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Increasing the productivity of truffières in Tasmania

A report for the Rural Industries Research and Development Corporation

by Duncan Garvey and Peter Cooper

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Foreword

Traditionally French truffles *(Tuber melanosporum)* which forms a symbiotic relationship with hazel (*Corylus avellana)* and oak *(Quercus spp*) trees have traditionally been produced in France, Italy and Spain. The French truffle is revered by the great chefs of the world and is considered the jewel of French cuisine.

In 1999 Perigord Truffles of Tasmania produced the first French Truffle in Tasmania and have subsequently produced truffles on a number of properties in Tasmania in recent years.

This publication investigates and records using a geographical information system a number of agronomic issues in increasing the productivity of the truffières in Tasmania. Experimentation is carried out on new and existing trufferies to assess key soil factors, which could lead to earlier and increased production.

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

This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our new plant products R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

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Simon Hearn
Managing Director
Rural Industries Research and Development Corporation

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Perigord Truffles of Tasmania would like to thank the following people for their assistance and support:

- To our joint venture growers who have supported a project to produce a product that in many cases they had not seen touched or tasted prior to their commitment;

- RIRDC for sponsoring and supporting the project;

- Members of the French truffle industry including scientists, producers and marketers for their assistance and support, and

- Don Beams, Beams Brothers Lime Quarries , Beaconsfield, Tasmania.

Executive Summary

Perigord Truffles of Tasmania Pty Ltd (PTT) was formed in 1992 to exploit the opportunity of producing and marketing the highly valued and sought after gourmet food product known as the French black truffle or Perigord truffle.

The French black truffle, which is the fruiting body of the fungus *Tuber melanosporum*, grows in a symbiotic relationship with oak and hazel trees and has been traditionally produced in regions of France, Italy and Spain for over a millennium.

The truffles which are formed in the top 20 cm of the soil are harvested manually after using dogs to detect their presence by the perfume they emit at maturity which occurs in the northern hemisphere winter months of December, January and February.

PTT recognised the opportunity to produce and market fresh French black truffles *Tuber melanosporum* in the southern hemisphere winter months of June, July and August.

In 1999 Perigord Truffles of Tasmania were recognised nationally for their success at producing Australia's first French Black Truffle. In subsequent years the production of French truffles from a number of trufferies in Tasmania has confirmed that PTT is well down the track to establishing a viable French truffle industry in Australia.

Research in the early nineties jointly funded by RIRDC allowed PTT to highlight the key issues to develop a strategy to successfully produce and market French black truffles. During the past 3 years PTT have continued the research program on the French Black truffle in addressing further issues on increasing the productivity of truffières in Tasmania.

The truffle industry in Tasmanian is unique in that it is based on soils that are not naturally calcareous, but have been heavily limed in order to increase the soil pH. A soil pH of 7.5 (1:5 water) and above is considered acceptable but production is at its maximum when the pH is in the range 7.9 to 8.1. The truffières in Tasmania are currently above the critical soil pH level of 7.5, but many are below the optimal range.

Perigord Truffles conducted two trials assessing liming rates one on existing truffières and another on a proposed truffières.

The Effect of Applied Lime on New Truffières

The objective of the lime trial was to determine the amount of lime required to raise the soil pH to the optimum level for French truffle production 7.9 to 8.1 (1:5 water).

A field experiment was established on three new truffières representing three soil types; a kraznozem, an alluvium and a podsolic soil. Three lime treatments of commercial grade lime were applied to each truffière the rates were: 50, 75 and 100 T/Ha respectively.

The lime was spread at the treatment rates on the trufferies then was incorporated through the soil profile to a depth of 20cm.

Soil pH readings were taken an analysed prior to the application of the limestone and at 1, 3, 6 and 12 months and annually thereafter. Measurements were taken at three depths in the soil profile 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

The results showed for all the lime treatments, there was a significant increase ($P<0.05$) in the pH from the level prior to lime application.

On the podsolic and alluvial soils, all three rates of lime brought the soil pH to about 8, which is in the vicinity of the maximum level obtainable by applying calcium carbonate. Whilst the application of 100T/Ha was able to make this process happen more quickly, by 24 months after the lime application (12 months for the podsolic) there was no significant differences ($P>0.05$) between the treatments.

The kraznozem on the other hand was still showing a significant difference ($P<0.05$) between lime treatments at 24 months. The 100 T/Ha treatment produced a higher pH than the 75 T/Ha treatment or the 50 T/Ha treatment.

The implications to Perigord Truffles of Tasmania and its joint venture truffle farmers is that new truffières can now be established in soil types with pH levels between 7.9 – 8.1 (1:5 water)

The significantly higher lime rates used to increase the soil pH will also have additional benefits to the truffières such as:

- large quantities of free lime in soil:
- greater buffer against the soil pH decreasing, and
- increased soil aeration and friability.

Applying very high rates of lime prior to planting will not add significantly to the cost of establishing the trufferie. If the current average price for truffles produced by PTT is maintained in excess of $2,000 per kilogram the potential return on the expense of the higher lime rate will be very economical.

As a result of the trial PTT are now recommending significantly larger quantities of finer grade lime prior for the establishment of new truffières.

It will be a number of years before the new truffières with the higher lime rates start producing French truffles, however PTT are confident that the additional expense of the high lime rates will be justified.

The Effect of Applied Lime on Existing Truffières

The objective of the lime trial on existing truffières was to determine the amount of lime required to raise the soil pH to the optimum level for French truffle production 7.9 to 8.1 (1:5 water).

A large number of the truffières in Tasmania are currently above the critical soil pH level of 7.5, but many are below the suggested optimum range for production. Less than optimal soil pH in existing trufferies has been an ongoing issue and a potential reason for disappointing truffle yield in some truffières.

A field experiment was conducted on three established truffières in Tasmania. Three lime treatments were applied to the three existing truffières representing three soil types. These soil types included a loam overlaying clay, a kraznozem and a clay loam overlying mudstone.

The three lime treatments were 7,14 and 21 T/Ha of fine grade lime. At the end of 12 months the treatment areas were cultivated to a depth of 100mm.

Soil pH readings were taken and analysed prior to the application of the limestone and at 1, 3, 6 and 12 respectively. Following the cultivation of the treatment areas pH reading were taken at 18 and 24 months respectively. Measurements were taken at depths in the soil profile 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

The results indicated there was an effect of the lime treatments on each of the soil types. There was no significant effect for any of the lime treatments prior to cultivation. Post cultivation, there were significant ($P<0.05$) responses to lime to a depth of 10cm and no significant response below 10cm. Where there was a significant response, the higher rates of lime gave a greater pH response than the lower rate of lime. For the three soil types, at a depth of 0 to 5cm, 21 T/Ha of lime raised the pH to approximately 7.9 which is a level that is thought to be suitable for truffle production.

The findings of the experiment will enable Perigord Truffles of Tasmania to develop a strategy for raising the soil pH in established truffières.

The use of a cultivation implement along the tree line to incorporate the lime will have additional benefits in reducing soil compaction, improving soil aeration, soil friability and assisting in early spring weed control.

Perigord Truffles of Tasmania have now recommended that additional lime be applied and incorporated along the tree line to existing truffières where the soil pH is below the optimal level.

Geographical Information System

The objective of the research was to develop a geographical information system to accurately map and record information on truffle production, parameters related to truffle production, and treatments of truffières in Tasmania, Victoria and NSW.

In conjunction with a Tasmanian Company Data Vision a truffle mapping extension was developed using a geographical information system (GIS) Arcview 3.2.

The truffle mapping extension allows for the plotting of a grid of trees and truffles found in relation to a tree in a grid and the recording of a range of parameters. The structure of the industry enables the acquisition of valuable information on production, applied treatments and other physical factors from at least 40 truffières established in Tasmania, Victoria and NSW.

This information then can be analysed annually to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

The truffières were mapped during 2001 and 2002 using a Global Positioning System.

A range of parameters were recorded and mapped, these included for truffières individual trees including date of planting, species, row and tree spacing infrastructure in truffière such as drainage and irrigation mains, lime treatments and soil types. During the truffle harvest details include tree type, date of harvest, truffle weight and quality, distance from tree, depth in the soil and angle from tree.

The ability to accurately map truffle production and parameters related to truffle production has greatly enhance the chances of detecting the factors that effect truffle yield.

The truffle mapping extension has the capacity to query one parameter against another so it is now possible for example to determine how many truffles were found within 1.5m of all the *Quercus robur* plants in a given truffière and thereby determine the productivity of that species for the site.

The ability to be able to access this data about the truffières and the producing trees will be of significant benefit to the truffle industry. As Perigord Truffles of Tasmania further expand the number of truffières the recording and analysis of all the information and data will be of paramount importance.

The development of the program has allowed for the information to be displayed spatially for easy accessibility. The information can now be analysed readily to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

The truffle mapping extension will be used by the company on all existing and new truffières, to record all parameters, which may have an influence on truffle production. This analysis process will be maintained indefinitely by PTT so as to be able to compare historical and current data from each truffière.

The production of French truffles on multiple sites in the winter of 2002 has confirmed PTT's success in achieving its goals. The company has confirmed its ability to transfer and apply the necessary technology and had its theories with respect to climate, geography and geology tested and confirmed. PTT has seen the creation of a unique production agreement with its joint venture growers that has withstood the test of time and has successfully harvested and marketed a premium quality product to an excited and receptive market at a price almost double its budget.

Perigord Truffles of Tasmania has always seen the rapid dissemination of their research and development work as one of the underlying strengths of the company structure. The nature of the joint venture agreement results in both the company and farmers sharing equally in any of the benefits gained from the research.

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Perigord Truffles of Tasmania Pty Ltd (PTT) was formed in 1992 to capatalise on the opportunity of producing and marketing the highly valued and sought after gourmet food product known as the French black truffle or Perigord truffle.

In 1999 Perigord Truffles of Tasmania were recognised nationally for their success at producing Australia's first French Black Truffle. In subsequent years the production of French truffles from a number of truffières in Tasmania has confirmed that PTT is well advanced to establishing a viable French truffle industry in Australia.

Research in the early nineties jointly funded by RIRDC allowed PTT to highlight the key issues to develop a strategy to successfully produce and market French black truffles.

During the past 3 years PTT have continued the research program on the French Black truffle in addressing further issues on increasing the productivity of truffières in Tasmania.

The following report covers the research undertaken.

Liming Experiment - Existing Truffières
PTT established a trial to determine the rate and cultivation technique involved to raise the soil pH in truffières already established in Tasmania. In the longer term PTT aim to assess whether the increase in pH equates to increased production.

Liming Experiment – New Truffières
A trial was established to determine the amount of lime required to reach optimum soil pH. The trial was conducted on a range of soil types representing soils where new truffières are being established. In future years the effect of reaching optimum soil pH more rapidly than previously achieved will be assessed against early truffle production

Geographical Information System
A geographical information system (GIS) Arcview was used to accurately map and record information on truffle production, parameters related to truffle production, and treatments of truffières in Tasmania.

The Effect of Applied Lime on Soil pH and Truffle Yield in Existing and New Truffières

Introduction

French literature and PTT's own research in France indicate that the majority of French truffles produced in France are on calcareous soils with soil pH (1:5 water) ranging from 7.5 – 8.2. Much of the information regarding the preferred soil ecology of *Tuber melanosporum* has been derived from soil surveys such as those conducted by Grente et.al. (1976). It is very difficult to determine from these surveys which parameters are influencing truffle production. It has been shown by Brown (1998) that applying lime to non-calcareous soils does increase the level of mycorrhization of *T. melanosporum*.

The truffle industry in Tasmanian is unique in that it is based on soils that are not naturally calcareous, but have been heavily limed in order to increase the soil pH. A soil pH of 7.5 (1:5 water) and above is considered acceptable but production is at its maximum when the pH is in the range 7.9 to 8.1. The truffières in Tasmania are currently above the critical soil pH level of 7.5, but many are below the optimal range. Discussions with leading soil scientists suggest that a minimum of 5% of free lime in the soil is required to maintain the soil pH in the range 7.9 to 8.1.

