RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

# JAPANESE GREEN TEA

## Continued Investigation into Commercial Production and Development in Tasmania

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

by Ms Angela Monks
Vegetables and Horticulture Branch
Department of Primary Industries Water and Environment, Tasmania

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**Researcher Contact Details**
Ms Angela Monks
Department *of* Primary Industry Water *and* Environment
St. Johns Avenue
New Town Tasmania 7050
Phone:  03 6233 6813
Fax:  03 6228 5936
Email:  Angela.Monks@dpiwe.tas.gov.au

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON  ACT  2600
PO Box 4776
KINGSTON  ACT  2604

Phone:  02 6272 4539
Fax:  02 6272 5877
Email:  rirdc@rirdc.gov.au.
Website:  http://www.rirdc.gov.au

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# Foreword

There are a variety of market opportunities for green tea and its extracts, or by-products. The extractive industry is growing and many companies are seeking natural alternatives to chemical components in products such as cosmetics and medicines. Tea which has been picked but is rejected during processing because the material is deemed as being of poor quality, may in fact be suitable for use in the extractive industry.

The three cultivars imported for Tasmanian trial work have shown marked differences in performance, yield and quality. Yabukita, which is the most popular cultivar in Japan, performs well under Tasmanian conditions if the site is selected to suit its preference for warm early spring conditions and a long summer. Yabukita propagates reasonably well with good root-striking and growth rates. The quality of the tea that this cultivar produces in Tasmania has impressed the Japanese experts.

Sayamakaori is a vigorous plant producing the most biomass (material for processing) of the three cultivars. It also produces roots during propagation faster than the other two cultivars with a comparatively higher strike rate. The quality of the finished tea product is not as high as Yabukita but has still been well received.

Performance and tea quality of the third cultivar, Okuhikaori, falls between the other two cultivars. This cultivar is a little more difficult to propagate and seems to require longer to complete the propagation cycle than the other two cultivars.

This report shows that site selection has proved to be critical in establishing green tea plantations. *Camellia sinensis* var *sinensis* is highly sensitive to: aeolian and soil salt deposition; frosts and wind chill; and to mechanical wind damage, especially to the young leaves. Most of the early trial sites had to be abandoned because of ongoing frost and salt deposition problems.

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

This report, a new addition to RIRDC's diverse range of over 450 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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**Peter Core**
Managing Director
Rural Industries Research and Development Corporation

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Personnel currently involved in the New Crops Group:

| | |
|---|---|
| Dr Tom Batchelor | Manager Vegetables and Horticulture Branch |
| Ms Angela Monks | Horticulturist, Vegetables and Horticulture Branch |
| Ms Ingrid van Putten | Agricultural Economist, Economics and Policy Research Branch |
| Dr Gordon Brown | Plant Physiologist, Tasmanian Institute of Agricultural Research |
| Ms Michele Buntain | Crop Agronomist, Vegetables and Horticulture Branch |
| Ms Karen Butler | Horticulturist, Vegetables and Horticulture Branch |
| Mr Bob Cockerill | Technical Officer, Vegetables and Horticulture Branch |
| Mr Bill Hutchins | Technical Officer, Vegetables and Horticulture Branch |

Former personnel involved during the project:

| | |
|---|---|
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### Editors Note

Over the course of this project the Department *of* Primary Industry, Water *and* Environment has undergone a number of name changes. Where applicable the name at the time of the event has been used. In 1991 when the project started it was the Department of Primary Industries by mid 1992 this had become the Department of Primary Industry and Fisheries. The current name change became effective in October 1998.

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# Executive Summary

In 1991 the Department of Primary Industries with the aid of RIRDC, initiated a project to investigate the viability of the commercial production of Japanese green tea in Tasmania. This project is an ongoing study which has been split into a number of units each producing a major report which has been submitted to the relevant funding body.

The first project report submitted by the Department of Primary Industry and Fisheries to RIRDC was entitled "*The Continued Investigation into the Commercial Production and Development of Japanese Green Tea* (Camellia sinensis)" (DPIF 1997).

The 1997 report gave details on: preliminary field trials in Tasmania; literature searches on green tea; a preliminary production guide; a preliminary economic analysis; details of quality assessment and measurement; and a study of the market opportunities for green tea in South America.

A report was submitted in 1996 to the Horticultural Research and Development Corporation (HRDC) by the Department of Primary Industry and Fisheries entitled *"Quality assessment and Market Evaluation of Tasmanian Green Tea for the South East Asian Market"*.

The green tea project began with the importation of 6000 *Camellia sinensis* var *sinensis* plants from Japan. The plants were placed into quarantine at the Kingston station (outside Hobart) in Tasmania. After the plants had been in quarantine for twelve months the Quarantine Entomologist, during a routine inspection, found a single unidentified mite. Quarantine regulations required that the plants be fumigated with methyl bromide and stay in quarantine for a further six months. The fumigation treatment with methyl bromide proved lethal to many of the plants resulting in the death of nearly 60% of the imported plants. This high mortality rate considerably reduced the availability of plant stock to establish field trials.

The three cultivars imported for Tasmanian trial work have shown marked differences in performance, yield and quality. Yabukita, which is the most popular cultivar in Japan, performs well under Tasmanian conditions if the site is selected to suit its preference for warm early spring conditions and a long summer. Yabukita propagates reasonably well with good root-striking and growth rates. The quality of the tea that this cultivar produces in Tasmania has impressed the Japanese experts.

Sayamakaori is a vigorous plant producing the most biomass (material for processing) of the three cultivars. It also produces roots during propagation faster than the other two cultivars with a comparatively higher strike rate. The quality of the finished tea product is not as high as Yabukita but has still been well received.

Performance and tea quality of the third cultivar, Okuhikaori, falls between the other two cultivars. This cultivar is a little more difficult to propagate and seems to require longer to complete the propagation cycle than the other two cultivars.

Site selection has proved to be critical in establishing green tea plantations. *Camellia sinensis* var *sinensis* is highly sensitive to: aeolian and soil salt deposition; frosts and wind chill; and to mechanical wind damage, especially to the young leaves. Most of the early trial sites had to be abandoned because of ongoing frost and salt deposition problems.

Only the Scottsdale site, established in 1993, continues to be productive and is now returning reasonably high yielding harvests. The length of time taken in striking cuttings and growing seedlings from seed

meant that there was a delay in establishing new sites. The two new sites, one in the north and another in the south of the State, are not yet yielding any quantifiable harvests.

In Tasmania the most appropriate sites for the production of green tea appear at this stage to be either in the milder north-east or north-west regions of the State, depending upon the future location of a commercial processing plant. Production in the south of the State will depend upon the performance of the cooler growing varieties introduced to the new trial sites and upon future cool climate cultivars being developed.

Assaying seedlings is being undertaken by the Department *of* Primary Industry, Water *and* Environment. This may lead to the introduction of new cultivars for use in Tasmania and throughout Australia. Research is being undertaken to determine whether cultivars can be produced with certain characteristics to enable them to cope better with different climatic conditions. Early or seasonally late frosts in Tasmania have caused significant damage to new and established tree hedges, sometimes resulting in a complete loss of the first harvest.

There are a variety of market opportunities for green tea and its extracts, or by-products. The extractive industry is growing and many companies are seeking natural alternatives to chemical components in products such as cosmetics and medicines. Tea which has been picked but is rejected during processing because the material is deemed as being of poor quality, may in fact be suitable for use in the extractive industry.

During the course of this project a number of contacts have been made both nationally and internationally and the ‘green tea network’ is continually expanding. These links are important in ensuring the long-term viability of commercial production through exploring new markets, researching and comparing different agronomic techniques and initiating investigations into new cultivar development.

## Outcomes and Recommendations

- Site selection is of paramount importance in establishing a green tea plantation. The plants, even when they have reached mature hedges, are susceptible to frost and wind damage which can significantly affect harvest returns.

- Propagation of green tea is relatively straight forward using clonal material (cuttings) or seedlings grown from seed collected from mother plants.

- Nursery crop care is important and plants being prepared for transplanting into the field must be of the right age and in a suitably vigorous state to cope with the stress of relocation.

- Harvesting of green tea can be carried out using a variety of machines and methods. The technology is present in Australia to build large harvesters suitable for big enterprises. Smaller tea farms can obtain equipment relative in size and budget to the enterprise.

- Information regarding tea harvesters from both Australia and overseas will continue to be sought and collated so that it can be passed to growers as required.

- The quality of the tea produced is dependent on the quality of the wet material harvested. Timing of the harvest is critical in order to obtain the best prices for the finished product. An increase in lignin content in the harvested material significantly reduces the quality of the tea, similarly any material damaged by frost affects the quality.

- The University study found that green tea has a rhythmic growth which allows for some predictions being made as to when flushes will occur. Field observations have confirmed this aspect of green tea growth.

- Consistent and regular monitoring of the growth patterns of green tea plantations aids considerably in increasing economic returns.

- Processing Japanese green tea involves some technical expertise. It is a matter of trial and error for the operator and there is a direct correlation between the operator's gain in experience and an increase in the quality of the end product

- The purchase cost of plants does not have a significant affect on the internal rate of return. However a reduction in the number of harvests from three to two does have an effect where plant prices are higher, making the enterprise uneconomical.

- An economic analysis model of green tea production shows the potential returns for the crop in Tasmania. It has been calculated that an increase in productive area reduces the risks significantly, particularly where harvests might be lost to early frosts.

- Larger enterprises need to be encouraged or a grower co-operative for smaller enterprises would help to minimise risks and ensure a good internal rate of return.

- For a small enterprise the quality (and therefore the price of the end product) must be kept high with more than two harvests per annum in order to make the project economical. A sale price of $75/kg will provide a good internal rate of return.

- Opportunities for further research include:
    - increasing strike rates for Okuhikaori and Yabukita cultivars to help reduce the time required for propagation;
    - investigation into the extractives industry for green tea by-products;
    - organic production of green tea.

# 1. Introduction

## 1.1 Situation in Japan

The Japanese green tea industry is suffering from an ongoing loss of productive land to urbanisation and an aging grower population. The current trend in green tea production is towards the very high quality teas such as ceremonial teas and gift packs. The demand for everyday drinking teas is being increasingly met by imports of both the final tea product and raw materials for local processing. It is expected that this trend will continue with local growers only producing for the top end of the market.

It is this increasing demand in Japan for imported green tea that prompted this study into the viability of commercial production of Japanese style tea in Tasmania. Tasmania was chosen for trials by Japanese industry experts, for its similar climatic conditions to the main tea growing region in Japan, Shizuoka prefecture. This region in Japan, has a mean annual temperature of around 15°C and an annual rainfall of 2,200 mm.

## 1.2 Project Description

The project sought to identify areas of missing or limited knowledge and to improve on data already collected on mainland Australia for the production of Japanese Green Tea, researching the various differences applicable to Tasmania. The main objective of the project was to assist the commercialisation of Japanese green tea production and processing in Tasmania through:

- An investigation of factors affecting yield, quality and the economics of production for Japanese green tea.
- Expansion of existing trial sites to allow for semi-commercial assessment of agronomic techniques and technology.
- A study of the micro market (ie. processing grade tea, drinking grade teas etc.) requirements for successful entry of Tasmanian green tea into commercial production.

Three cultivars of *Camellia sinensis* var *sinensis* were chosen for trials in Tasmania, largely on the recommendation of Japanese green tea industry experts. These were:

- Yabukita
- Sayamakaori
- Okuhikaori

Of the three, Yabukita is generally the most popular with Japanese green tea consumers, favoured for its taste and piquancy. Okuhikaori was suggested for the Tasmanian trials as it is a relatively new cultivar and its performance under this State's growing conditions, compared to the other two cultivars, would be of particular interest.

## 1.3 Project Outline

Five main components of this project are covered in this report:

- Agronomic Background
- Establishment and Processing Trials
- Commercial Potential
- Economic Analysis
- Industry Liaison

The *Agronomic Background* section provides information on how the cultivars were imported, including quarantine issues, how they were propagated from cuttings and seeds and the maintenance of nursery crops for transplanting into the fields.

The *Establishment and Processing Trials* cover the entire growing process from transplanting to harvesting and look at some of the problems encountered and how these were overcome. A detailed look at the processing stages is presented and recommendations on how the various components of the plant might be made more productive are given. This section is well illustrated with photographs of harvesting machinery, field techniques and processing plant components. A brief outline on the potential for an organic industry in green tea production is also provided.

The section on green tea's *Commercial Potential* looks at Tasmania's competitive advantage, including its climate, pest and disease-free status and international image. It also explores various market opportunities for green tea and its extracts. The extractive industry is proving to be a growing area with many products looking for natural alternatives to chemical inputs in the cosmetic and health industries.

An *Economic Analysis* model investigates the costs involved in establishing a green tea plantation and the returns and benefits over time. It provides a detailed break-down of infrastructure costs as well as ongoing production requirements.

Finally, the *Industry Liaison* section provides information on how the Tasmanian project team is helping with work being undertaken in other states, including several trials in Western Australia. A major workshop was held in Tasmania which provided an opportunity for Japanese experts in the industry to share their knowledge with local and mainland researchers and potential growers. Papers from this workshop are included as an Appendix to this report.

## 1.4 University Project

As part of the green tea project a joint funding venture by the DPIWE and the University of Tasmania was undertaken in the form of a PhD study.

Under the supervision of Professor Bob Menary and Dr Gordon Brown, Ms Tina Botwright examined the relationships between growth and development of *Camellia sinensis* var *sinensis* and harvesting amounts with final yields. In the study four growth stages of shoots were used to detail changes in plant development and the effect of different environment conditions on rhythmic growth, harvest yield and quality of poured green tea.

Ms Botwright's thesis '*Growth and Quality of Green Tea, (*Camellia sinensis var sinensis*)* (Botwright 1997) is submitted to RIRDC as an annex to this report but as a separate volume.

# 2. Agronomic Background

## 2.1 Cultivar Selection

### *2.1.1 Camellia sinensis*

The genus *Camellia* is one of around thirty genera in the family Theaceae which evolved in Asia. Many members of this family have been cultivated for ornamental, food or oil bearing plants for hundreds of years.

Both black and green teas are derived from the species *Camellia sinensis*. Black tea is encouraged to ferment before being processed, whilst green tea is steamed to prevent the enzymes which cause fermentation and the associated blackening from becoming active. Even though black and green tea are produced from the same species, breeding of *Camellia sinensis* has produced distinctive varieties and cultivars. Black tea is produced from the variety *Camellia sinensis* var *assamica,* green tea from *Camellia sinensis* var *sinensis*. From the green tea variety numerous cultivars have been produced including Sayamakaori, Yabukita and Okuhikaori.

Several different types of tea, all classed as green tea, are produced in countries other than Japan. China, Indonesia and Korea all produce various types of semi-fermented green tea, where the fermentation process is stopped at different stages to produce the required flavour. Examples of semi-fermented teas are pan fried gun powder tea from Indonesia (this tea is semi-fermented, steamed then roasted in a hot pan to give it a unique flavour) or Chinese Lung Ching tea. Japanese green tea refers to wholly unfermented green tea where harvested material is steamed as soon as possible after picking, to prevent any fermentation. Tasmanian trials of green tea aim to produce good quality Japanese style unfermented green tea.

### *2.1.2 Importation and quarantine issues*

Quarantine controls prevent the entry of pests and diseases into Australia, which might threaten agriculture and the environment. In Japan a serious pest, the Kanzawa mite *Tetranicus kanzawa*, is becoming resistant to most available chemicals. Fumigation with the gas methyl bromide is the preferred quarantine control method to ensure that any mites present on plants are killed. However, green tea plants appear to be sensitive to methyl bromide and suffer severe damage.

The alternative quarantine control method is a dip consisting of a miticide, fungicide and insecticide mix which may be used as the first disinfectant method for plants or propagation material. If the plant material is examined after the dip method is used and found to still bear pests, the material is then fumigated with methyl bromide. The dip appears to damage the cuticle of *Camellia sinensis* and may make the effects of the fumigant worse.

Attempts to introduce other varieties of green tea into Tasmania have so far been unsuccessful. Problems encountered included the importation of cuttings when they were actively growing, making the soft tissue much more susceptible to the fumigant and the alternative dip. Cuttings were also sent by air mail but encountered an importation delay, resulting in the living cuttings sweating inside the plastic packaging and many succumbed to fungal rot.

Several attempts have been made to import propagation material as unstruck (rootless) cuttings but to date all have been unsuccessful into Tasmania. All imported plant material must pass through the disinfestation procedure and quarantine period. One batch of cuttings in 1996 survived for two weeks after the disinfestation procedure but died soon after new shoots appeared on the cuttings before roots had struck.

### 2.1.3 *Varieties*

There are only three cultivars currently available in Australia for production of green tea, Sayamakaori, Yabukita and Okuhikaori. When this project began in 1991 the three cultivars were imported as two-year-old plants from Japan and placed in quarantine in Hobart, Tasmania. After 12 months in quarantine a single mite was found on one plant. All of the plants (6,000) were taken out of their pots, bare rooted and fumigated with methyl bromide. Around 58% of the plants were lost and the rest were used for propagation.

Of the three cultivars, Yabukita represents about 80% of plantings in Japan. As the most desirable cultivar for producing high quality tea, Yabukita is often used as a quality term to describe the final product. Japanese experts recommended Sayamakaori for trial work in Tasmania as it performs well under cool conditions. Yabukita prefers slightly warmer conditions. Okuhikaori was recommended by Japanese experts as a newly released cultivar which might perform somewhere between the other two varieties.

Sayamakaori flushes earlier and more evenly than either Okuhikaori or Yabukita in cool conditions such as those experienced in spring in southern Tasmania. Yabukita prefers warmer conditions like those found in the north of the State at Herrick and Scottsdale.

When the plants were released from the quarantine station in January 1993, of the three varieties imported Sayamakaori had survived the best. This is the most vigorous of the three species trialled, it is also the most cold tolerant and has the highest strike success rate. Yabukita although the most desirable variety of the three imported was less vigorous than Sayamakaori. Okuhikaori, a relatively new variety in Japan, was numerically the smallest post quarantine; in the Tasmanian trials it has shown itself to be more vigorous late season than the other two varieties.

## 2.2 Propagation

Traditional propagation in Japan has utilised outside, open-rooted cutting beds with cuttings taken between 15-30 cm long and without using any root promotants. The cuttings are then left to grow for almost a year. At the transplanting stage the roots are undercut and the young plants are relocated.

There is a large amount of traditional custom associated with growing green tea. Japanese experts prefer to have tea initially struck into 100 mm pots. This may be due to the vigour of the root system upon striking, if the plant is potted into too small a pot then it quickly girdles itself and dies after it is planted out in the field. This problem is readily overcome by careful attention to re-potting of young plants, root pruning and top pruning.

Large numbers of cuttings were required for the trial work but the imported plants from Japan were very small, especially after being pruned back to rid them of damaged tissue. They were unable to produce the large amounts of new growth required to take cuttings for quite some time. Due to this shortage of plant material in the early stages of the project, one-leaf and bud cuttings were used for the majority of propagation. Later two or three bud and leaf cuttings were used to produce larger plants.

