Factors affecting specific gravity loss in crisping potato crops in Koo Wee Rup, Victoria

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Institute for Horticultural Development

Project Number: PT01051

PT01051

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the potato industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the potato industry.

ISBN 0 7341 0531 2

Published and distributed by:
Horticultural Australia Ltd
Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

Horticulture Australia

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BY

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HORTICULTURE AUSTRALIA PROJECT NUMBER: PT01051

INSTITUTE FOR HORTICULTURAL DEVELOPMENT

SEPTEMBER 2002

State Government Victoria Department of Natural Resources and Environment

Horticulture Australia

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Agriculture Victoria, Department of Natural Resources and Environment
Horticulture Australia Project Number: PT02034

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September 2002

ISBN 1 74106 237 3

Acknowledgments

The authors acknowledge the assistance and support provided by the following organisations and people in this project.

- Horticultural Australia for providing the funds to conduct this project.

- Tony Gietzel and Allan Smith (Snack Brands Australia) for supporting the project and providing SG data, valuable comments and suggestions.

- Kan Moorthy (The Smith's Snackfood Company) for the information provided on potato specific gravity in Koo Wee Rup.

- Peter Carr (NRE-Knoxfield) for his assistance in planing, organising and facilitating the grower workshop in Koo Wee Rup.

- Potato growers in Koo Wee Rup for completing the survey form, providing valuable information and participating in the workshop. We are grateful for their contribution and comments.

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Summary

Potato growers and processors reported that specific gravity (SG) of potatoes sourced from Koo Wee Rup has been declining. Data collected from processors showed that SG of the Atlantic variety declined substantially between 1995-2001.

Horticulture Australia with consultation with the potato processing industry and growers agreed to fund this project to determine possible causes of SG decline in Koo Wee Rup and suggest research priority areas to improve potato SG.

The aims of the project were to conduct a literature review on potato SG, survey selected individual crisp potato growers and processors in Koo Wee Rup and organise a focus group discussion to review management practices and identify possible causes of potato SG decline.

The literature review indicated that potato SG is affected by a large number of factors, which can be classified under three categories: cultivars, crop production management and climate conditions.

Planting time is very critical to dry matter content. Early planting during a period of increasing day length and temperature increase tuber dry matter content by lengthening the growth period.

Physiologically old seeds produce high stem number, high tuber yield and dry matter. Low or high plant densities caused by incorrect seed spacing can result in lower potato SG.

High temperatures and short periods of moisture stress can reduce dry matter percentage and increase sugar content. Potatoes grown during a period of increasing day length, temperature and light intensity produce tubers of high SG.

Irrigation during the early stages of growth increases dry matter content, but continuous or late season irrigation can reduce dry matter

High levels of nitrogen may lead to foliage development that is too abundant, a delay and/or reduction in tuber initiation, reduced yields, harvest of immature crops, low SG and may affect tuber quality.

Using Muriate of potash (KCl) as a source for potassium reduces dry matter level slightly more than sulphate of potash (K_2SO_4).

The availability of potassium, phosphorus, magnesium and calcium to potato plants decreases substantially and insoluble iron and aluminium phosphates are formed if soil was too acidic (pH below 5.5).

The average maximum daily temperature in Koo Wee Rup during potato growing season between 1994 and 2001 was about 0.75°C higher than Colac and 1.6°C higher than Thorpdale. While the average minimum (night) temperature in Koo Wee Rup was 0.62°C higher than Colac and 1.35°C higher than Thorpdale for the same period.

Most soils in Koo Wee Rup are black clay loam and highly acidic (pH=4.7). They had high levels of phosphorus (P), aluminium (Al), sodium (Na) and organic carbon.

Atlantic grown in Koo Wee Rup declined by more than 11 units (from 1.096 to 1.084) between 1996 and 2002 according to Snack Brands Australia records, however, the decline was not obvious in the Smith Snackfood Company's records.

According to the Smith Snackfood Company, the SG levels tend to decrease as the harvest season progress from February to May.

Results from the individual grower interview indicated that production management and weather conditions are the most important factors affecting potato SG level in Koo Wee Rup. Ninety percent of growers believed that nutrition and irrigation are the most important factors affecting potato SG in Koo Wee Rup.

All potato growers surveyed in Koo Wee Rup believed that temperature has a big influence on potato SG. Most growers (60%) indicated that rainfall is important and affecting potato SG.

Ninety percent of growers indicated that potato SG readings are not consistent for the same variety and tend to vary a lot between processors, paddocks, and loads.

Growers participated in the workshop in August 2002, identified nutrition and irrigation management as the main causes and high research priority areas for the potato SG decline in Koo Wee Rup.

The decline in potato SG levels in Koo Wee Rup is complex and caused by combination of factors. Relatively higher temperature and lower rainfall in Koo Wee Rup compared to Colac and Thorpdale during potato growing season had negative effect on potato SG. The heavy peat soil structure (chemical and physical properties), fertiliser recommendations were the most likely factors causing the decline in potato SG level in Koo Wee Rup.

Growers used high level of phosphorus at planting to increase its availability to plants but potato SG in Koo Wee Rup had not increased instead soil phosphorus level increased substantially causing the soil to be more acidic.

The continuos supply of fertilisers in Koo Wee Rup in spite of the high level of some nutrients caused some nutrients to build up and potato SG to decline.

At this stage it is recommended to conduct a research to correct soil structure and nutrient composition and study fertiliser regimes, which includes fertiliser types, application times and rates, and foliar application of macronutrients and trace elements suitable to Koo Wee Rup soils.

Research is also needed on irrigation management to address the influence of water and irrigation frequency (time between irrigations) at various growing stages and the effect of water stress before harvesting on yield and potato SG level.

FACTORS AFFECTING SPECIFIC GRAVITY LOSS IN CRISPING POTATO CROPS IN KOO WEE RUP, VICTORIA

1. Introduction

In recent years, the crisp potato industry has experienced a decline in potato dry matter sourced from Koo Wee Rup in Victoria. The average specific gravity of potatoes has dropped from 1.093 in 1996 to 1.084 in 2002 (Snack Brands Australia, 2002).

The trend has resulted in big losses to potato growers and processors and imposed pressure on processors to increase their product price to compensate for the higher cost of processing and yield losses of processed potatoes. Low dry matter levels have also affected grower income because processors pay growers based on potato weight and dry matter content.

The dry matter content of tubers is an important measure of potato quality and it is used to assess suitability for processing purpose. Tubers with a high dry matter content require less energy input during frying to remove water, they have a greater product yield per unit fresh weight than tubers with lower dry matter content, and absorb less oil during frying.

There is a high correlation between dry matter and specific gravity (SG). Although processors are interested in dry matter, SG is easier to determine and it is extensively used to estimate dry matter contents of potatoes.

Snack Brands Australia and the Institute for Horticultural Development (IHD) engaged in discussion about the continuous decline of potato SG grown in Koo Wee Rup and recommended a project to investigate the causes of this phenomenon.

Horticulture Australia with consultation with the potato processing industry and potato growers in Koo Wee Rup agreed to fund this project on SG with the scope to conduct further research in the future based on the outcomes of this project.

The aims of this project were to:

- Conduct a literature review to collect information about the effects of various growing conditions and management practices on SG.

- Survey selected individual crisp potato growers and processors in Koo Wee Rup.

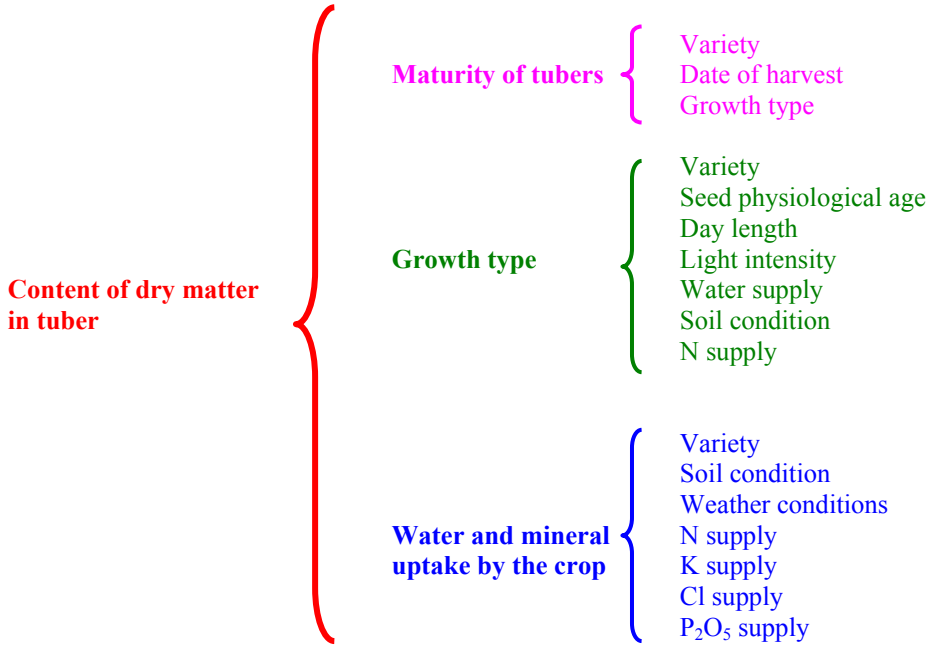
- Organise a group discussion involving crisp potato growers and processors in Koo Wee Rup to review management practices and identify possible causes of SG decline.

2. Literature Review

Specific gravity (SG) is the most common measurement of potato quality for crisping. Research results have shown that there is a high correlation between SG, dry matter (DM) and starch content. Consequently, as a general indicators of DM content, SG determination has much merit because of its ease of measurement and is widely used for determining DM (Harris, 1992).

Slight differences have been found in the relationships between SG, DM and starch because of variations between cultivars and crop growing conditions (Porter et al., 1964; Houghland, 1966; Verma et al., 1971; Schippers, 1976; van Es and Hartmans, 1987a; Nelson et. al., 1988).

The DM is influenced by a large number of factors. The main factors are cultivars, maturity, and growth pattern as influenced by fertiliser application, water supply and climatic conditions. The following figure shows the main factors that may have an effect on dry matter content as reported by Beukema and van der Zaag 1979.



Simplified version of survey of factors influencing the percentage of dry matter in tubers. (From Beukema and van der Zaag 1979,p. 111).

2.1 Maturity of Tubers

2.1.1 Variety

Dry matter varies considerably between potato varieties. The varietal differences are related to the inheritable differences in maturation of tubers, growth type, water and mineral uptake, intercellular space and the composition of tuber dry matter. To obtain tubers with a high dry matter content a variety should be selected which is known for this characteristic (Kushman and Hayes, 1971; Beukema and van der Zaag, 1979, 1990).

Potato varieties can be classified into three main categories:

- **Low specific gravity:** such as Wilwash, Nadine, Bison and Seguoia
- **Medium specific gravity:** such as Kennebec, Shepody, Crystal and Coliban.
- **High specific gravity:** such as Atlantic, Denali, Trent and Russet Burbank (Hegney, 1990; Kirkham, 1997).

The dry matter content of early maturing cultivars has been reported to be usually lower than that of later maturing varieties (Burton, 1966).

2.1.2 Planting & Harvesting Time

Planting time is very critical to dry matter content. Early planting during a period of increasing day length and temperature increases tuber dry matter content by lengthening the growth period. However, if potatoes were planted into cold wet soils then tuber emergence will be slow and the advantage of early planting is lost (Kellock, 1995; Hegney, 1990).

In general, cool years and short growing seasons reduce dry matter production in tubers whilst the reverse occurs in warm sunny years and long growing season (Harris 1992).

During the potato-growing season, dry matter content of tubers increases gradually while the sugar content decreases. Harvested immature tubers tend to have lower dry matter content and higher sugar content compared to mature tubers.

Research has shown that dry matter content increases as the growing season progresses but it tends to decrease at the end (Nelson et al., 1988; Beukema and van der Zaag, 1990).

A rapid kill of crops by chemical or mechanical means would result in lower dry matter because there is not enough time to transfer nutrients from the plants to tubers. This may result in higher sugar levels along with lower starch levels, thus causing deterioration in fry quality (chips colour) (Kellock, 1995).

Therefore, for potatoes to achieve optimal maturity and reach good dry matter levels, harvest should be delayed until all tubers reach their maturity.

Small size tubers are usually initiated about the same time as large tubers but as they receive fewer assimilates the dry matter content remains low (Beukema and van der Zaag, 1990). The maximum percentage of dry matter occurs in medium size tubers with a diameter of 50 mm. The dry matter content tends to decline for large size tubers (Wurr and Allen, 1974; Cole, 1975; Wurr et.al., 1978; Nelson et. al. 1988).

If crops were planted late, harvesting should not be delayed if there is a risk of increased soil moisture from autumn rains. Excessive moisture before harvesting may lower dry matter or even cause harvesting problems (Kellock, 1995).