An additional 50 T of lime per hectare costs in the order of $2,500. At today's prices, this is less than the price of one kilogram of truffles or 1.6% of the budgeted annual harvest. Hence the lime treatment only needs to increase production by one kilogram over the period of its effect in order to break even. We believe the potential returns of applying more lime are very high.

There have been no replicated field experiments that have sought to determine the effects of applied lime on truffle production. This is most likely a result of the fact that most truffières in Europe are grown on calcareous soils with abundant free limestone.

On a truffière in northern Tasmania that was established in November 1996, additional lime treatments were applied to the truffière in the winter of 1999. Subsequently, there have been indications of a yield response to the additional applied lime. If this is the case, the result is very significant to all the other established truffières and highlights the importance of the ongoing lime and pH trials in the existing and new truffières.

The need for these experiments was to determine how much liming material is required to obtain the optimum pH on both existing sites and new sites. In the longer term we aim to assess whether the increase in pH equates to increased production.

The Effect of Applied Lime on New Truffières

Methodology

Overview

A field experiment was established on three new truffières representing three soil types; a kraznozem, an alluvium and a podsolic soil. Three lime treatments were applied to each truffière. These were:

- 50 T/Ha Commercial grade lime,
- 75 T/Ha Commercial grade lime, and
- 100 T/Ha Commercial grade lime.

Soil pH readings were taken an analysed prior to the application of the limestone and at 1, 3, 6 and 12 months and annually thereafter. Measurements were taken at three depths in the soil profile 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

Treatments

The 3 treatments were replicated 3 times within each truffière. Each replicate consisted of 10 trees in three subsequent rows. A total of 270 trees were treated.

Prior to the lime being applied the sites were sprayed with the herbicide Roundup.
The lime was spread at the treatment rates on the truffières then was incorporated through the soil profile to a depth of 20cm. Initially a disc plough was used followed by 3 passes with a tyned implement.

The Truffières

To gain the maximum information from the trials, the trial was replicated on three soil types with a different level of clay and organic matter to measure the responsiveness to lime.

Site 1. Situated in Southern Tasmania the area has been previously used for livestock grazing. The truffière was established in the spring of 2001. The truffière covers an area of 1.0 hectares of alluvial soil with good drainage characteristics. (Soil analysis Table 1)

Site 2. Situated in north west Tasmania the area has been previously used for a range of intensive crops including peas, potatoes and cereals. The truffière was established in the spring of 2001. The truffière covers an area of 2.0 hectares of deep red basalt with excellent drainage characteristics. (Soil analysis Table 1)

Site 3. Situated in the southern Highlands, NSW the area has been previously used for livestock grazing. The truffière covers an area of 2.0 hectares of a podsolic soil. (Soil analysis Table 1)

Table 1 Chemical analysis of the soil.

Soil Property	Unit	Alluvium	Kraznozem	Podzolic
pH(1:5 water)		5.8	6.3	5.4
Exchangeable calcium	ppm	2173	2222	1335
Total calcium	%	.7	.37	.17
Free $CaCO_3$	%	.01	.3	.01
Organic matter	%	6.34	6.9	4.1
Organic carbon	%	3.68	4.04	2.36
Potassium	ppm	309	315	98
Phosphorus	ppm	53	12.8	15.8
Total phosphorus	ppm	700	1000	400
Magnesium	ppm	242	348	79
Total nitrogen	ppm	2700	2600	1590
Carbon/Nitrogen	ppm	13.6	14.1	14.8

Soil analysis conducted by Ag Lab Services Moolap, Victoria.

Measurements

Soil samples were collected from each treatment area prior to the lime application to determine the pH (1:5 water). After the lime application, soil samples were taken and analysed at 1, 3, 6 and 12 months and annually thereafter. Measurements were taken at 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

The soil was sampled randomly in the replicate areas at the designated depths. Twenty samples were randomly collected from each replicate and mixed to represent one sample for analysis.

The data was analysed using analysis of variance to determine the effect of the lime treatment on pH.

Timetable

The timetable of events is shown in Table 2

Table 2 Timetable of Events

Date	Activity
October 2000	• Collection and analysis of soil prior to the lime application.
November 2000	• Application and incorporation of lime
December 2000	• Commencement of soil sampling for measuring soil pH change. • Samples taken at 1,3, 6, 12 18 and 24 month intervals
November 2001	• Trees planted
November 2002	• Completion of soil sampling.

Results and Discussion

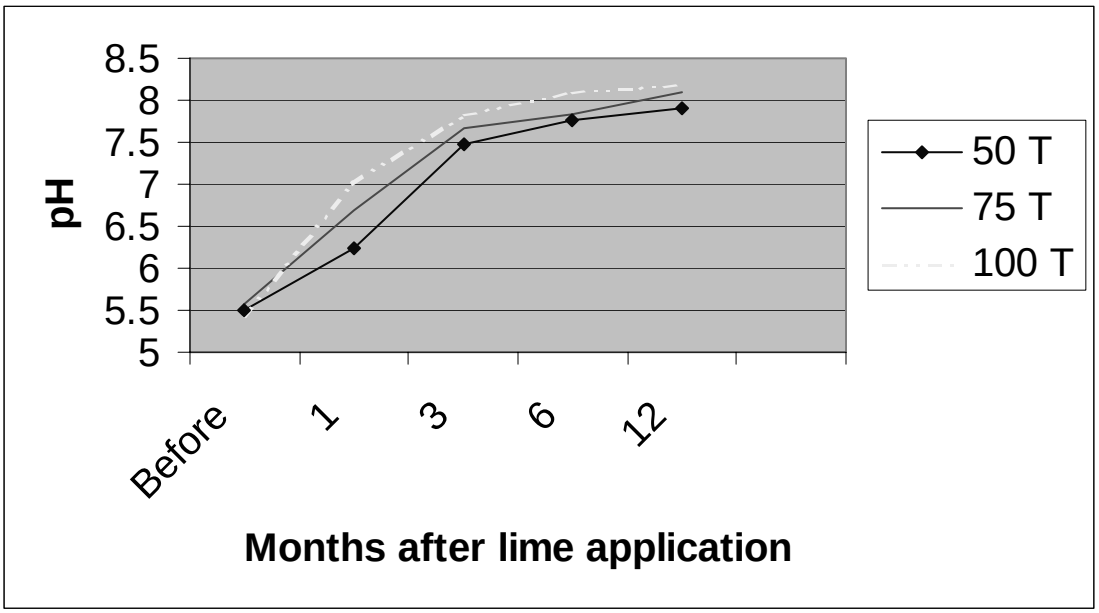
The figures below illustrate the effect of lime on the soil pH. For all the lime treatments, there was a significant increase ($P<0.05$) in the pH from the level prior to lime application. On the podzolic and alluvial soils, all three rates of lime brought the soil pH to about 8, which is in the vicinity of the maximum level obtainable by applying calcium carbonate. Whilst the application of 100T/Ha was able to make this process happen more quickly, by 24 months after the lime application (12 months for the podzolic) there was no significant differences ($P>0.05$) between the treatments.

The kraznozem on the other hand was still showing a significant difference ($P<0.05$) between lime treatments at 24 months. The 100 T/Ha treatment produced a higher pH than the 75 T/Ha treatment or the 50 T/Ha treatment.

Soil depth had no impact on the effect of the applied lime. This was to be expected as the lime was thoroughly incorporated to depth.