Mother plants were initially kept in 200 mm pots outside but these were then moved into glasshouses to promote an increase in internode length, making the cuttings easier to handle. As the mother plants increased in size they were re-potted until they required a pot size of 500 mm. At each re-potting stage the mother plants received a light root pruning.

All plants were potted into a standard potting mix made in-house by the then DPIF, consisting of composted pine bark (5 parts), peat (2 parts) and medium-coarse sand (3 parts). The fertiliser was a mix of dolomite, long and short-term slow release osmacote® and micromax® at the recommended rates. During storage the potting mix was mixed as needed to prevent spoilage.

### 2.2.1 Cutting preparation

Cuttings were prepared initially from freshly collected material from glasshouse mother plants and later from the field. Semi-ripe (new growth) material proved the most successful for cuttings, although mature wood will strike given sufficient time.

Glasshouse grown plants were maintained at 25°C day time and 15°C night time temperatures. Cuttings were taken in the early morning to prevent water stress in the shoots during the main photosynthetic period.

Field grown propagation material was cut into branches, placed in plastic bags in the early morning to avoid the heat of the day and internal water deficiencies. Wet towelling was also placed in the bags. The bags were transported in the shade near ice or inside a car with the air conditioning on and protected from direct sun.

The shoots were cut into one or two node cuttings depending on the amount of material available and/or the length of internode. It was found that cuttings about 50 mm long were the easiest to handle particularly when there was a lot of material to prepare and treat.

An oblique cut was made above each node leaving a piece of stem with a node, bud and leaf at the top. If the leaf was large then it was trimmed to half its size leaving a piece of leaf around 3 cm long. The base of the cutting was then dipped into Indolebutyric acid (IBA) hormone (8%) solution for five seconds to stimulate the production of callus tissue and roots. The cutting was put into a black plastic nursery flat and then placed on heated sand under mist (refer Figure 1).

### 2.2.2 Rooting medium

A mixture (50:50) of quartz (bedding) sand and vermiculite was used. Perlite can be used where vermiculite is unavailable. The rooting medium is dampened to swell the vermiculite before being placed into flats. The flats are then filled with cuttings of each cultivar and placed onto a heat bed filled with sand. Moisture (mist) is maintained using an artificial wet leaf system with a mercury switch.

The use of peat in the rooting medium led to poor, or complete lack of, root development and slow plant growth. It was found that peat could be added after the cuttings had struck at which point there was no adverse affect on the plants' development.

Figure 1: Cuttings Prepared in a Black Plastic Nursery Flat

### 2.2.3 Environmental conditions

The heat bed was maintained at around 22°C and the glasshouse at around 18°C. Coarse sand was used in the heat beds to a depth of about 10 cm. A shallow hollow was dug in the sand in which the flats were placed, the sand was then mounded around the edges of the flats. Shade cloth was placed over the heat bed to prevent scorching of the cuttings from sunlight entering through the roof of the glasshouse and to reduce rapid evaporation of the applied moisture.

### 2.2.4 Striking

Checks for blackening of the stems or shedding of leaves were carried out regularly. Blackening can often indicate that stem tissue was too soft (young) and green or the rooting medium too wet. Yellowing of the leaves can be an indication of fungal infection. Blackened stems and shed leaves were removed every two to three days from the flats. Monitoring of the condition of the base of the cutting was also carried out to check the formation of callus tissue. Often roots will emerge without obvious callus formation. If the majority of cuttings had struck after six to ten weeks then the unstruck material was discarded and fresh material prepared. Some cuttings were found to have struck within a week but this was not common.

The three cultivars show slight but definite differences in ease of propagation (refer Table 1).

Table 1: Comparison in Strike Rate Between Varieties

| Variety | % Strike Success Rate | Comparison |
|---|---|---|
| Sayamakaori | 100 | Better than Yabukita and Okuhikaori |
| Yabukita | 80-90 | Slower than Sayamakaori and Okuhikaori |
| Okuhikaori | 60-70 | Slower than Sayamakaori but faster than Yabukita. |

Once the cuttings had struck, each was progressively removed from the flat and heat beds and potted into 100 mm pots (refer Figure 2).

### 2.2.5 Nursery crop care

The growing apical bud was removed from the cuttings when they reached a stage where four to five nodes had developed, this encouraged branching, the cuttings also had flower buds removed. Tea bushes are encouraged to form branches very low on the stem so that the bush gains the maximum width early in its life for tea production. Cuttings can be encouraged to produce a shoot that is retained on the plant until it is semi-ripe and suitable for propagation material at which point it is harvested and one or two nodes are left on the original cutting to re-sprout.

Figure 2: Cuttings Transplanted from Flats to 100 mm Pots

The young plants were kept in a glasshouse until they were established and then moved outside to a sheltered position. Before transplanting in the field, the plants were progressively hardened off by being set in direct sunlight and by being denied adequate nutrients in order to prevent a flush of growth. A growth flush would make the plants soft and easily susceptible to drought or animal foraging.

## 2.3 Seed production

Due to the difficulty in obtaining new varieties from overseas and successful importation into Australia, some seedling germination and culture was carried out at the DPIF in Tasmania. The need to develop local varieties arises not only from local agronomic requirements but also because methyl bromide fumigation will probably be phased out in the future, possibly resulting in a greater restriction on the importation of certain 'high pest risk' plants.

There could be problems in obtaining large amounts of seed for commercial production. Although seed is often advertised in seed catalogues both in Australia and overseas eg. in Indonesia, there is often uncertainty as to its parentage and some seed could be from *Camellia sinensis* var *assamica* cultivars (black tea). Seed from known green tea cultivars is the preferred option, for example from Yabukita mother plants without the influence of *C. sinensis* var *assamica* in the parentage.

Performance under different environmental conditions and plant growth characteristics are attributes which can be selected for in breeding programmes. Uniformity and predicability of times of flushing lead to reduced management inputs for crop maintenance and harvesting.

Seedling development may give opportunities in the future to access a larger variety of plant types. Other features which might be gained from breeding programmes would be different growth characteristics such as tolerance to cold or later flushing to avoid cold periods in early spring. In time an assessment of seedlings for their polyphenol content and suitability for tea production under different climates may also be carried out. Polyphenols give green tea most of its flavour characteristics as well as the health benefits from its anti-oxidant (anti-cancer) ability. Higher polyphenol content is associated with increased tea quality and taste.

### *2.3.1 Seed collection*

Seed was collected from pot grown mother plants, the parent variety being noted. The majority of seed was collected from the more popular Yabukita seed parents. As tea seed is classified as 'recalcitrant', seed was harvested and sown whilst still fresh. Recalcitrant seed loses its viability if stored for any length of time resulting in a significant decrease in germination rate.

Recalcitrant and orthodox seeds (which are long lived and their internal moisture can be reduced to as low as 5% for long term storage) are different in several general ways. Recalcitrant seeds contain higher levels of internal moisture at maturity, up to 40% more internal moisture content, but when dehydrated to 30% moisture germination ceases. Recalcitrant seeds are generally found in perennial tropical plants, they have larger embryos than orthodox seeds and it is believed that they do not experience true dormancy but continue in development towards germination.

If storage of green tea seeds is necessary it should be short term, the seeds should be placed in moist sand and kept at room temperature (around 20°C).

Green tea seeds are large (up to 15 mm across), brown with a smooth seed coat, which appears to be fairly woody. The seed capsule is fleshy and as the seed matures it splits open rejecting the seed only when the capsule is completely desiccated. It is not necessary to prime the seeds to induce germination.

### 2.3.2 Germination

Green tea seed should be cleaned of any detritus and washed in a fungicide solution registered for seed treatment. The seed should then be placed into a moist vermiculite and sand mixture (50:50) in a beaker and enclosed in a snap top sandwich bag, to prevent the sand and vermiculite from drying too rapidly. Good results have been obtained with seed germinating rapidly at room temperature.

It has been found that a dinner fork is the best implement for removing germinating seeds from the sand and vermiculite mix. Germinating seeds grow vigorously and so require a larger initial pot size than the cuttings, usually about 150 mm. The seedlings should then be potted into 250 mm pots and pruned back to encourage branching to obtain a strong shape in the young plant.

The DPIWE at New Town is maintaining potted plants in its greenhouses for planting out at a later date.

## 2.4 Conclusions

Success has been achieved in production of both cuttings and seedlings by the DPIWE in Tasmania. This success has aided other states to begin a green tea production programme using mother plants supplied by the DPIWE and knowledge gained through the course of this project.

Propagation of cuttings is time consuming and requires approximately 18 months to complete the cycle. Striking can take between 8 to 12 weeks, the young plants are then over-wintered in a glasshouse. The plants are encouraged to grow until their roots fill the current pot, at which point they are re-potted. A height of 30-50 cm is ideal for transplanting into the field.

Cuttings are the best way of achieving plantations of the same cultivar and standardised quality in the finished product. Since green tea quality is closely linked with polyphenol content, this is the characteristic which has been particularly selected for over the many years of green tea breeding.

Seed germination is relatively straightforward and only requires minimum input from bees to obtain open pollination. The benefits of this would be the opportunity of new cultivars arising from seedling stock for breeding purposes, the relative in-expense of using seedlings for plantations and seedling vigour. The disadvantage would lie in the very nature of the open gene pool of the seedlings in that they would all be genetically different producing an aspect of unknown characteristics, quality in the finished product and potential uneven growth characteristics.

# 3. Commercial Potential

## 3.1 Tasmania's Competitive Advantage

### *3.1.1 Environment*

Tasmania's international image of being a "clean green environment" would aid significantly in the State achieving a market edge in growing and producing Japanese style green tea.

The warmer climate of northern Tasmania and the region's rich red krasnozem soils, should particularly suit commercial production of green tea. Southern Tasmania is renowned for premium grade temperate fruit and vegetables. Many regions in the State are primary wine producing areas and Tasmania's fine wines are now recognised internationally.

Tasmania has developed various specialised industries, including the extractive oil industry and there are several privately run steam distilleries for extracting high value plant oils. Solvent extraction is also used in Tasmania to remove plant oils from harvested material such as boronia flowers. The State played a key role in the development of one of the highest value pharmaceutical crops in the world, the poppy industry.

The wide variety of high value agricultural crops in Tasmania is a good indicator that a green tea industry would be easily established in this state.

### *3.1.2 Pests and diseases*

Tasmania has strict quarantine controls over the importation of plant materials. This has led to a relatively disease-free status for the State. In Japan the green tea industry is under immense pressure from disease and pests. There has been increased resistance of one particular pest, the Kanzawa mite *Tetranicus kanzawa*, to most available pesticides. Tasmania has managed to avoid the introduction of this serious pest through good quarantine practices, providing the State with another market edge opportunity.

### *3.1.3 Commercial propagation*

Numerous inquiries have been made to the DPIWE from several propagators in Western Australia, New South Wales and Victoria regarding mother plants for commercial production of young plantation stock. Three or four year old mother plants are considered to be the most suitable for nursery production. Negotiations are taking place between commercial propagators and the DPIWE to supply the necessary stock plants to propagators. Issues of concern are the number and age of available plants as well as purchase and transport costs.

The disease-free status of Tasmania could provide the State with the opportunity to become the primary source of high quality mother plants, supplying commercial nurseries in other states. The DPIWE is currently supplying other states with propagation material for the establishment of green tea trials (refer Section 6 *Industry Liaison*).

## 3.2 Market Requirements

### *3.2.1 Potential size of the market*

It is difficult to gauge accurately the potential size of the market for green tea production. Data collected by the Australian Bureau of Statistics combine figures for the importation of both black and green tea. There are a number of green tea products sold in Australia, these are either blends of imported teas or Australian grown tea.

### *3.2.2 Market opportunities*

There are several market opportunities within Tasmania and the other states. For example, there are various specialty shops which deal in different types of tea and tea extract products. Several businesses operating in Tasmania and other states including Queensland, New South Wales and Victoria, use green tea as an ingredient for value added products, such as soaps and other skin care products.

Interest has been received from several companies around Australia which deal in wholesale foods, herbs, medicinals and beverages. There appears to be a significant demand in Australia for green tea and green tea extracts. However, at present Australian producers are unable to meet the market's demand necessitating ongoing imports from various sources world-wide including China, Malaysia and Japan.

### *3.2.3 Role of Department of State Development*

Tasmania's Department of State Development is working with the DPIWE looking at market opportunities overseas for potential green tea exports. To this end in March 1999 a delegation led by the DSD and the Japanese External Trade Organisation (Jetro) attended one of the world's major international Food Expos, 'Foodex' in Japan

### *3.2.4 Market reseach*

Work commissioned by the DPIWE included market analyses carried out by the international firm Tea Craft. The following reports have been published: *Green Tea - Production and Marketing in South East Asia*; *Green Tea - Production and Marketing in Japan*; and *Tea in South America* (Melican 1996).

The reports published by Tea Craft give a detailed insight into the processed green tea industries in several countries. A review of opportunities for Australian grown green tea also identifies other potential value added products which utilise green tea.

## 3.3 Alternative Uses for Green Tea Extracts

Many other commodities use green tea by-products as an ingredient for products such as: cosmetics; skin care products eg. soaps, shampoo and sun screens; and medicinals which are becoming popular due to the anti-oxidant components in green tea. Green tea by-products may include the residual 'chaff' from the processing phase or be tea which is deemed of insufficient quality to be sold as green tea.

The anti-oxidant fraction of green tea binds powerful oxidising agents such as hydrogen peroxide preventing oxidation taking place. Oxidation of a material generally results in its spoilage, for example rusting of a metal or rancid fat products. A practical example of using an anti-oxidising agent can be seen in the prevention of spoilage of oils and fats contained in food through the addition of polyphenols. Green tea extract can be used as an alternative to the chemical preservatives (Toceropherol (vitamine E) and butylated hydroxyanisole (BHA)) used in foods and cosmetics containing lipids and other fats, to prevent them from becoming rancid when exposed to air and sunlight.

### *3.3.1 Cosmetics*

The cosmetic industry is looking towards using green tea polyphenol extracts which are proving more efficient than previously used ingredients. For example, whilst sun screens provide a physical barrier to harmful ultra-violet radiation, the presence of green tea polyphenols in the sun screen helps to prevent free radicals from reacting with skin proteins, by binding with the free radicals and rendering them harmless (Ruch 1989).

### 3.3.2 Medicinal

Studies have revealed that green tea extract aids in the: control and prevention of many types of cancer; reduction in cholesterol; reduction of blood pressure; reduction of blood sugar levels; and can act as an anti-bacterial and anti-viral agent (Toda et al. 1992).

The anti-oxidant fraction of green tea extract is found in a group of polyphenols which constitute 15-30% of Japanese style green tea. Also referred to as "catechins", they include one of the most potent anti-oxidising agents Epigallocatechin gallate *(*EGCg) which is the dominant polyphenol in green tea. EGCgs have been shown to prevent certain virus particles, such as the influenza virus, attaching themselves to cells thus preventing infection (Nakayama et al. 1993).

Green tea contains 90% more polyphenols than black tea and has been used in the control of bacterial diseases, by increasing the activity of different types of antibiotics such as oxacillin (Takahashi 1995).

A 500 mg capsule of green tea extract provides the equivalent of 10 cups of green tea. The beneficial aspects of green tea have been documented for thousands of years. The renewed interest in traditional medicines in the west has increased interest in Australian grown green tea for extractive purposes (Fitton pers comm1998).

## 3.4 Rate of adoption

The rate of adoption will depend on the availability of good quality plants for commercial sized plantations. Discussions are currently being held with commercial propagators for the production of large numbers of plants suitable for the scale of crops being planned in several sites.

The access to processing facilities will also have an impact on the rate of adoption. The capital outlay is a daunting prospect for many investors and foreign interests, in the form of input from Japanese green tea producing companies, are being sought by several states. Overheads might be reduced through the formation of grower co-operatives or through using alternative processing techniques such as reducing the processing to steaming and drying only for the production of tea bags. Value adding opportunities may also increase the rate of adoption by accessing alternative product markets eg. the extractive industry.

## 3.5 References

Melican, Nigel, 1996 Green Tea - Production and Marketing in Japan Tea Technology Associates
Melican, Nigel, 1996 Green Tea: Production and Marketing in Japan Volume 2 The Appendices

# 4. Economic Analysis

## 4.1 Introduction

Reliable information on the financial details and economic benefits of growing Japanese green tea has been difficult to ascertain. The analysis carried out by DPIWE economist Ms Ingrid van Putten presented here was based on: the green tea trials; market information gained during the course of the project from the pilot processing plant; and the resulting quality assessments of the finished product of Tasmanian grown Japanese style green tea. Ms van Putten was also supplied with financial details of the agronomic and processing costs involved in the production of green tea in Tasmania by the scientists involved in this project.

It must be noted that the cost of a full-scale processing plant for 10 to 50 ha has been quoted as being from 1 to 4 million Australian dollars. There have been no detailed quotes for specific sized processing plants relating to a certain hectarage of tea to base the analysis on. Costs associated with processing plants must also take into account importation costs, freight, instalment and occupational health and safety standards modifications.

## 4.2 Green Tea Investment Model

An investment model assesses the potential returns and economic benefits that can be obtained from an investment. The model should be able to reflect a realistic situation. The investment in this case is in a green tea plantation. Decision as to the shape and size of the plantation underlies the economic benefits of the investment over time.

### *4.2.1 Input variables*

The result of any analysis that is undertaken will be dependent on the assumptions that are made. It is important to decide on these assumptions, such as the size of the operation, the price that can be obtained etc., prior to analysing the results. Each of the input variables appears on a separate EXCEL sheet in the model (refer Appendix II). The variables are discussed in the following sections.

#### 4.2.1.1 Size of the plantation

An important variable is the size of the plantation. The easiest way that can be used to describe the area of production is to decide:

- The number of plants that are going to be planted (say 12,500); the distance between the plants (say 40 cm); and the distance between the rows (say 2 m).
- The area of production (in hectares) is simply: the number of plants divided by the number of plants per ha.
- The number of plants per ha is derived from: the number of rows per ha multiplied by the number of plants per row.

#### 4.2.1.2 Number of harvests

The returns of a plantation will depend on the number of harvests that can be obtained per annum. In Tasmania the number can be up to three.

#### 4.2.1.3 Yield

In Tasmania the experience over the past three years has been between 20 to 110 grams of wet product per plant. The wet yield per plant multiplied by the number of plants and the number of harvests will return the total wet yield in grams per annum. The average wet yield per plant is assumed to be 44 grams in this analysis.

Important for the calculation of the returns is the yield of dry product. The yield of dry product as a proportion of wet product is approximately 0.18 grams (or 18%). Therefore, for every 1 gram of wet product, 0.18 grams of dry green tea can be obtained.

#### 4.2.1.4 Price

The price of green tea is likely to be dependent on the quality of the product. The average price that can be obtained in Tasmania is assumed to vary between $35 and $75 per kilogram The most likely price is around $70 per kilogram of dry product which has been used in this analysis.

#### 4.2.1.5 Capital

The main categories in capital costs for a plantation are the purchase of the land, machinery, a shed, irrigation equipment and fencing materials.

