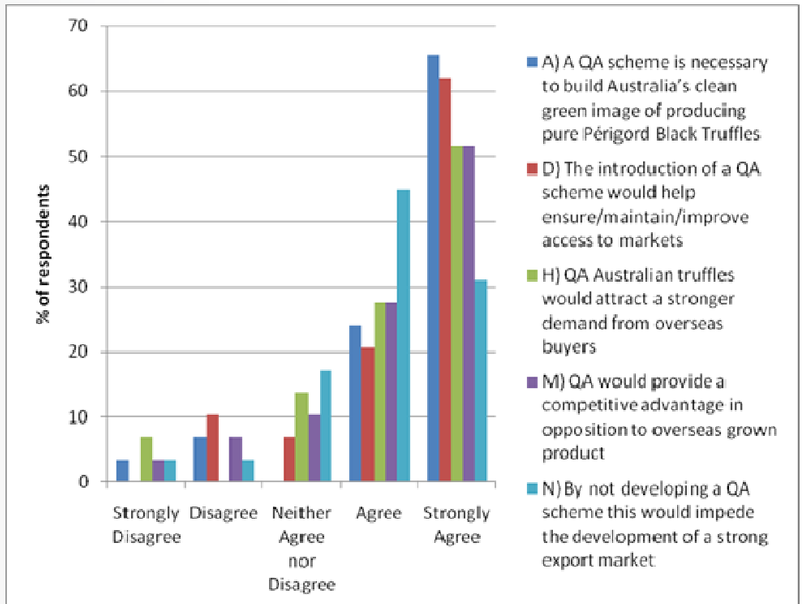
The statements grouped under the theme of international competitiveness refer most strongly to the industry as a whole, but also to individual business. They stem from the capacity of a quality assured product being more desirable and at a competitive advantage relative to internationally produced truffles.

Figure 7 demonstrates that there is a high level of agreement that a QA scheme will improve the performance of Australian grown truffles and open up and maintain markets. The large majority of respondents believe a competitive advantage can be obtained over international competitors with the implementation of a QA scheme.

Once again there appears to be a consistent level of agreement within this group of statements (Figure 7). Statements 4(a), 4(d), 4(h) and 4(m) all have means greater than 4 and medians of 5 (Strongly agree). The frequency of strongly agree for statement 4(a) and 4(d) is extremely high with 66 percent and 62 percent respectively selecting this option.

Four (10 percent) of the respondents did disagree or strongly disagree with Statements 4(a) and 4(d). These all had operations greater than one hectare in size (i.e. 1-5ha or >5ha).

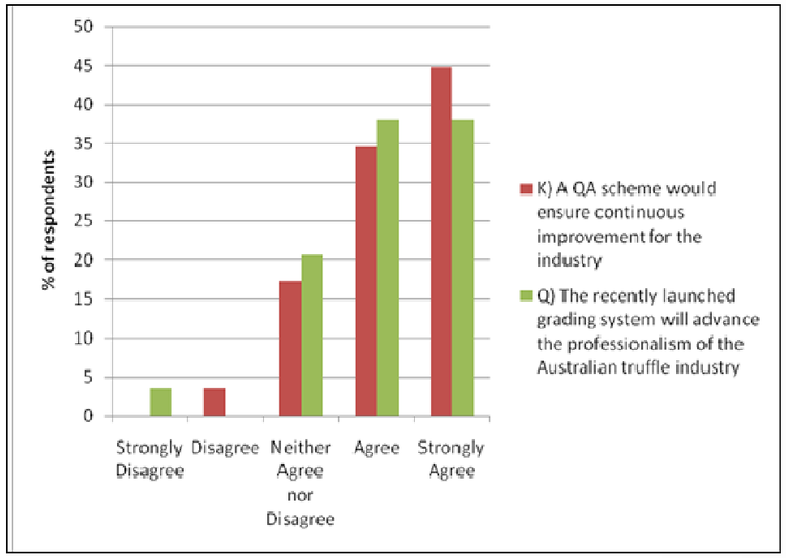
Figure 7: Frequency of respondents selecting different levels of agreement towards questions 4(a), 4(d), 4(h), 4(m) and 4(n) (n = 29)