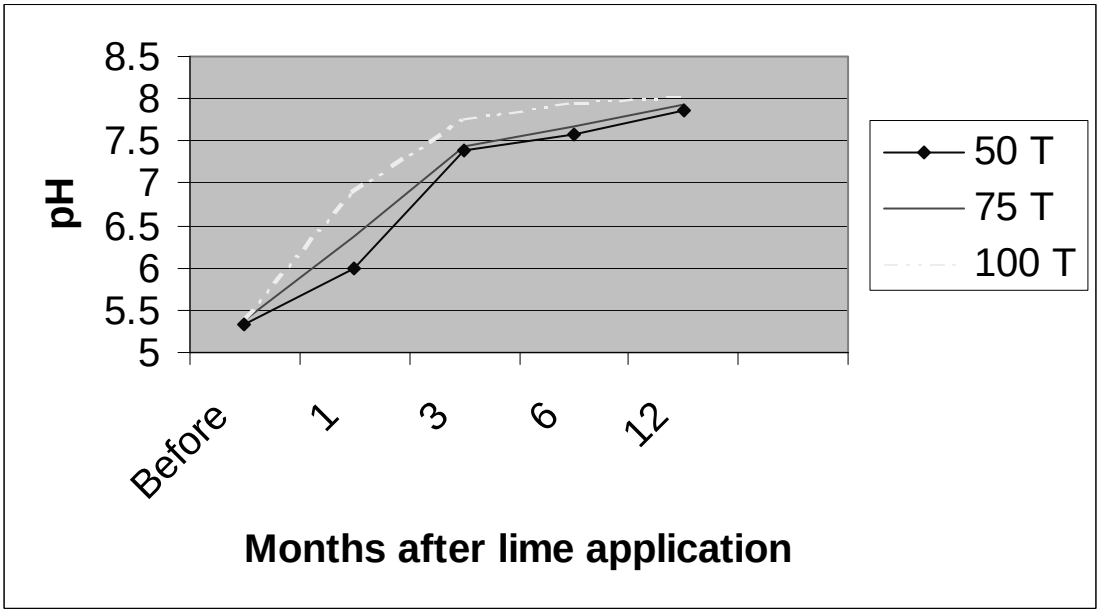
Podzolic

0 to 5 cm



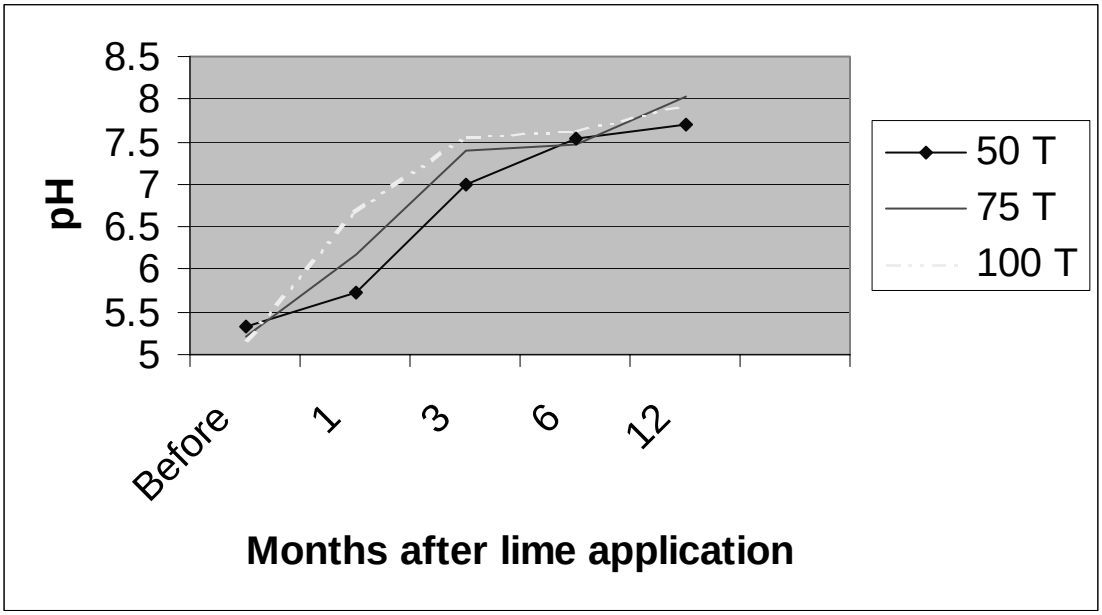
LSD(5%)=0.20

5 to 10 cm



LSD(5%)=0.15

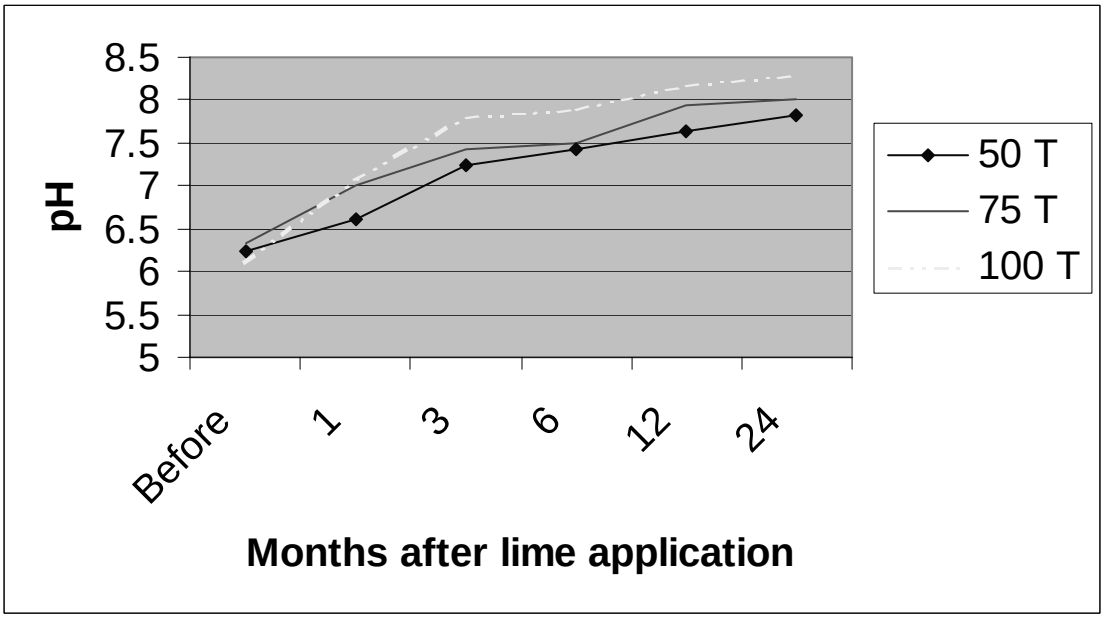
10 to 20 cm



LSD(5%)=0.18

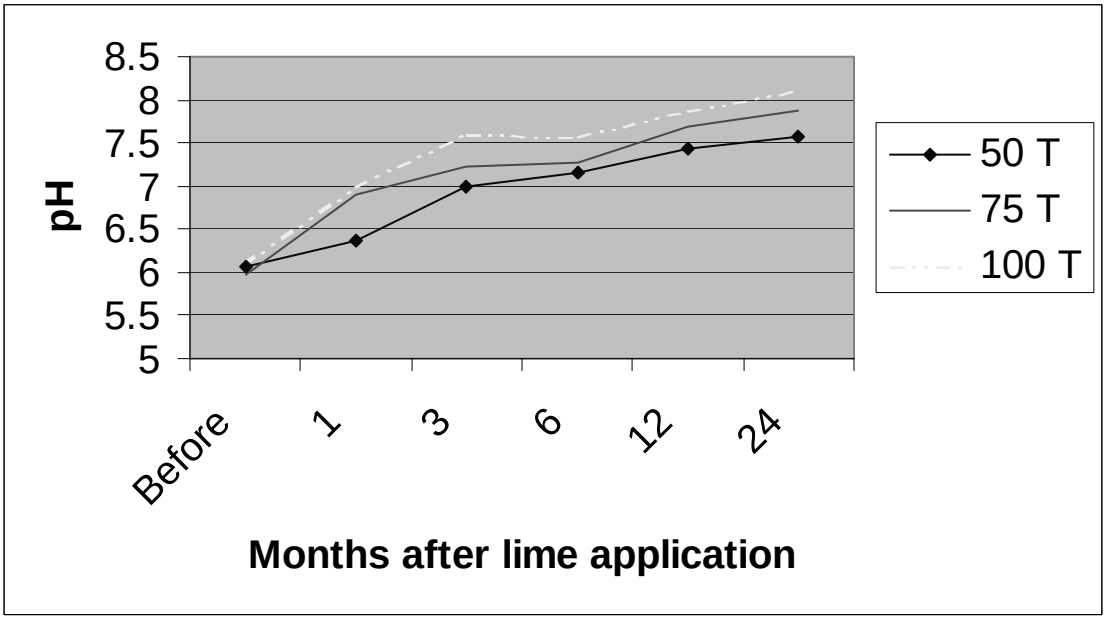
Kraznozem

0 to 5 cm



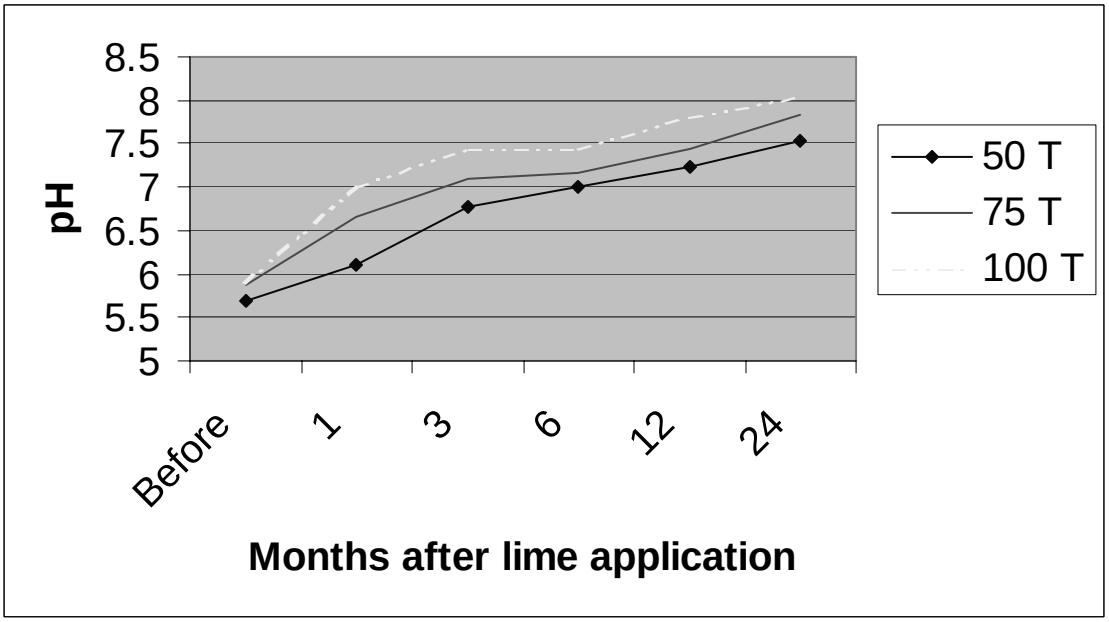
LSD(5%)=0.2

5 to 10 cm



LSD(5%)=0.21

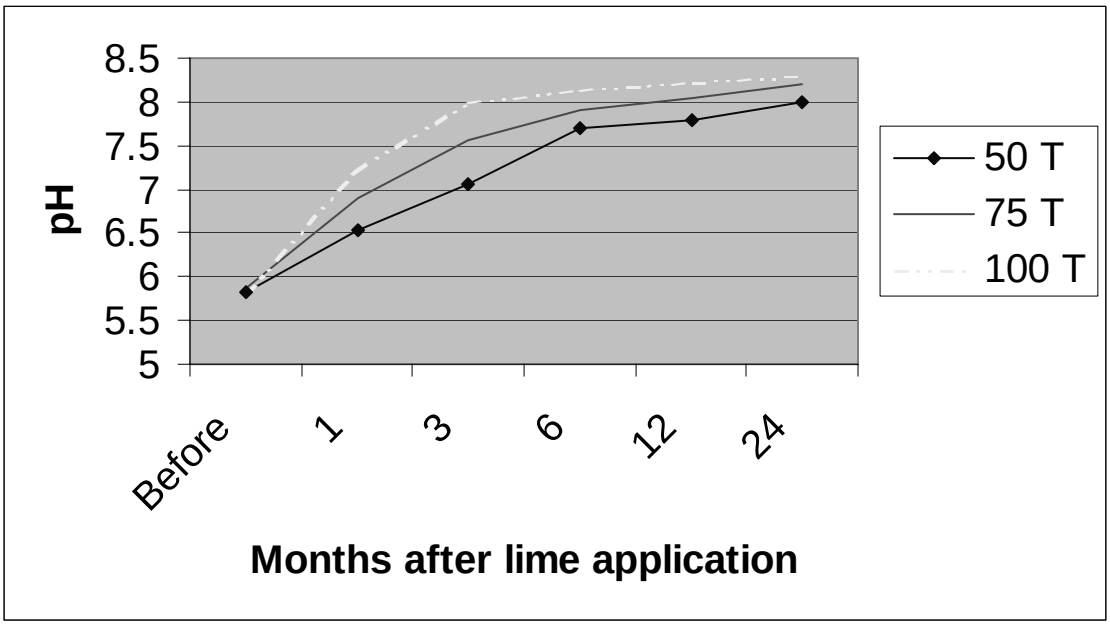
10 to 20 cm



LSD(5%)=0.21

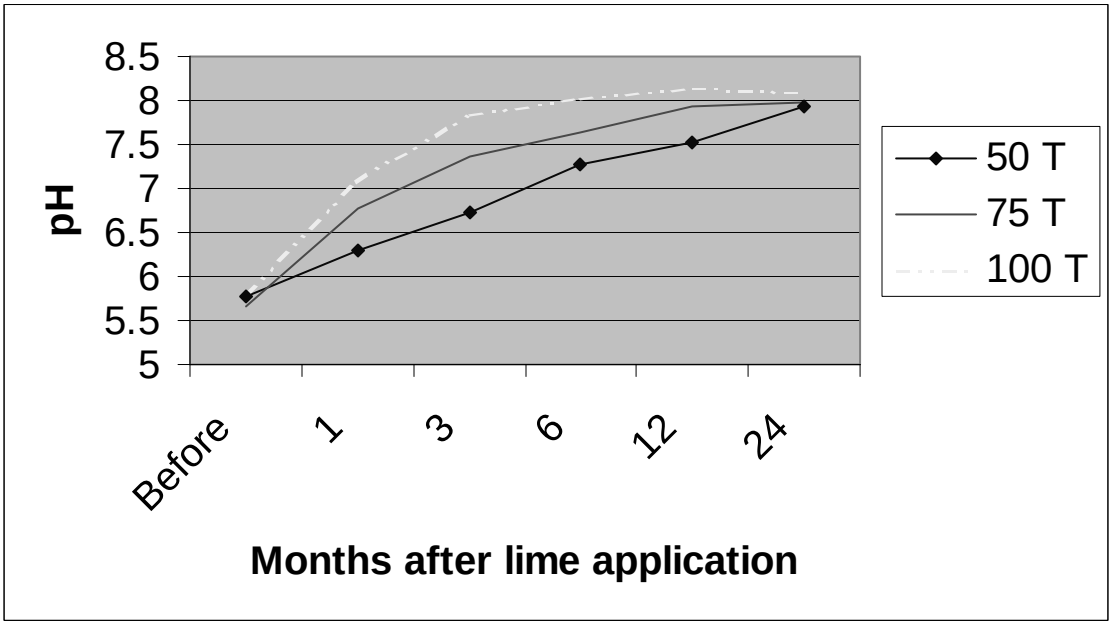
Alluvium

0 to 5 cm



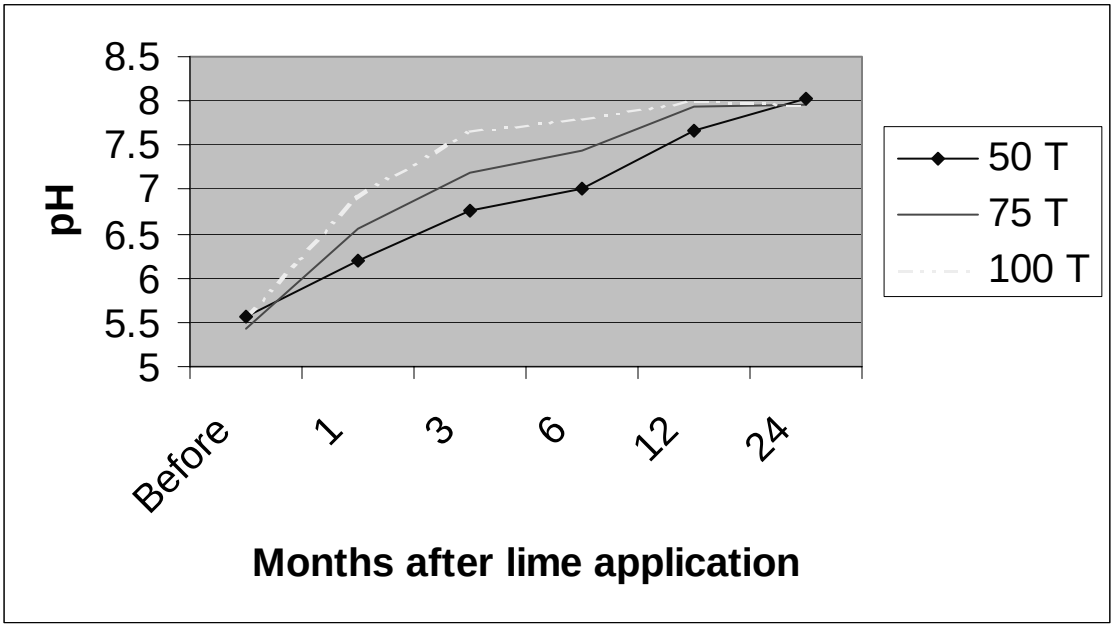
LSD(5%)=0.17

5 to 10 cm



LSD(5%)=0.18

10 to 20 cm



LSD(5%)=0.18

Implications

The truffle industry in Tasmanian is unique in that it is based on soils that are not naturally calcareous, but have been heavily limed in order to increase the soil pH. A soil pH of 7.5 (1:5 water) and above is considered acceptable, but French literature suggests production is at it's maximum when the pH is in the 7.9 – 8.1(1:5 water).

The results of the field experiment have indicated that it is possible to raise the soil pH to it's optimum level for French truffle production by applying very high rates of limestone on a range of different soil types. The trufferies can now be established in soil types with pH levels between 7.9 – 8.1 (1:5 water) with free lime hence making them more typical of the calcareous soils in France.

The significantly higher lime rates used to increase the soil pH will also have additional benefits to the truffières such as:

- large quantities of free lime in soil:
- greater buffer against the soil pH decreasing, and
- increased soil aeration and friability.

Applying very high rates of lime prior to planting will not add significantly to the cost of establishing the truffière. If the current average price for truffles produced by PTT is maintained in excess of $2,000 per kilogram the potential return on the expense of the higher lime rate will be very economical.

Recommendations

PTT are now recommending significantly larger quantities of finer grade lime prior for the establishment of new truffières.

It will be a number of years before the new truffières with the higher lime rates start producing French truffles, however PTT are confident that the additional expense of the high lime rates will be justified.

There will be a continuation of regular testing soil pH at different soil depths to gain a further the understanding of the optimum lime rates for different soil types. The use of the GIS system will allow for regular recording of the different treatments and the assessment of any response in truffle yield

PTT will continue to work with the local agronomists and major limestone suppliers in Tasmania, Victoria and NSW to ensure the best product and advice is utilised.

The Effect of Applied Lime on Existing Truffières

Methodology

Overview

A field experiment was conducted on three established truffières in Tasmania. Three lime treatments were applied to the three existing truffières representing three soil types. These soil types included a loam overlaying clay, a kraznozem and a clay loam overlying mudstone.

The three lime treatments were:

- 7 T/Ha Fine grade lime,
- 14 T/Ha Fine grade lime,
- 21 T/Ha Fine grade lime,

The lime applied was of a finer quality previously available in Tasmania. Perigord Truffles of Tasmania had worked with a Northern Tasmanian lime supplier to produce a product with a high percentage of particle size less than 300 micron.

At the end of 12 months the treatment areas were cultivated to a depth of 100mm. The decision to cultivate the areas was base on a poor pH response to the lime in the treated areas. It was considered that cultivation would improve the response.

Soil pH readings were taken and analysed prior to the application of the limestone and at 1, 3, 6 and 12 months. Following the cultivation of the treatment areas further pH readings were taken at 18 and 24 months. Measurements were taken at the following depths in the soil profile; 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

Treatments

The 3 treatments were replicated 3 times within each truffière. Each replicate consisted of 10 trees in three subsequent rows. A total of 270 trees were treated.

A fine grade lime was used in an effort to improve the rate of pH increase. A modified spreader was used to ensure an even distribution of the lime spread the lime.

In October 2001 the treated areas between the rows of trees were cultivated using a narrow tyned implement to a depth of 100mm. Existing farm implements were modified to allow the tynes to be placed 100 – 150mm apart). The cultivation was undertaken between the end of harvest and before the soil temperature at 100mm rising to 12 degrees C.