Some enterprises may already be in the possession of a significant number of capital items, for instance much of the machinery and the land. The analysis is flexible and capital items that do not need to be purchased can be excluded from the capital cost items.

### *4.2.2 Returns*

The returns from a green tea plantation are simply the amount of product multiplied by the price obtained minus the costs incurred. The returns are dependent on the amount of time it takes to reach full production. In this analysis it has been assumed that full production is achieved in year 5. Prior to year five, 0%, 20%, 50%, 75% in years 1, 2, 3, and 4 respectively is achieved.

### *4.2.3 Cost factors*

An investment analysis takes into consideration all capital cost, establishment cost, variable cost and overhead cost over time. The capital and establishment costs are generally incurred in the first years of development. The variable and overhead costs are incurred every year of operation. Each of these costs is broken down into its component parts in the relevant EXCEL sheet in Appendix II. The individual cost sections are discussed below.

(Please note that the figures presented here are the result of the assumptions discussed above.)

#### 4.2.3.1 Capital cost

Depending on whether the user of the model has included the particular capital item for purchase in the input EXCEL sheet, the capital cost will be included in year one.

In this analysis only the machinery and equipment specific to green tea production has been included. The total capital cost in this analysis is $78,591 in year one. The capital cost would not increase with area, rather economy of scale would be experienced.

#### 4.2.3.2 Establishment cost

The purchase of the plant stock and labour of planting the tea plants is the main establishment cost incurred in year one. Other costs are land preparation and irrigation costs, which are expressed in terms of tractor running cost and labour cost. In year one each of the tea plants is also mulched. In this analysis for one hectare of green tea a total of $10,223 in establishment (capital) cost is incurred in year one.

A total of $762 in establishment labour cost is also incurred in year one which included ground preparation activities.

#### 4.2.3.3 Variable cost

Every year pest and disease control costs are incurred. The cost of pest control is not only for the actual product but also for the labour and tractor running cost associated with the application. Other variable costs are transport costs to the drying facility and freight costs of the finished product either locally or overseas. Costs associated with obtaining the finished product are drying operating cost and packaging cost. A major variable labour cost element is harvesting cost, which is incurred every year.

In year 5 (the first year of full production) a total of $1,533 variable cost per hectare is incurred. An additional $107 in variable tractor running and $1,887 in variable labour costs are added to this. The variable labour costs are high due to harvesting and drying having a high labour component.

#### 4.2.3.4 Overhead cost

Overhead costs are highly variable and should be adapted to the situation of the grower. In this analysis there is a total of $10,400 per annum in overhead costs. Owner operator labour of $30,000 has not been included. The overhead cost can be excluded from the analysis if the green tea is not grown as the main crop for instance.

### *4.2.4 Economic indicators*

Several economic indicators can be used to assess the viability of a project. The most straight forward is the cash flow over time and the cumulative balance. Economic indicators that are widely used by financial institutions are the Internal Rate of Return (IRR), and the Net Present Value (NPV).

#### 4.2.4.1 Cash flow

The net cash flow is the return minus all costs incurred. For most projects there is a negative cash flow over the first several years. This is mainly due to all capital and establishment costs being incurred in the first year of operation and low returns from the product that is being produced.

The net cash flow for green tea production is negative for a total of three years. The net cash flow stabilises at $6,864 in year 5. The gross margin (returns minus variable costs only - excluding overheads) stabilises at $17,264 in year 5.

#### 4.2.4.2 Cumulative balance

The cumulative balance is the sum of the net cash flow over the years. Where the cumulative balance becomes positive, the project breaks even. The production of green tea will not break even over the 20 years period according to this analysis.

#### 4.2.4.3 NPV & IRR

The NPV of the plantation establishment is defined as today's value of a series of future payments (negative values) and income (positive values). The NPV is dependent on the interest rate as the periodic cash flows are discounted.

The NPV for the production of one hectare of green tea over a 20 year period at an 8% discount rate is negative at $56,313.

The internal rate of return is the interest rate received for an investment consisting of payments (negative values) and income (positive values) that occur at regular periods. If the money were invested in the bank approximately 4% interest would be received. The risk associated with the development of the plantation has to be weighed against the difference between the percentage interest that can be obtained in the bank and the IRR of this project.

The IRR for the production of one hectare of green tea is 1.23% which is low in general and for an agricultural enterprise.

## 4.3 Discussion of the Results

A sensitivity analysis using different sizes of the operation, purchasing cost per plant, wet yield per plant, sale price per kilo and the number of harvests is shown in the tables below. The analysis is for one hectare of production.

Table 1: Sensitivity of the IRR to Changes in the Number of Harvests and the size of the operation

*12,500 plants per hectare

| | Growing area (ha)* | | |
|---|---|---|---|
| No of harvests | 1 | 1.5 | 2 |
| 2 | - | 0.42% | 4.95% |
| 3 | 1.23% | 8.09% | 12.86% |

An increase in area will substantially increase the IRR for green tea production. An increase from one hectare to 2 hectares and 3 harvests per annum raises the IRR from 1.23% to 12.86%.

In a one hectare size operation less than three harvests per annum would be uneconomical.

Table 2: Sensitivity of the IRR to Changes in the Number of Harvests and the Cost per Plant

| | Cost per plant | | |
|---|---|---|---|
| No of harvests | $0.50 | $0.80 | $1.50 |
| 2 | -% | -% | -% |
| 3 | 1.50% | 1.23% | 0.65% |

The cost of planting material does not have a significant impact on the IRR in this analysis. An increase of $1.00 in the cost (from $0.50 to $1.50 per plant) only reduces the IRR by 0.85 percent.

Less than 3 harvests per annum would be uneconomical at any price of the planting material, ie. the IRR is negative.

Table 3 Sensitivity of the IRR to Changes in the Number of Harvests and the Yield per Plant

| | Yield per plant (grams) | | |
|---|---|---|---|
| No of harvests | 35 | 45 | 55 |
| 2 | - | - | - |
| 3 | - | 1.68% | 5.56% |

At a wet yield per plant of 35 grams the production of one hectare of green tea is uneconomical. This also applies to a yield of 45 and 55 grams and 2 harvests per annum.

An increase of 10 grams per plant (from 45 to 55 grams per plant) at 3 harvests will increase the IRR for one hectare of green tea by approximately 3.88 percent.

Table 4 Sensitivity of the IRR to Changes in the Number of Harvests and the Sale Price per Kilo

| | Sale price per kilo | | |
|---|---|---|---|
| No of harvests | $40 | $60 | $80 |

| | | | |
|---|---|---|---|
| 2 | - | - | - |
| 3 | - | - | 4.20% |

For a sale price of $40 and $60 the production of one hectare of green tea is uneconomical. If the sale price is $80 per kilo, more than 2 harvests per annum are needed to make this project economical.

## 4.4 Conclusions

The best outcome for a green tea venture would be to have three good quality harvests, with high yields each year with two of the harvests obtaining premium prices at market. The worst outcome would be a frost eliminating the first harvest and poor quality tea being made from low-yielding subsequent harvests.

If there were more than one year that had an out-of-season frost during the first harvest, then the poor economic returns would be extremely difficult to bear for most agricultural enterprises.

The cost and arrangement of the machinery plays a role in the economic returns of the crop. If a similar arrangement of equipment to the one used by the DPIWE were to be purchased without doubling-up on several of the machines like the tea rollers, then the outcomes would be similar to the above analysis. If several of the machines were to be doubled-up or larger capacity machines purchased, then the associated costs would be increased. The limiting factors associated with the pilot plant used by the DPIWE is the 2 kg capacity of several of the machines. If all three of the cultivars are harvested together the machinery must be run continuously to process the fresh leaf before it spoils in storage.

Without firm details of the cost of processing equipment the economic analysis should be regarded as a guide only.

# 5. Industry Liaison

## 5.1 Field days

Information dissemination at various field days was a priority for the project. As well as those conducted within Tasmania, information sessions, including field days and public workshops, were presented in Western Australia and Victoria by members of the Tasmanian project team.

## 5.2 Meetings and Conferences

### *5.2.1 SCARM*

The Standing Committee on Agriculture and Resource Management met in Tasmania in February 1998. SCARM comprises Commonwealth and State government departmental heads and is chaired by the Secretary of the Department of Agriculture, Fisheries and Forestry. At this meeting an informal discussion of the potential for a green tea industry was undertaken which included a tasting of Tasmanian grown green tea.

### *5.2.2 Supermarkets to Asia*

The ‘Supermarkets to Asia’ project, an initiative of the prime minister, has held field days across the country for several crops, including green tea. Green tea field days held in Victoria were attended by the DPIWE and have lead to Tasmania having an ongoing involvement in Victorian trials.

## 5.3 National Liaison

### *5.3.1 Plants sent to other states*

Young plants and mother plants have been sent to other states to begin trial work by state governments, privately run trials and for production of young plantation stock. Plants are now present in Western Australia, New South Wales, Victoria and South Australia. The plants have been provided by the DPIWE as either mother plants or young plantation stock.

Information exchange on production issues between the various states continues.

### *5.3.2 Western Australia Agriculture*

In 1998 Western Australia Agriculture held a public meeting introducing green tea as an opportunity for WA growers. A presentation of findings from the Tasmanian trials was given by members of the DPIWE project team. More than 60 people attended the information session and took part in a tasting of Tasmanian grown green tea.

During the visit farms were assessed as potential sites for green tea establishment. Commercial propagators’ facilities were also investigated for their suitability for green tea propagation.

Mother plants will be sent to WA during winter 1999 to provide propagation material for trial establishment.

## 5.4 International Liaison

The DPIWE has been developing a network of commercial and research contacts worldwide. These include processing companies who have interests in the raw product for processing or value adding in the extractives industry and companies interested in the finished product for retail.

## 5.5 Workshop

### *5.5.1 Introduction*

A workshop was held at the New Town offices of the Department of Primary Industry and Fisheries on 14-15 February 1996. Its aim was to share the expertise of three visiting Japanese scientists and Australian experts with local growers and interested parties. The financial cost of the workshop was absorbed by the DPIF, the Ministry of Agriculture Fisheries and Forestry Japan (MAFF) and the participants of the workshop.

The workshop was opened by Mr John Thorp the General Manager of Plant Industries and was chaired by Dr Gordon Brown and Ms Angela Monks, members of the green tea project team.

Participants attending the two day workshop included representatives from the DPIF, The University of Tasmania, The Tasmanian Institute of Agricultural Research (TIAR), The University of Queensland and members of the farming community from Tasmania, Victoria, New South Wales and Queensland.

Over the two days a tour of the pilot processing plant installed at New Town Research Laboratories was undertaken as well as product sampling and tastings of green tea grown in Tasmania.

### *5.5.2 Speakers at the workshop*

| | |
|---|---|
| Dr Satoshi Yamaguchi, | Tea Breeder, (MAFF)* |
| Mr Hitoshi Yoshimoto | Tea Researcher (MAFF)* |
| Mr Atusushi Nesumi, | Tea Breeder, (MAFF)* |
| Professor Bill Dodd, | Research Scientist Tissue Culture (University of Queensland) |
| Miss Tina Botwright, | University of Tasmania PhD candidate, (Department of Agriculture Western Australia)[1] |
| Dr Gordon Brown, | Post Harvest Physiologist, TIAR* |
| Mr Lindsey Williams, | Tasmanian Grower from Scottsdale |
| Mr Les Baxter, | DPIF representative |
| Mr Hugh Griffiths, | DPIF representative |
| Dr Brian Chung, | DPIF representative |
| Dr Anne Kitchener | DPIF representative[2] |

* Papers presented at the workshop are included at the end of this report as Appendix IV.
[1] Thesis accompanies this report.
[2] Refer Appendix I for paper.

### *5.5.3 Acknowledgements*

The DPIWE was extremely fortunate to have such distinguished speakers and participants attend the workshop and we would like to extend our thanks to the speakers, participants and staff involved in organising and ensuring the smooth running of the workshop.

## 5.6 Publications

The DPIWE produces various publications which help growers on a wide range of agricultural and horticultural topics. A Service Sheet has been produced specifically for green tea production, covering basic site selection, costs associated with a new venture and the capital costs associated with processing facilities. This Service Sheet is continually being updated and is mailed to anyone expressing an interest in the industry.

Local industry groups and growers in Tasmania are enthusiastic about the potential for green tea production in this State. However, one of the main areas of concern for potential growers is the economic costs and returns involved in establishing a green tea crop. To date there has been a significant gap in knowledge in this area and this report seeks to provide information through the model analysis given in Section 5 *Economic Analysis*.

## 5.7 Media reports

Both the print and broadcast media have provided good coverage of the DPIWE's Green Tea project. These reports often generate a significant number of inquiries.

## 5.8 World Wide Web page

The Tasmanian Government's Web site includes a summary section of the green tea project carried out by the DPIWE. Inquiries for information have been received from a wide variety of locations and countries including the USA, India and mainland states in Australia. Information is disseminated either through printed material or through direct telephone and email contact.

# 6. Appendices

## Appendix I: Green Tea Field Trials in Tasmania

By Anne E. Kitchener


### Summary

The ability to establish 3 cultivars of Japanese green tea (*Camellia sinensis* var *sinensis*) at a range of locations throughout Tasmania has been demonstrated with varying degrees of success. Pests recorded included snails, cutworm, root aphids, small native mammals and rabbits. The incidence of putative fungal disease was low and unverified. Frost damage was recorded at most sites, and was particularly severe at the trial site at Grove, where leaf drop due to frosting occurred. Mechanical damage by wind was also evident at 2 of the 5 sites. Mean daily temperature during the growing season may at least partially contribute to differences in shoot growth observed between the trial sites, however, deficiencies in K and Cu could conceivably account for the comparatively reduced shoot growth observed at 4 of the 5 sites. Timing of first flush was similar at all sites. At least one other cycle of flushing appears to have occurred early in the new year. Analysis of maximum mean shoot length indicated that, in general, highest shoot growth was recorded for cultivar Sayamakaori.


### Introduction

Green tea consumption has been associated with the decreased incidence of certain diseases, including bowel and liver cancer, and diabetes. In Australia, there is increasing interest in alternative beverages and the curative benefits these may impart.
In 1991, the Department of Primary Industry and Fisheries (DPIF) began investigation into the potential for establishment of a green tea industry for Tasmania. In 1993, in conjunction with the Rural Industries Research and Development Corporation (RIRDC), and with the assistance of a number of growers, trial work aimed at evaluating the commercial potential for this crop in Tasmania was commenced.

Today I would like to present the preliminary results of field trials conducted by the New Crops Group. The primary aim of our research was to assess the suitability of the Tasmanian environment for the sustainable production of Japanese Green Tea. As the relative performance of tea plants at each site was considered a reflection of a site's suitability, several performance indicators were selected. These are as follows:

- visual observation of plant health — a) evidence of pests and disease
- nutritional status of plants — a) soil mineral analyses; b) foliar mineral analyses
- extension growth of shoots — a) number and frequency of flushes per season; b) relative amount of extension growth

I will briefly discuss these points, before concluding with our preliminary assessment of the suitability of the Tasmanian environment for the sustainable production of Japanese Green Tea.

### Plant material

Six thousand Japanese green tea plants (*Camellia sinensis* var *sinensis*) were obtained from the Shizuoka Prefecture, Japan, via a commercial tea grower, Mr. Watanabe. Cultivars Yabukita, Okuhikari and Sayamakaori were imported as bare-rooted cuttings into Kingston Quarantine Station, at the end of 1991, where they were quarantined for a period of 18 months prior to their establishment in field trials. This extended quarantine period was necessary to disinfest plants of the exotic Kanzawa mite (*Tetranychus kanzawa*) identified on plants during the quarantine period. Disinfestation was by fumigation with methyl bromide.

## Planting locations

A number of different sites throughout the state were selected for evaluation of their potential for Green Tea production. Five potential commercial co-operators and trial sites were identified for Japanese green tea establishment on the basis of location, climate, grower experience, potential for development and level of interest. The sites were located throughout the state at Don Heads (near Devonport in the North of the state), Scottsdale (in the Northeast of the state), Westerway and Plenty (in the Derwent Valley), and at Grove (in the Huon Valley). An additional trial site was later established at Forthside, also near Devonport, but further inland than the site at Don Heads.

## Site descriptions

### Scottsdale

A field trial was established at "Braeside" in West Scottsdale (grower - L. Williams). This site is exposed and windy and is characterised by cool winters, warm summers and relatively high rainfall. The soil at this site is a deep red kraznozem.

### Devonport

Field trials were established at Don Heads (grower - J. Hill) and Forthside (grower - L. Butler). These sites are characterised by relatively mild winters, warm summers and moderate rainfall. Trial sites were situated on deep red kraznozem soils.

### Derwent Valley

Field trials were established at Plenty (grower - P. Cooper) and Westerway (grower - R. Clark). These sites are characterised by cool to mild winters, warm to hot summers and moderate rainfall. Both sites were situated on alluvial loam flood plains of fast flowing river systems.

### Huon Valley

A field trial was established at Grove Research Station (GRS), located in Southern Tasmania and characterised by cool to cold winters, warm summers and moderate rainfall. The soil at this site is a silty loam over clay.

Table 1: Elevation, annual rainfall and temperature range over winter and summer for 5 Japanese green tea (*Camellia sinensis* var *sinensis*) trials in Tasmania

| Location | Elevation (m) | Annual Rainfall (mm) | Winter Temp (°C) | | | Summer Temp (°C) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Av | Max | Min | Av | Max |
| Scottsdale | 190 | 1167 | 2.5 | 7.1 | 12.0 | 10.5 | 18.2 | 22.1 |
| Devonport | | | | | | | | |
| -Forthside | 130 | 1057 | 3.8 | 7.4 | 11.9 | 10.7 | 16.6 | 20.2 |
| Derwent Valley | | | | | | | | |
| -Westerway | 175 | 583 | 1.5 | 5.7 | 9.9 | 8.2 | 14.9 | 21.6 |
| -Plenty | 70 | 583 | 1.2 | 6.1 | 11.0 | 10.0 | 16.8 | 23.6 |
| Grove | 130 | 827 | 1.9 | 6.9 | 11.81 | 9.3 | 15.8 | 22.2 |

### Planting dates

Trials were planted at Scottsdale, Don Heads, Westerway, Plenty and Grove during January and February 1993. The Scottsdale, Westerway and Plenty sites each received 330 plants with equal numbers of each cultivar; about 500 were planted at Grove, and approximately 3,500 were planted at Don Heads.

Plants growing at Don Heads were later transplanted at Forthside during late May to early June 1994. However, these were pulled up during early January 1995 to make way for replanting in February 1995 with 3000 plants from cuttings propagated at Hill's Transplants (Don Heads). The trial site at Plenty was also abandoned at this time due to lack of irrigation by the grower, and the plants were left as forage for sheep.