2.2 Growth Type

The effect of growth type, water and mineral uptake on the dry matter content of tubers is very complex. Generally the factors which stimulate foliage growth tend to decrease dry matter content, and the factors which stimulate tuber growth increase dry matter content. The main factors, which influence crop growth, are: seed physiological age, planting density, weather conditions and soil types.

2.2.1 Seed physiological age

Seed (tuber) physiological age has an important influence on the behaviour of seed potatoes. Physiologically old seed tubers produce greater numbers of sprouts, stems and tuber number (smaller but more potatoes) in a long growing season. While physiologically young seed potato tubers are likely to produce high potential yield with few tubers of large size (PAAH, 1997; Beukema and van der Zaag 1990).

As tubers increase in size during the season, the dry matter content increases, but this relationship is not linear and a maximum percentage of dry matter occurs in medium size tubers (Ifenkwe et. al., 1974).

A study in two main crop cultivars showed that maximum dry matter was reached at a tuber size of about 50-mm (Wurr and Allen, 1974). By using physiologically old seeds, the number of medium size tubers will increase and consequently potato dry matter will rise.

Physiologically old seeds have a higher starch synthesis activity and tuber initiation occurs earlier than young seeds (Caldiz et al., 1996). This is supported by other findings, that increasing age of seed tubers resulted in earlier emergence and tuber initiation, larger early leaf areas and increased tuber yields and dry matter (O'Brien et al., 1983).

2.2.2 Planting density

Low plant densities caused by incorrect seed spacing, skips or early decay of the seed pieces can result in lower dry matter. On the contrary, very high plant densities can lead to early crop maturity and lower dry matter due to excessive competition for nutrients, light and water (Hegney, 1990).

Plant density greatly affects multiplication rate. By increasing the plant population, the number of stems and tubers per plant gradually decreases while the number of tubers produced per m^2 increases. This means the multiplication rate will be lower at higher plant density but the yield will be higher (Beukema and Van der Zaag, 1990; Struik and Wiersema, 1999).

Potatoes can be grown best in the field at wide row distances (75-90 cm) with row spacings between 20-25 cm. Most potato growers in Australia use 80 and 90 cm row spacing. The plant spacing is normally ranged between 20 and 30 cm (Lovatt 1997).

It is generally assumed that 15 to 20 stems per m^2 are needed for normal field potato crops that is equivalent to 35,000-45,000 plants per ha. According to the grower survey, most growers in Koo Wee Rup in 2002 used 80 – 85 cm row spacing and 15 to 30 cm plant spacing that is equivalent to a plant population of 40,000- 45,000 plants/ha.

2.2.3 Weather conditions

1. Temperature

Temperature has one of the greatest effects on dry matter. At high temperatures, tuber respiration rates increase and cause dry matter to burn up faster than it is formed, resulting in decrease in dry matter. If night temperatures are also high, the effect will be greater. That is why dry matter content of tubers is usually rather low in hot climates, which is a disadvantage for processing (Beukema and van der Zaag, 1990; Kellock, 1995).

Short periods of moisture stress or temperatures greater than 35°C can reduce dry matter percentage and increase sugar content. Temperatures below 10°C close to harvest can cause a significant decrease of dry matter/sugar and increase in reducing sugar content of tubers (Hegney et. al., 1991).

Cool night temperatures are important because they affect the accumulation of carbohydrates and dry matter in the tubers. At low night temperatures (10-12°C), the respiration process is slowed, less dry matter is burned up and is stored in the tubers as starch (Lemmen 1990, Schaupmeyer 1997).

The optimum ambient temperature for potatoes is 15-20°C depending on light intensity. As the light intensity decreases, the optimum temperature decreases as well (Beukema and van der Zaag 1990, Hegney et. al., 1991).

2. Light intensity

When light intensity is high, tuber initiation and development start earlier, maximum stem length is reached earlier, yields are higher and tubers contain more dry matter than at lower light intensities.

Generally, at lower light intensities, foliage growth is stimulated with taller plants with thinner stems and smaller leaves, and tuber growth delayed (Demagante and van der Zaag 1988).

Scott and Wilcockson (1978) showed that the amount of intercepted solar radiation was correlated with the total dry matter yield. Allen and Scott (1980) demonstrated a linear relationship between total radiation and dry matter weights for a range of agronomic treatments. They also showed that tuber dry matter weight was directly related to intercepted radiation.

3. Day length

Day length also has a significant effect on dry matter. Potatoes grown during a period of increasing day length and temperature will produce tubers of high SG. The longer the potato crop grows the more likely it is to produce tubers with high SG (Beukema and van der Zaag, 1990).

The average conditions identified as being most conductive to production of high processing quality tubers comprise intermediate temperature (15-20°C), short to intermediate day length (12-15 h), high light intensity (400-450 w/m^2) and maintenance of soil moisture content over 50% of field capacity (Hegney et. al., 1991).

2.2.4 Soil Type

Sandy soils generally produce potatoes with lower dry matter than heavier textured soils. However, with proper irrigation and nutrition management, tubers with high dry matter can be still harvested from sandy soils. Soil pH is not regarded as having a direct effect on dry matter but can affect total dry matter per hectare by its effect on yield (Kellock, 1995; Hegney, 1990).

2.3 Water and Mineral Uptake

2.3.1 Water Supply

Irrigation during the early stages of growth increases dry matter content because starch production is increased, but continuous or late season irrigation can depress dry matter (Harris, 1992).

Too much water can lead to disease, excessive vine growth, low yield, enlarged lenticels and low dry matter. Frequent irrigation during tuber initiation at soil water

potential of 40 kPa gives higher yields, more tubers, 1.2% higher starch content than with irrigation at high water stress, reduction in common scab infection, better cork quality, but reduced cooking quality for boiling and chips (Jorgensen, 1984).

High moisture after tuber initiation results in an increase in tuber size and reduces the dry matter of tubers (Beukema and van der Zaag, 1990).

Over watering before harvest causes excessive water uptake by tubers which reduces dry matter content. Water uptake by roots and influx into the tuber following defoliation increases fresh weight but there is a corresponding reduction in percentage of dry matter during the interval from defoliation to harvest. Whilst desirable to increase fresh weight yield there may be disadvantages, particularly for short season processing crops (Hogge, 1989; Hegney et. al., 1991). Further research is needed to determine the effects of water stress before harvesting on yield and dry matter content of potatoes.

2.3.2 Nutrition:

Nitrogen

Nitrogen stimulates foliage growth and has a negative effect on tuber set and dry matter. High levels of nitrogen may lead to foliage development that is too abundant, a delay and/or reduction in tuber initiation, reduced yields, harvest of immature crops, low SG and may affect tuber quality (Morrow, 1999; Beukema and van der Zaag, 1990).

Nitrogen applications tend to delay early tuber growth rates and crop maturity and may also indirectly decrease dry matter content. High rates of nitrogen lead to deterioration in nutritional and processing quality of potato tubers due to decreased dry matter content and increase levels of reducing sugars, free amino acids and phenol. (O'Beirne and Cassidy, 1990; Stanley, 1990; Harris; 1992; Peshin and Singh 1999).

For starch production, it is recommended to apply 60% of N before planting, 20% after tuber initiation, and 20% later in the growing season (van Loon et. al., 1995).

Potassium

Potassium has been found to have a significant effect on tuber dry matter content. It is suggested that the effect of potassium is on the tuber hydration (van der Zaag and Meijers, 1970; Kunkel et. al., 1972) and this may be an indirect effect through the foliage (Hiller et. al., 1985). The mineral element composition of the tuber is reported to be relatively constant regardless of the amount of fertiliser applied (Kunkel et. al., 1972; Harris, 1978, 1992).

Research has indicated that using Muriate of potash (KCl) as a source for potassium reduces dry matter level slightly more than when K is applied as sulphate of potash (K_2SO_4). The decrease is due to the chloride ion rather than

potassium itself (Holm et. al., 1974; Prummel,1981; Maier et. al., 1986; Hegney, 1990; Chapman et.al., 1992; Kellock, 1995; Sparrow, 1999).

In Victoria, a soil analysis of 150-ppm available potassium is considered sufficient for normal growth. Below this level potassium application has a marked negative effect on yield and dry matter. With soil availabilities of 200-300 ppm, applied potassium didn't affect yield, but when it was applied as Muriate (KCl) it reduced tuber dry matter (Kellock, 1995).

The availability of potassium decreases substantially from 6 to 4.5. At pH in the range 6-9, availability of potassium is not affected (Westermann, 1993).

Phosphorus

Phosphorus does not seem to have either a consistent or a marked effect on tuber dry matter. Researchers have reported an increase and a decrease of dry matter for higher application rates of phosphorus (Kunkel and Holstad, 1972; Freeman et al., 1998).

The optimum pH range for phosphorus uptake is 6-7. At pH values <5.5-6, insoluble iron and aluminium phosphates form. At pH values > 7-7.5, sparingly soluble phosphates form thereby limiting the availability of phosphorus (Maier et. al. 1998).

The availability of phosphorus decreases substantially as the pH decreases below 6.5 and in the range 7.5 to 8.5. At pH in the range 8.5-9, availability of phosphorus increases (Westermann, 1993).

Magnesium

Deficient magnesium concentrations in plants can affect negatively plant growth, chemical composition and quality of the tubers (dry matter) produced (Monday and Ponnampalam, 1986).

The availability of magnesium decreases with increasing soil acidity (as the pH decreases from 6.5 to 4.5) (Westermann, 1993).

Calcium

Calcium is essential for plant growth and development and cell extension. Deficient or high calcium concentrations can affect plant growth and chemical composition, and quality of tuber produced. Calcium deficient plants grow slowly, have poorly developed root systems, reduced yields and tuber quality (Maier et. al. 1998).

Potato SG is affected by a number of factors, some of which can be controlled. Timing of potato harvest is very crucial to potato SG. Mature tubers of the same

variety tend to have higher dry matter content compared to immature potatoes. To achieve optimal maturity and increase dry matter levels, harvest should be delayed until all tubers reach their maturity.

Planting physiologically old seeds will increase the number of medium size tubers at harvest and consequently will improve potato dry matter content.

Low plant densities caused by incorrect seed spacing, skips or early decay of the seed pieces can result in lower dry matter. On the contrary, very high plant densities can lead to early crop maturity and lower dry matter due to excessive competition for nutrients, light and water.

High temperatures during potato growing season have negative effects on potato SG. Suitable growing conditions for high processing quality tubers comprise intermediate temperature (15-20°C), short to intermediate day length (12-15 h), high light intensity (400-450 w/m^2) and maintenance of soil moisture content over 50% of field capacity.

Irrigation during the early stages of growth increases dry matter content because starch production is increased, but continuous or late season irrigation can depress dry matter.

High rates of nitrogen lead to deterioration in nutritional and processing quality of potato tubers due to decreased dry matter content and increase levels of reducing sugars. Nitrogen should be applied 2-3 times during potato growth instead of all at once during planting to improve potato SG.

Using muriate of potash (KCl) as a source for potassium reduces dry matter level slightly more than sulphate of potash (K_2SO_4). The decrease is due to the chloride ion rather than potassium itself.

The availability of phosphorus decreases substantially as the pH decreases below 6.5. At pH values less than 5.5 insoluble iron and aluminium phosphates are formed which may affect tuber set and consequently potato SG. The research results on the affects of phosphorus on tuber dry matter are inconsistent.

Insufficient magnesium and calcium may especially at low soil pH level affect negatively plant growth, chemical composition and quality of the tubers (dry matter) produced.