Measurements

The pH (1:5 water) of each treatment was measured prior to the lime application, then post application at 1, 3, 6, 12, 18 and 24 months. Measurements were taken at 0 to 5 cm, 5 to 10 cm and 10 to 20 cm.

The soil was sampled randomly in the treatment areas at the designated depths. Twenty samples were collected from each replicate and mixed to represent one sample for analysis.

The data was analysed to determine the effect of the applied lime on soil pH.

The soil analysis was conducted by Ag Lab Services Moolap, Victoria.

Truffières

The three truffières chosen for the trial were established in 1995 and 1996. The truffières chosen represent a range of the soil types where trufferies have been established.

Site 1. Located near Carrick in Northern Tasmania, the truffière was established in November 1996. The truffière covers an area of 1.0 hectare planted in of loam over ironstone with good drainage characteristics. (Soil analysis table?). The truffière is a mixture of hazelnut trees (*Corylus avellana*), deciduous oaks (*Quercus robur*) and evergreen oaks (*Quercus ilex*).(Soil analysis Table 3).

Lime was applied at the rate of 27 tonnes to the hectare. The lime was then incorporated through the soil profile to a depth of 20cm prior to the planting of the trees. An additional 7 tonnes per

hectare was applied in the spring 1999 to the whole 3 hectare trufferie. In addition a further 7 tonnes per hectare was spread to 4 rows of trees in both the 1996 and 1997 plantings.

An underground drainage system was installed in 2000.

French truffles were first produced in the truffière in the winter of 2000. The production on trees of three and half years is equal to the world's best practice. The truffière has continued to produce with increased yields in 2001 and 2002 respectively. (Soil analysis Table 3)

Site 2. Located near Westbury in Northern Tasmania, the truffière was established in the spring of 1995. The truffière covers an area of 1.0 hectare planted in a kraznozem soil of good granular texture.

The inoculated trees in the truffière are hazelnut (*Corylus avellana*). Prior to the establishment of the truffière, lime was applied at the rate of 30 tonnes to the hectare and incorporated through the soil profile to a depth of 20cm.

French truffles were first produced in the trufferie in the winter of 2001. A small amount of truffle was harvested in 2002. (Soil analysis Table 3)

Site 3. Located in the Derwent Valley in Southern Tasmania, the truffière was established in the autumn 1995. The truffière covers an area of 1.0 hectares planted in clay loam overlaying mudstone. The inoculated trees in the trufferie are hazelnut (*Corylus avellana*). (Soil analysis Table 3)

Prior to the establishment of the truffière, lime was applied at the rate of 27 tonnes to the hectare and incorporated through the soil profile to a depth of 20cm. French truffles were first produced in the truffière in the winter of 2002.

Table 3 Chemical analysis of the soil.

Soil Property	**Unit**	**Loam/Ironstone**	**Kraznozem**	**Clay loam /mudstone**
pH(1:5 water)		7.51	7.5	7.5
Exchangeable calcium	ppm	1720	6264	2938
Total calcium	%	.52	.24	.088
Free $CaCO_3$	%	2.88	1.26	.01
Organic matter	%	5.2	9.1	5.2
Organic carbon	%	2.98	4.87	3.35
Potassium	ppm	76	488	258
Phosphorus	ppm	8.5	12.9	22.9
Total phosphorus	ppm	300	940	270
Magnesium	ppm	83	538	303
Total nitrogen	ppm	1900	3600	2390
Carbon/Nitrogen	ppm	15.7	13.5	14.0

Soil analysis conducted by Ag Lab Services Moolap, Victoria.

Timetable

Table 4 Timetable of Events

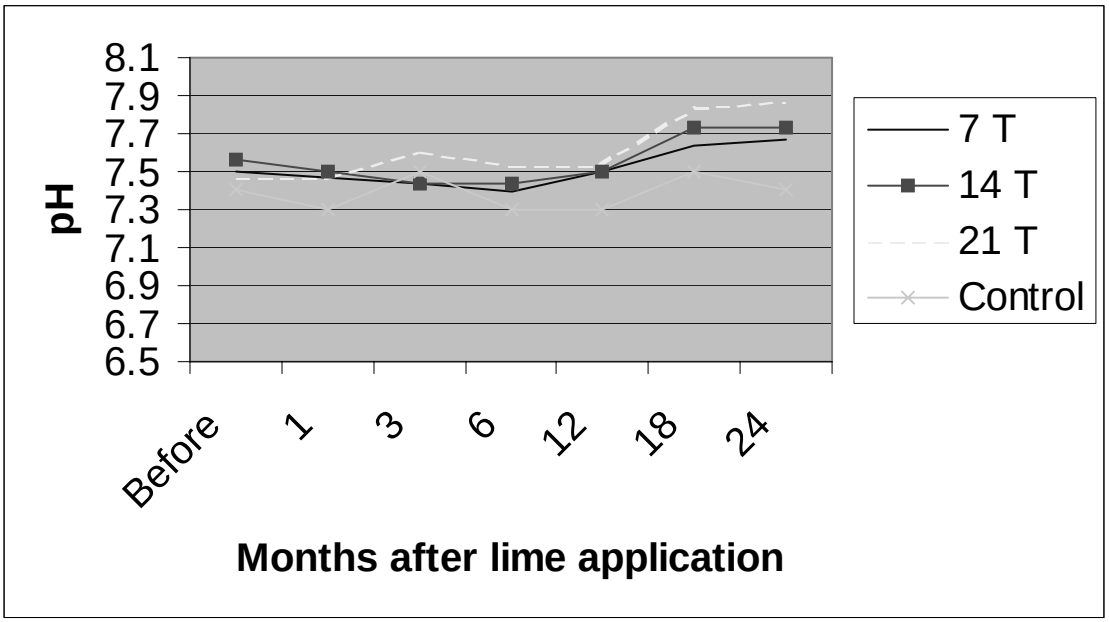
Date	Activity
September 2000	• Collection and analysis of soil prior to the lime application.
October 2000	• Application of lime treatments
November 2000	• Commencement of soil sampling for measuring soil pH change. • Samples taken at 1, 3, 6, 12 18 and 24 month intervals
October 2001	• Cultivation of treatment areas.
May 2002	• Soil samples taken at 6 and 12 month intervals after cultivation.

Results and Discussion

The figures below show the effect of the lime treatments on each of the soil types. There was no significant effect for any of the lime treatments prior to cultivation. Post cultivation, there were significant ($P<0.05$) responses to lime to a depth of 10cm and no significant response below 10cm. Where there was a significant response, the higher rates of lime gave a greater pH response than the lower rate of lime. For the three soil types, at a depth of 0 to 5cm, 21 T/Ha of lime raised the pH to approximately 7.9 which is a level that is thought to be suitable for truffle production.