Lever for industry improvement

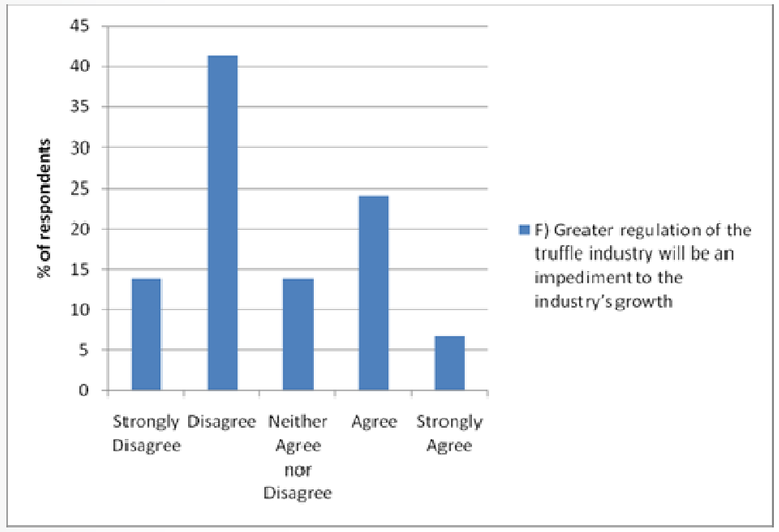
The majority of respondents agreed or strongly agreed that a QA scheme would ensure continuous improvement for the industry and the recently launched grading system would advance the professionalism of the industry (Figure 8). The one person who strongly disagreed that with 4(q) was a grower from NSW and the one person who disagreed with 4(k) was the grower from Tasmania.

Figure 8: Frequency of respondents selecting different levels of agreement towards questions 4(k) and 4(q) (n=29)



The turnaround statement here to ensure validity of responses is 4(f). The results to this statement are widely spread with a standard deviation of 1.20. This can be visually seen in Figure 9 also with each level of agreement receiving at least two responses from participants. Whilst 55 percent of respondents disagreed with the statement nearly one third (31 percent) agreed.

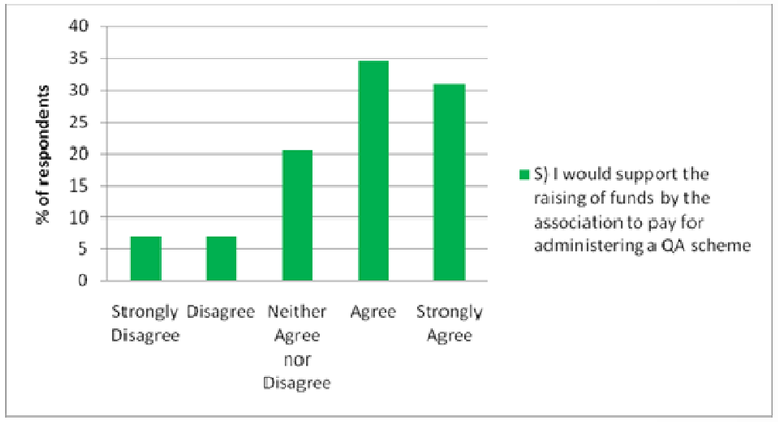
Figure 9: Frequency of respondents selecting different levels of agreement towards question 4(f) expressed as a percentage