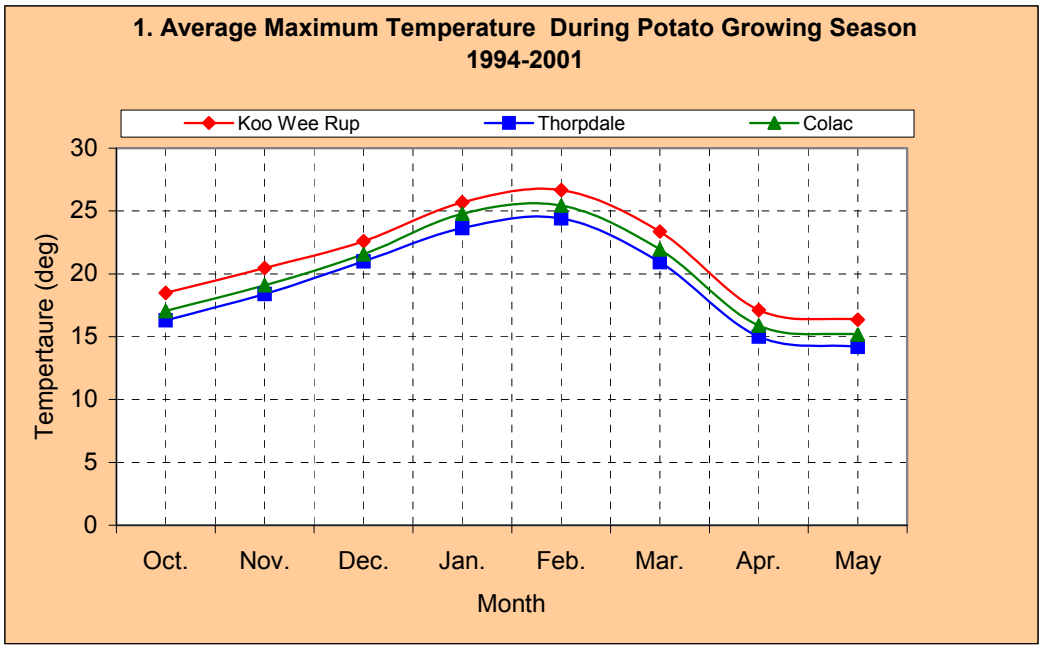
3. *Industry Survey*

3.1 Climate Conditions

Weather data (maximum and minimum temperatures, rainfall and solar radiation) for Thorpdale, Colac and Koo Wee Rup for the last 8 years were collected from Bureau of Meteorology Australia (Silo database) and analysed.

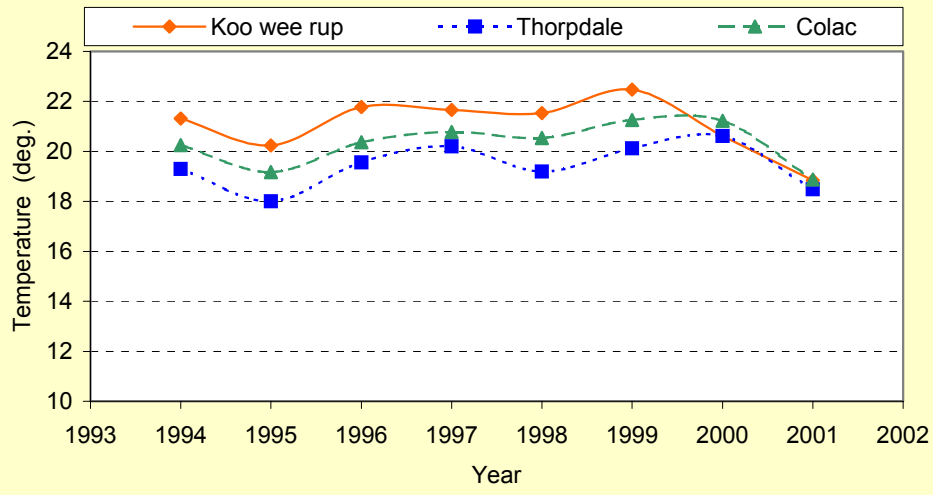
The highest maximum daily temperatures during potato growing season (October-May) for the last 8 years were recorded in Koo Wee Rup followed by Colac then Thorpdale. The highest average daily temperatures between 1994 and 2001 were recorded during February.

The average daily temperatures recorded in February were 26.6°C for Koo Wee Rup, 25.41°C for Colac and 24.4 for Thorpdale. The lowest average daily temperatures for the same period were recorded in May (16.34°C for Koo Wee Rup, 15.17°C for Colac and 14.2°C for Thorpdale) (Figure 1).



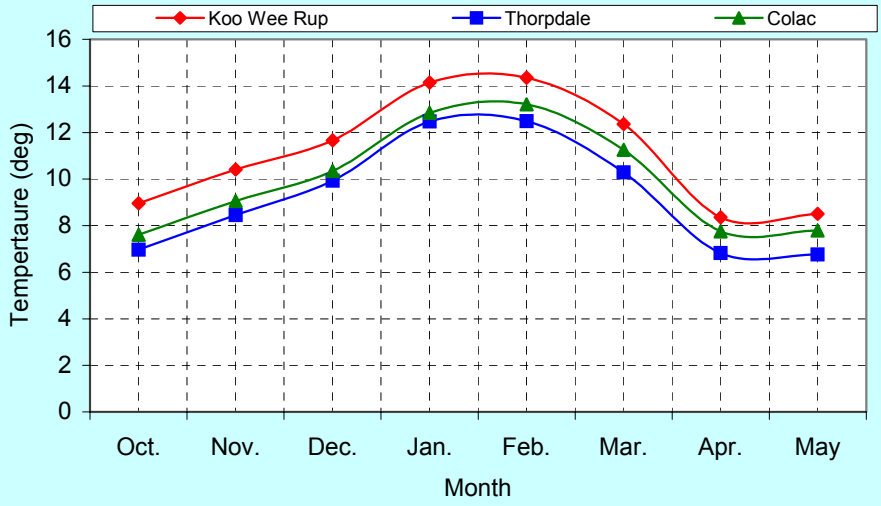
The average maximum daily temperature in Koo Wee Rup during potato growing season over the last 8 years was about 0.75°C higher than Colac and 1.6°C higher than Thorpdale. In 2001 season, the average maximum temperature in Koo Wee Rup dropped to its lowest level in 10 years and reached 18.8°C (Figure 2).

Figure 2. Average Max Temperature Between October and May for Kooweerup, Thorpdale and Colac



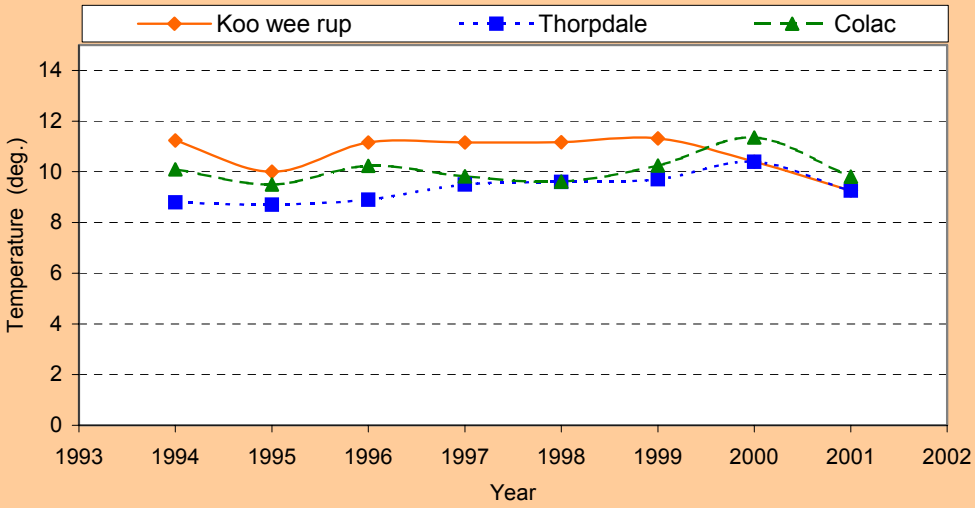
The highest average minimum (night) temperatures between 1994 and 2001 were recorded also in February. The average maximum night temperatures were 14.35°C for Koo Wee Rup, 13.2°C for Colac and 12.48°C for Thorpdale (Figure 3).

Figure 3. Average Minimum Daily Temperature During Potato Growing Season 1994-2001



The average minimum temperatures (night temperature) during potato growing season between 1994 and 2001 were 10.7°C for Koo Wee Rup, 10.08°C for Colac and 9.35°C for Thorpdale. The average minimum temperature in Koo Wee Rup was about 1.35°C higher than Thorpdale and 0.62°C higher than Colac (Figure 4).

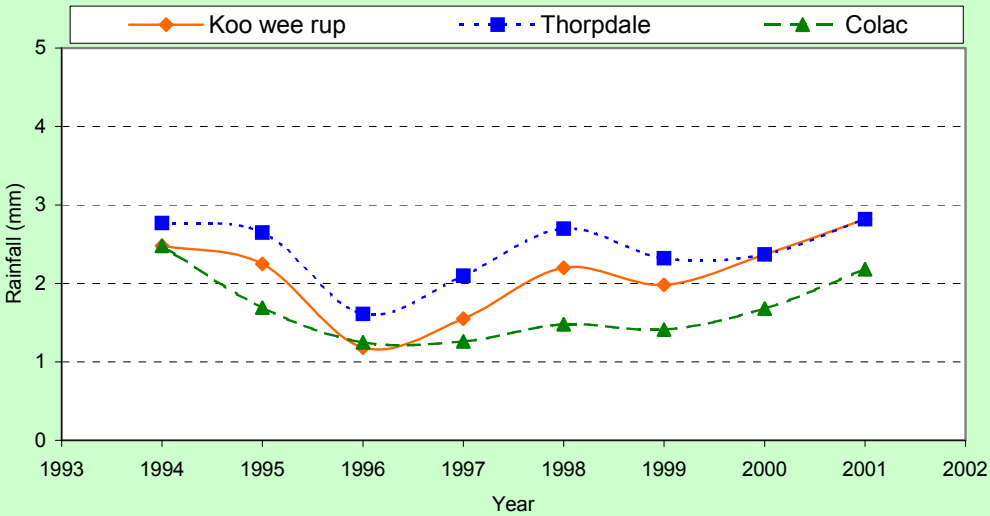
Figure 4. Average Min Temperature Between October and May for Kooweerup, Thorpdale and Colac



Higher day and night temperatures in Koo Wee Rup compared to Thorpdale and Colac may have influenced dry matter contents in potatoes. Higher temperature especially at night means higher respiration rates, which causes dry matter to burn up at a faster rate.

The average daily rainfall during potato growing season was highest in Thorpdale (2.41 mm) followed by Koo Wee Rup (2.10 mm) then Colac (1.67 mm) (Figure 5).

Figure 5. Average Daily Rainfall Between October and May for Kooweerup, Thorpdale and Colac

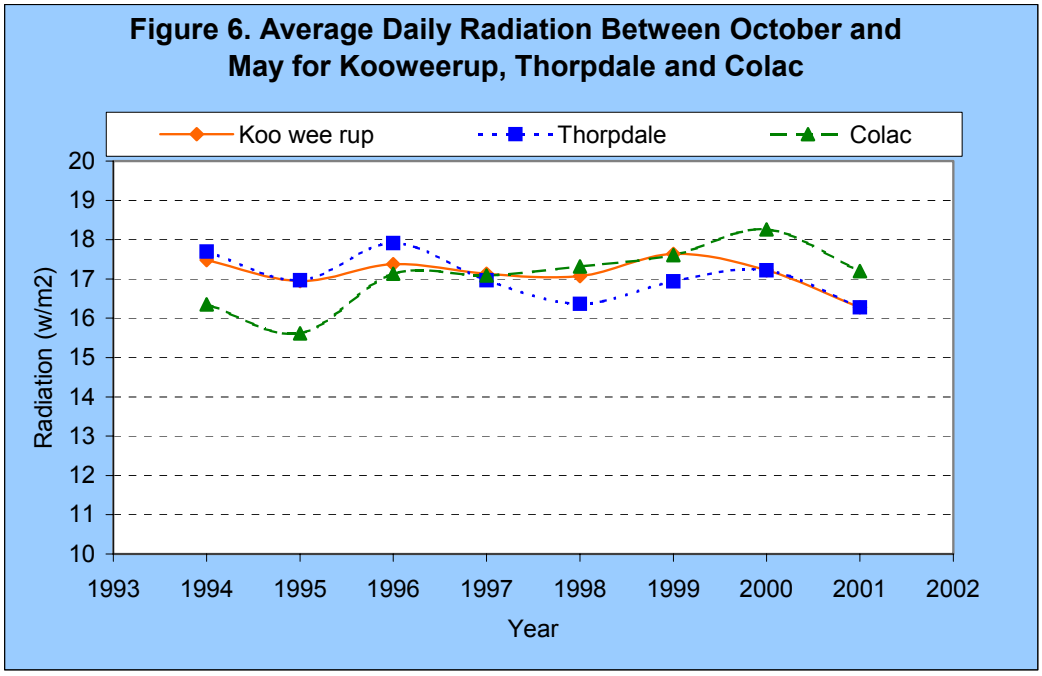


In irrigated regions, rainfall has less influence than temperature on SG of potatoes because growers normally irrigate crops as required during the season. However, the timing of rainfall is very critical. Specific gravity could be reduced substantially if heavy rain occurred at the end of season before harvest.

Daily radiation for a particular location usually fluctuates between seasons and days as cloud cover influences it. The average daily radiations during potato growing season for Koo Wee Rup, Thorpdale and Colac between 1994-2001 were very close.

The average daily radiations were 17.14, 17.04 and 17.07 W/m^2 for Koo Wee Rup, Thorpdale and Colac respectively (Figure 6).