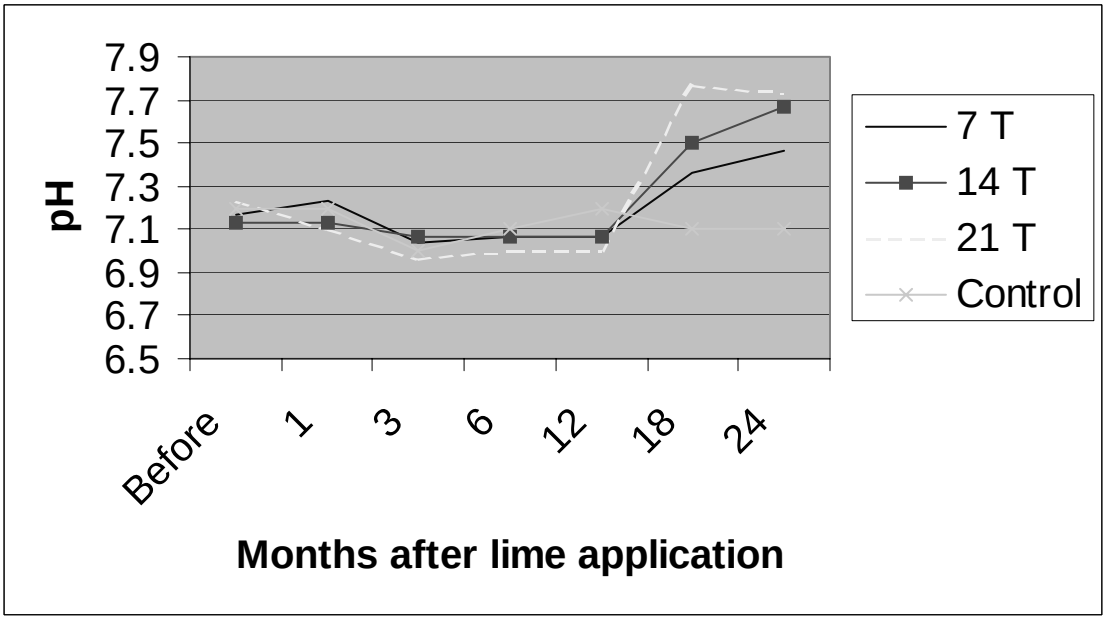
Ironstone Loam

0 to 5 cm



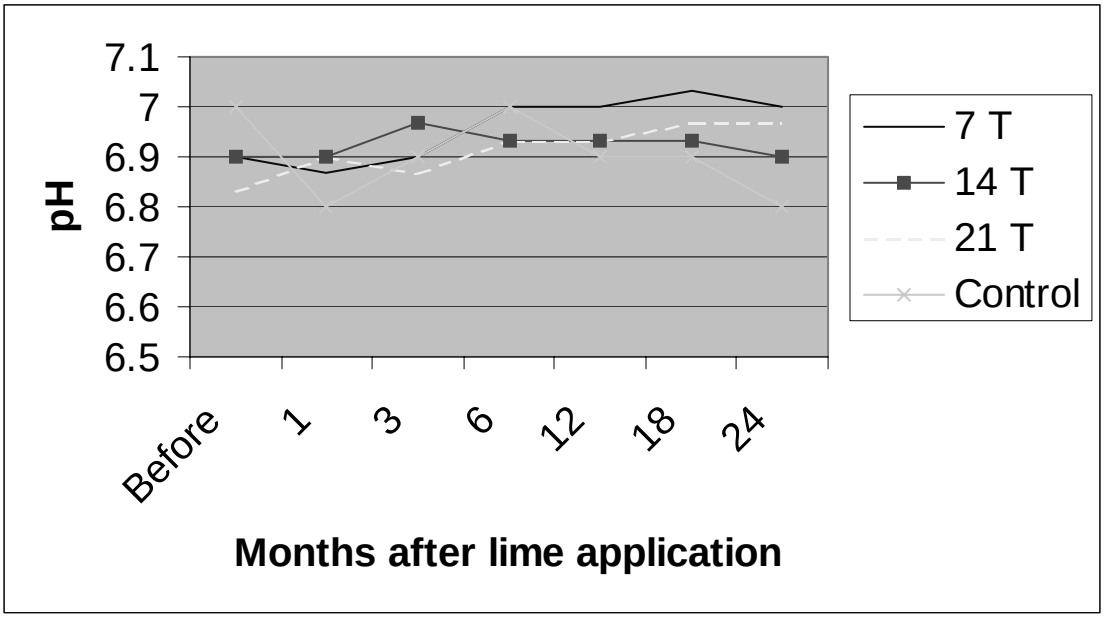
LSD(5%)=0.16

5 to 10 cm



LSD(5%)=0.18

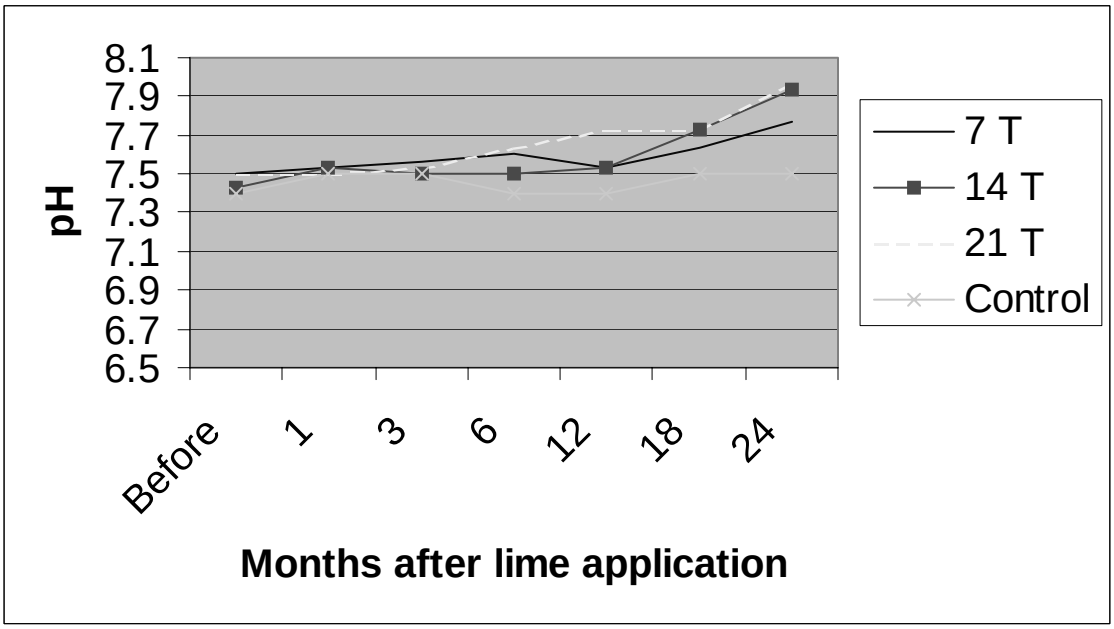
10 to 20 cm



LSD(5%)=0.17

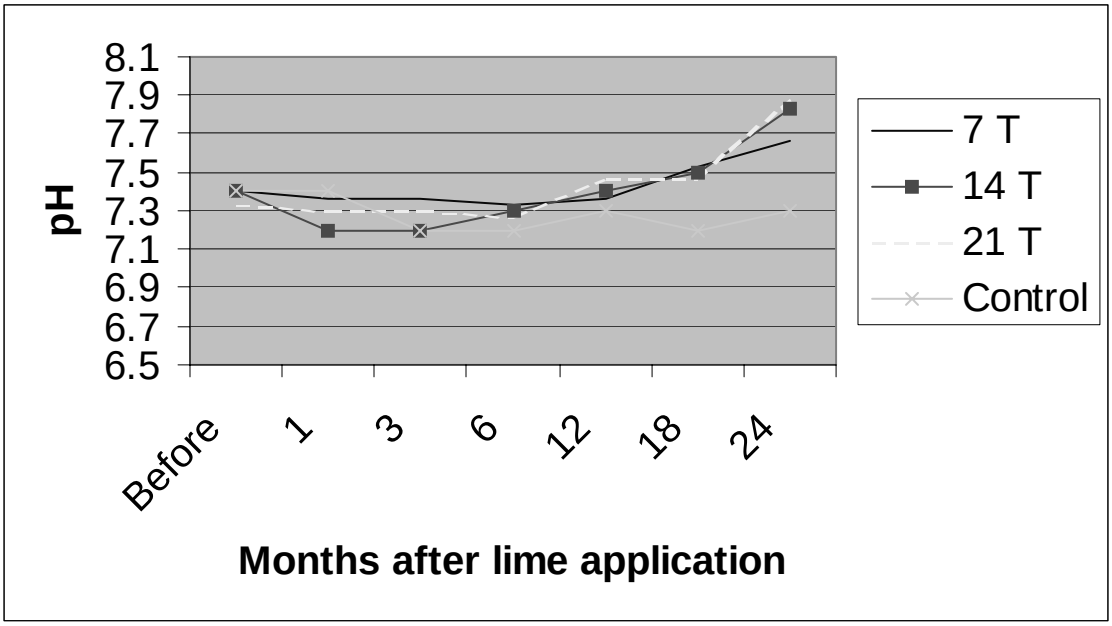
Kraznozem

0 to 5 cm



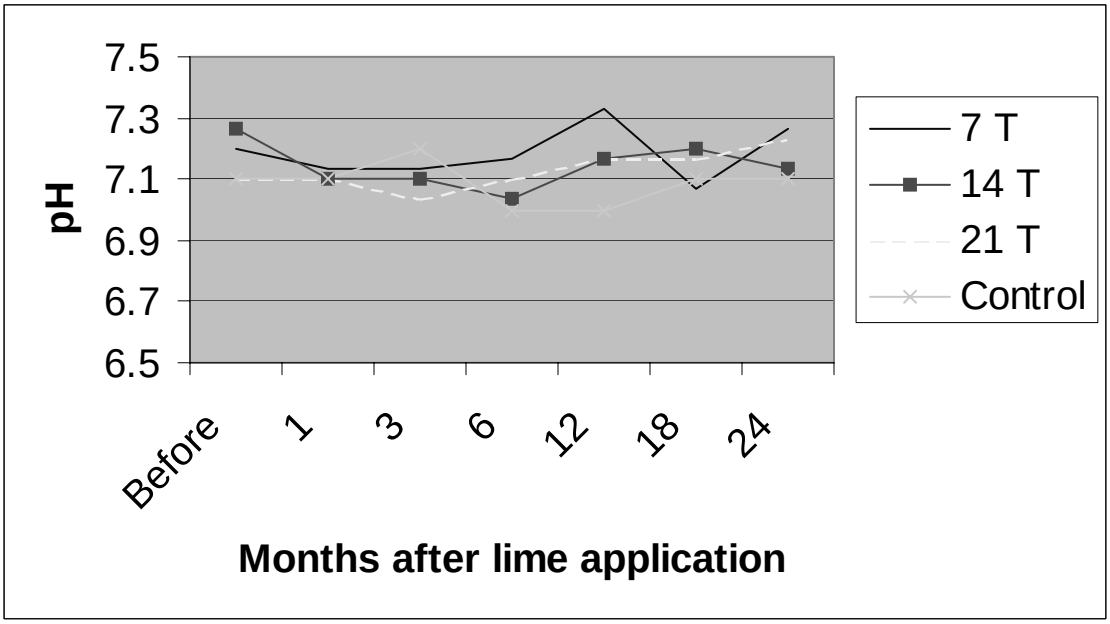
LSD(5%)=0.16

5 to 10 cm



LSD(5%)=0.26

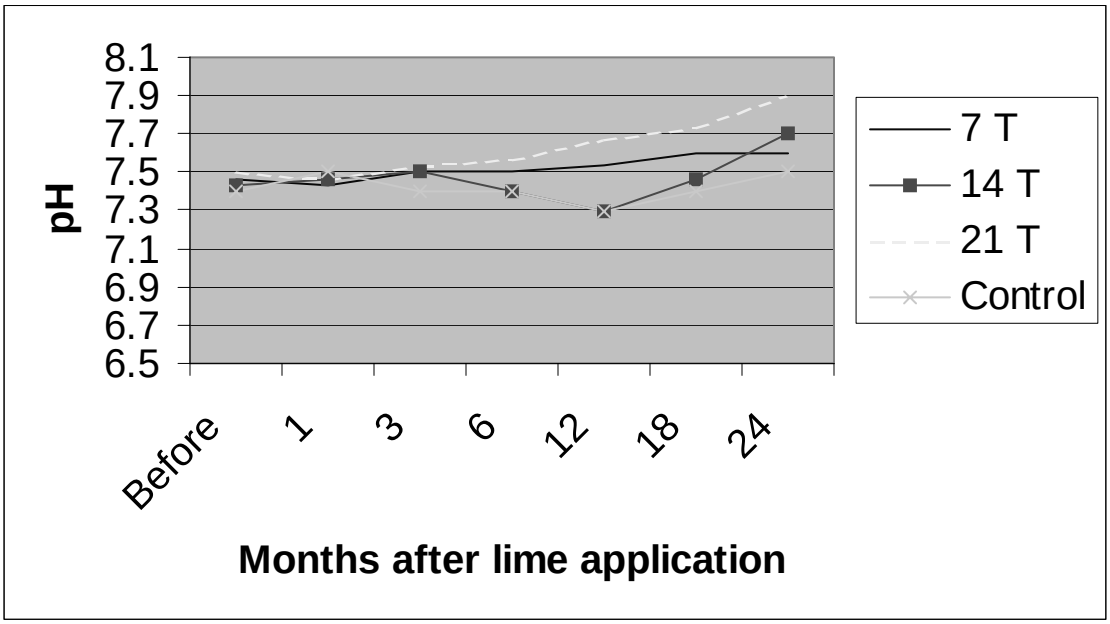
10 to 20 cm



LSD(5%)=0.20

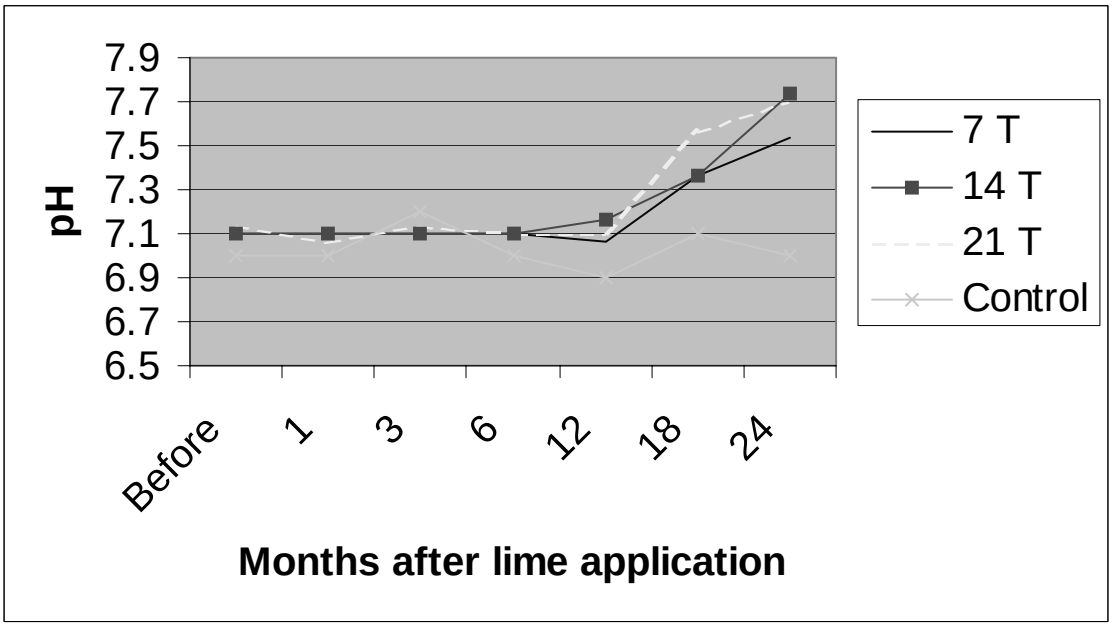
Clay Loam on Mudstone

0 to 5 cm



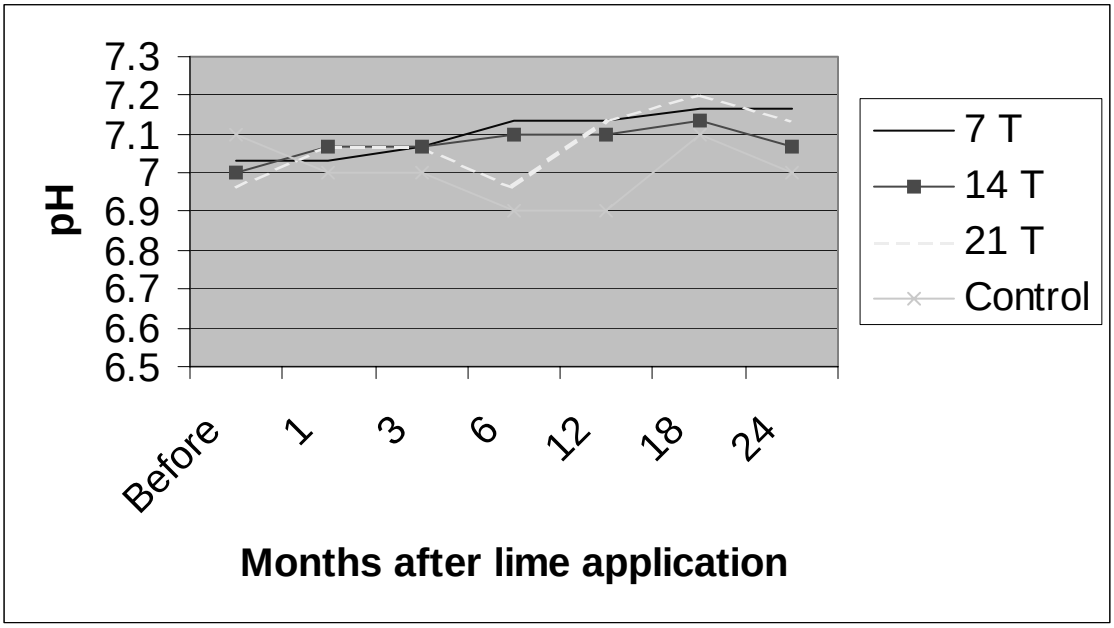
LSD(5%)=0.16

5 to 10 cm



LSD(5%)=0.19

10 to 20 cm



LSD(5%)=0.23

Implications

The findings of the experiment will enable Perigord Truffles of Tasmania to develop a strategy for raising the soil pH in established trufferies. Less than optimal soil pH in existing trufferies has been an ongoing issue and a potential reason for disappointing truffle yield in some truffières.

Truffières have been established on a range of soil types with different structures and textures. Now with the knowledge that the soil pH can be raised successfully through the additional of limestone and a shallow cultivation PTT are confident the soil pH of existing truffières can be raised to the optimum level.

The use of a cultivation implement along the tree line to incorporate the lime will have additional benefits in reducing soil compaction, improving soil aeration, soil friability and assisting in early spring weed control.

A further potential benefit to the farmers of the cultivation is that anecdotal evidence from France suggests that a shallow cultivation in early spring can reduce the number of shallow truffles in the following winter subject to damage from frost.

The current average price for truffles produced by PTT is $2,2000 per kilogram. Small increases in yield per hectare dramatically increase the profitability of the enterprise. In future years if there is a correlation between truffle yield resulting from additional lime and cultivation the return on the extra costs of lime will be significant.

Recommendations

PTT have now recommended that additional lime be applied and incorporated along the tree line to existing trufferies where the soil pH is below the optimal level.

PTT will continue to work with the joint venture farmers on fine tuning the cultivation procedure for incorporating the lime. Particular emphasis will be placed on depth control to avoid any unnecessary root damage and also on the timing of the cultivation to ensure that all soil disturbance is completed before the soil temperature rises to 12 degrees C.

There will be a continuation of regular testing soil pH at different soil depths. The use of the GIS system will allow for regular recording of the different treatments and the assessment of any response in truffle yield