### Site preparation

Sites were prepared by the general methods I will now briefly outline. Previously cropped paddocks were sprayed with Roundup® and cultivated. Pre-plant fertiliser (NPK) was applied at varying concentrations by the growers. Planting was into mechanically made furrows; the soil was hilled up by hand post-planting. Straw mulch was applied to suppress weeds beneath tea plants at Grove. Natural litter from poplar trees formed a light mulch for tea plants at Westerway. Irrigation was by overhead sprinklers as required at Scottsdale, Devonport, Westerway and Grove. At Plenty a mobile irrigation system was used to supply water to plants. Soil was fumigated with methyl bromide prior to planting at Forthside.

### Experimental design

A random block design was used with an inter-row spacing of 180 cm and an intra-row spacing of 30 cm.

### Site maintenance

### Weeds

Weeds were controlled as required by herbicide application with a hooded knapsack sprayer and/or hand weeding. A considerable number and variety of weeds were recorded at each of the trial sites. Herbicide application and/or hand weeding appear to have performed adequately as control measures to date. It is expected that the combined effect of weed control measures to date and mulching will be largely sufficient to suppress weed growth in the mature tea crop.

### Pests

Sites were monitored on a regular basis for evidence of disease and for pests or damage caused by pests and appropriate control measures were taken. Pests observed included snails and cutworm at Scottsdale. Although snails may have been feeding upon weeds in preference to the tea plants, snail bait (Defender®; active ingredient metaldehyde) was distributed around plants as a precautionary measure. Browsing damage by rabbits was observed at Forthside, while at Grove grazing damage was attributed to small native mammals. A rabbit proof fence was erected at Forthside. Root aphids were sporadically found on the tap roots of larger plants, or deeper in the soil, at Westerway.

### Disease

Chlorosis of leaves, the cause of which remains undetermined, was observed at Forthside. At Grove, black spots were observed on the abaxial surface and reddish-brown lesions on the adaxial surface of leaves. Adaxial lesions were usually associated with inward curling of the leaf margins. Pathology tests failed to find any evidence of fungal disease. A single report of *Colletotrichum* sp. at Grove remains unverified. Unusual leaf spotting at Westerway may be attributable to fertiliser damage.

Damage due to frost occurred at Scottsdale, Plenty, Westerway and particularly at Grove, where leaf drop due to frosting was recorded. Mechanical damage, especially of young leaves, by wind was evident at Westerway and Scottsdale. At Westerway, examination of a number of dead trees revealed a region of cracked bark around the lower stem, usually associated with callus material immediately above the cracked area. Wind damage was considered causal in this instance, although frost damage may also have contributed to the observed damage. The severity of wind damage at Scottsdale necessitated the construction of a shade cloth shield in addition to the established pine tree wind break. Field observations subsequent to erection of the shade cloth has indicated that young leaves nearest the shade have darkened considerably.

To date no economically damaging pests or fungal disease has been observed during field trials. The primary cause of plant health appears to be damage by frost, although at some sites other factors have contributed. These include mechanical damage by grazing or wind, waterlogging and damage by airborne salt spray.

### Sodium chloride toxicity trial

The hypothesis that leaf tip and margin necrosis observed at the Don Heads site resulted from sodium chloride toxicity induced by air-borne salt spray was tested in our laboratory.

The cut ends of new and old shoot tips (3-4 leaves) of Sayamakaori, Yabukita and Okuhikari plants grown under glasshouse conditions were immersed in NaCl solutions of either 0.2% or 0.4% in deionised water. Control shoots were immersed in deionised water. Table 2 shows the range of toxicity symptoms induced by immersion of cut ends of shoot tips in the different concentrations of NaCl.

Table 2 Toxicity symptoms NaCl on Japanese green tea leaves of different maturity

| | Tip Necrosis | Margin Necrosis | Leaf Fall |
|---|---|---|---|
| Control | | | |
| young | | | |
| Sayamakaori | None | None | None |
| Yabukita | None | None | None |
| Okuhikari | None | None | None |
| old | | | |
| Sayamakaori | None | None | None |
| Yabukita | None | None | None |
| Okuhikari | None | None | None |
| 0.2% NaCl | | | |
| young | | | |
| Sayamakaori | Light | Light | None |
| Yabukita | None | None | None |
| Okuhikari | Light | Light | None |
| old | | | |
| Sayamakaori | Moderate | Moderate | None |
| Yabukita | Light | Light | None |
| Okuhikari | Light | Light | None |
| 0.04% NaCl | | | |
| young | | | |
| Sayamakaori | Severe | Severe | None |
| Yabukita | Severe | Severe | None |

| | | | |
|---|---|---|---|
| Okuhikari old | Severe | Severe | Complete |
| Sayamakaori | Severe | Severe | None |
| Yabukita | Severe | Severe | None |
| Okuhikari | Severe | Severe | Some |

Neither necrosis nor leaf fall was observed on either young or old shoots of any cultivar for plants immersed in deionoised water alone. In contrast, for the 0.02% NaCl treatment, leaves of young shoots (except Yabukita) showed light tip necrosis and leaves of older shoots developed light to moderate tip and margin necrosis. Further, leaves of both young and old shoots of all 3 cultivars immersed in the 0.04% NaCl solution showed severe tip and margin necrosis, while complete leaf loss from young shoots of Okuhikari was recorded.

In order to demonstrate that shoots were taking up the salt solution, leaves were later analysed for NaCl content. Table 3 shows the results of leaf mineral analyses following the toxicity trial.

Table 3 Analysis of Japanese green tea leaves of different maturity following NaCl toxicity trials

| Leaf stage | % NaCl | P | Zn | B | Fe | Ca | Mg | Na | S | K | Mn | Cu | Cl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| old | 0 | 0.18 | 37.0 | 20.2 | 113 | 0.74 | 0.24 | 0.07 | 0.16 | 1.25 | 405 | 20.9 | 0.22 |
| new | 0 | 0.27 | 34.6 | 8.93 | 86.1 | 0.58 | 0.21 | 0.09 | 0.19 | 2.12 | 263 | 4.29 | 0.38 |
| old | 0.2 | 0.21 | 24 | 12.8 | 76.6 | 0.61 | 0.22 | 0.67 | 0.17 | 1.31 | 325 | 7.98 | 1.17 |
| new | 0.2 | 0.28 | 39.0 | 12.5 | 72.3 | 0.59 | 0.26 | 1.06 | 0.17 | 1.91 | 272 | 6.80 | 1.82 |
| old | 0.4 | 0.02 | 26.1 | 8.78 | 78.4 | 0.63 | 0.22 | 1.25 | 0.17 | 1.38 | 315 | 7.58 | 2.19 |
| new | 0.4 | 0.26 | 30.5 | 10.1 | 63.9 | 0.56 | 0.22 | 2.18 | 0.16 | 1.80 | 263 | 4.13 | 2.98 |

Analysis of foliage following NaCl treatment showed increased levels of both sodium and chloride in the leaves of both young and old shoots.

The NaCl toxicity trial conducted in our laboratory supports the hypothesis that leaf tip and margin necrosis observed on trial tea plants growing at Don Heads resulted from NaCl toxicity caused by air-borne salt spray. Both field trial and NaCl toxicity trial highlight the susceptibility of at least 3 cultivars of Japanese Green Tea to injury by salt spray.

## Nutritional status of plants

## Soil analyses

At each site, soil analysis was conducted prior to planting and at intervals following planting (Table 4). Soil was analysed for pH, electrical conductivity (which gives a measure of soil salinity), extractable P and K, and organic carbon (which gives an indication of fertility).

Table 4 Soil analyses for Japanese green tea trials.

| Site | pH | Electrical conductivity (Salinity dS.m$^{-1}$) | Extractable P (mg.kg$^{-1}$) | Extractable K (mg.kg$^{-1}$) | Organic carbon g/100g |
|---|---|---|---|---|---|
| Scottsdale | 6.0 | 0.112 | 107.8 | 635.6 | 7.1 |

| | | | | | |
|---|---|---|---|---|---|
| Devonport | 6.7 | 0.118 | 521.6 | 459.2 | 3.5 |
| Westerway | 6.5 | 0.047 | 160.8 | 211.8 | 1.4 |
| Plenty | 6.1 | 0.145 | 389.3 | 619.5 | 2.2 |
| Grove | 6.5 | 0.119 | 89.0 | 383.2 | 2.8 |

Table 5 Soil chemical properties of some tea soils; from Othieno (1992)

| | pH | Extractable P (mg.kg-1) | Extractable K (mg.kg-1) | Organic carbon (g/100g) |
|---|---|---|---|---|
| Lowest level | 4 | 0.00 | 15.0 | 0.53 |
| Highest level | 5.3 | 24.00 | 308.0 | 8.46 |

Based on a list of soil chemical properties compiled by Othieno (1992) (Table 5), analyses of soils from 5 planting sites indicated that, in general, soils were very high in extractable P, normal to high in extractable K and had adequate organic carbon levels. Analyses also indicated a relatively high soil pH, with averages ranging from pH 6.0 at Scottsdale to pH 6.7 at Devonport. This high pH suggests the potential for nutritional deficiencies in plants grown at all 5 sites.

## Foliar analyses

Since soil nutrient status does not necessarily reflect plant mineral status, foliar analyses were conducted as a further assessment of plant nutritional status. At intervals during growth, a random sample of the top 3-4 leaves (not less than 50 g dry weight in total) were hand plucked and placed into plastic bags which were sealed and refrigerated prior to analysis. Table 6 lists the results of these analyses.

Table 6: Leaf analyses for Japanese green tea trials. U = unwashed, W = washed. 1, 2, 3 corresponds to Grove gradient soil analyses Table 4)

| Site | Date | P % | Zn ppm | B ppm | Fe ppm | Ca% | Mg% | Na% | S % | K % | Mnppm | Cu ppm | NO3 ppm | N % | Cl% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scottsdale | | | | | | | | | | | | | | | |
| | 24/1/95 | 0.29 | 58.2 | 13.6 | 77.9 | 0.36 | 0.22 | 0.02 | 0.19 | 1.73 | 694 | 17.6 | 42.8 | - | - |
| | | 0.46 | 84.9 | 19.5 | 163 | 0.41 | 0.19 | 0.05 | 0.25 | 1.98 | 989 | 12.6 | - | 4.41 | - |
| Say | 28/11/95 | 0.4 | 41.3 | 13.5 | 131 | 0.29 | 0.18 | 0.07 | 0.24 | 2.11 | 729 | 11.4 | - | 4.41 | - |
| Yab | 28/11/95 | 0.30 | 18.8 | 10.4 | 69.9 | 0.25 | 0.14 | 0.04 | 0.17 | 2.12 | 601 | 14.8 | - | 4.79 | - |
| Ok | 28/11/95 | 0.44 | 52.9 | 12.5 | 97.0 | 0.33 | 0.18 | 0.05 | 0.23 | 2.08 | 797 | 12.2 | - | 4.26 | - |
| Jap | 28/11/95 | 0.31 | 18.8 | 10.3 | 70.3 | 0.24 | 0.14 | 0.05 | 0.18 | 2.11 | 603 | 6.18 | - | 3.14 | - |
| Don Heads | | | | | | | | | | | | | | | |
| old (u) | 28/1/94 | 0.3 | 28.2 | 24.3 | 492 | 0.92 | 0.32 | 0.16 | 0.27 | 1.09 | 154 | 13.3 | - | 3.26 | 0.97 |
| old (w) | 28/1/94 | 0.31 | 83.1 | 18.5 | 234 | 0.88 | 0.30 | 0.15 | 0.27 | 1.13 | 885 | 11.4 | - | 3.38 | 1.02 |
| new (u) | 28/1/94 | 0.39 | 35.1 | 17.5 | 160 | 0.54 | 0.31 | 0.28 | 0.27 | 1.39 | 633 | 10.4 | - | 4.42 | 1.58 |
| new (w) | 28/1/94 | 0.41 | 102 | 17.0 | 128 | 0.56 | 0.30 | 0.25 | 0.28 | 1.43 | 461 | 10.9 | - | 4.58 | 1.58 |
| poor | 4/1/94 | 0.46 | 54.4 | 23.7 | 442 | 0.57 | 0.31 | 0.18 | 0.34 | 1.29 | 556 | 20.6 | - | - | - |
| good | 4/1/94 | 0.43 | 68.4 | 22.2 | 179 | 0.46 | 0.28 | 0.17 | 0.3 | 1.19 | 801 | 21.0 | - | - | - |
| Forthside | | | | | | | | | | | | | | | |
| | 10/11/94 | 0.13 | 11.4 | 11.1 | 525 | 1.43 | 0.29 | 0.13 | 0.2 | 0.8 | 619 | 20.3 | - | 2.88 | - |
| Westerway | | | | | | | | | | | | | | | |
| | 17/1/95 | 0.48 | 30.4 | 14.8 | 74.2 | 0.57 | 0.18 | 0.04 | 0.35 | 1.96 | 262 | 2.54 | 40.6 | - | - |
| | 28/2/95 | 0.28 | 26.4 | 16.1 | 88.4 | 0.67 | 0.16 | 0.02 | 0.21 | 1.51 | 240 | 2.29 | 26.6 | - | - |
| Grove | | | | | | | | | | | | | | | |
| new | 22/3/94 | 0.36 | 146 | 12.9 | 115 | 0.35 | 0.24 | 0.06 | 0.21 | 1.81 | 479 | 8.31 | - | - | - |
| old | " | 0.18 | 36.8 | 20.4 | 149 | 0.64 | 0.25 | 0.06 | 0.20 | 1.51 | 925 | 5.84 | - | - | - |
| 1: new | 23/5/94 | 0.27 | 59.3 | 11.9 | 225 | 0.90 | 0.25 | 0.07 | 0.20 | 1.10 | 220 | 3.76 | - | - | 1.31 |
| 1: old | " | 0.15 | 57.9 | 16.4 | 665 | 1.63 | 0.40 | 0.08 | 0.21 | 1.77 | 453 | 7.33 | - | - | 1.98 |
| 2: young | " | 0.29 | 64.2 | 10.8 | 241 | 0.72 | 0.25 | 0.07 | 0.21 | 1.95 | 231 | 4.46 | - | - | 0.89 |
| 2: old | " | 0.12 | 74.0 | 11.4 | 543 | 1.62 | 0.40 | 0.07 | 0.21 | 1.55 | 520 | 1.80 | - | - | 1.31 |
| 3: young | " | 0.24 | 64.5 | 13.2 | 267 | 1.07 | 0.30 | 0.09 | 0.23 | 2.10 | 235 | 4.69 | - | - | 1.24 |
| 3: old | " | 0.12 | 39.8 | 11.4 | 646 | 1.71 | 0.40 | 0.06 | 0.20 | 1.35 | 472 | 4.81 | - | - | - |
| | 17/1/95 | 0.28 | 27.8 | 12.8 | 98.9 | 0.46 | 0.17 | 0.03 | 0.19 | 1.57 | 130 | 4.43 | 26.6 | - | - |
| | 31/1/95 | 0.39 | 55.7 | 8.51 | 67.4 | 0.44 | 0.21 | 0.04 | 0.34 | 2.10 | 245 | 5.22 | 33.0 | - | - |

Critical levels of nutrients for tea were based on references in Tanton (1992), and Reuter and Robinson (1986). Analyses indicated that plants from the Scottsdale site had adequate levels of most nutrients tested. Exceptions were marginal levels of Fe, which were improved but not entirely corrected by the addition of Fe as iron chelate (0.01 g/L), and marginal levels of P, which were adjusted by the addition of superphosphate (100 kg/ha). With the exception of Westerway, plants growing at other trial sites also appeared marginally deficient in P.

Plants growing at Don Heads were marginal to deficient in K and Cu, as were plants at Westerway and Grove. It seems possible that the severe deficiency of Cu at Westerway and Grove may account, at least in part, for the relatively slow growth of plants at these sites. Although only small quantities of Cu are required by plants, many Australian soils are extremely deficient in this element. It is suggested that a schedule of foliar application of copper, such as is applied in Japan as a fungicide, may benefit plants growing at these sites.

Apparently excessive levels of Zn at Grove and Fe at Forthside should not be overlooked.

A fertiliser schedule based on macronutrients NPK was commenced in Spring 1994 (Table 7). Continuous N application appeared to be superior to 3 or 4 side dressings. Continuation of this fertiliser schedule, in addition to application of micronutrients as indicated by leaf analyses is recommended at all sites.

Table 7 Fertiliser schedule for green tea trials

| Site | Fertiliser | Rate |
|---|---|---|
| Westerway | | |
| | superphosphate | @ 100 kg/ha (9% P = 9 kg/ha) |
| | potassium sulphate | @ 100 kg/ha (50% K = 75 kg/ha)<br>i.e. 495 g/row or 16.5 g/m |
| | sulphate of ammonia | @ 300 kg/ha (21% N = 63 N/ha)<br>i.e. 825 g/row or 27.5 g/m |
| Grove, Plenty and Scottsdale | | |
| | superphosphate | @ 100 kg/ha (9% P = 9 kg/ha)<br>i.e. 330 g/row or 11 g/m |
| | potassium sulphate | @ 50 kg/ha (50% K = 725 kg/ha)<br>i.e. 165 g/row or 5.5 g.m |
| | sulphate of ammonia | @ 300 kg/ha (21% N = 63 N/ha)<br>i.e. 990 g/rpw or 33 g/m |

## Extension growth of shoots

To determine timing and amount of extension growth during flushing in field-grown tea plants, length of shoot growth from the terminal bud was measured at regular intervals at 4 of the 5 trial sites. Average extension growth was calculated for each cultivar (Figs 1-4). All 1993/94 season measurements were collected by DPIF staff; 1994/95 measurements for Grove and Westerway were collected by Ms Tina Botwright (Department of Agriculture, University of Tasmania).

Rapid increases in shoot length (first flush) occurred around October-November in all 3 cultivars. Timing of first flush was similar at all sites, but was not recorded at Scottsdale, where measurement of shoots did not commence until the end of the first flushing cycle. At least one other cycle of flushing appears to have occurred early in the new year. Other cycles of flushing may have been obscured by unfavourable local weather conditions including damage by wind or frost, or by poor nutrition, resulting in reduced or uneven extension growth. Nevertheless, the data does give an indication of time of first flush and interval between successive flushes. It is expected that flushing cycles in trial harvested tea will be more pronounced, and will provide a more accurate estimate of yield cycles for commercial harvesting.

Analysis of maximum mean shoot length attained by each of the three cultivars indicated that, in general, highest shoot growth was recorded for Sayamakaori. The exception was at Grove, where Sayamakaori had the lowest extension growth. Mean shoot growth tended to be lowest for the cultivar Yabukita, significantly so at Westerway.

Overall shoot growth was significantly greatest at Scottsdale, reaching 250-280 mm in comparison to 150-200 mm at Westerway in the 1995 growing season, and values of around only 100-140 mm at Grove and Plenty in the 1994 growing season.

## Discussion

6 trial sites were established to asses the suitability of the Tasmanian environment for the sustainable production of Japanese green tea. Plant performance at each site was assessed by 1) visual observations of plant health, 2) analysis of the nutritional status of plants, and 3) by recording the extension growth of shoots.