Figure 6. Average Daily Radiation Between October and May for Kooweerup, Thorpdale and Colac



3.2 Soil Nutrients

To understand the general nutrient status of the soil in various regions, randomly selected growers from Koo Wee Rup, Thorpdale and Colac were asked to provide copies of paddock soil test results from last season. The average nutrient levels for each region were then calculated.

The nutrient analysis of 15 soil samples collected from Koo Wee Rup indicated that most soils in Koo Wee Rup are black clay loam and highly acidic. They had high levels of phosphorus (P), aluminium (Al), sodium (Na) and organic carbon.

The average phosphorus (Colwell) level in Koo Wee Rup soils was 240 mg/kg, which was double the maximum level (120 mg/kg) of the phosphorus optimal range specified by Pivot before applying any fertilisers. In highly acidic soils, phosphorus becomes bound and unavailable to plants.

The aluminium level was extremely high (22.5%), about 5 times the maximum recommended level because of low soil pH (4.7). At low pH level (<5.5) insoluble iron and aluminium phosphates are formed and increased.

The calcium level (42%) was lower than the minimum recommended level (65%) while sodium level (7.1%) was slightly higher than the maximum limit (5%) (Table 1).

Table 1. Average Soil Nutrients in Koo Wee Rup and Thorpdale

Test	Unit	Koo Wee Rup	Thorpdale	Min Limit*	Max limit*
Nitrate (NO3)	mg/kg	24.8	17.0	40.0	60.0
Olsen (P)	mg/kg	65.4	14.0	36.0	50.0
Colwell (P)	mg/kg	239.9	56.0	70.0	120.0
Available (K)	mg/kg	281.3	151.0	250.0	400.0
Sulphur (S)	mg/kg	39.7	10.0	10.0	100.0
ECe	ds/m	1.7	0.4	0.0	1.0
Organic C (OC)	%	5.4	3.4	2.0	2.5
Elect. Conduct (EC)	ds/m	0.2	0.1	0.0	0.5
pH-H2O		4.7	5.4	6.5	7.0
pH-CaCl2		4.1	4.6	6.5	7.0
Cation Exchange	meg/100gm	10.4	9.1		
Aluminium (Al)	%	22.46 (2.24 meq/100 gm)	11 (1.1 meq/100 gm)		5.0
Calcium (Ca)	%	42.4 (4.24 meq/100 gm)	72 (7.2 meq/100 gm)	65.0	80.0
Magnesium (Mg)	%	15.3 (1.53 meq/100 gm)	12 (1.2 meq/100 gm)	10.0	20.0
Sodium (Na)	%	7.1 (0.7 meq/100 gm)	2 (0.2 meq/100 gm)		5.0
Potassium (K)	%	6.1 (0.6 meq/100 gm)	3.3 (0.3 meq/100 gm)	5.0	15.0
Ca/Mg		2.7	6.1		2.4
K/Mg		0.4	0.3		

* Min and Max range of various nutrients (Soil Analysis Report, Pivot Limited).

Three soil test result samples were collected from growers in Thorpdale and analysed. The results indicated that soil in Thorpdale is brown volcanic clay.

The average phosphorus level was within expected level but much lower than Koo Wee Rup. Both Thorpdale and Koo Wee Rup soils had high level of organic carbon.

The soil in Thorpdale was less acidic compared to Koo Wee Rup soil. The average soil pH level in Thorpdale was 5.5 while it was 4.7 in Koo Wee Rup. Research has shown that the availability of phosphorus, potassium, magnesium and sulfur decreases substantially as the soil acidity drops below 5.5 pH level.

The aluminium level in Thorpdale soil was high (11%) but was 50% less than its level in Koo Wee Rup soil. That could be attributed to relatively high soil pH level in Thorpdale compared to Koo Wee Rup.

The average soil calcium level in Thorpdale (72%) was within acceptable range. However, it was relatively high compared to Koo Wee Rup (42%). Agricultural lime chemically described as the oxide, hydroxide or carbonate of calcium and/or magnesium could be used to correct soil pH. Gypsum (calcium sulphate) could be also used to supply calcium, but has no effect on soil pH.

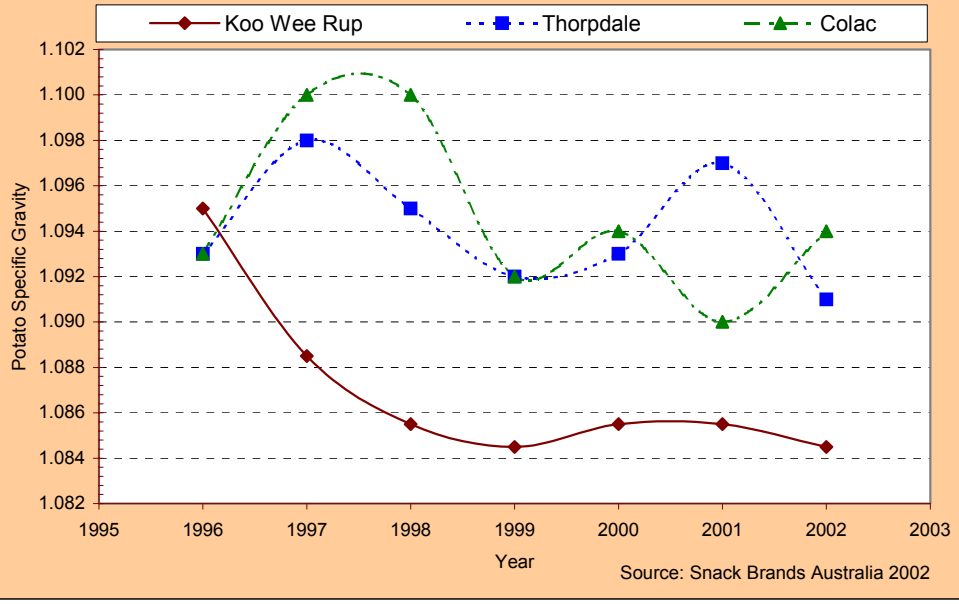
The average soil sodium level in Thorpdale (2%) was relatively lower than its level in Koo Wee Rup (7.1%).

3.3 Processor Survey

3.3.1 Specific gravity trends

According to Snack Brands Australia data, the average SG levels of variety Atlantic grown in Koo Wee Rup declined by more than 11 units (from 1.096 to 1.084) between 1996 and 2002. While the average SG levels of potatoes sourced from Thorpdale and Colac fluctuated between 1.093 and 1.091 over the same period. The maximum levels of potato SG recorded in Thorpdale and Colac in 1997 were 1.098 and 1.10 respectively (Figure 7).

Figure 7. Average SG Levels in Variety Atlantic at Various Locations



The average potato SG levels of variety Atlantic supplied from Koo Wee Rup to the Smith's Snackfood had similar trends. The SG levels declined from 1.086 in 1996 to 1.078 in 2000 and increased slightly to 1.083 in 2002. If SG level in 2000 was not considered, then the SG decline was only 3 units (Figure 8).

The average SG levels in 2002 were 1.083, 1.084 for the Smith's Snackfood Company and Snack Brands Australia respectively.

3.3.2 Effect of harvest time

The potato SG levels of variety Atlantic grown in Koo Wee Rup have a high correlation with harvest time. According to the Smith Snackfood Company, the SG levels tend to decrease as the harvest season progress from February to May. The average SG levels over 2001 and 2002 seasons were 1.087 for crops harvested in February and declined to 1.082 for crops harvested in May. The

trend was also confirmed by data provided by Snack Brand Australia (Figure 9).

Figure 8. Average SG Levels for variety Atlantic in Koo Wee Rup between 1996-2002

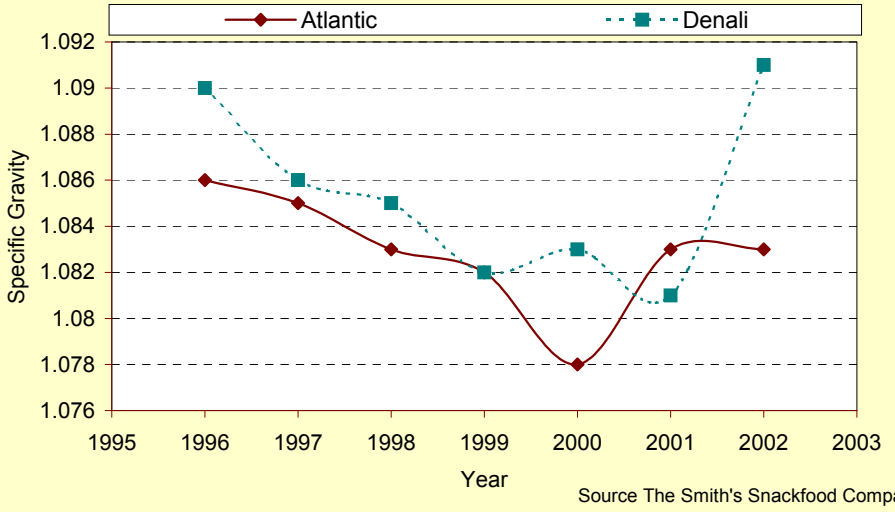
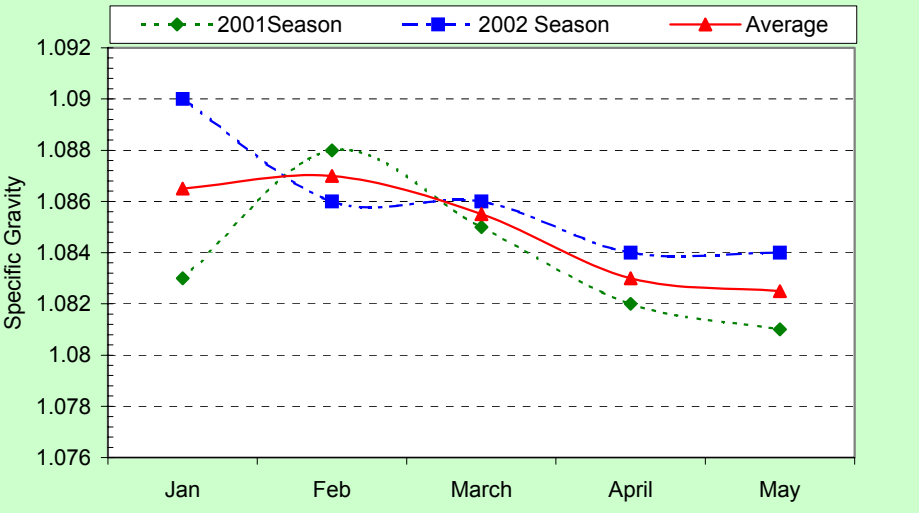


Figure 9. Potato SG Levels in variety Atlantic sourced from Koo Wee Rup in 2001-2002 at various harvest time



3.4 Individual Grower Survey

3.4.1 Grower interview

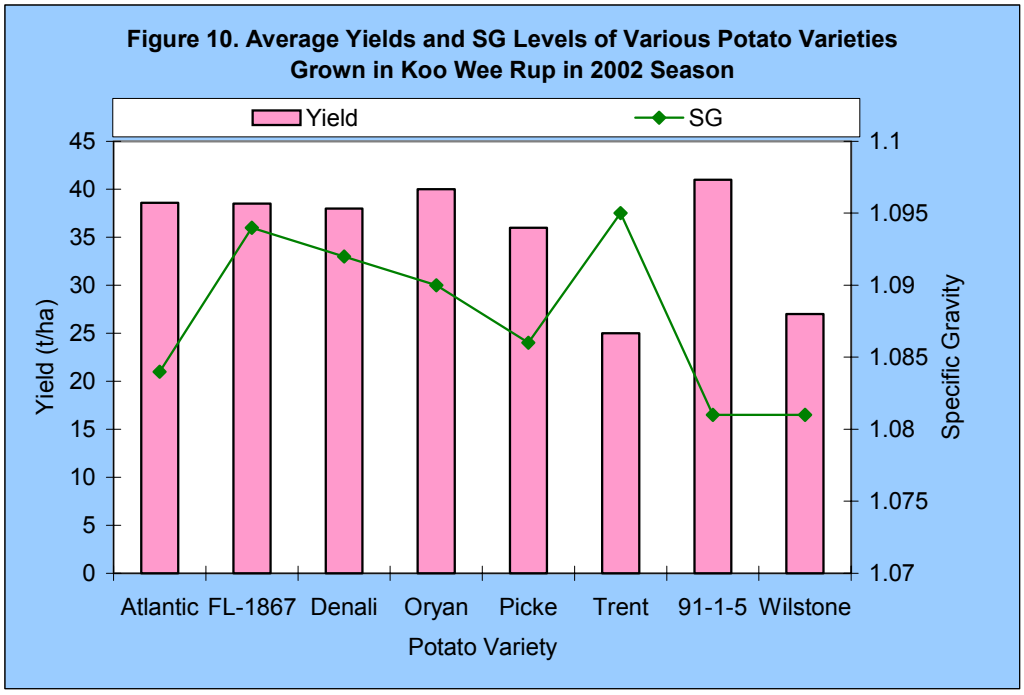
A grower questionnaire covering main potato management practices was developed. The questionnaire consisted of 40 questions covering 5 main areas: crop details, production management, weather conditions, pest and diseases and harvest and postharvest (Appendix A).