PTT will continue to work with the major limestone supplier to develop lime products and techniques to spread the fine grades of lime.

PTT has always seen the rapid dissemination of their research and development work as one of the underlying strengths of the company structure. The nature of the joint venture agreement results in both the company and farmers sharing equally in any of the benefits gained from the research and development program.

A director of the company regularly visits each site in order to discuss with the owner management issues such as irrigation management, weed control and plant nutrition as well as informing the grower on the overall development of the industry. These visits provide the ideal opportunity to convey any new management practices that have arisen as a result of research.

Geographical Information System

Introduction

Relating truffle production to other physical parameters within a truffière has revealed some valuable findings. Shaw *et. al*. (1996) found a significant correlation between truffle production and stem diameter of *Quercus ilex*. Callot and Jaillard (1996) examined the relationships between soil structure, mycorrhization and truffle production. While neither of these researchers used a geographical information system, their work demonstrates the value of gathering such information.

The structure of the industry enables the acquisition of valuable information on production, applied treatments and other physical factors from at least 40 truffières established in Tasmania, Victoria and NSW.

The objective of the research was to develop a geographical information system to accurately map and record information on truffle production, parameters related to truffle production, and treatments of truffières in Tasmania, Victoria and NSW.

This information then can be analysed annually to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

Methodology

In conjunction with a Tasmanian Company Data Vision a truffle mapping extension was developed using a geographical information system (GIS) Arcview 3.2.

The truffle mapping extension allows for the plotting of a grid of trees and truffles found in relation to a tree in a grid and the recording of a range of parameters.

The truffières were mapped during 2001 and 2002 using a Global Positioning System.

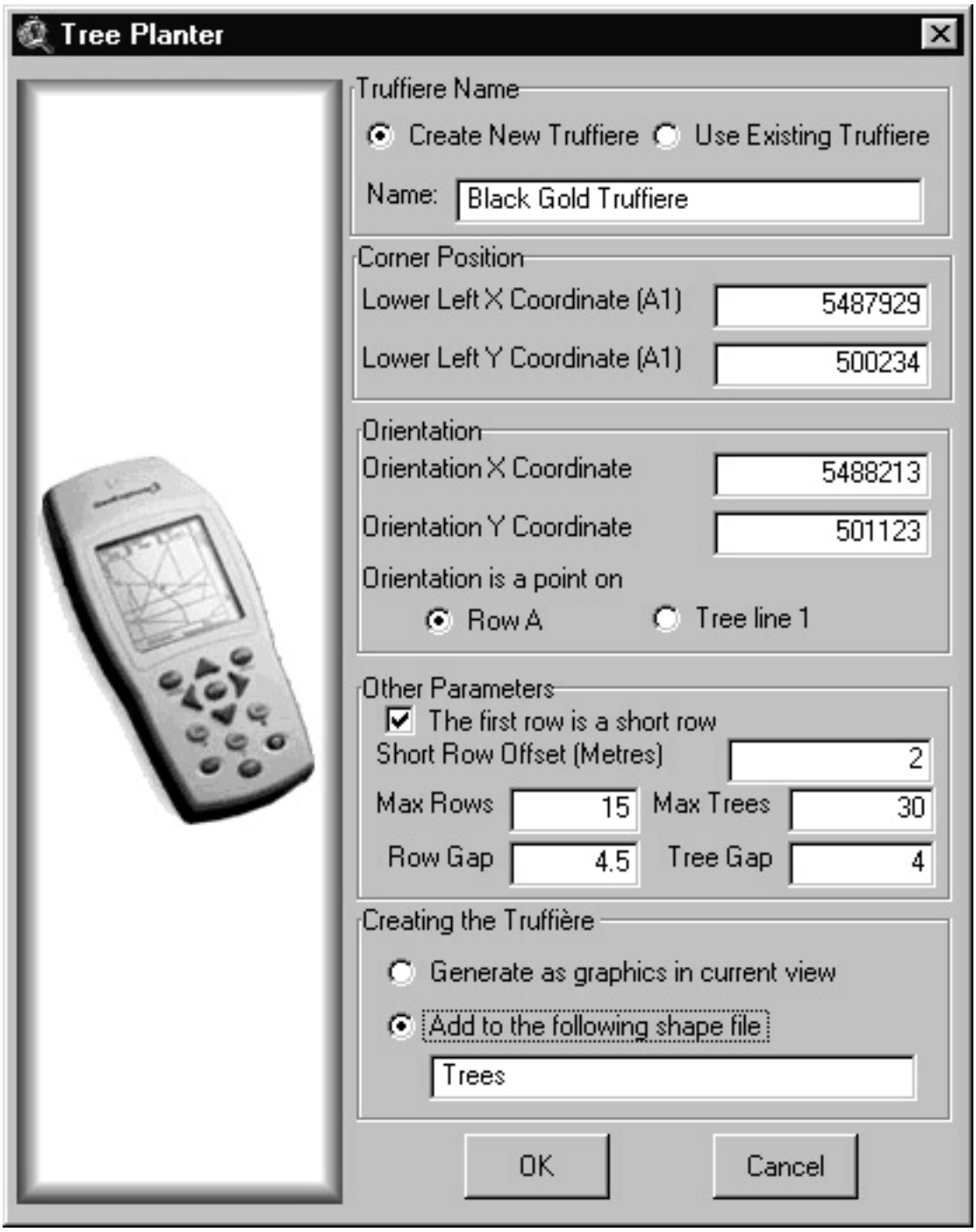
A range of parameters were recorded and mapped, these included:

For truffières

- Individual trees including date of planting, species;
- Row and tree spacing;
- Infrastructure in truffière such as drainage and irrigation mains;
- Lime treatments, and
- Soil types.