Of the trial sites, Scottsdale appears to experience conditions most favourable for green tea growth. It is widely accepted that temperature is a major factor controlling shoot growth rate (Carr 1972, Fordham 1977; cited in Tanton 1992). Mean daily temperature during the growing season may at least partially contribute to the differences in shoot growth observed between the trial sites. In support of this hypothesis, Scottsdale receives higher average summer temperatures in comparison to the other sites. Recent installation of data loggers at these sites will facilitate collection of climatic data and allow a detailed investigation of the relationship between flushing and temperature.

The Scottsdale site, while subject to moderate frosting at times, did not experience frosts of the same degree of severity as those experienced often at Grove and occasionally at Westerway. This relative freedom from frosting has also contributed to the superior performance of plants at the Scottsdale site.

In addition to a possibly more favourable temperature regime, analysis of foliar nutrient levels indicated that plants grown at Scottsdale appeared more adequately supplied with essential nutrients, in comparison to plants from the other trial sites.

In addition to frosting damage at Westerway and Grove, marginal levels of, or deficiency in K and Cu at Don Heads, Westerway and Grove could conceivably account for the comparatively reduced shoot growth observed at these sites. The suggestion that copper deficiency may reduce frost tolerance in plants (G Brown, pers. comm.) may at least partially explain the poor performance of plants at Grove, a site where severe frosts are not uncommon. The use of frost chamber equipment in conjunction with nutritional studies may allow investigation such a relationship.

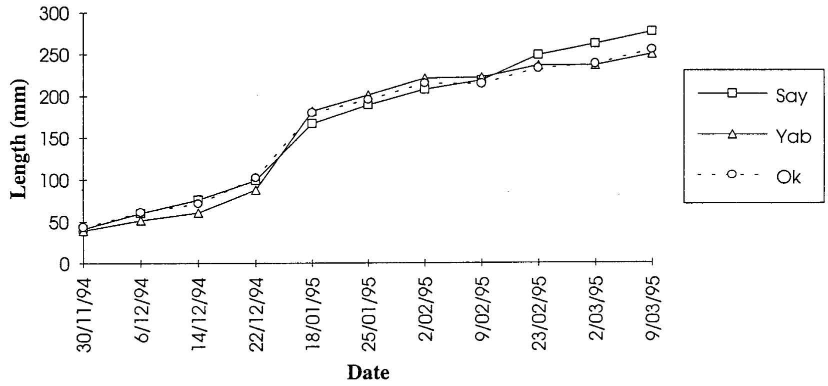


Figure 1 Mean growth of terminal shoots of green tea (*Camellia sinensis* var. *sinensis* at Scottsdale)

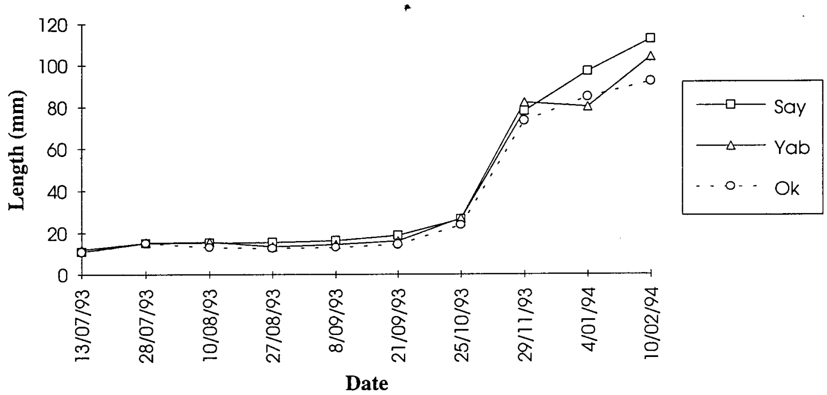


Figure 2 Mean growth of terminal shoots of green tea (*Camellia sinensis* var. *sinensis* at Plenty)

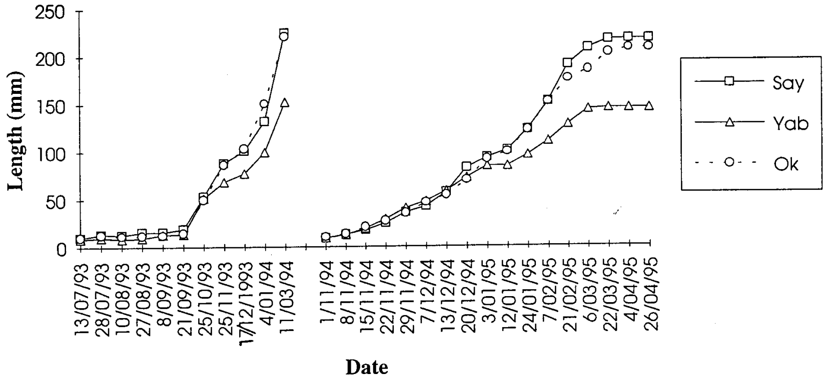


Figure 3 Mean growth of terminal shoots of green tea (*Camellia sinensis* var. *sinensis* at Westerway)

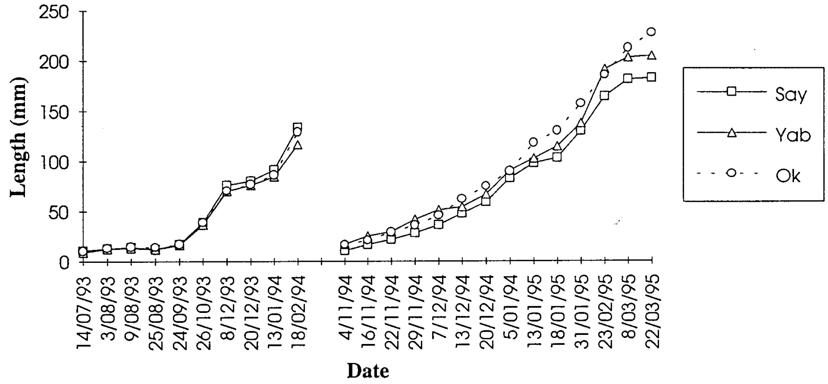


Figure 4 Mean growth of terminal shoots of green tea (*Camellia sinensis* var. *sinensis* at Grove)

Failure of the trial at Plenty may also have been avoided, given more consistent irrigation by the grower, although risk of damage by frosting may exclude this site as a potential location for tea production.

On the basis of severe damage (and sometimes death) the Don Heads trial site was abandoned. All plants were removed and after an attempt made to re-establish healthy plants at Forthside, all plants were destroyed. These results suggest that the Don Heads trial site is an unfavourable location for further development of tea as a plantation crop. The exposed nature of the site is unlikely to accommodate attempts to establish wind breaks that could potentially reduce the severity of salt damage to the tea plants.

The Don Heads trial and subsequent NaCl toxicity trial conducted in our laboratory have highlighted the susceptibility of at least 3 cultivars of Japanese green tea to injury by salt spray.

Plants at Forthside, while situated further inland than at Don Heads, are growing very slowly, and are exhibiting scorched foliage not dissimilar to that seen on plants growing at Don Heads. While severe damage caused by grazing rabbits may partially account for the lack of success at this site, it is suggested that salt toxicity may also be contributing. As a result of continued poor performance, this trial has recently been terminated.

The ability to establish green tea at a range of locations throughout Tasmania has been demonstrated with varying degrees of success. Establishment of further trial plantations at additional trial sites throughout the state is considered necessary to broaden the range of locations potentially suitable for supporting green tea as a commercial crop. In addition, the mineral requirements of tea plants at established sites must be further refined before sustainable production of this product can succeed.

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# Appendix II: Quality Improvement at the Adequate Application Level of Nitrogen Fertiliser to Reduce Pollution

Satoshi Yamaguchi (Dr.Agr.)
The Head of laboratory of Breeding
Department of Tea Agronomy
National Research Institute of Vegetables, Ornamental Plants and Tea,
MAFF, Kanaya-2769, Haibara, Shizuoka 428.JAPAN

## Introduction

In Japan, tea production supports the agriculture activity of mountainous hill regions with very high acid soils. Tea is the most economic crop for such regions because it is very tolerant to high acidic soils (pH5 to 3), it is vigorous even in drought conditions, and tea products are light in weight, easy to transport and maintain high prices per unit weight. Cultivation of tea is also very easy, even for an ageing population and due to recent mechanisation. Tea fields are easily established in the steep valleys, help to prevent land erosion and land slides and retains soil water.

On the whole, tea cultivation is labor saving. Only 25 days of one person's work are spent in the management of 10a tea field, an income of about 400,000 yen average is made by processed tea in Shizuoka Pref. If a farmer refines the tea himself for retail market, the income will be twice large.

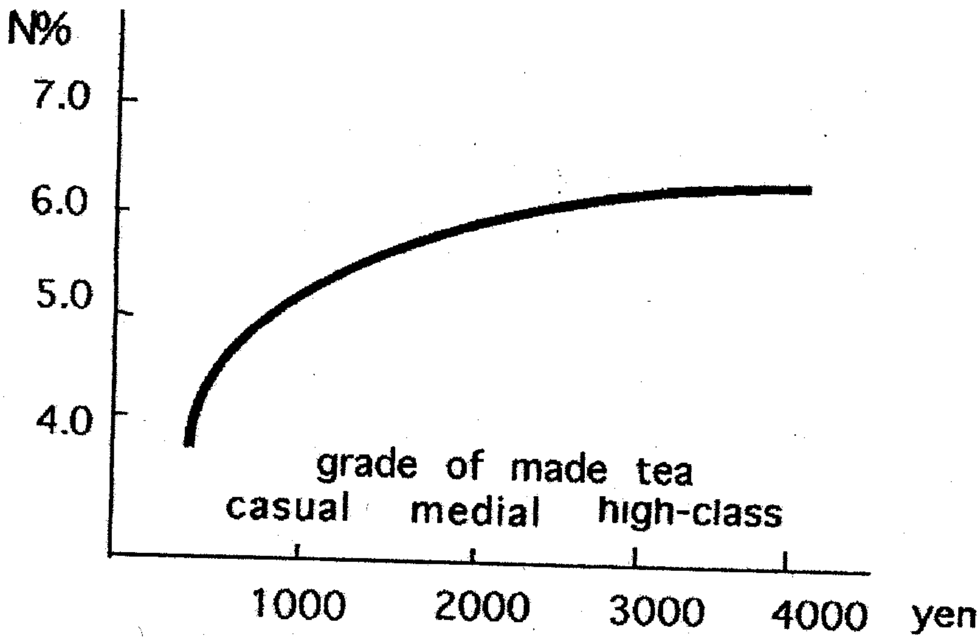
These days in Japan, consumption of tea is gradually decreasing. So, the competition between tea farmers, local corporations, and productive areas is becoming increasingly severe. Many farmers struggle to improve the quality of tea to produce superior taste and aroma. In Japan, many farmers have a superstition about tea quality, in that higher total nitrogen content of tea corresponds to higher quality and higher price, also that by applying increased nitrogen fertiliser they can improve the quality of the tea. Excess application of nitrogen fertiliser has become a common factor in production of tea in Japan. Unfortunately, leaching of excess nitrogen fertiliser from tea field into ground water supplies has been increasing over the last decade. The pollution of ground water is becoming a serious social problem in the areas surrounding tea production regions such as Shizuoka Pref. Now, we must investigate lowering fertiliser level input in farming to reduce water pollution without lowering the quality of made-tea. Effective application principles are needed now in tea field management.

## Fertiliser application of tea fields in Japan

Tea production in Japan has a 500 years history in a practical sense. In an early period of cultivation, dried fish and seaweed was used as natural fertiliser. However, in the early Edo era, human faeces became an important compost for high quality tea production in the Kyoto area.

Currently human faeces are not applied in the production of tea. Instead high levels of chemical fertilisers are used. Just after World War II, the Japanese government needed foreign currency, and intended to get it by exporting agricultural products.

Tea and silk were expected to obtain high levels of foreign currency. To increase the yield of tea, high input of fertiliser was applied onto tea fields. This was the beginning of high levels of application of fertiliser. The average application level of Nitrogen was around 200kg/ha, however, at present it is around 500kg/ha in a year. So 30 years since tea fields have received at least two to three times the amount of chemical fertiliser. At present Japan has nearly 60000ha of tea fields. The present tea production areas in Japan receive at least 30,000 tons of total N content (500*60,000=30,000,000kg=30,000ton). However, a more serious problem is occurring in Japan. Tea farmers tend to ignore the recommended level of fertiliser application. They believe that the higher fertiliser level produces the better quality tea, this is misunderstanding. We can see the linear correlation between the nitrogen content of the made tea and retail price. This is accepted only in the case of lower and medial grade teas. In reality, there is scarce positive correlation between the quality (grading or prices) and the content of nitrogen in made tea.




**Start of fertiliser test**

Using cultivar Meiryoku, fertiliser application tests were started at the different fertiliser levels (Nitrogen content:0,67,134,201,286kg per 10a). After four and five years' continuous applications, several biological and agronomic characters were measured ie, plant height, plant weight, number of shoots, root length, root weight, number of flowers produced, budding date, leaf size, leaf colour, number of adventitious shoots from root, and tea quality with total nitrogen, caffeine, tannin, free amino acid and theanine content.

### Change of leaf size

By heavy application of fertiliser, leaf size increased by 20%.

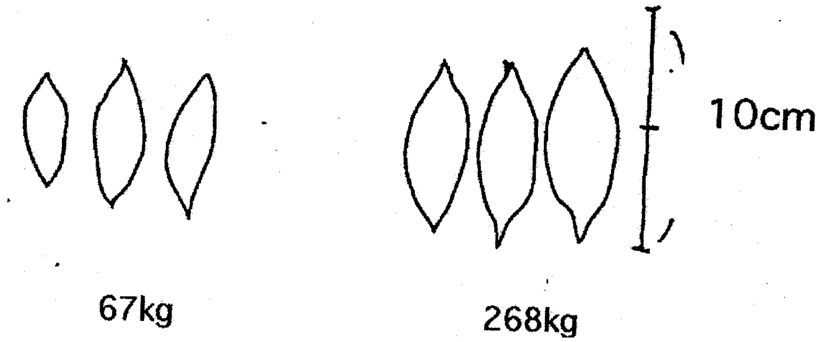



**Fig. Comparison of leaf size at the first year's growth after planting**.

### Leaf colour became deeper green by application of fertiliser.

Heavy application increased the colour strength of overwintering and new emergent leaves of tea.

**Table. Leaf colour and fertiliser level**

| | Measured values for green degree by chlorophyll meter | | |
|---|---|---|---|
| N. App. level | New shoots of '94 Spring | | Overwintering leave of '95 |
| | Top Leaf | Fifth Leaf | |
| 0 (Cont) | 0.68 | 0.89 | 2.54 |
| 67kg/year/10a | 0.76 | 0.95 | 2.68 |
| 134/kg/year/10a | 0.67 | 1.04 | 2.43 |
| 201kg/year/10a | 0.87 | 1.09 | 2.92 |
| 268kg/year/10a | 0.85 | 1.13 | 2.96 |

### Budding time was accelerated

Budding date was nearly two days earlier than control. This would be one of the reasons for early budding and harvesting of Yabukita after heavy application of fertiliser to the crop.

**Table. Progressive data of budding index of new shoots under the variable fertiliser level.**

| Fertiliser | Time course of budding index development | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Level | 1994 Spring | | | | 1995 Spring | | | | | | |
| | 4/11 | 4.18 | 4/26 | 5/4 | 4/10 | 4/13 | 4/17 | 4/21 | 4/24 | 4/26 | 4/28 |
| o (Cont) | 1.7 | 3.3 | 4.4 | 5.1 | 2.0 | 2.1 | 3.0 | 3.3 | 4.0 | 4.0 | 4.1 |
| 67kg | 1.9 | 3.9 | 5.2 | 5.6 | 2.8 | 2.6 | 3.4 | 3.8 | 4.5 | 4.2 | 4.3 |
| 134kg | 2.1 | 4.4 | 5.1 | 5.7 | 2.9 | 3.0 | 4.0 | 3.9 | 4.5 | 4.5 | 4.4 |
| 201kg | 2.0 | 4.3 | 4.9 | 5.7 | 3.0 | 3.3 | 4.0 | 4.2 | 4.6 | 4.9 | 4.9 |
| 268kg | 2.4 | 4.5 | 5.3 | 6.2 | 3.0 | 3.6 | 4.0 | 4.4 | 4.5 | 4.6 | 4.9 |

**Growth was actually accelerated by heavy applications of fertiliser**

Plant volume and weight were increased according to the amount of nitrogen application.

**Table. Metric traits changed after three to four years cultivation under the various fertiliser level.**

| Fertiliser level | Total shoots weight (T) | Root weight (R) | T/R ratio | Leaf Length | Leaf Width | Leaf shape (l/w) |
|---|---|---|---|---|---|---|
| 0kg | 233 | 167 | 1.4 | 8.2 | 2.7 | 3.0 |
| 67kg | 833 | 333 | 2.5 | 8.89 | 3.1 | 2.9 |
| 134kg | 933 | 500 | 1.9 | 8.4 | 2.7 | 3.1 |
| 201kg | 1400 | 600 | 2.3 | 8.1 | 2.7 | 3.0 |
| 268kg | 1167 | 333 | 3.5 | 8.0 | 2.88 | 2.9 |

**Root mass was injured by heavy fertiliser and over flowering was induced.**

Heavy fertiliser, plants root became distorted in their growth and also caused excessive flowering.

**Table. Flower induction effects of heavy fertilisation application on to tea plants**

| Fertiliser level | No. flowers induced on each plant | No. flowers per shoot weight | No. flowers root weight |
|---|---|---|---|
| 0kg | 53 | 229 | 317 |
| 67kg | 78 | 93 | 234 |
| 134kg | 116 | 125 | 232 |
| 201kg | 170 | 121 | 283 |
| 268kg | 307 | 263 | 922 |

**Chemical content of mature leaves was** not variable and did not correlate with fertiliser levels. Accumulation of chemical contents into mature leaves gradually progressed in second and third years after planting. In the third year, there were no significant differences observed in matured leaves.

Table. Chemical contents (%) of matured leaves analysed two and three years after planting

| Fertiliser Level | Total (N) '93 | Nitrogen '94 | Theanine '94 | Total Tannin '94 | Caffeine '94 | Tasty Index (T/N ratio) '94 |
|---|---|---|---|---|---|---|
| 0kg | 2.2 | 3.9 | 0.21 | 10.1 | 0.9 | 2.6 |
| 67kg | 2.6 | 3.8 | 0.13 | 9.1 | 0.9 | 2.4 |
| 128kg | 2.5 | 4.2 | 0.13 | 9.2 | 1.0 | 2.2 |
| 201kg | 2.6 | 4.3 | 0.11 | 8.7 | 0.7 | 2.0 |
| 268kg | 2.7 | 3.9 | 0.10 | 6.8 | 0.3 | 1.7 |

### Recovery after the first skiffing at the third year after planting

The first cut back (skiffing) was carried out two years after planting. The recovering growth was similar to each different fertiliser level. Even plants receiving higher 'P' levels showed nearly the same re-growth as low fertilised tea. Therefore there was no significant increase in growth with increased fertiliser.