During July 2002, selected growers from Koo Wee Rup were interviewed individually and asked to provide information on the questions covered in the questionnaire. They were also asked to provide copies of previous soil test results and fertiliser recommendations.

3.4.2 Grower Survey Results

1. General Information:

The number of Koo Wee Rup growers participated in the survey was 10 (60% the Smith's, 30% Snack Brand and 10% both). The main crisp potato variety in Koo Wee Rup was Atlantic. The crop produced an average yield of 38.6 t/ha with a specific gravity of 1.084 (Figure 10).



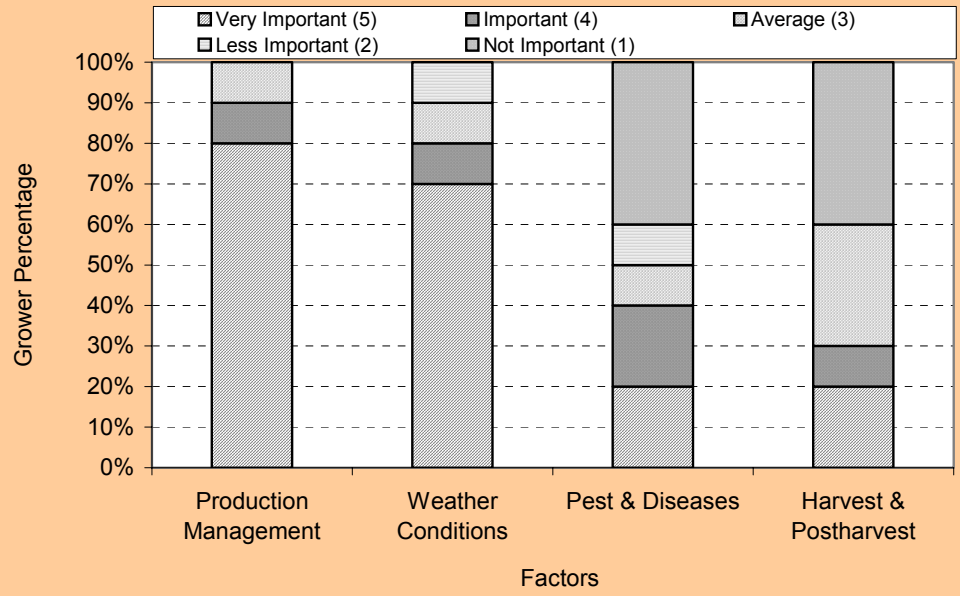
60% of growers participated in the survey noticed a decline in SG and 40% believed that SG has not declined but fluctuated in the last 7 years (Appendix B).

2. Important of Various Production Factors

Most growers participated in the survey indicated that production management and weather conditions were very important factors (90 and 80% respectively) to SG level.

About 50% of growers believed that pest and diseases and harvest and post harvest had little influence on SG level (Figure 11).

Figure 11. Importance of Various Factors to SG



A. Production Management Issues

Plant spacing was not an important issue to growers, only 20% of growers believed that plant spacing has significant effect on SG in Koo Wee Rup. Most growers plant potato at a row spacing of 80-85 cm and plant spacing of 15-30 cm depending on varieties and they have not changed them in the last 7 years.

50% of growers indicated that seed physiological age is an important issue in Koo Wee Rup while the rest disagreed.

Most growers (90%) indicated that planting time is very important issue and affects potato SG, however, they could do nothing about it because processors control delivery time and that forces them to plant at certain times to meet factory schedules.

Nutrition and irrigation were very important issues to growers. Ninety percent of growers believed that nutrition and irrigation have very big influences on SG in Koo Wee Rup (Figure 12).

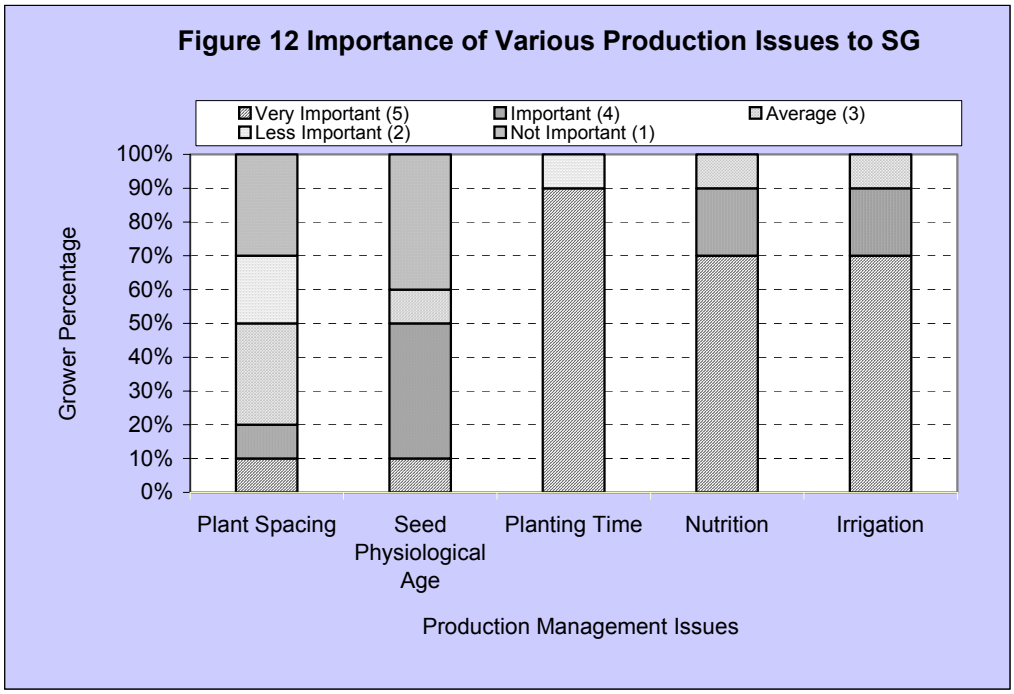


Figure 12 Importance of Various Production Issues to SG

Some growers believed that soil structure has big influence on potato SG. A grower suggested conducting soil and leaf nutrient tests for potato plants that have various SG levels and find out if there is any correlation between nutrients and SG levels.

Growers also express their concern about the distribution of rain and the effect of water stress on SG level.

Physiological Age

Most growers (90%) receive young seeds (4-6 weeks old) from seed suppliers. 60% of growers indicated that they store the seeds for 4-6 months and 40% for 2-4 months before being planted in the field.

Most growers (70%) have not changed their seed suppliers in the last 7 years and 80% believed that there is a variation in the physiological age of seeds.

Planting

Only 10% of growers who participated in the survey used whole seeds, 40% cut and 50% both.

The survey also showed that most potato crops in Koo Wee Rup were planted in November and December (53%, 21% respectively) and only 2% of potato crops were planted in September.

Nutrition

Most growers (70%) participated in the survey indicated that they had changed their fertiliser recommendations in the last 7 years.

Most growers use different blends of Pivot 800 fertilisers at various application rates (according to soil test results). The most common N-P-K blends are 11-15-14, 13-15-15, 8-10-11 and 8-11-10.

Sixty percent of growers indicated that they use 1000-1300 kg/ha, 30% 1300-1600 kg/ha and 10% 700-1000 kg/ha of fertiliser to grow potatoes. Most growers (80%) apply their fertiliser once (banded at planting) and 20% twice (banded at planting and hilling) during the potato growing season.

Only 20% of growers indicated that they apply high K Kendon and high K Kendon and urea fertilisers on the plant foliage during potato growing season.

Most growers (80%) indicated that they use ammonium nitrate as a source for nitrogen.

Most growers (60%) indicated that they use sulphate of potash, 20% muriate and 20% both as a source of potassium and all growers use mono-ammo phosphate as a source of phosphorus.

Irrigation

The survey results indicated that growers use various irrigation methods. Travelling gun and lateral irrigators were the most common methods used in Koo Wee Rup. Eighty percent of growers use travelling gun, lateral move irrigator, or a combination of both and only 20% use travelling gun and central pivot.

Most growers (90%) irrigate their crops during the season as required and 70% determine irrigation requirement by visual observation. Only 10% of growers indicated that they use tensiometers and 20% use gopher for that purpose.

Some growers (50%) indicated that they have not changed their irrigation management. However, 30% changed to central pivot and 20% reduced the time between irrigations.

It seemed that irrigating the crop before harvesting is common practice. Only 10% of growers irrigate 3 days before harvesting, 10% 1-2 weeks before harvest and 30% more than 2 weeks. However, 50% of growers indicated that they irrigate their crops according to soil conditions.

Most growers (80%) indicated that they have not noticed any changes in soil conditions in Koo Wee Rup while 20% indicated that the soil has become drier.

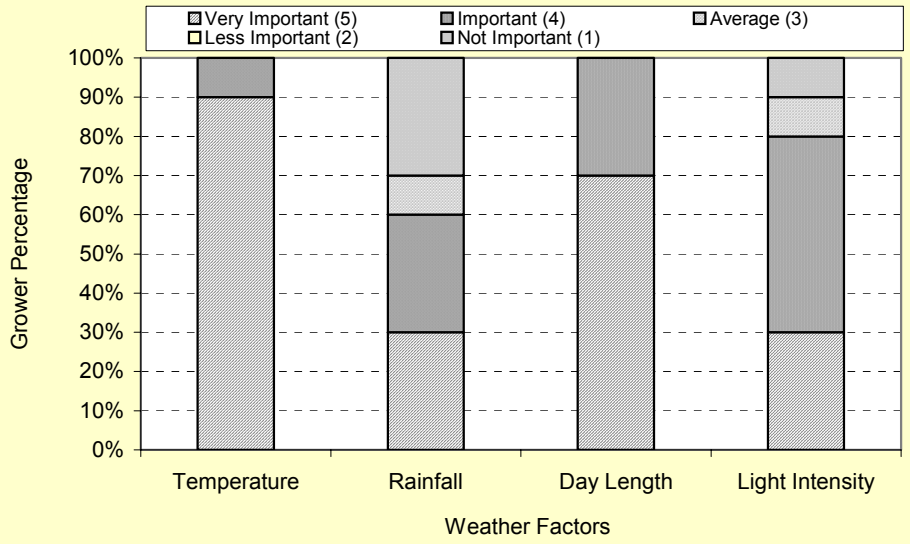
B. Weather Conditions

Most growers (80%) indicated that they have not noticed any changes in the weather pattern in Koo Wee Rup in the last 7 years. Only 20% indicated that the soils in Koo Wee Rup were drier for the last 5 seasons before 2002. They also indicated that the best yield and potato SG level was obtained in 1995 when Koo Wee Rup soils were flooded as a result of excessive rain in that year.

All potato growers surveyed in Koo Wee Rup believed that temperature has a big influence on potato specific gravity. Most growers (60%) indicated that rainfall is important and affect SG.

All growers indicated that day length has big influence on potato SG level, and 80% believed that light intensity is very important and has significant impact on SG (Figure 13).

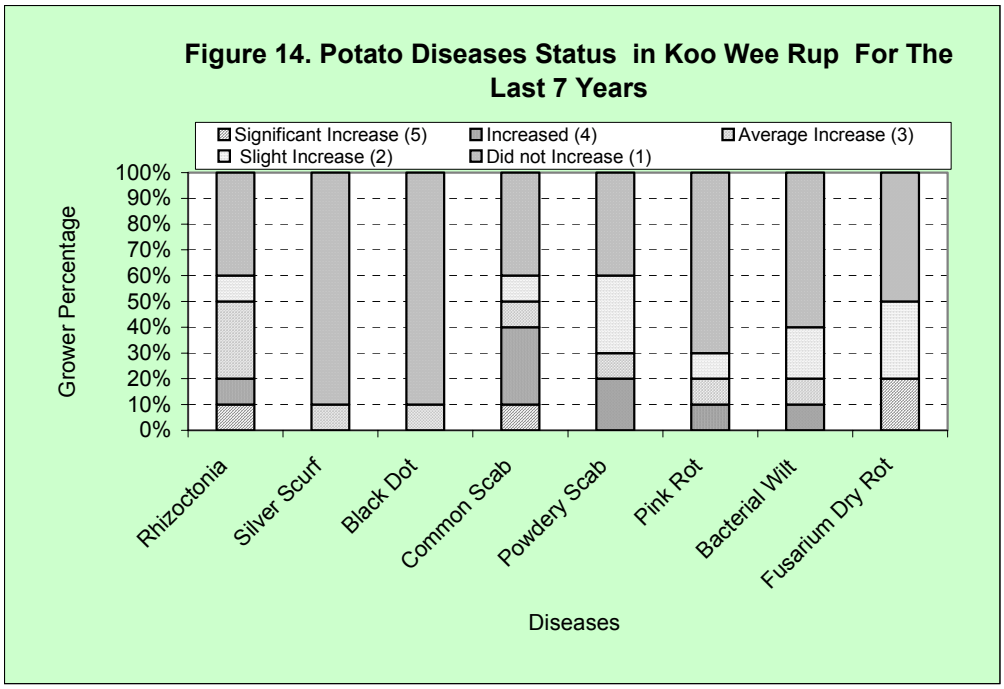
Figure 13. Importance of Various Weather Factors to SG



Most growers (60%) indicated that change of planting and harvesting time is very important to obtain high SG level, however, they are arranged according to the contract with the processors.

