Developing a Sustainable Soil Management Model to Increase Farm Gate Returns in Tasmania

Dr Kevin Clayton-Greene
Harvest Moon

Project Number: VG08106

VG08106

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

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

ISBN 0 7341 3291 3

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

Horticulture Australia

HAL Project: VG08106

Milestone No. 190: Final Report (22/11/2011)

Developing a Sustainable Soil Management Model to Increase Farm Gate Returns in Tasmania

Clayton-Greene, K. A. and Rigby, L. M.

VC Project by Harvest Moon

Hal Project No. VG08106 22/11/2011

Developing a Sustainable Soil Management Model to Increase Farm Gate Returns in Tasmania

Project Leader: Dr. Kevin Clayton-Greene
Harvest Moon, Leith Rd, Forth, Tas., 7310
Mobile: 0428 575 233
Email: kevin@harvestmoon.com.au

Project Officer: Lydia Rigby
Harvest Moon, Leith Rd, Forth, Tas., 7310
Mobile: 0439 378 865
Email: lrigby@harvestmoon.com.au

Funding Acknowledgment: This project has been funded by HAL using voluntary contributions from industry and matched funds from the Australian Government.

TABLE OF CONTENTS

SUMMARY

A large number of physical, chemical and biological soil properties together with management practices were analysed against carrot and potato crop performance over a three year period. Soil organic carbon, aggregate stability and soil type were found to have an influence on potato quality. On average potatoes performed better when produced in red Ferrosol soils compared with other soil types. Soils other than ferrosols produced higher quality potatoes with higher organic carbon and aggregate stability levels. Sampling of paddocks using PCR testing revealed a good correlation between disease expression on washed tubers and the levels of soil DNA for black dot (*Colletotrichum coccodes)* and powdery scab *(Spongospora subterranea)*. The results for other diseases such as; rhizoctonia and common scab *(Streptomyces scabies)* were less conclusive. None of the soil or management measures which were collected were found to have a consistent influence on carrot quality over the three seasons. Relationships between carrot quality, sap nitrate and soil compaction were found in the first two seasons but not in year three. Other factors found to have an impact on carrot quality in the first two seasons such as day degrees also failed to occur in 2010/11. This was thought to be due to the extreme weather events that characterised 2010/11 which probably masked other factors. The relationships between carrot quality and plant sap nitrate and soil compaction found in the first two years require further research over longer time frames in order to establish their significance.

INTRODUCTION AND OBJECTIVES

Intensive vegetable production is under constant economic pressure due to continual increases in the cost of production without commensurate increases in the prices paid for produce. For fresh market produce, the relative value of the product in the market place is determined by its quality. Growers can receive up to a ten-fold difference in prices paid for first and second grade produce, whilst receiving no income for produce which is unsaleable (waste). Consequently there exists a significant opportunity to increase returns to growers through increasing produce quality and therefore reducing the fraction of lower grade product and waste.

Whilst yield is important, an examination of the performance of root and onion crops marketed by Harvest Moon shows that improving pack-out (quality) can offer a significant increase in financial returns to growers and the industry. In most cases pack-outs hover around 50-60% of high grade product, giving considerable potential for improvement. Yields by contrast are close to optimum and offer less hope for increases in returns. It is known *(Cotching and Belbin, 2007)* that the general health and condition of the soil may have a considerable influence on crop results. Soil parameters such as compaction, bulk density and structure may play a critical role in carrots; particularly tap root shape, whilst other parameters such as organic matter and soil biology may be important for the cosmetic or aesthetic appearance of carrots and potatoes. However, there is a lack of information and understanding, particularly at the commercial level about how soil may interact to influence the quality of root crops such as potatoes and carrots.

The purpose of this project was to identify which factors that are commonly available to commercial producers influence product quality, in order to provide;

1. An ability to predict, with greater accuracy, the likely suitability of paddock soils for a root crop.
2. To produce guidelines to be followed to improve soils where problems have been identified.
3. Provide guidance on a more sustainable production system for potatoes and carrots.