Table. Re-growth of tea three months after skiffing

| Fertiliser Level | Average of regrowth in length of new shoots of tea |
|---|---|
| 0kg | 17.6cm |
| 67kg | 33.3 |
| 134kg | 33.0 |
| 201kg | 33.5 |
| 268kg | 32.7 |

## Quality of spring made tea was not affected by heavy fertiliser application

The first harvested new shoots were processed and measured for their chemical contents by NIR Tea Contents Analyser. There appeared to be no clear relationship between the quality concerning chemical components and the degree of application of nitrogen fertiliser. Many tea farmers in present Japan apply non-effective heavy fertilisers onto their tea fields, wasting their labour time, money and pollute their environment. We must accurately manage our tea fields at the proper level of nitrogen fertiliser application lowering the present levels. Lowering the fertiliser level is just as important in continuing the sustainable tea cultivation. According to the present results, the officially recommended level is enough to keep moderate quality tea produced.

Table. Analysis of chemical contents of quality related components of the first cropped made-tea under the different level of fertiliser application

| Fertiliser level | Total Nitrogen (N) | Total Free Amino Acid | Theanine | Caffeine | Total Tannin (T) | Tasty Index (T/N) |
|---|---|---|---|---|---|---|
| 0kg | 4.9 | 2.6 | 1.22 | 2.5 | 16.1 | 3.3 |
| 67kg | 5.9 | 4.1 | 2.14 | 2.6 | 13.3 | 2.3 |
| 134kg | 5.8 | 3.9 | 2.05 | 2.5 | 12.3 | 2.1 |
| 201kg | 5.8 | 4.1 | 2.25 | 2.6 | 12.3 | 2.1 |
| 268kg | 5.9 | 4.1 | 2.15 | 2.6 | 12.2 | 2.1 |

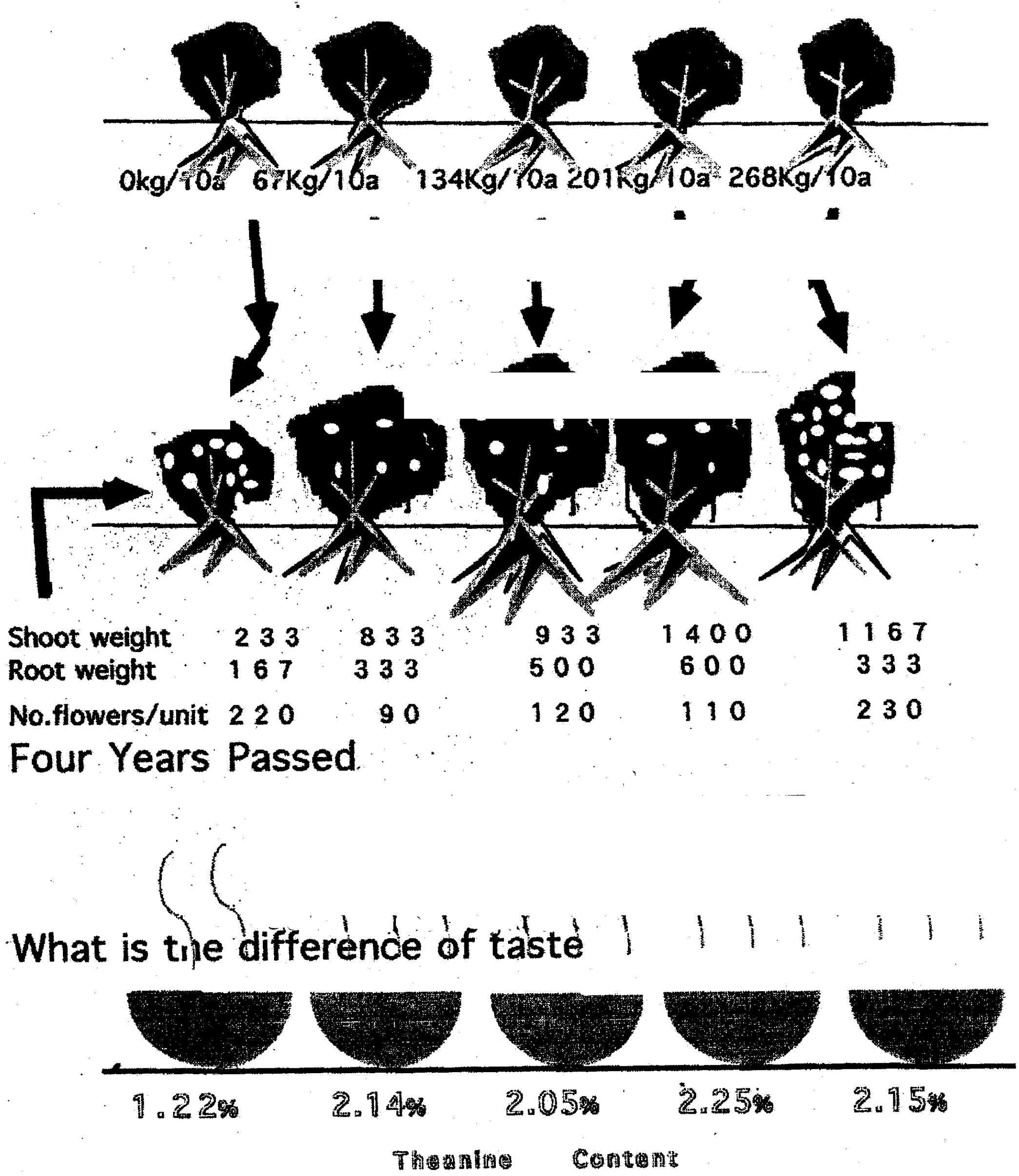
## Generalised remarks

My preliminary experiment showed several interesting results. A brief summary follows:

- Excess fertiliser causes unexpected flower induction. This is the symptom of damage of root part of tea plants, affected by heavy fertiliser.
- Well nourished tea bud breaks about two days earlier than control plants. Vegetative growth was accelerated by excess fertiliser. This is good for early harvest of new shoots, but there is a danger of late frost damage in early spring.
- Excess application does not improve the quality of the final product. Chemical contents relating to tea quality were rather similar in every level of experimental plot of fertiliser application of the recommended rate (67kg), ordinal (twice as much)(134kg), rather excess (201kg) and must excess (268kg) level.

How do fertiliser applications change the growth habit, yield and made-tea quality?

Excess application has been injuring the tea growth. You must be aware of the harmful effects of excessive fertiliser on tea.



# Appendix III: Automatic Control in Tea Manufacturing

Process of Green Tea

Hitoshi YOSHITOMI
National Research Institute of Vegetables, Ornamental Plants and Tea
2769 Kanaya, Kanaya-cho, Haibara-gun, Shizuoka 428 JAPAN

## Abstract

Non-oxidized green tea which is drunk daily in Japan is made through particular manufacturing processes. These traditional manufacturing processes were replaced with tea processing machines, however it is very difficult for a non-expert to operate these machines. We developed an automatic control system for the tea manufacturing process which controls the machines. This system is comprised of three controllers and six tea processing machines used in six sub-processes which are included in a typical tea manufacturing process. It can adequately control all machines throughout the tea manufacturing process, and adapt to differences in the tea and the environment.

## Introduction

Sencha, the standard green tea of Japan, was manufactured by hand in earlier days. However, at present its manufacture is totally mechanised and includes six sub-processes (Fig.1) During this process, the harvested tea leaves are initially steamed to deactivate the oxidising enzymes, and are then dried to a threshold moisture level at which there can be no spoilage of tea during storage. The physical properties of tea leaves change greatly during drying. Therefore the six special mechanism machines used respectively in these processes, must be tuned to the state of tea leaves including temperature, moisture content, and the surface moisture of tea leaves. It is only the skilled manufacturer with a good knowledge and a deep understanding of tea manufacture who would be able to produce a desirable product. However, at present there is a scarcity of such personnel owing to their retirement. Thus, it is thought timely to automate the tea manufacturing process in order to fill the critical vacuum.

## Basic Concept

The final purpose of this study is to develop an operatorless system for tea manufacturing process. Moreover, the system is expected to be able to manufacture teas as good as those that are manufactured by an expert. The newly developed system is one of the solutions and has distinct features which include:

- Feed-back control systems are applied to most of the sub-processes. The control of machines is based on the state of tea leaves that is estimated by the data gathered from the sensors during processing. In addition, feed-forward control based on the experimental data and the knowledge of experts is also applied.
- Considering that the six sub-processes are component of one system, the user interface I concentrated on the supervisor controller. Since an individual control unit attached to each machine can be removed, the cost for instrumentation would be minimal.

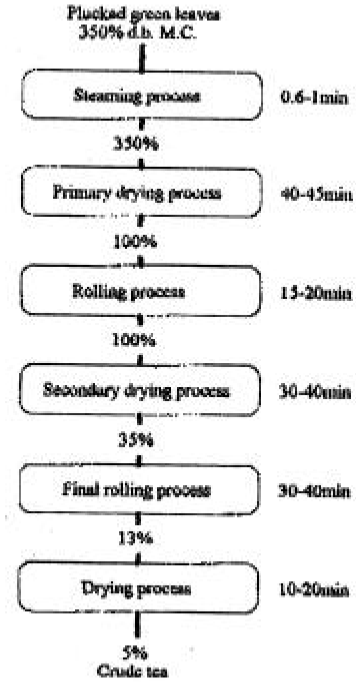



**Figure 1 Manufacturing process**

The supervising control program can be independent of hardware because the difference in hardware is absorbed by the data processor and the I/O processor. Therefore this program can easily be applied to any machine or any system made by other companies.

An object oriented graphical user interface (GUI) is adopted in order to provide an easy operation. it could easily be understood by an operator who is not familiar with the operation of a computer or tea processing machinery.

A feature in this system is its ability to store the information of tea leaves which is symbolised by the icon. Then the stored information is transmitted to the respective machine as the tea leaves move though the serial sub-processes. Each of the machines is able to detect the variability such as maturity in the batch of leaves in situ and adjust itself to optimise the manufacturing parameter. Therefore it would not be necessary to re-adjust frequently when different tea leaves are manufactured in series.

## Hardware

The newly developed system which comprises of three stratified controllers and six green tea processing machines (Fig 2). The controller unit of this system consists of a supervisor, a data processor, and an I/O processor. They are linked to one another through communication lines, each being controlled by its own set of programs. More than 40 sensors are attached to the tea processing machines to measure the state of the leaves and the environment. A total of 18 operations take place in these machines.

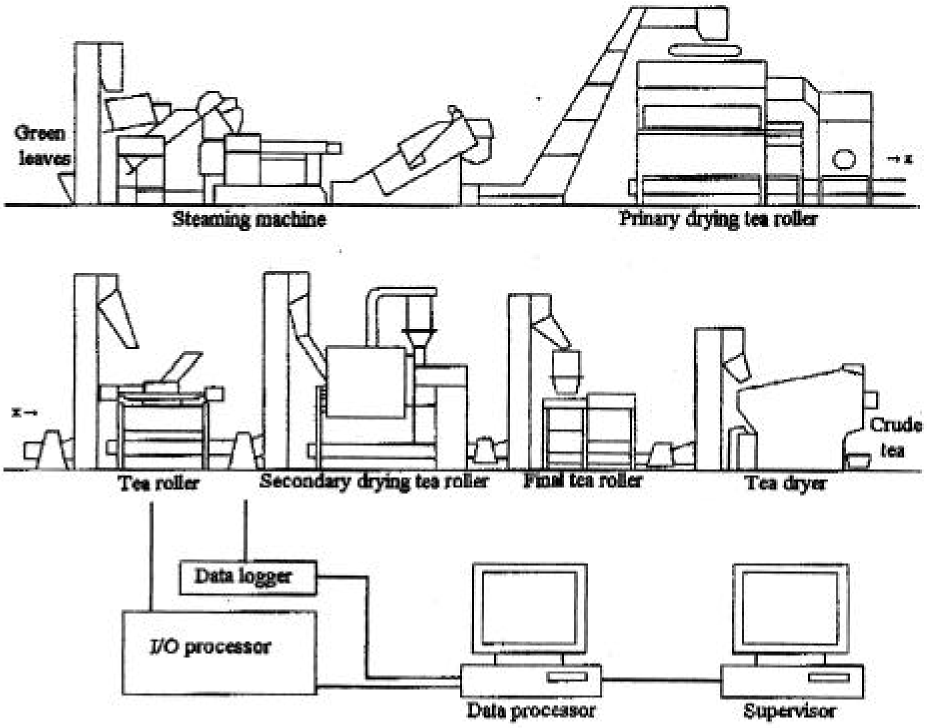



**Figure 2**

**Automatic Control System for Tea Manufacturing Process**

The I/O processor or the data logger acquires the measured data from the sensors, and transmits them to the data processor. The data processor then converts these data into physical values. The supervisor then receives the physical values and calculates controlled values, and transmits them back to the data processor. The data processor converts the control values again for the hypothetical machines into those for actual machines, and transmits them to the I/O processor for execution for the control of the machines.

## Sensing

It is important that respective sensors monitor the state of the tea leaves during the manufacturing process. The key parameters include temperature, moisture content, and the dampness of the surface of the tea leaf. In manufacturing the entire process is considered a drying process. Some of these parameters can be measured directly with the sensors attached to the machines, while the others must be estimated by computing the data that is gathered by some sensors (Table 1).

For example, the moisture content of tea leaves during primary drying process can be estimated from the accumulated quantity of evaporation. The quantity of evaporation is also calculated from the absolute humidity of the supplied air, the absolute humidity of the exhaust air, and the volume of supplied air.

**Table 1. Measurement of the State of Tea Leaves**

| Sub-Process | Temperature of Tea Leaf | Moisture Content of Tea Leaf | Damp of Tea Leaf Surface |
|---|---|---|---|
| Primary drying | Thermister | *Humidity difference*<br>*Integration*<br>Supplied air humidity<br>Dry and wet bulb hygrometer<br>Exhaust air humidity<br>Dry and wet bulb hygrometer<br>Supplied air quantity<br>Pitot tube | Resistance meter<br>*Calculation*<br>Supplied air humidity<br>heated air temperature<br>Thermocouple<br>Temperature of Tea Leaf |
| Rolling | | Resistance meter | Resistance meter |
| Secondary drying | Radiation thermometer | *Humidity difference*<br>*Integration*<br>Supplied air humidity<br>Dry and wet bulb hygrometer<br>Exhaust air humidity<br>Dry and wet bulb hygrometer<br>Exhaust air quantity<br>Propeller meter | *Calculation*<br>Supplied air humidity<br>Heated air temperature<br>Thermocouple<br>Temperature of Tea Leaf |
| Final drying | Temperature dependent resistor | Resistance meter | *Resistance meter* |
| Drying | Temperature dependent resistor | Near-infra-red moisture meter | |

### Control

The supervisor controls the tea processing machinery according to the information collected from tea leaves. It receives information regarding the state of the green tea leaves during processing. The strategy of manufacturing high quality tea is based on a good leaf standard and the attention to details of manufacture. For example, tea leaf temperature must be kept low, and the surface of tea leaves must be kept wet during processing. The schematic diagram about control of primary drying process is show in Figure 3.

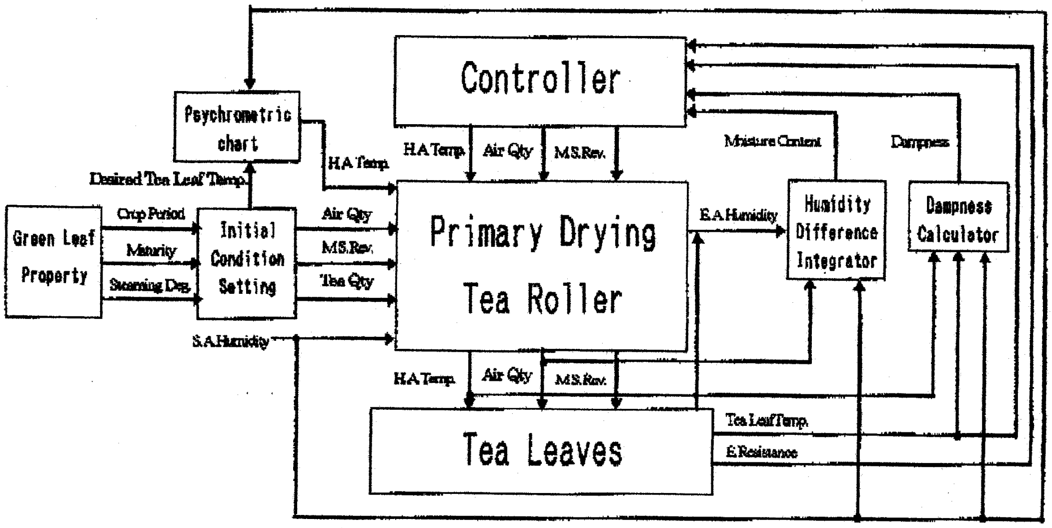



**Figure 3**

**Schematic Diagram about Measurement and Control of Primary Drying Process**

A fuzzy control method is adopted in the program of the supervisor. The tea processing machines can be controlled by not numerical values but language owing to the introduction of fuzzy logic. For example, the rules for the control of the heated air temperature are described in the following:

| | | |
|---|---|---|
| ***Rule 1*** | **If** | the tea leaf temperature is high |
| | | **then** lower the heated air temperature. |
| ***Rule 2*** | **If** | the tea leaf temperature is slightly high |
| | | **then** slightly lower the heated air temperature. |
| ***Rule 3*** | **If** | the tea leaf temperature is slightly low |
| | | **then** rise the heated air temperature. |

The schematic diagram about fuzzy control is shown in Figure 4. A fuzzifier converts the numerical data to the grade of membership of the fuzzy set which is defined by the ambiguous word like “slightly high”, and a defuzzifier converts conversley. In other words, the measured value is replaced with the linguistic equivalent and its grade of membership, and the linguistic description of the control value and its grade of membership are converted to the numerical control value. Therefore the rules of determining the control value can be described with the ambiguous words as mentioned above.

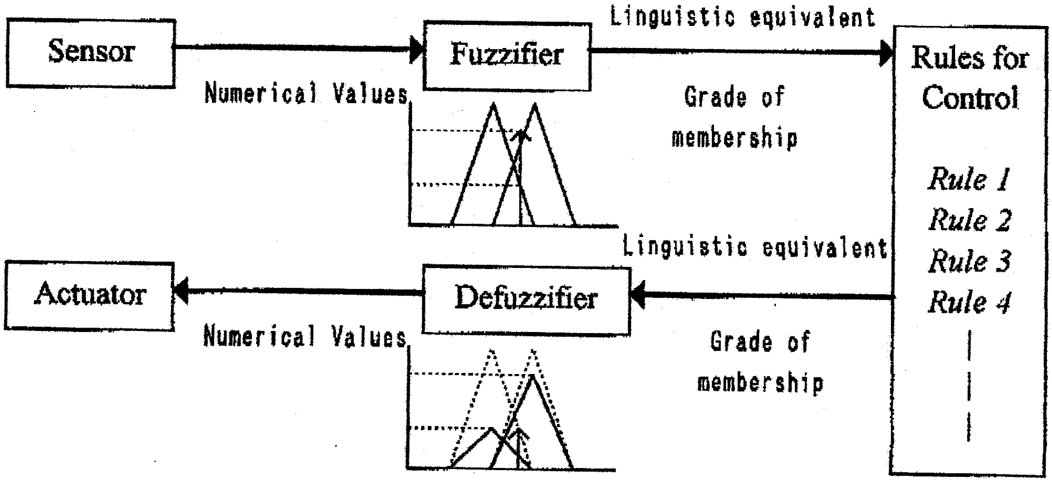



**Figure 4**
**Schematic Diagram about Fuzzy Control**

### Operation

The operator controls the supervisor with the help of a computer mouse. The object oriented interface of this supervisor enables even a laymen to operate it with relative ease.