Industry willingness to pay and expected uptake

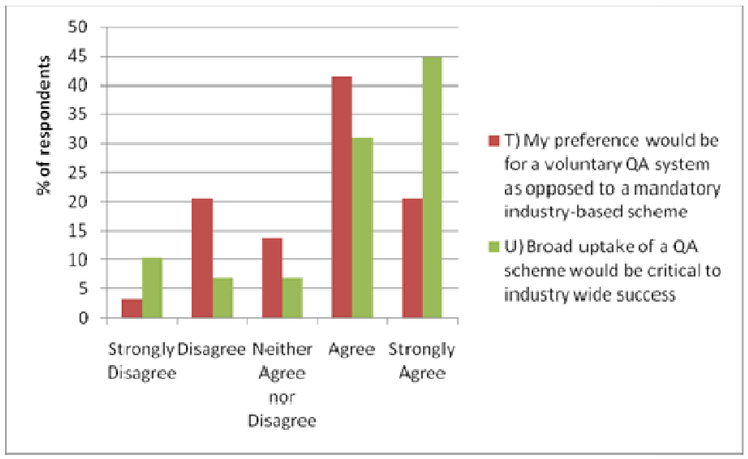
The survey captures different layers of support for QA implementation (Figure 10). Item 4(s) indicates support for the raising of funds by the industry association to pay for QA administration. However, as stated in the comments by growers, this issue was difficult to respond to without knowing the costs of running the scheme and who would bear the cost. Nonetheless, 66 percent supported the raising of funds to administer a QA scheme. There were no significant differences in responses to these items between the managers of younger (<4 years) and older operations.

Figure 10: Frequency of respondents selecting different levels of agreement towards question 4(s) (n = 29)



75 percent of respondents agreed that broad uptake of a QA scheme would be critical to industry wide success; at the same time there was still reasonable strong preference for a voluntary as opposed to mandatory scheme (Figure 11).

Figure 11: Frequency of respondents selecting different levels of agreement towards questions 4(t) and 4(u) (n = 29)



Perceived benefits and drawbacks of a QA scheme

Respondents were asked to comment on the main benefit and then drawback to the implementation of a QA scheme. The benefits can be summarised as:

- Improved marketing opportunities to help producers of all sizes sell their product overseas.
- Stability and maintenance of high prices.
- Formation of clear guidelines for better practice.
- More objective grading of quality and price recognition.

11 of the 26 respondents who commented on the drawbacks of QA raised the issue of cost although the general expectation was that the benefits by way of price premium would outweigh the costs. There was some appreciation of the cost impact on smaller growers and the general scope to alienate such growers.

One respondent stated that "[t]here should be none (drawbacks) in a sound QA scheme. An inhibitive price for annual audits is what causes people within agriculture to avoid QA systems. Small growers can be penalised disproportionately. Signing a code of conduct may help sort out the commitment or otherwise of producers. ...."

There were some stronger negative responses on the issue of drawbacks. One grower stated "I don't want to be part of a compulsory system. I expect any QA system to be more of a burden than a help." Another response was " ... [v]ery little as we will continue to do what we have done for the past four seasons and would only adopt the QA if forced to."

Elements of the industry were sceptical of regulation seeing it as an impediment and additional cost. One view was that current systems and facilities in Australia already exceed likely certification requirements. There were countervailing views regarding the overseas experience. For example, one view was that the French have been successfully harvesting and selling pure French Black Truffles for a thousand years without QA so why should the emerging Australian industry. The contrasting view was that the European industry was infested with inferior Chinese truffles with the potential to devalue product. France is one of the largest importers of Chinese black truffle while its import is banned in Spain and Italy.

Respondents commented on the difficulty or subjectivity involved in selecting truffles based on aroma, flavour and shape. The point was made that the end user i.e. restaurant chefs, regardless of certification will be the determinant's of value and mechanism for quality control. One view was that the perfume and flavour of the product was too subtle for the E-nose technology.

Conclusion

The survey of ATGA members indicated there was general agreement with the development of an industry based approach to QA. Yet, the survey also captured the tensions within the industry in response to the QA debate. Some growers took the view that the supply chain integrity has adequately been maintained through the continuity and strength of consumer demand for their product. There were also concerns by members with the impact of QA requirements on the smaller, less established enterprises.