C. Pest and Diseases

Most growers indicated that pest and diseases have little influence on SG level and they have not increased in the last 7 years (Figure 14).



D. Harvest & Post-harvest

Fifty percent of growers indicated that harvest time is not important to SG and 80% believed that tuber physiological damage during harvesting and handling is not affecting SG in Koo Wee Rup.

The time the potato stayed in the field before sent to processors was not an important factor to most growers (70%). More than 70% of growers also indicated that factory scheduling and storage do not affect SG levels (Figure 15).

Growers expressed their concern about the way SG is being measured by processors. 90% of growers indicated that potato SG readings are not consistent for the same variety and tend to vary a lot between processors, paddocks, and loads.

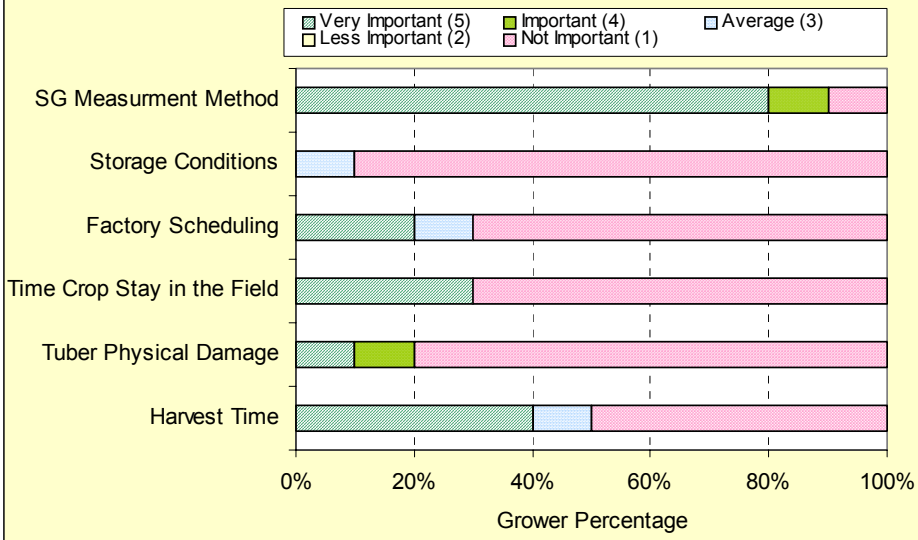
Most growers (60%) indicated that they have not changed harvesting practices in the last 7 years. Ninety percent indicated that they leave the crop in the field until foliage dies naturally and 60% of growers harvest the crop 2-4 weeks later.

When growers were asked to identify the most important single cause of decreasing SG, the responses were not consistent. 10% of growers said planting time, 20% weather, 20% nutrition and water stress, 20% combination of factors and 30% were not sure.

Most growers (60%) indicated that they measure SG themselves before sending their load to processors and more than 70% expressed their interest in owning a new technology such as Near Infrared spectrometry (NIR) to measure SG.

Ninety percent of growers support using R&D levy to fund a research project on SG to help them improve the current level.

Figure 15. Importance of Key Harvest & Postharvest Issues



3.5 Group Discussion

A workshop involving crisp potato growers and representatives from the potato industry was held on 7th August 2002 in Koo Wee Rup and lasted for 4 hours (6:00-10.00 pm).

The workshop was organised by Stephanie Andreata (vegetable extension officer, Vegcheque team, CAS) and Peter Carr (vegcheque team leader, IHD-Knoxfield) as part of the Vegcheque extension program for the potato industry in Koo Wee Rup in 2002. The aims of the workshop were to review management practices in potato farming, identify possible causes of potato specific gravity decline and determine future research needs.

The workshop was attended by 16 potato growers from Koo Wee Rup region and a representative from the Pivot fertiliser company in west Gippsland. The workshop program covered background information about specific gravity issues, project objectives and workshop aims, brainstorming aiming to identify factors and practices influencing SG levels, grouping the factors into common themes, naming the common themes and identifying priority research areas (Appendix C).

Potato growers and a Pivot Company representative were actively involved in the discussion and contributed positively into the workshop. They identified the main factors and practices affecting SG level in Koo Wee Rup, shared their own experience, involved in the group discussion, asked questions about the effects of various factors on SG, and identified research priority areas.

The research priority areas identified by workshop participants were classified under two main categories: most important issues and less important issues (Figure 13).

3.5.1 Most Important Issues

The most important issues for future research were divided into two main areas:

A. Nutrition:

1. Potassium (K):

Participants felt that the effects of potash fertiliser on SG in Koo Wee Rup are not fully understood. They indicated that the effect of using sulphate potash and chloride potash on potato SG level is not consistent and want to investigate that issue.

2. Nitrogen (N):

Growers indicated that they want to know more about plant's requirements for nitrogen during potato growing stages (application rates and time).

3. Trace Elements & Foliar Spray:

The availability of trace elements to plants and the effects of foliar fertilisers on SG have not been addressed in Koo Wee Rup and need to be understood.

4. Soil Structure & Composition:

This is one of the most important issues to Koo Wee Rup growers. Growers felt that high phosphorus and aluminium levels and low pH in the soil may be contributing to the decline of potato SG levels. Soil structure was also raised, growers wanted to study soil physical and chemical properties, and determine the effects of using calcium (lime) on soil structure, potato SG and the spread of common scab disease.

B. Irrigation:

Irrigation management was identified as an important issue to SG level in Koo Wee Rup. The amount of water, frequency of irrigation at various growing stages and when to stop irrigation before harvest are not fully understood.

Growers would like to know the effects of plant stress (water and nutrient stress) during growing stage on SG levels. Growers have been using various irrigation methods and management but have not been able to identify the most suitable one for SG.

3.5.2 Less Important Issues

A. Controllable issues

Identified issues, which can be controlled by growers by using different management practices. These issues include variety, crop rotations, planting density, length of growing time, presence of foliage diseases, planting and harvesting time and seed quality. Although these issues have significant impact on SG, however, they are not considered as research priority areas at this stage.

B. Non-Controllable issues

These include issues which are not controllable or difficult to control such as light intensity, day length, soil temperature, day and night temperature and inconsistent SG measurements by processors.

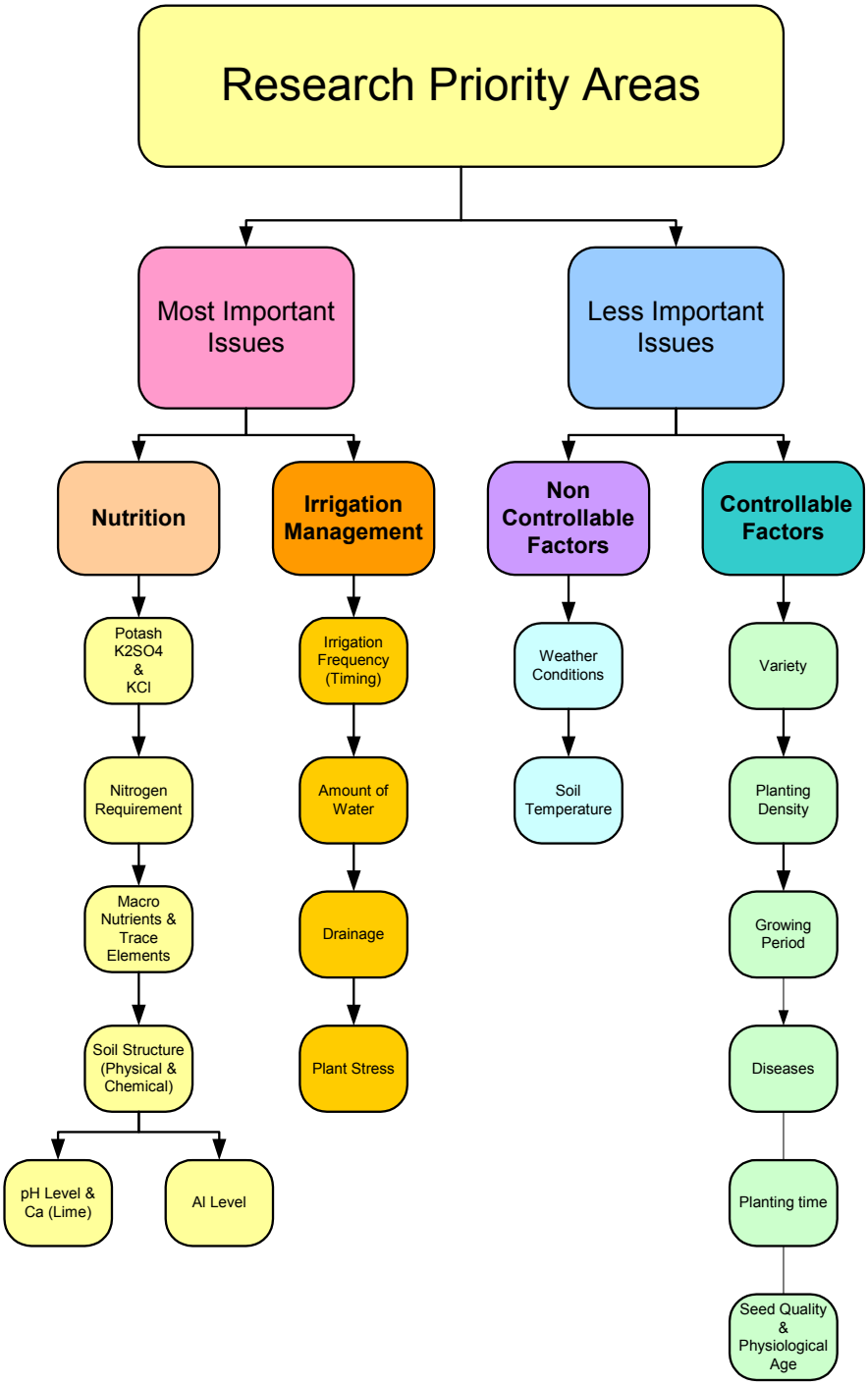


Figure 13. Research priority areas identified by the potato industry in Koo Wee Rup during SG workshop in August 2002

4. Discussion

The low level of potato SG in Koo Wee Rup is complex and believed to be caused by a combination of factors (Table 2).

Table 2. Comparison between SG factors influencing potato SG

Factors	Current Status		Unit	Trends
	Koo Wee Rup (KWR)	Thorpdale (TD)		
Ave. SG in 2002	1.084	1.091		SG in KWR lower by 7 units
Ave. daily temp. (last 8 years)	21.06	19.43	°C	Daily temp. in KWR is 1.6°C higher
Ave. night temp. (last 8 years)	10.71	9.36	°C	Night temp. in KWR is 1.35°C higher
Daily Rainfall (last 8 years)	2.10	2.41	mm	Daily rainfall in TD is 0.31 mm higher
Nitrate (NO3)	24.8	17	mg/kg	N level in TD is lower than min. recommendation (40), needs fert.
Olsen (P)	65.4	14	mg/kg	P (Olsen) level in KWD is higher than max. recommendation (50)
Colwell (P)	239.9	56	mg/kg	P (Colwell) level in KWD is higher than max. recommendation (70)
Available K	281.3	151	mg/kg	K level in TD is lower than min. recommendation (250), needs fert.
Sulphur	39.7	10	mg/kg	Both within recommended range
Ece	1.7	.4	ds/m	Ece in KWR is higher than max recommendation (1.0)
Organic C (OC)	5.4	3.4	%	OC level in KWR is 2.0 higher.
Elect. Cond. (EC)	0.2	.1	ds/m	Both within recommended range
PH-water	4.7	5.4		pH in water level in KWR is 0.7 lower.
PH-CaCl2	4.1	4.6		pH in CaCl2 level in KWR is 0.5 lower.
Cation Exchange	10.4	9.1	meg/ 100 gm	Cation Exchange level in KWR is 1.3 higher.
Aluminium (Al)	22.46	11	%	Al level in KWR is double TD level and both exceed max. (5%)
Calcium (Ca)	42.4	72	%	Ca in KWR is 30% lower
Magnesium (Mg)	15.3	12	%	Both within recommended range
Sodium (Na)	7.1	2	%	Na in KWR is 5% higher
Potassium (K)	6.1	3.3	%	K level in TD is 2.8% lower
Ca/Mg	2.7	6.1	%	Ca/Mg in KWR is 3.4% lower
K/Mg	0.4	.3	%	Both within recommended range

Relatively higher temperature and lower rainfall in Koo Wee Rup compared to Colac and Thorpdale during potato growing season had negative effect on potato SG. The average day and night temperatures in Koo Wee Rup were 1.60 and 1.35°C higher than Thorpdale and that would have contributed to the low potato SG.