Truffle harvest details

- Tree type;
- Date of harvest;
- Truffle weight and quality;
- Distance from tree;
- Depth in the soil, and
- Angle from tree.



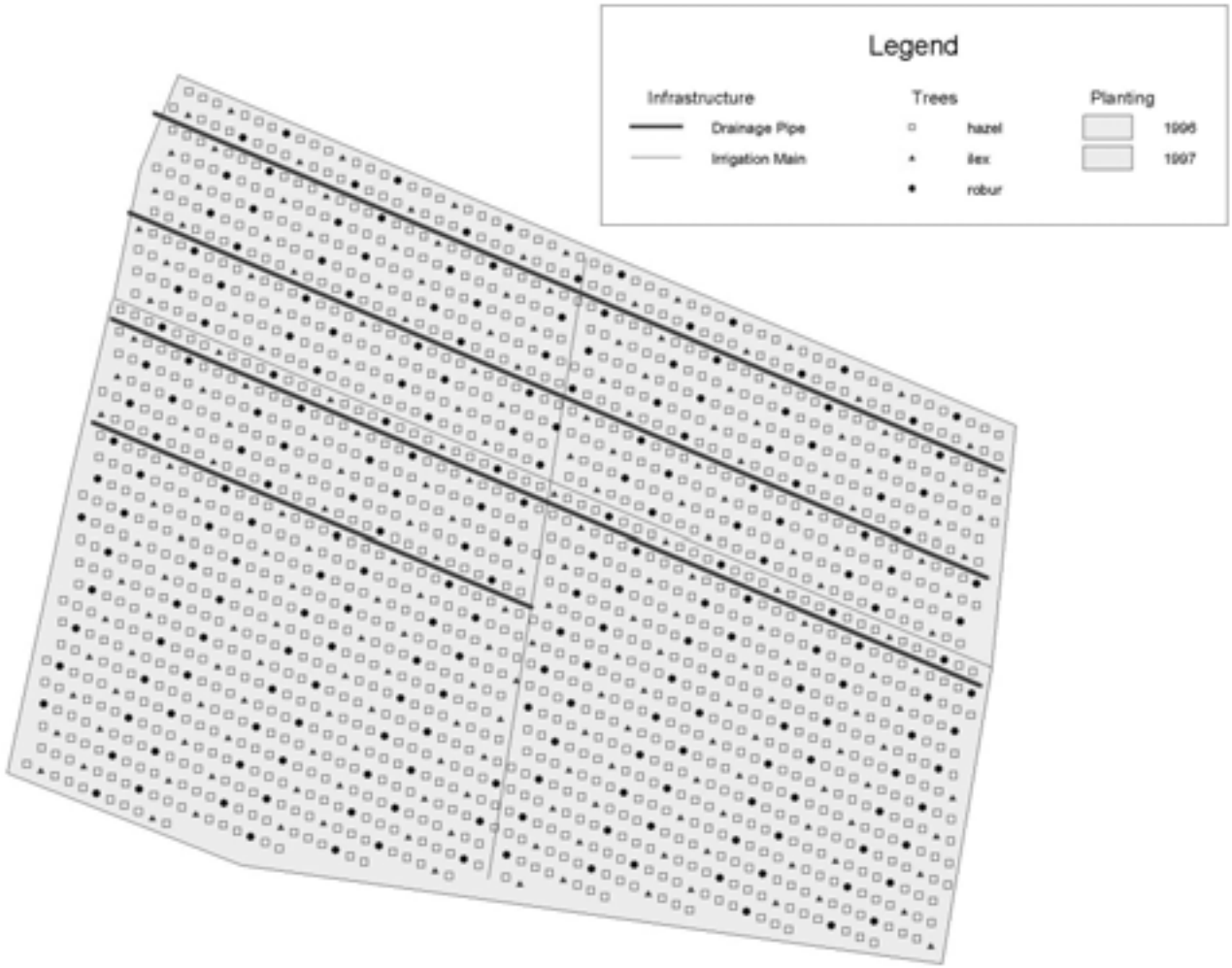
Results and Discussion

The development of the program has allowed for the information to be displayed spatially for easy accessibility. The information can now be analysed readily to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

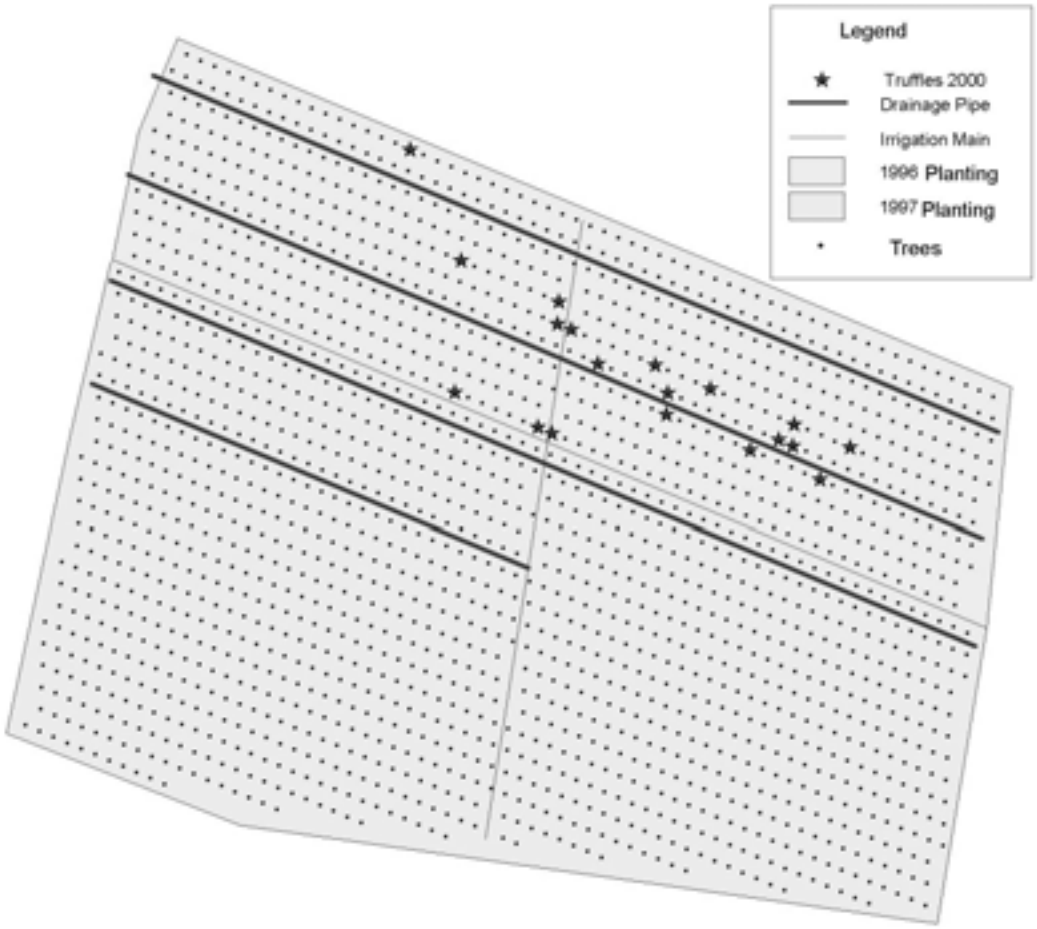
A number of observations from truffières using the truffle mapping extension as a management tool are:

- A high percentage of trees appear to produce in alternative trees;
- higher percentage of truffles harvested from the hazels as opposed to the two oak varieties;
- better truffle production from areas where soil has naturally better drainage conditions or soil is effected by the artificial drainage system;
- no correlation between truffle production in relation to angle from tree;
- correlation between the age of the tree and the distance from the tree truffles are harvested. Initially truffles are harvested within 10cm of the trees as the trees age the distance the truffles are harvested from increases;
- a high percentage of early season truffles harvested from a soil depth less than 3cm;
- more observable frost damage in early season truffles;
- late season truffles are harvested from deeper in the soil;
- no correlation between cultivation and depth of truffles, and
- the initial response to applied lime not observable in other areas of the truffière.

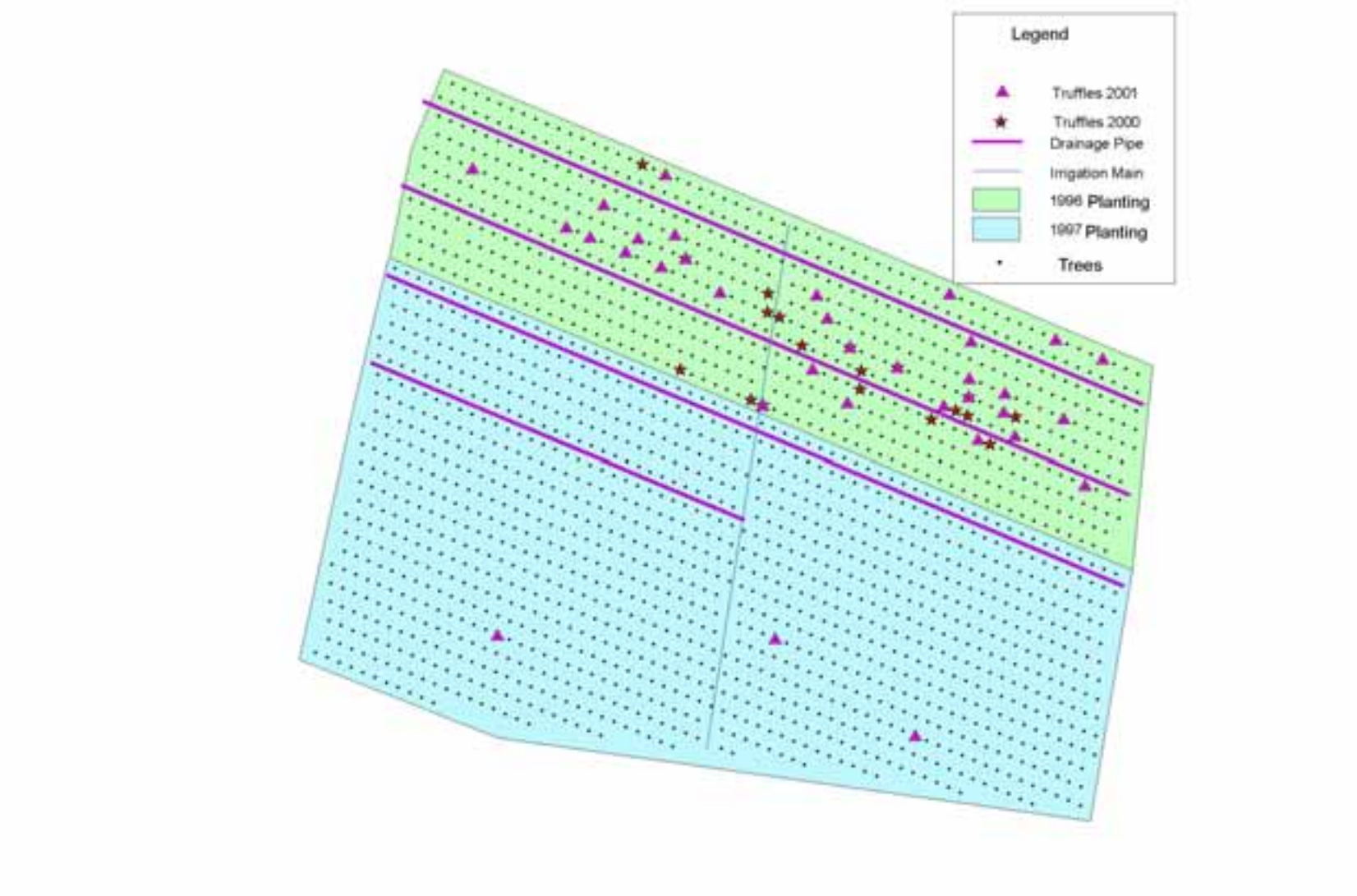
Tree Layout


Legend
Infrastructure
Drainage Pipe
Irrigation Main
Trees
hazel
ilex
robur
Planting
1996
1997