The commission of manufacturing to the system is started by a click of the receipt button. The relevant data of the tea leaves that is used for manufacture can be chosen from the list box. Then an icon, an image which consists of a tea flush appears. The steaming machine would be initiated by positioning the icon on the figure that presents the steaming machine on the supervisor screen.

As the tea leaves move through the serial sub-processes, its actual position can be monitored by observing the icon on the screen. The information regarding the tea leaves which is transmitted to the control module would be used for optimum control of the respective machine. At any moment, the operator can monitor the measured values and the control values of any sub-process by the more click of the button corresponding to the respective sub-process (Fig. 5). Further, all the data can be stored in a floppy disk for further use or for reference.

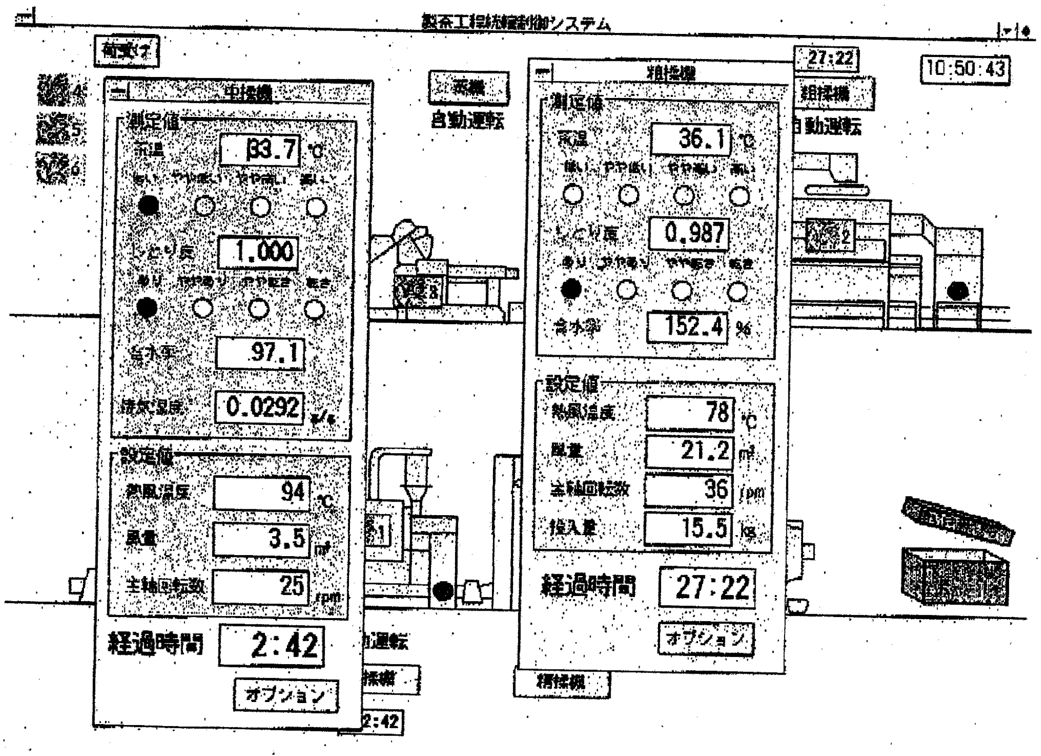



**Figure 5**

**Graphical User Interface of the System**

This system operated very well in some experiments with fresh tea leaves. As an example, experimental results obtained from the primary drying process is shown in Fig 6. The computer automatically reduced the heated air temperature to maintain tea leaf temperature at a constant level and also reduced the supplied air quantity to keep the surface of the tea leaf wet. However, the measured value of tea leaf temperature did not coincide with the actual value during the initial stage of the primary drying process as the sensor had been over heated during preheating before processing.

Attempts to improve the above system are continued. A fuzzy expert system using artificial intelligence is to be adopted in the next set of trials, and new sensors would be added. It is envisaged that in the near future an operator less tea processing system would be able to produce high quality tea as well as an expert.

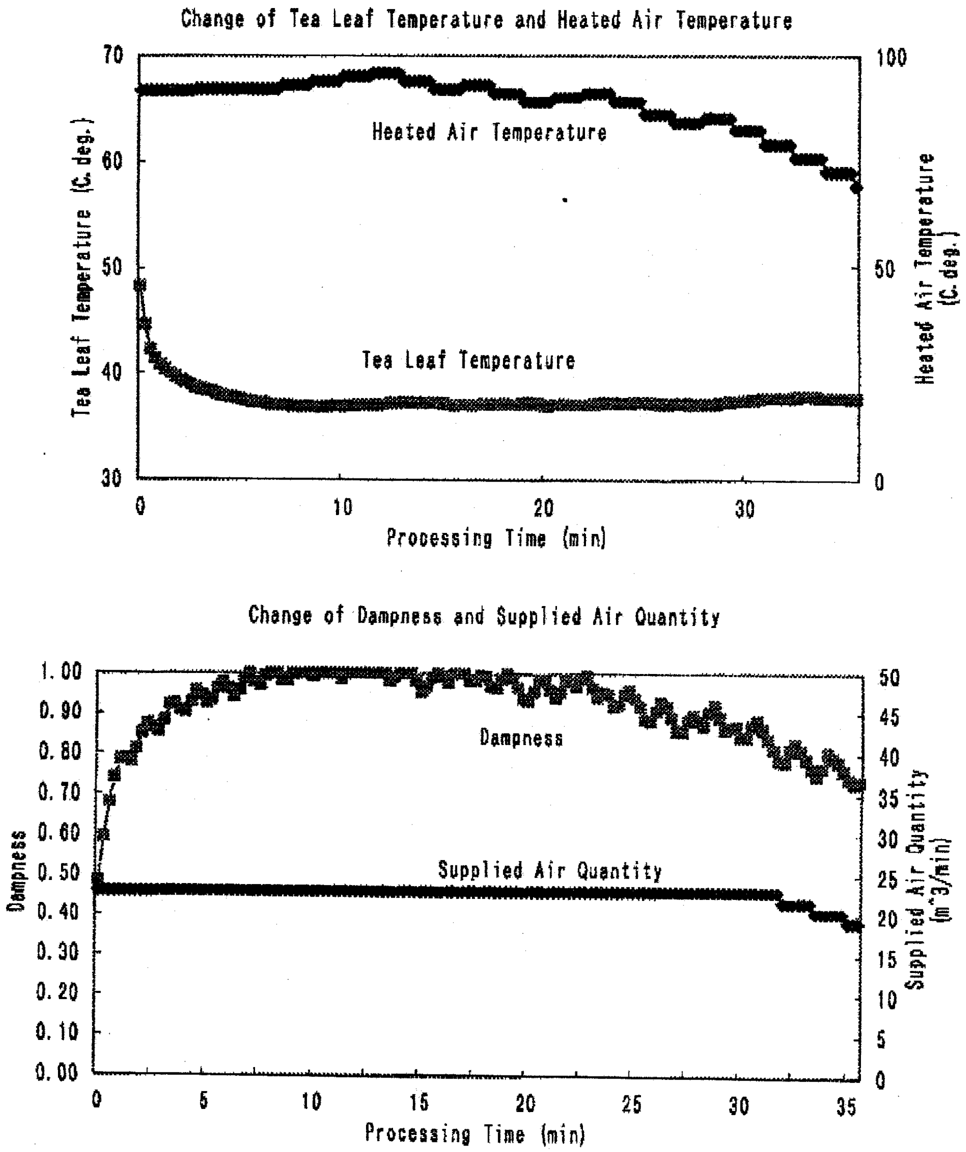



**Figure 6 Experimental Results**

## Appendix IV: Varietal Characteristics of Dormancy of Tea Cultivars in the Warm Region of Japan

Atsushi Nesumi
Laboratory of Tea Breeding
Makurazaki Station
National Research Institute of Vegetables, Ornamental Plants and Tea (NIVOT)
MAFF
Beppu, Makurazaki, Kagoshima Pref

### Introduction

The history of tea production in Japan is very old, it started more than 1200 years ago. It is said that planting area of tea had already spread around Japan by the 10th century to the present distribution.

Japanese green tea was one of the most important exports in the late 19th century, and in that time the tea breeding had already started by the government. Tea breeding has been carried out at four research stations to develop new cultivars suitable for different climatic regions (Fig 1). Kanaya, which is located in Shizuoka prefecture is a main station of National Research Institute of Tea (Nivot). Makurazaki, in Kagoshima prefecture is a sub-station of Nivot. Saitama and Miyazaki are prefectural research stations, officially registered as substantial to (Nivot).

Breeding objects of each station are as follows:

- (Saitama) cultivars for the cool hilly regions around Kanto district.
- (Kanaya) cultivars for temperate regions around Honshu and Shikoku districts.
- (Miyazaki) cultivars for temperate and mountainous regions in Kyushu district, and ones for Kamairi-cha (pan fired tea) which is a type of green tea especially produced in northern parts of Kyushu.
- (Makurazaki) cultivars for warm regions around southern parts of Kyushu, Shikoku and Honshu, where the annual mean temperature is higher than 17°C.

In this paper, I will introduce the present conditions of tea production in Japan, especially in the warm region, and experiments regarding dormancy in tea plants that have been investigated at the Makurazaki station.

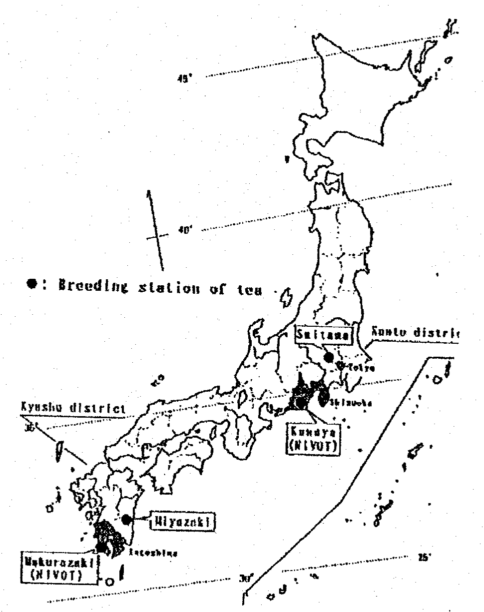


**Fig. 1. Breeding stations of tea in Japan, supported by the Japanese Government**

## Cultivation of Tea in Japan

Before World War II, most of tea plants were propagated by seed in Japan. Clonal cultivars have been spread rapidly after 1960 by the advance of cutting nursery techniques, combined with the release of the elite cultivar "Yabukita" (Fig. 2). Now tea is cultivated economically in all prefectures south of the 37° north latitude (Fig. 3).

Total tea planting areas is 55,278ha and the ratio of clonal cultivars amount to 83%. About 70 clonal cultivars have been released in Japan. However the leading cultivar "Yabukita" occupies 86.5% of all total clonal cultivars planted. (Fig 4).

Monopolisation by one cultivar "Yabukita" brings about positive and negative effects to tea cultivation and industry. The positive effects are popularisation of growing and manufacturing techniques of tea and this brings remarkable improvement of tea quality. The negative effects are unification of tea taste and aroma, increase in disease and insect injuries and centralisation of tea manufacturing.

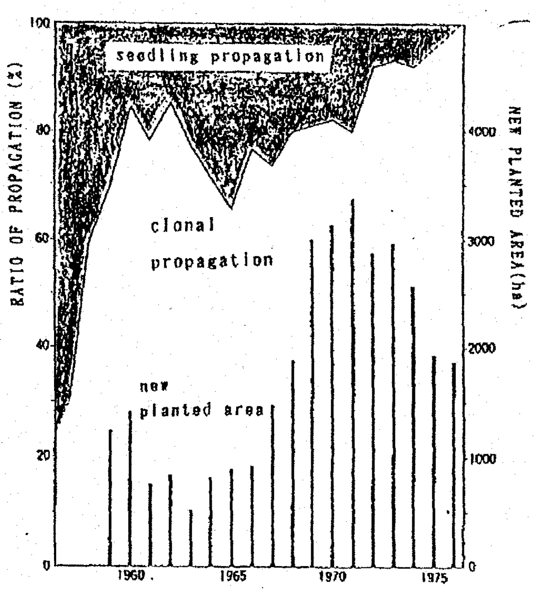



**Fig. 2. Changes of Propagation method and newly planted areas.**

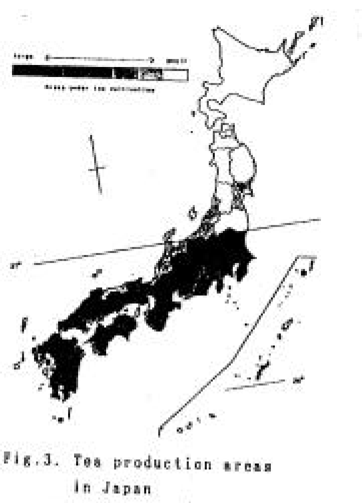



**Fig. 3 Tea production areas in Japan**

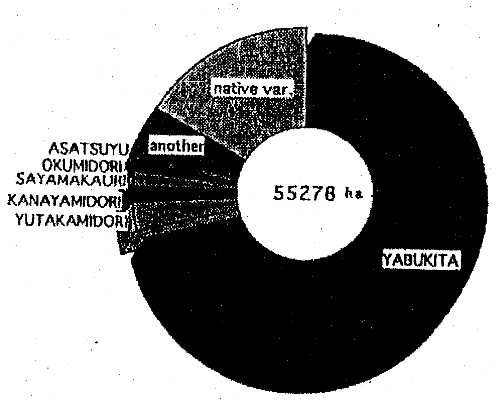



**Fig. 4. Ratio of cultivars**

## Characteristics of tea production in the warm region

Timing of the first harvest of tea is very important in Japan. The earlier tea is sent to the market, the better the prices in Japan. (fig 5) This phenomenon seemed to be based on Japanese thought that eating the first made crops are good for health and luck.

So the early harvested teas obtain higher prices than the later ones comparatively. Early budding tea cultivars in the warm region are sent to the market earlier and more profitable than those in the temperate and the cool hilly regions. (Fig 6). For example, a mean price of early products in Kagoshima was about 6000 to 8000 yen per kg of made tea, but “Yabukita” in Shizuoka and Kagoshima prefectures are about 3000 to 5000 yet (new shoots were harvested with a plucking machine). Therefore in Kagoshima prefecture, ratio of early budding cultivars are higher than that of other prefectures (Fig 7).

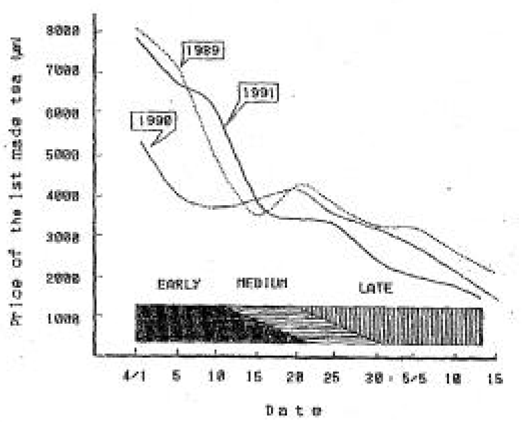



**Fig. 5. Fluctuations in prices of the 1st made tea in Kogoshima market**

## Breeding Objects in Makurazaki (Nivot)

Makurzaki, a sub-station of tea research (Nivot) is located in the southern part of Kagoshima prefecture. Annual mean temperature is about 17.6°C, and mean minimum temperature in January is about 6°C.

Our main breeding object is to develop new cultivars suitable for warm regions in Japan, for example, they are early budding cultivars with high yielding ability, insect and disease resistance, resistance to cold and frost injuries and excellent taste and aroma.

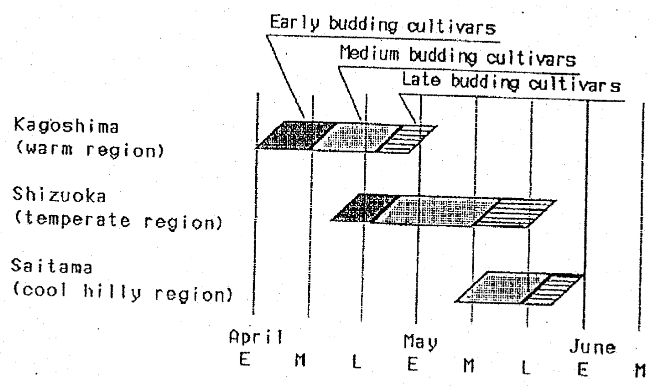



**Fig 6. Differences of plucking term in Kagoshima, Sizuoka and Saitama prefectures**

In 1991 we released a new early budding cultivar Saemidori, which has high yielding ability, resistance to tea anthracnose and excellent taste and aroma. Bud opening and plucking time of Saemidori are earlier about 4 days than Yabukita in Kagoshima. However, Saemidori is sensitive to the frost in early spring as well as other early cultivars. Farmers have to utilise electric fans or irrigation to protect from the frost damage even in a warm region. Therefore, raising the new cultivars with resistance to the late frost injury is a one of important breeding objectives.

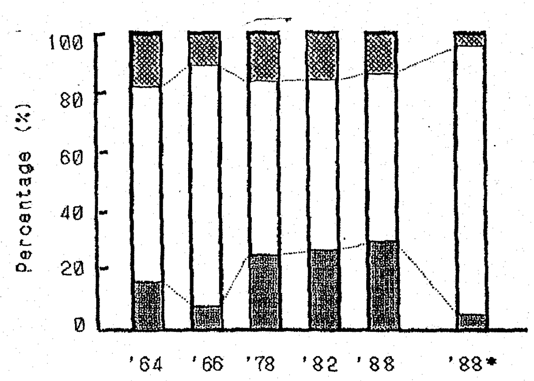



**Fig. 7. Ratio of cultivars in Kagoshima prefecture**

## Characteristics of dormancy in Tea Cultivars

It is said that cold resistance of tea plants is related to the dormancy in winter. Yanase (1) reported cold resistance is connected with earliness of tea cultivars (1971), (2) Uniformity of budding was influenced by degree and term of dormancy (1973), (3) Shifting of the winter buds to the dormant stage was induced by short-day and low temperature (1974).