The heavy peat soil structure (chemical and physical properties), fertiliser recommendations were the most likely factors causing the decline in potato SG level in Koo Wee Rup.

Although 70% of surveyed growers in Koo Wee Rup changed their fertiliser recommendations, however, potato SG level has not improved significantly. This could be attributed to the following facts:

The low soil pH level in Koo Wee Rup (4.7%) compared to Thorpdale (5.4%) caused most nutrients to become fixed in the soil and unavailable to plants. The continuos supply of fertilisers in Koo Wee Rup in spite of the high level of some nutrients caused some nutrients to build up and potato SG to decline. Research has shown that the availability of potassium, phosphorus, magnesium and sulphur can decrease substantially if soil pH drops below 6. Higher level of soil pH level in Thorpdale compared to Koo Wee Rup believed to be contributed to the higher level of potato SG in Thorpdale.

The phosphorus level in Koo Wee Rup soils was about 8 times higher than its level in Thorpdale and about 5 times higher than the recommended maximum level by Pivot. Most of this phosphorus was fixed in the soil because of the low pH level.

Growers used high level of phosphorus at planting to increase its availability to plants but potato SG in Koo Wee Rup had not increased instead soil phosphorus level increased substantially causing the soil to be more acidic.

Pivot believed that adding extra fertiliser to the soil in Koo Wee Rup was essential to encourage plant growth and improve yield and quality otherwise the crop could suffer. The solution could increase temporarily the availability of phosphorus to the plants. However, it may get the soil acidity worse by forming phosphoric acid as a result of phosphorus reaction in the soil and consequently reducing further the availability of nutrients as the soil pH level drops.

The low soil pH level in Koo Wee Rup contributed also to the high aluminium level. The soil test results indicated that the aluminium level in Koo Wee Rup soils was 22.47%, which represented double its level in Thorpdale soils (11%). Research has shown that in high acidic soils (pH less than 5.5) insoluble iron and aluminium phosphates are formed which may have influenced potato SG level in Koo Wee Rup.

Banding all fertilisers during planting was a common practice among potato growers. It is scientifically proven that too much nitrogen during planting can increase foliage growth, delay tubers set and reduce potato SG. Dividing nitrogen application into two applications during potato growth may improve potato SG level in Koo Wee Rup.

Early planting may increase potato SG, however, growers had little influence on planting and harvesting times as they were set according to delivery times scheduled by processors.

Most growers (70%) irrigate their crops as required using their own observations. The amount of required water, time between irrigations during growing stages and the effect of water stress before harvesting on potato SG were not fully understood. The unique structure of Koo Wee Rup soils had made it necessary to investigate various irrigation management strategies to improve potato SG in Koo Wee Rup.

Growers have concern about the way processors are measuring SG and believe that SG measurements are inaccurate and inconsistent. Slight variations of potato SG levels among potato samples are quite normal because of the variation in potato growing conditions in paddocks, shape and size of tubers and measuring conditions. If potato SG varies greatly between loads, then it is recommended to calibrate the measuring devices annually, improve measuring procedure, increase the number of samples and provide appropriate training to staff.

Exploring the possibility of using other technologies such as near infra red sensors to measure potato SG are helpful to the processing industry and may improve the accuracy of current procedure.

The study has shown that in spite of some changes in some practices (nutrition regimes and irrigation methods and management), growers have not been able to identify the causes and solutions for the decline of potato SG in Koo Wee Rup. This could be attributed to the fact that growers have limited capacity to run scientific trials, keep record of changes and identify possible causes and find appropriate solutions.

5. Conclusion

Low soil pH level in Koo Wee Rup and continuous supply of fertilisers caused some nutrients to build up and become bound in the soil and unavailable to potato plants. That is believed to cause potato SG to decline in Koo Wee Rup.

Higher day and night temperatures and less daily rainfall during potato growing season in Koo Wee Rup compared to Thorpdale may have contributed to the lower level of Potato SG in Koo Wee Rup.

Soil nutrition and irrigation management were identified by the project and growers as high research priority areas to improve potato SG in Koo Wee Rup.

At this stage, it is recommend to investigate soil nutrition and irrigation management in Koo Wee Rup with the aim to improve SG:

- **Soil Structure & Nutrients:**

    1. Soil physical and chemical properties by studying the effects of calcium sources (lime, and gypsum), application times and rates to correct soil structure, pH, nutrients uptake, and aluminium level.

    2. Fertiliser regimes which includes fertiliser types, application times and rates.

    3. Foliar applications of macronutrients and trace elements.

- **Irrigation management:**

    1. Amount of water and irrigation frequency (time between irrigations) at various growing stages using water gun and lateral irrigator.

    2. Effect of water stress before harvesting on yield and potato SG level.

The majority of growers (90% of growers participated in the individual grower survey, and 100% of growers participated in the workshop) support using R&D funds to address research priority areas identified in this project.

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Appendix A

Grower Questionnaire

SPECIFIC GRAVITY PROJECT
POTATO INDUSTRY QUESTIONNAIRE
HAL PROJECT No: PT-011051

Grower Code No.:……

Region:……

CONFIDENTIAL

PREPARED BY

GHASSAN AL SOBOH

INSTITUTE FOR HORTICULTURAL DEVELOPMENT
NATURAL RESOURCES AND ENVIRONMENT

July 2002

INDUSTRY QUESTIONNAIRE

1. Please provide the following information.

Paddock size in last season (ha)	Crisp Variety	Amount of potato Supply (tonne)	Processing company Name
1.			
2.			
3.			
4.			
5.			

2. Please provide an estimate of the average yield and specific gravity of your crops last seasons (2002).

Paddock	Harvest Year & Date	Yield (tonne/ha)	SG Level
1.			
2.			
3.			
4.			

3. Have you notice any decline in Specific Gravity for the last 7 years.

Your Answer	Your comments
Y N	

4. Rate the importance of the following factors to specific gravity in your farm by assigning a score between (1 to 5).

Item	Circle Order of Importance 5 is very important, 1 is not important
Production Management	1 2 3 4 5
Weather conditions	1 2 3 4 5
Pest and diseases	1 2 3 4 5
Harvest & Post Harvest	1 2 3 4 5

A. Production Management

5. Rate the importance of the key production management issues to specific gravity.

Item	Circle Order of Importance 5 is very important, 1 is not important
Plant spacing	1 2 3 4 5
Seed physiological age.	1 2 3 4 5
Planting time	1 2 3 4 5
Nutrition	1 2 3 4 5
Irrigation	1 2 3 4 5

- ***Plant and row spacings***

6. What plant and row spacings do you use? Example (30 cm x 80 cm).

7. Have you changed plant and/or row spacings for the last 7 years. If yes what did you use in the past?

Your Answer	Your comments
Y N	

- ***Seed Physiological Age:***

8. What is in general the physiological age status of seeds you receive from your supplier?

Your comments
Young or old: How old they are: How long do you store them before planting:

9. Is there any variation in the physiological age of seeds you receive from your supplier? If yes, do you treat the seeds to bring them to the same physiological age before planting?

Your Answer	Your comments
Y N	

10. Have you changed your seed supplier in the last 7 years? If yes, have you noticed any difference in potato SG or yield? Please comment?

Your Answer	Your comments
Y N	

- ***Planting:***

11. What type of seeds do you use cut or whole?

12. When did you plant your crop last season, Please put ✔ in front of the right answer?

Time	Paddock 1	Paddock 2	Paddock 3	Paddock 4
September				
1st half of October				
2nd half of October				
1st half of November				
2nd half of November				
1st half of December				
2nd half of December				
After December				

- ***Nutrition***

13. Has your fertiliser supplier changed your fertiliser recommendations (fertiliser types and application times) for the last 7 years.

Your Answer	Your comments
Y N	What have you changed?

14. What type of fertilisers, application time and rates per ha did you use last season:

Fertiliser Type	Application Rate kg/ha	Application Time

15. Do you apply fertilisers during irrigation on plant foliage (Fertigation)?

Yes	No

16. If yes, please indicate what type of fertiliser, application rate, and time of application.

Paddock	Foliar Fertiliser		
	Type	Application Time	Application Rate
1			
2			
3			
4			

17. Please indicate which forms of N fertiliser, application time and method you used last season.

Paddock	Form of N fertiliser				Application	
	Nitrate	Ammonium Sulphate	Ammonium Nitrate	Urea	Time	Method
1.						
2.						
3.						
4.						

18. Please indicate which forms of K fertiliser, application time and method you used last season.

Paddock	Form of K fertiliser		Application	
	Muriate (KCl)	Sulphate of potash (K_2SO_4)	Time	Method
1.				
2.				
3.				
4.				

19. Please indicate which forms of Phosphorus (P) fertiliser, application time and rate you used last season.

Paddock	Form of P fertiliser				Application Time
	Soluble Phosphates	Super Phosphate	Mono-Ammo Phosphate	Mono-Ammo + Ammonium Phosphate	
1.					
2.					
3.					
4.					

- ***Irrigation:***

20. What irrigation method do you use? Please place ✔ where appropriate.

Paddock	Irrigation Method			
	Travelling gun	Lateral move irrigator	Central pivot	Others, please specify
1				
2				
3				
4				

21. How often do you irrigate?

22. How do you decide when to irrigate your crop?

23. Have you changed your irrigation management in the last 7 years. If yes, please indicate.

Your Answer	Your comments
Y N	

24. How long before harvesting did you stop irrigation? Please circle most appropriate answer.

Paddock	Time of last irrigation before harvest			
	3 days	1 week	2 weeks	Others, please specify
1				
2				
3				
4				

25. Have you noticed any changes in soil conditions for the last 7 years? If yes, please indicate.

Your Answer	Your comments
Y N	

Weather Conditions

26. Have you noticed any change in the weather pattern in Koo Wee Rup for the last 7 years? If yes, please indicate.

Your Answer	Your comments
Y N	

27. Rate the importance of the following weather factors to the specific gravity in Koo Wee Rup by assigning a score between (1 to 5).

Item	Circle Order of Importance 5 is very important, 1 is not important
Temperature	1 2 3 4 5
Rainfall	1 2 3 4 5
Day length	1 2 3 4 5
Light intensity	1 2 3 4 5

28. Do you think it is important to change planting and/or harvesting time to cope with the change of weather pattern?

Your Answer	Your comments
Y N	

Pest and Diseases

29. Do you think that pest and diseases are affecting specific gravity in your farm?

Your Answer	Your comments
Y N	

30. Which of the following diseases have increased for the last 7 years?

Item	Circle Order of Importance
Rhizoctonia	1 2 3 4 5
Silver Scurf	1 2 3 4 5
Black dot	1 2 3 4 5
Common scab	1 2 3 4 5
Powdery scab	1 2 3 4 5
Pink rot	1 2 3 4 5
Bacterial wilt	1 2 3 4 5
Fusarium dry rot	1 2 3 4 5
Root knot nematode	1 2 3 4 5
Potato moth	1 2 3 4 5

Harvest & Post harvest

31. How do you rate the importance of the key harvest & post harvest issues to specific gravity.

Item	Circle Order of Importance
Harvesting time	1 2 3 4 5
Tuber physical damage during harvesting	1 2 3 4 5
Time crop stay in the field before sent to processing plant.	1 2 3 4 5
Factory scheduling and handling of potatoes.	1 2 3 4 5
Potato storage conditions in the processing plant.	1 2 3 4 5
Specific gravity measurement method.	1 2 3 4 5

32. Have you changed your harvesting practices for the last 7 years, if yes, please indicate.

Your Answer	Your comments
Y N	

33. Do you use any means to kill your crop top at the end of the season before harvesting? If yes, please indicate what method do you use.