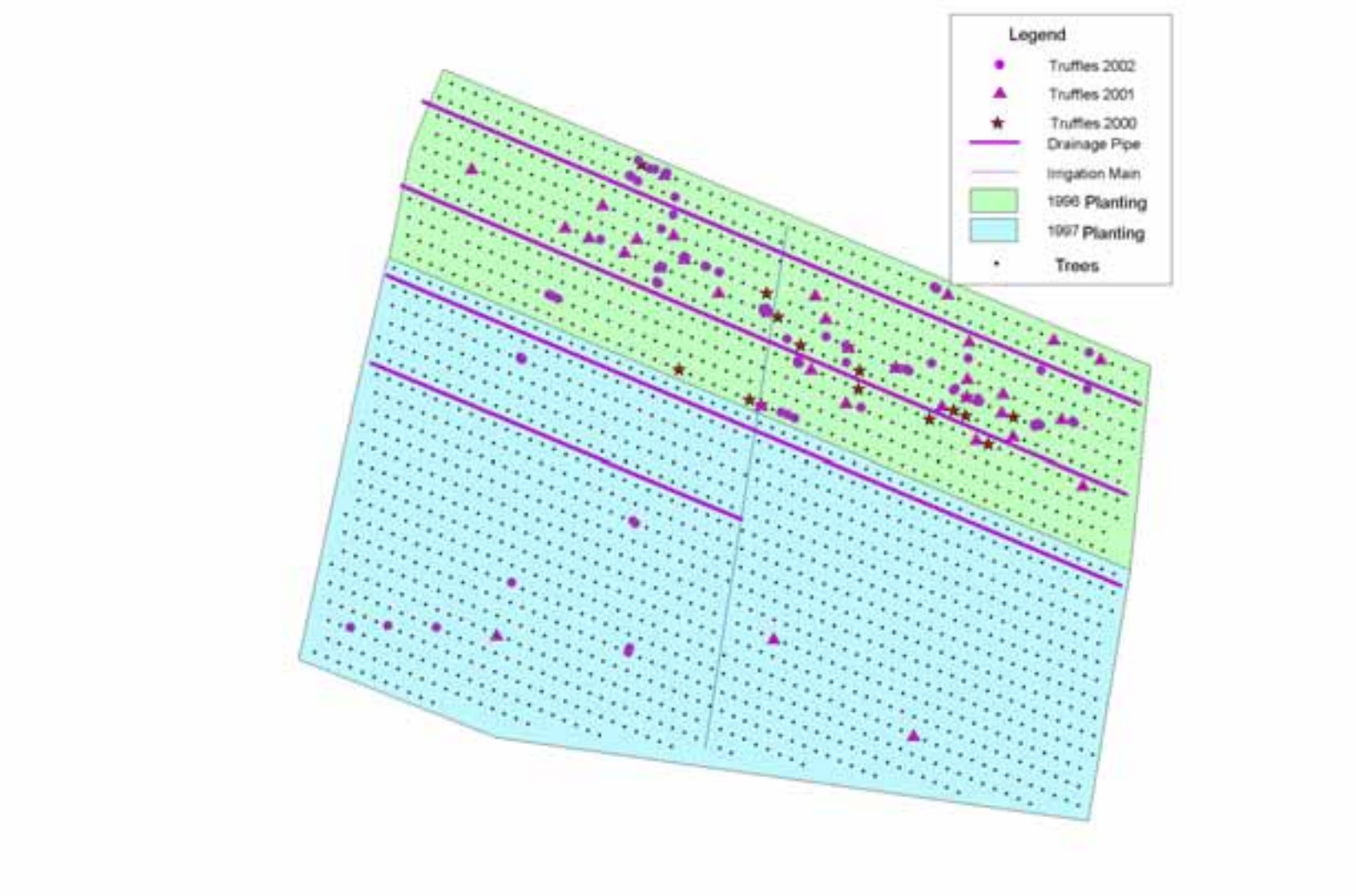
Harvest 2000



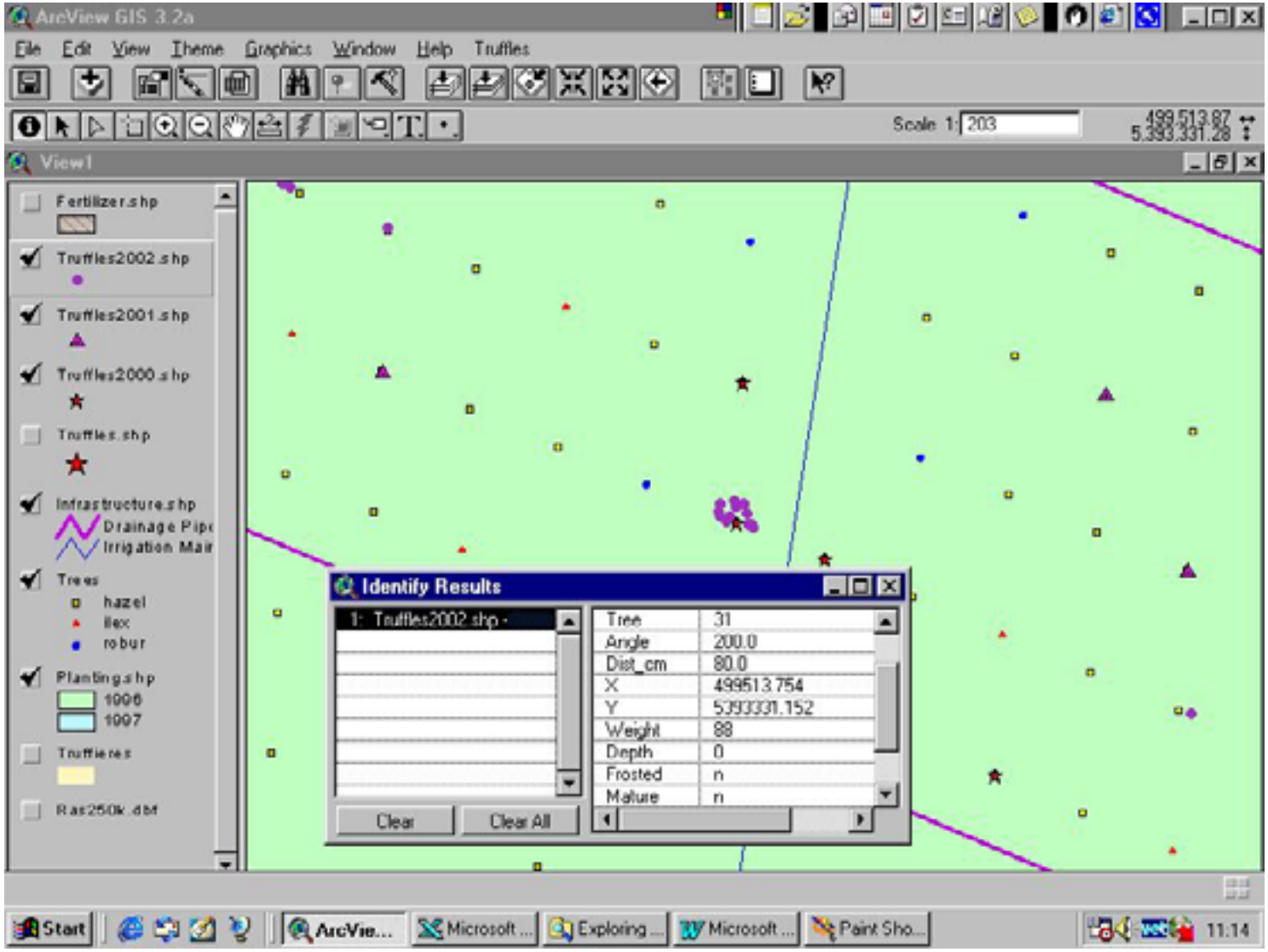
Harvest 2001



Harvest 2002



Information on Individual Truffles



Implications

The ability to accurately map truffle production and parameters related to truffle production has greatly enhanced the chances of detecting the factors that effect truffle yield.

The truffle mapping extension has the capacity to query one parameter against another so it is now possible for example to determine how many truffles were found within 1.5m of all the *Quercus robur* plants in a given truffière and thereby determine the productivity of that species for the site.

The ability to be able to access this data about the truffières and the producing trees will be of significant benefit to the truffle industry. As Perigord Truffles of Tasmania further expand the number of truffières the recording and analysis of all the information and data will be of paramount importance.

Recommendations

Perigord Truffles of Tasmania will use the truffle mapping extension in all existing and new truffières to record all parameters, which may have an influence on truffle production.

This analysis process will be maintained indefinitely by PTT so as to be able to compare historical and current data from each truffière.

The information system is integral to much of the field experimentation that will be carried out in the future and has the added benefit that it may reveal effects from existing physical parameters in the field such as soil type, slope, drainage, aspect etc.

Appendices

Appendix 1. AgLab Soil analysis procedure

- Electrical Conductivity - EC of 1:5 soil/water extract.
- Soil pH - pH of 1:5 soil/water suspension
- Organic Carbon - Walkley & Black.
- Nitrogen - Total Nitrogen (Combustion - Dumus)
- Carbon/Nitrogen Ratio - Total organic carbon/total nitrogen ratio.
- Phosphorous - Ammonium Acetate + 0.03M EDTA extractable phosphorous,
- Ion Exchange Properties - Exchangeable bases (Ca2+,Mg2+,Na+,K+),
  - 1M ammonium acetate at pH 7.0,
  - Cation exchange capacity measurement - automated determination of ammonium ions,

Appendix 2. Lime analysis

Beams Brothers. Beaconsfield, Tasmania.

Commercial Grade

Calcium Carbonate	CaCO3	%	95.5
Calcium	Ca	%	40.0
Magnesium Carbonate	MgCO3	%	3.4
Effective Neutralising Value	ENV	%	94

Particle Size

- 75 um	2 %
75 – 150 um	24 %
150 – 250 um	54 %
250 – 500 um	22 %

Fine Grade

Calcium Carbonate	CaCO3	%	95.5
Calcium	Ca	%	40.0
Magnesium Carbonate	MgCO3	%	3.4
Effective Neutralising Value	ENV	%	94

Particle Size

- 75 um	66 %
75 – 150 um	30 %
150 – 250 um	3 %
250 – 500 um	1 %

Omya Southern. Moss Vale, NSW

F70 superfine Limestone

Calcium Carbonate	CaCO3	%	97.5
Calcium	Ca	%	39.0
Magnesium Carbonate	MgCO3	%	1.0
Effective Neutralising Value	ENV	%	99

Particle Size

- 75 um	78%
75 – 150 um	18%
150 – 250 um	3%
250 – 500 um	1%

References

Grente, J., Delmas, J., Poitou, N., and Chevailier, G. (1976). Faits nouveaux sur la Truffle Mushroom Science 9, 815-846.

Shaw, P.J.A., Lankey, K., and Jourdan, A (1996). Factors affecting the yield of *Tuber melanosporum* in a *Quercus ilex* plantation in southern France. *Mycological Research 100, 1176-1178.*