Australian truffle industry reviews have highlighted the importance of ensuring the quality of the Australian product as one of the requirements for strengthening the market for Australian truffles overseas. Such reviews also reflect the changing demands placed on the global supply chains for food and fibre and the need for greater supply chain integrity. At the same time, while a QA scheme will be an important feature in the development of truffle growing as a niche industry, QA is no guarantee of the future purity of Australian produced Truffles.

To date, as a relatively young industry, the focus of the Australian truffle growers has been toward achieving productivity and quality improvement enhancements with a strong focus on the production techniques and the cultural requirements required for truffle growing in Australian conditions. The development of external production standards and certification systems is perhaps the next focus for the development of the industry. This is especially the case as the newer growers' trees come into production.

Within the Australian industry, there is evidence of grower's using different accreditation systems. These include nursery industry accreditation, organic certification, customer quality system and food safety certification. There seems to be little use of environmental certification. The challenge for the industry is to tailor elements of QA to its specific requirements more than likely blending in elements of these other accreditation / certification systems.

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Appendix 1. Statistical analysis of survey data (n = 29)

	STATEMENT	Mean Score	Std dev	Median	Mode	% Agree	% Disagree	% NA nor DA
4a	A QA scheme is necessary to build Australia's clean green image of producing pure Périgord Black Truffles	4.41	1.05	5	5	90%	10%	0%
4b	QA is inevitable as truffles are part of the food supply chain	4.00	1.2	4	5	72%	10%	18%
4c	QA is more applicable to bigger players in the industry	2.14	1.13	2	1/2	14%	69%	17%
4d	The introduction of a QA scheme would help ensure/maintain/improve access to markets	4.34	1.01	5	5	83%	10%	7%
4e	QA is the start of greater regulation of truffle production	3.59	1.02	4	4	55%	17%	28%
4f	Greater regulation of the truffle industry will be an impediment to the industry's growth	2.69	1.2	2	2	31%	55%	14%
4g	QA truffles would attract a price premium	4.17	0.89	4	5	76%	3%	21%
4h	QA Australian truffles would attract a stronger demand from overseas buyers	4.17	1.14	5	5	79%	7%	14%
4i	QA adoption would be worthwhile regardless of a price premium	4.03	1.09	4	5	76%	10%	14%
4j	A QA scheme would give me better control over my production systems and prevent problems	3.83	1.23	4	5	69%	21%	10%
4k	A QA scheme would ensure continuous improvement for the industry	4.21	0.86	4	5	79%	3%	18%
4l	A QA scheme would be cost effective for the industry as a whole	3.93	0.96	4	5	66%	7%	27%
4m	QA would provide a competitive advantage in opposition to overseas grown product	4.17	1.1	5	5	79%	10%	11%
4n	By not developing a QA scheme this would impede the development of a strong export market	3.97	0.98	4	4	76%	7%	17%
4o	A QA scheme would be too complex for small operations	2.45	0.87	2	2	10%	62%	28%
4p	A QA scheme would be too expensive to implement and maintain	2.66	0.72	3	3	10%	41%	49%
4q	The recently launched grading system will advance the professionalism of the Australian truffle industry	4.07	0.96	4	4/5	76%	3%	21%
4r	An ENose (Electronic Nose) would be a worthwhile addition to a QA scheme for distinguishing between truffle species and also ripeness	3.90	0.98	4	4	69%	10%	21%
4s	I would support the raising of funds by the association to pay for administering a QA scheme**	3.76	1.18	4	4	66%	14%	20%
4t	My preference would be for a voluntary QA system as opposed to a mandatory industry-based scheme	3.55	1.15	4	4	62%	24%	14%
4u	Broad uptake of a QA scheme would be critical to industry wide success	3.93	1.33	4	5	76%	17%	7%
5a	The overall benefits to the business obtained from introducing a QA scheme would outweigh the costs **	3.97	1.05	4	5	69%	7%	24%

** no significant difference between growers with operations less than four years old and growers with older operations.