Experimentation was carried out by Hachinohe *et al.* To clarify the relationship between the dormancy of tea cultivars and climatic factors in warm regions. The results were as follows:

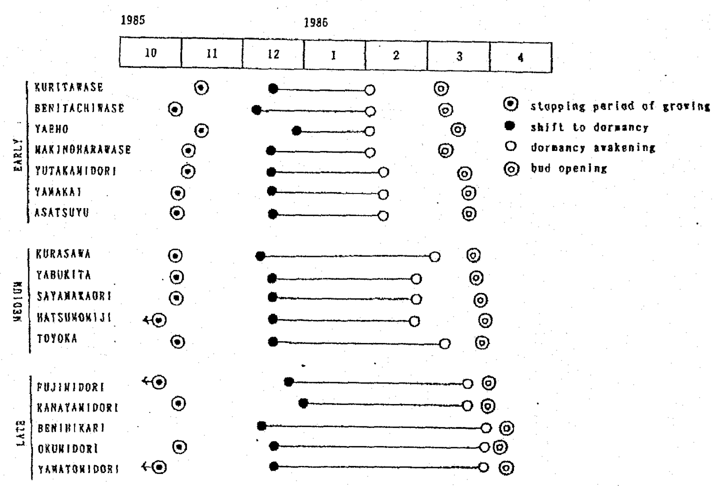
- It was possible to test varietal differences of the dormant characteristics by using a vase-method. Dormant cut-shoots were collected and kept in water culture in a growth chamber controlled at 20°C and 25°C for 12 hours respectively under an artificial lighting condition for 24 hours. The time taken to break dormancy indicated by bud break the shoots was judged to be dormant when bud break of shoots was not observed after 7 days in water culture. On the other hand, dormancy breaking time was determined when bud break of shoots was observed in less than 7 days (Table 1).
- The time taken to break dormancy and bud break was different to the dormancy and awakening time from the dormant stage was different. The term and degree of dormancy of late budding cultivars was longer and deeper than those of the early budding cultivars. The

medium budding cultivars were in the middle range of these cultivars. The dormancy breaking time of the late budding cultivars were generally later than the early budding cultivars, and the medium budding cultivars were in the middle range of them (Fig 8). It was estimated that dormant period, degree of dormancy and dormancy awakening time were genetically related to the time of bud opening.

**Table 1. Degree of dormancy in winter (Hachinohe et al, 1988)**

| Cultivars | Days to the bud break (Degree of dormancy) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nor./ | | | | Jan./ | | | | Feb./ | | | | Mar./ | | |
| | 3 | 10 | 17 | 24 | 31 | 7 | 14 | 21 | 28 | 4 | 10 | 18 | 25 | 4 | 11 | 18 | 25 |
| Early budding | | | | | | | | | | | | | | | | | |
| Benitachiwase | | | | 13 | 16 | 13 | 13 | 11 | 10 | | | | | | | | |
| Makinoharawase | | | | | | 13 | 13 | 17 | 16 | 13 | 11 | 11 | | | | | |
| Yutakamidori | | | | 10 | 19 | 20 | 18 | 14 | 13 | 18 | 13 | 11 | | | | | |
| Asatusyu | | | | | 13 | 13 | 13 | 11 | 7 | 13 | 7 | 11 | | | | | |
| Medium budding | | | | | | | | | | | | | | | | | |
| Kurasawa | 10 | 13 | 41 | 26 | 27 | 25 | 24 | 23 | 16 | 17 | 14 | 14 | 11 | 10 | 10 | | |
| Hatsumomiji | | | | 10 | 27 | 20 | 13 | 11 | 13 | 13 | 14 | 11 | | | | | |
| Yabukita | | | | 16 | 19 | 18 | 17 | 16 | 13 | 7 | 11 | | | | | | |
| Sayamakaori | | | | 10 | 16 | 16 | 13 | 7 | 13 | 13 | 7 | 11 | 7 | 7 | 10 | | |
| Toyoka | | | | 26 | 13 | 13 | 18 | 11 | 16 | 7 | 7 | 16 | | | | | |
| Late budding | | | | | | | | | | | | | | | | | |
| Kanayamidori | | | 13 | 13 | 27 | 25 | 21 | 20 | 16 | 20 | 19 | 14 | 11 | 10 | | | |
| Okumidori | 10 | 11 | 13 | 23 | 27 | 20 | 21 | 23 | 20 | 25 | 22 | 18 | 17 | 17 | 15 | 14 | 10 |
| Benihikari | | | | | 19 | 13 | 13 | 20 | 20 | 20 | 7 | 11 | 7 | 17 | 14 | 10 | |
| Yamatomidori | 10 | 13 | 17 | 28 | 27 | 25 | 24 | 23 | 20 | 25 | 22 | 21 | 14 | 17 | 17 | 14 | |

1986 to 1987 (Makurazaki)




- It was observed that many cultivars began to shift to the dormant stage in Dec. 20. Path coefficient analysis between the degree of dormancy and climatic factors (air temperature and day-length) indicated that the dormancy of tea plants growing in a warm climatic region was begun by short-day effect bud break was induced by a long-day effect (Table 2).

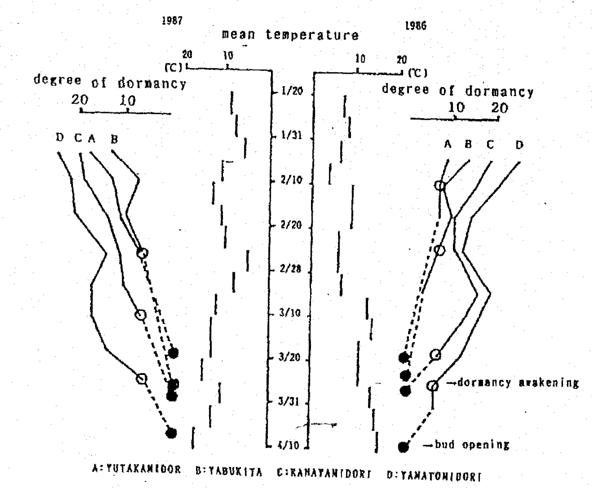
**Table 2. Effect of climatic factors to degree of dormancy by path coefficient analysis (Hachinoke et al., 1988)**

| | Earliness of cultivars | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Early | | | Medium | | | Late | | |
| | X1 | X2 | X3 | X1 | X2 | X3 | X1 | X2 | X3 |
| via | | | | | | | | | |
| X1 | <u>-0.171</u> | -0.141 | 0.001 | <u>-0.200</u> | -0.183 | 0.017 | <u>-0.803</u> | -0.763 | -0.484 |
| X2 | 0.030 | <u>0.037</u> | 0.008 | -0.062 | <u>-0.068</u> | 0.000 | 0.322 | <u>0.339</u> | 0.179 |
| X3 | 0.004 | -0.186 | <u>-0.864</u> | 0.068 | 0.003 | <u>-0.823</u> | -0.192 | -0.168 | <u>-0.319</u> |
| total | -0.137 | -0.290 | -0.855 | -0.194 | -0.248 | -0.806 | -0.673 | -0.592 | -0.624 |
| rθI | -0.137 | -0.290 | -0.855 | -0.194 | -0.248 | -0.806 | -0.673 | -0.592 | -0.624 |
| effects | | | | | | | | | |
| direct | X1($d_{01}$) 0.029 | | | 0.040 | | | 0.645 | | |
| | X2($d_{02}$) 0.001 | | | 0.005 | | | 0.115 | | |
| | X2($d_{03}$) 0.746 | | | 0.677 | | | 0.102 | | |
| indirect | (d0…)-0.026 | | | -0.003 | | | -0.324 | | |
| residual | (d0..) 0.250 | | | 0.281 | | | 0.462 | | |

X1: lowest temperature, X2: highest temperature, X3: day length
Numbers with underline show path coefficient

- It seemed to be varietal differences in the degree of the dormancy. The change of the phase from dormant stage to the growing one in late budding cultivars were closely related to the air temperature (Fig 9). Therefore, it's estimated that varietal differences in the degree of dormancy are caused by the differences in the sensitivity to temperature.

- Medial budding cultivar "Kuraswa" showed a long and deep dormancy, like late budding cultivars (Fig 8). These characteristics differed from the other medium budding cultivars. On the basis of this information, the breeding of early budding cultivars with longer and deeper dormancy seems to be possible.




## Dormant characteristics of hybrids

Characteristics of dormancy in "Kuraswa" seemed to be effective for breeding. Degree of dormancy and time taken breaking dormancy of hybrids were investigated in the cross combinations of "Yabukita x Kutakamidori", "Kutakamidori x Kanayamidori" and "Yabukita x Kurasawa". Characteristics of dormancy and earliness of these parents were showed in Table 3. It was said that degree and awakening time of dormancy and bud opening time are relatively (Yanase). If we can estimate the degree and awakening time of dormancy in tea cultivars from earliness of bud opening time, mean of depth and dormancy breaking of hybrids are expected as follows: "Yutakamidori x Kanayamidori" ≥ "Yabukita x Kurasawa" > "Yabukita x Yutakamidori". However, degree of dormancy and dormancy breaking of "Yabukita x Kurasawa" were deeper and later than the crosses of "Yutakamidori x Kanayamidori" and "Yabukita x Yutakamidori" (Table 4).

Frequency distribution of degree of dormancy is shown in Fig 10. As they showed normal distributions, we can say the dormancy of "Kurasawa" has quantitative genetic characteristics. From these results, it seems that we can develop the early plucking (rapid growth after bud break) cultivar with late budding traits, suitable for avoiding from the late frost damage in early spring.

**Table 3. Characteristics of dormancy and earliness in parents cultivars by hybrids at Makurazaki**

| Cultivars | Earliness | The day of shift to dormancy | Dormancy awakening day | Term of dormancy | Bud opening time |
|---|---|---|---|---|---|
| | | | | (days) | |
| Yutakamidori | (E: -7,-4) | 12/16 | 2/18 | 62 | 3/19 |
| Kurasawa | (M: -4,-1) | 12/9 | 3/11 | 92 | 3/22 |
| Yabukita | (M: 0, 0) | 12/19 | 2/25 | 68 | 3/26 |
| Kanayamidori | (L:+3,+4) | 12/16 | 3/15 | 89 | 3/29 |

E: early, M: medial, L: late

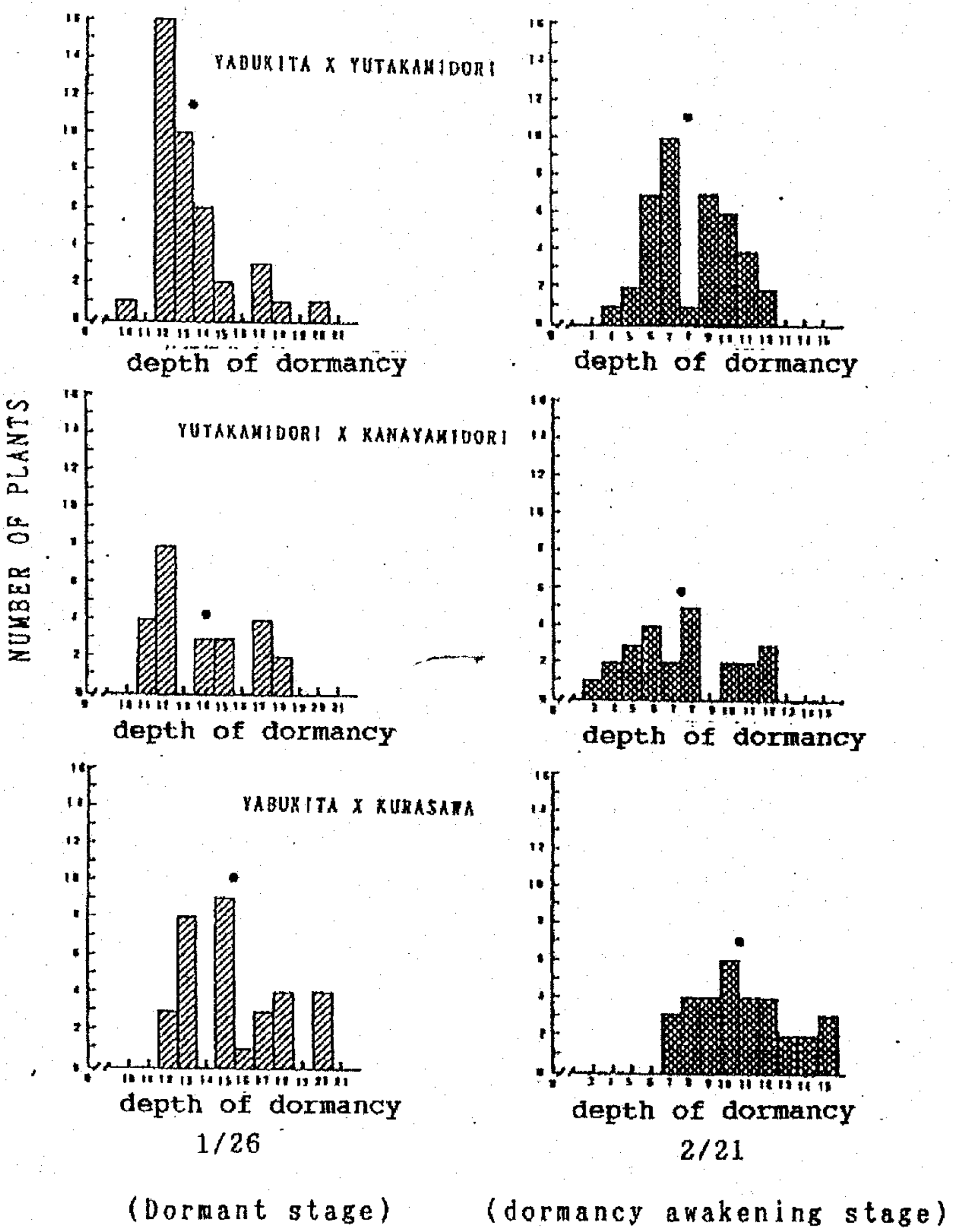
( , ) : left side shows time of bud opening, right side shows plucking time.

- means number of days earlier than Yabukita, and + number of days means later than Yabukita.

Term of dormancy: It shows the number of days of the change from dormant to dormancy breaking.

Table 4. Degree of dormancy in dormant and dormancy awakening stage

| Combinations | | Degree of dormancy | |
|---|---|---|---|
| | | Dormant period(1) | Awakening period(2) |
| Yabukita | x Yutakamidori | 13.5 | 8.1 |
| Yutakamidori | x Kanayamidori | 14.2 | 7.6 |
| Yabukita | x Kurasawa | 15.5 | 10.6 |


NUMBER OF PLANTS
YABUKITA X YUTAKAMIDORI
depth of dormancy
depth of dormancy
YUTAKAMIDORI X KANAYAMIDORI
depth of dormancy
depth of dormancy
YABUKITA X KURASAWA
depth of dormancy
depth of dormancy
1/26
2/21
(Dormant stage)
(dormancy awakening stage)

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# Appendix V: Tasmanian Green Tea Quality

Gordon S Brown
Tasmanian Institute of Agricultural Research
Department of Primary Industry and Fisheries
GPO Box 192b, Hobart, Tasmania, Australia 7001

## Introduction

The Tasmanian Department of Primary Industry and Fisheries initiated research in the early 1990's on the potential of establishing a Japanese style green tea industry in Tasmania. The first phase of the project involved the importation of green tea plants from Japan. To this end three cultivars were successfully imported through plant quarantine. These were 'Yabukita', 'Okuhikari' and 'Sayamakaori'.

The second phase of the project involved the multiplication and establishment of the three cultivars at 5 sites in Tasmania.

The third phase of the project involved the assessment of the field grown plants for yield and quality. The first harvest of leaves from the most advanced site (Scottsdale in Tasmania's north east) was made on 10 November 1995. These leaves were transported to New Town where they were processed in a small scale Japanese green tea processing plant. The tea quality from these leaves forms the basis of this report.

## Quality Assessment Methods

The tea was assessed by five independent systems.

*System 1*
The tea was assessed for total nitrogen, di methyl sulphide (DMS), dried leaf colour and made tea colour and turbidity in our laboratories in Tasmania. For these parameters the teas were compared with a medium quality Japanese grown green tea.

*System 2*
A Hobart based tea merchant (Jeffersons Tea House) assessed the tea for quality compared with Japanese green tea available on the international market.

*System 3*
Samples of the teas were sent to NIVOT (National Research Institute of Vegetables, Ornamental Plants and Tea) in Japan for assessment of quality using NIR equipment. This equipment analysed the tea for water content, total nitrogen, caffeine, tannin, free amino acids and theanin. In addition teas were visually assessed and tasted by a variety of staff.

System 4
Samples of the teas were sent to Dr Goto at the Shizuoka Tea Experiment Station in Japan for assessment by their NIR equipment. In addition to the characteristics at NIVOT the tea at this station was also assessed for neutral detergent fibre (NDF) and vitamin C. The teas were visually assessed and tasted.

*System 5*
Samples of the teas were sent to Mr Watanabe, manager of Kisaku-en, a major Japanese green tea processor and wholesaler based in Shizuoka, Japan.

## Results

*System 1*

The Tasmanian grown green teas were found to be higher in total nitrogen and DMS while made tea was clearer (less turbid) but, with the exception of 'Okuhikari' it was not as green. These results indicate that the Tasmanian green tea, with the exception of made tea colour, was superior to the Japanese standard.

*System 2*

Jeffersons Tea House considered the Tasmanian grown green tea to be of a very high quality. They commented that the tea does not go bitter with overbrewing, a common feature of Japanese green tea and that the leaves unfurled extremely well. They placed a wholesale value of $70 -$100 / kg for the sample.

*System 3*

Moisture content was too high, total nitrogen, caffeine, free amino acids and theanin content all indicated high quality tea. Tannins indicated middle quality tea. Apart from the colour of the made tea which was considered too yellow the tea was classed as middle to high quality.

*System 4*

As for system 3 for the chemical analysis with the exception that Vitamin C was average and NDF was extremely low compared with Japanese grown teas. Low NDF is associated with high quality teas. This assessment of the tea was also critical of the aroma of the teas as well as the made tea colour. The aroma of 'Yabukita' was reported to be "not so good" while 'Sayamakaori' was "musty" and 'Okuhikari' was "scorched". These aromas were all related to various stages of the processing of the tea leaf and not due to the growing environment. Dr Goto concludes that we probably harvested our tea at a less mature stage than is practiced in Japan.

*System 5*

"We received the samples you sent us. We really appreciate it. We tasted and tested them, and they were very good. Honestly, I was very impressed by them. You really did a very good job. If I say, they remind me the good times green tea which I like very much," Mr Watanabe then went on to comment that colour and aroma needed some improvement.

## Conclusion

The evidence indicates that Tasmanian green tea more than adequately meets the quality requirements of the Japanese. There were some problems with made tea colour and poor aroma. The colour problem appeared to be related to fresh leaf colour which markedly improved on the plants after the application of chelated iron. The poor aroma appeared to be related to processing problems and not due to problems in the fresh leaf.

It is concluded that these results demonstrate that this site has a clear potential for the production of quality Japanese green tea. Further seasons research are required to verify this and to provide an indication of yield from the site.