Your Answer	Your comments
Y N	

34. How long does the crop stay in the field after crop foliage dies?

35. Do you store the crop in your farm before you send to processing plant? If yes, please indicate how long usually.

36. Do you know the number of tubers per plant you got last season? If you do please indicate.

37. What do you think is the single most important cause of decreasing SG?

38. Do you measure SG yourself? Would you like to do that if there is an appropriate device in the market?

39. Do you support using R&D levy to conduct a project to help you improve current SG level?

40. We are planning to organise a group discussion at the end of July or early August, what is the most connivent time for you to attend.
    - Morning 10:00 – 13:00
    - Afternoon 1:00- 4:00 pm
    - Evening 6:00 – 9:00 pm

Appendix B

Grower Questionnaire Results

GROWER QUESTIONNAIRE RESULTS

1. Growers participated in the survey

Response	Processing Company		
	The Smith's Snack Food	Snack Brand Australia	Both
Number of growers	6	3	1
Overall %	60	30	10

2. Potato varieties, yields and SG levels during 2002 season provided by Koo Wee Rup growers participated in the survey.

Grown variety	Average yield t/ha	Average SG level
Atlantic	38.6	1.084
FL-1867	38.5	1.094
Denali	38	1.092
Oryan	40	1.090
Picke	36	1.086
Trent	25	1.095
91-1-5	41	1.081
Wilstone	27	1.081

3. Have noticed decline in Specific Gravity for the last 7 years.

Response	Yes	No (fluctuating)
Number of growers	6	4
Overall %	60	40

4. The Importance of:

a. Production management:

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	0	1	1	8
Overall %	0	0	10	10	80

b. Weather conditions

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	1	1	1	7
Overall %	0	10	10	10	70

c. Pest and diseases

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	4	1	1	2	2
Overall %	40	10	10	20	20

d. Harvest & post-harvest

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	4	0	3	1	2
Overall %	40	0	30	10	20

A. Production Management

5. The importance of key production management issues

a. Plant spacing

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	3	2	3	1	1
Overall %	30	20	30	10	10

b. Seed physiological age.

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	4	0	1	4	1
Overall %	40	0	10	40	10

c. Planting time

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	1	0	0	9
Overall %	0	10	0	0	90

d. Nutrition

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	0	1	2	7
Overall %	0	0	10	20	70

e. Irrigation

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	0	1	2	7
Overall %	0	0	10	20	70

6. Plant and row spacings

Row spacing 80 – 85 cm.
Plant spacing 15 to 30 cm.

7. Have changed plant and row spacing for the last 7 years.

Response	Yes	No
Number of growers	0	10
Overall %	0	100

8. Seed Physiological Age Status:

- **Seed age when arrived to growers**

Response	Young	Old
Number of growers	10	0
Overall %	10	0

- **Seed age from harvesting**

Response	4-6 weeks	Older
Number of growers	9	1
Overall %	90	10

- **Storage time:**

Response	2-4 months	4-6 months	More
Number of growers	4	6	0
Overall %	40	60	0

9. Existence of variation in seed physiological age

Response	Yes	No
Number of growers	8	2
Overall %	80	20

10. Have changed seed supplier/s in the last 7 years.

Response	Yes	No
Number of growers	3	7
Overall %	30	70

- ***Planting:***

11. Seed Type

Response	Whole	Cut	Both
Number of growers	1	4	5
Overall %	10	40	50

12. Seed Planting Time:

Response	September	1St half of Oct.	2nd half of Oct.	1st half of Nov.	2nd half of Nov.	December
Paddocks	1	4	8	10	16	10
Overall %	2	8	16	21	32	21

- ***Nutrition***

13. Have changed fertiliser recommendations for the last 7 years.

Response	Yes	No
Number of growers	7	3
Overall %	70	30

14. Fertiliser application rate

Response	700- 1000 (kg/ha)	1000-1300 (kg/ha)	1300-1600 (kg/ha)	More
Number of growers	1	6	3	0
Overall %	10	60	30	

- **Fertiliser application time**

Response	Banded at planting	Banded at planting & Hilling
Number of growers	8	2
Overall %	80	20

15. Application of foliar fertilisers.

Response	Yes	No
Number of growers	2	8
Overall %	20	80

16. Type of foliar fertiliser, application rate, and time of application.

Foliar Fertiliser		
Type	**Application Time**	**Application method and Rate**
High K Kendon Product	During growing stage, 1st application 4 weeks after planting	By sprayers at 5 L/ha
High K Kendon and Urea	10-12 weeks after planting	By plane

17. Forms of N fertiliser, application time and method.

Response	Form of N fertiliser				Application	
	Nitrate	Ammonium Sulphate	Ammonium Nitrate	Urea	Time	Method
Number of growers	0	2	8	(2 as foliar)	At planting	Banded
Overall %	0	20	80			

18. Forms of K fertiliser, application time and method.

Response	Form of K fertiliser			Application	
	Muriate (KCl)	Sulphate of potash (K_2SO_4)	KCL + K_2SO_4	Time	Method
Number of growers	2	6	2	At planting	Banded
Overall %	20	60	20		

19. Forms of phosphorus (P) fertiliser and application time.

Response	Form of P fertiliser				Application Time
	Soluble Phosphates	Super Phosphate	Mono-Ammo Phosphate	Mono-Ammo + Ammonium Phosphate	
Number of growers	0	0	10	0	Banded at planting
Overall %	0	0	100	0	

- ***Irrigation:***

20. Irrigation method

Response	Irrigation Method				
	Travelling gun	Lateral move irrigator	Travelling Gun & Lateral	Central pivot	Travelling Gun & Central pivot
Number of growers	2	2	4	0	2
Overall %	20	20	40	0	20

21. Frequency of irrigation

Response	1 week	2 weeks	As required (1-3 weeks)
Number of growers	1	0	9
Overall %	10	0	90

22. Ways to determine irrigation time?

Response	Visual Observation	Tensiometers	Neutron Probe	EnviroSCAN	Gopher
Number of growers	7	1	0	0	2
Overall %	70	10	0	0	20

23. Have changed irrigation management for the last 7 years.

Response	No	Yes "changed to central pivot"	Yes "reduced time between irrigation)
Number of growers	5	3	2
Overall %	50	30	20

24. Time of last irrigation before harvest.

Response	3 days	1-2 weeks	More	Depending upon soil moisture.
Number of growers	1	1	3	5
Overall %	10	10	30	50

25. Have noticed changes in soil conditions for the last 7 years.

Response	Yes	No
Number of growers	1 (drier soil) 1 (not as much cracks and insect problems)	8
Overall %	20	80

Weather Conditions

26. Have noticed changes in the weather pattern in Koo Wee Rup for the last 7 years.

Response	Yes	No
Number of growers	2 (drier soil before this year)	8
Overall %	20	80

27. The importance of the following weather factors to the specific gravity in Koo Wee Rup:

- **Temperature:**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	0	0	1	9
Overall %	0	0	0	10	90

- **Rainfall**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	3	0	1	3	3
Overall %	30	0	10	30	30

- **Day Length**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	0	0	0	3	7
Overall %	0	0	0	30	70

- **Light Intensity**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	1	0	1	5	3
Overall %	10	0	10	50	30

28. Change of planting and/or harvesting time.

Response	Important	Important but depends on Processors	Not important
Number of growers	3	6	1
Overall %	30	60	10

Pest and Diseases

29. Effect of pest and diseases on specific gravity.

Response	Important	Not important
Number of growers	4 (not pest but diseases)	6
Overall %	40	60

30. Diseases which have increased for the last 7 years?

- **Rhizoctonia**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	4	1	3	1	1
Overall %	40	10	30	10	10

- **Silver Scurf**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	9	0	1	0	0
Overall %	90	0	10	0	0

- **Black dot**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	9	0	1	0	0
Overall %	90	0	10	0	0

- **Common scab**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	4	1	1	3	1
Overall %	40	10	10	30	10

- **Powdery scab**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	4	3	1	2	0
Overall %	40	30	10	20	0

- **Pink rot**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	7	1	1	1	0
Overall %	70	10	10	10	0

- **Bacterial wilt**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	6	2	1	1	0
Overall %	60	20	10	10	0

- **Fusarium dry rot**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	5	3	0	0	2
Overall %	50	30	0	0	20

- **Root knot nematode**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	10	0	0	0	0
Overall %	100	0	0	0	0

- **Potato moth**

Response	Didn't increased (1)	Increased slightly (2)	Average increase (3)	Increased (4)	Significant Increase (5)
Number of growers	9	1	0	0	0
Overall %	90	10	0	0	0

Harvest & Post harvest

31. The importance of the key harvest & post harvest issues to specific gravity.

- **Harvesting time**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	5	0	1	0	4
Overall %	50	0	10	0	40

- **Tuber physical damage**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	8	0	0	1	1
Overall %	80	0	0	10	10

- **Time crop stay in the field**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	7	0	0	0	3
Overall %	70	0	0	0	30

- **Factory scheduling**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	7	0	1	0	2
Overall %	70	0	10	0	20

- **Storage conditions in factory.**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	9	0	1	0	0
Overall %	90	0	10	0	0

- **Specific gravity measurement method.**

Response	Not Important (1)	Less Important (2)	Average (3)	Important (4)	Very Important (5)
Number of growers	1	0	0	1	8
Overall %	10	0	0	10	80

32. Have changed harvesting practices for the last 7 years.

Response	Yes	No
Number of growers	4	6
Overall %	40	60

33. The way potato crop foliage die at the end of the season before harvesting.

Response	Naturally	Chemically
Number of growers	9	1
Overall %	90	10

34. Time crop stay in the field after crop foliage dies?

Response	1-2 weeks	2-4 weeks	4-6 weeks	More
Number of growers	1 1 (digging green)	6	2	0
Overall %	20	60	20	0

35. Storage of potato crop before sent to processing plant

Response	No	Yes
Number of growers	7	3
Overall %	70	30

36. Number of tubers per plant of var Atlantic.

Response	5-6 tubers	7-8 tubers	8-10 tubers	Don't know
Number of growers	4	3	2	1
Overall %	40	30	20	10

37. Most important cause of decreasing SG?

Response	Time of planting	Weather	Stress (nutrition and water)	Combination of factors	Don't know
Number of growers	1	2	2	2	3
Overall %	10	20	20	20	30

38. Do you measure SG yourself?

Response	No	Yes
Number of growers	4	6
Overall %	40	60

- **Willingness of owning a new technology to measure SG.**

Response	No	Yes	Depends on cost
Number of growers	2	7	1
Overall %	20	70	10

39. Support of using R&D levy to conduct a project on SG

Response	No	Yes
Number of growers	1	9
Overall %	10	90

Appendix C

Specific Gravity Workshop Plan

Potato Specific Gravity Workshop Plan

<table>
<tr>
<td rowspan="2">Context
Highlight topic:
What we are here for tonight is to identify factors and/or possible causes influencing specific gravity under current management practices and then to priorities them according to future research requirements

Explain outcome:
The outcomes of this session are form a list of key factors influencing potato SG and then rank them in terms of research priorities.

Outline process:
The process we are going to follow is a workshop method (flipchart image), we start at the context where we set the scene. Then we will be going through the process of brainstorming, generating ideas … following is grouping the ideas into pairs and then clusters … denoting a name to that group or pair and finally reflecting on the relationships and/or image we have constructed. From this we shall be able to note what may be the next step.</td>
<td colspan="2">Rational Aim(s)
To identify factors and/or possible causes that influence specific gravity (SG) and nominate which factors we could do future research/study to improve SG.</td>
<td colspan="2">Experiential Aim(s)
Growers motivated to create group action
Optimum for understanding of SG factors
Interactive audience directed to action</td>
<td rowspan="2">Reflect
OK, what we have is a group of named clustered … read clusters out. Now what we need to do is to create an image … to create the image we need to bear in mind what are the relationships we see among the groups.

What do we think happens when we don’t have one of the groups?

Draw the relationships/image?

Next Step:
How do you think we need to proceed?
What are the areas/indicators that we need more insight so that we can understand it more … research!</td>
</tr>
<tr>
<td>Brainstorm
Referring to focus question, get growers to think about factors … ask for a few examples (make sure we are on track).

Brainstorm individually:
Write down 5 – 10 specific factors you believe influences SG.

Select best ideas:
Going around the group call out one factor you think is the most important … adding to the list [make sure no duplication]

List:
Once we have a fairly completed list ask for any final contributions. Factors that growers think should be up there but haven’t been mentioned</td>
<td>Group
Here we have some great data

Forming pairs:
The next step is to identify common themes and we are going to do that by pairing like indicators/factors.
[Get approx 6 – 8 pairs]

Develop clusters:
Now are there any single factors that match to the pairs … can we start developing groupings

Relate all ideas:
We need to make sure all ideas are in a cluster.
Always ensure that we have group consensus.</td>
<td>Name
To recap we have brainstormed about the factors affecting SG, we then proceeded to cluster the factors into groups and the process we are up to is to name the group. We want a short description to name the group so one word up to but no more than five words.

Read out each indicator … and ask what is the common theme. Word mining may be required… is there a way to combine the key words?
Bring people to a consensus</td>
</tr>
<tr>
<td>Time: 15 minutes</td>
<td>Time: 15 minutes</td>
<td colspan="2">Time: 20-30 minutes + break 15</td>
<td>Time: 30 minutes</td>
<td>Time: 15 minutes</td>
</tr>
</table>