METHOD

Data was collected from over 150 different carrot and potato paddocks from the north- west coast and northern midlands of Tasmania, over three cropping seasons from September 2008 through to May 2011. A comprehensive soil analysis was undertaken for each paddock which aimed to assess the soils chemical, physical and biological status. All measurements were completed using standard laboratory or field techniques as specified in Appendix 1. Qualitative data was also collected for all sites; including paddock history, soil preparation and crop management.

Soil Chemistry

Soil chemical status was assessed by a full nutrient analysis of the root zone (0-30cm depth), which measured P, K, S, Ca, Mg, Na, Cl, Al, Zn, Fe, Mn, Cu, B as well as total and available nitrogen, organic carbon, electrical conductivity and pH. Plant tissue and petiole sap testing was also undertaken to determine nutrient status within the plant.

Soil Physical Attributes

The physical condition of the soil was measured using a number of techniques. Soil cores were taken from the root zone at 15-22cm depth to assess bulk density. Aggregate stability was measured for soil depth of 0-30cm. Soil structure was assessed in field using the Cotching soil structure score (Cotching, 1997). Soil resistance and compaction were measured in-field with a penetrometer (Spectrum technologies Soil Compaction Tester), whilst soil water infiltration and sorptivity were also measured in-field using the Cornell infiltrometer.

Soil Biology

The biological health of the soil was also measured using a number of techniques. Soil microbial indicator assessments were undertaken on soil samples taken from the 0-15cm depth. This assessment used agar plating methods to determine levels of fungi, yeast, anaerobic and aerobic bacteria, azotobacter and actinomycetes. These assessments were undertaken on 133 different paddocks during the first two seasons of the project, but had to be discontinued due to the closure of the laboratory.

Active or labile carbon was also measured using potassium permanganate extraction as a means for assessing biological activity (Rayment and Lyons, 2010). Bean root bio-assays as outlined in the ‘Cornell Soil health manual’ were also used as a way to assess the biological health of the soil (Gugino *et al*.,2007).

Finally soils were tested using SARDI's quantitative PCR test for potato diseases as a means to assess the levels of rhizoctonia, powdery scab, common scab and black dot disease in the soil and compare these against commercial crops (Keller *et al*., 2009). A preliminary sampling of some paddocks was also performed in year 3 of carrot paddocks to see if there was any relationship between these diseases and carrot packout. The reasoning was that many pathogens are weak competitors and thus may thrive in soils where biological diversity is low and thus disease levels may reflect overall soil health.

Crop Performance Indicators

The data was then compared with measures of crop performance. These measurements were; financial returns, packout performance and percentage waste. The units used for packout performance were % Class1 mediums for potatoes and % Class1 mediums and med/large for carrots. These units were chosen as they are the most valuable portion of the crop, and are graded to the same standard throughout the season. Assessments of waste were also done in the packing shed in order to determine what factors were reducing saleable yield and to link these back to data collected from the paddocks.

Data Analysis

Data was analysed by Glen McPherson Consultancy using stepwise multiple regressions to determine relationships between all measured variables and paddock performance.

RESULTS

Unfortunately the final years data was compromised by extreme weather events which occurred throughout Australia in 2010/11. Nonetheless consistent significant results were found in the potatoes over the three years. Significant relationships were also found in the carrot data for the first two seasons however these were not present in the third.

Potatoes

Organic Carbon (OC), aggregate stability (WSA) and soil type were all found to have a significant positive relationship with potato packout across all three years of the project. Potato packout increased with increasing organic matter, (Figure 1) and higher water stable aggregates (Figure 2, Tables 1 & 2). The relationship between OC and WSA with potato packout may be influenced by soil type, the lower lying values are mostly non-ferrosol soils whilst the higher figures are predominately red Ferrosols (Figure 3). It is likely however that there is also a degree of interdependence between organic carbon, WSA and soil type. In all three years the packout from crops grown in red Ferrosol soils was higher than those from other soil types (Table 3). However, the strength of this relationship varied between years (Table 4).

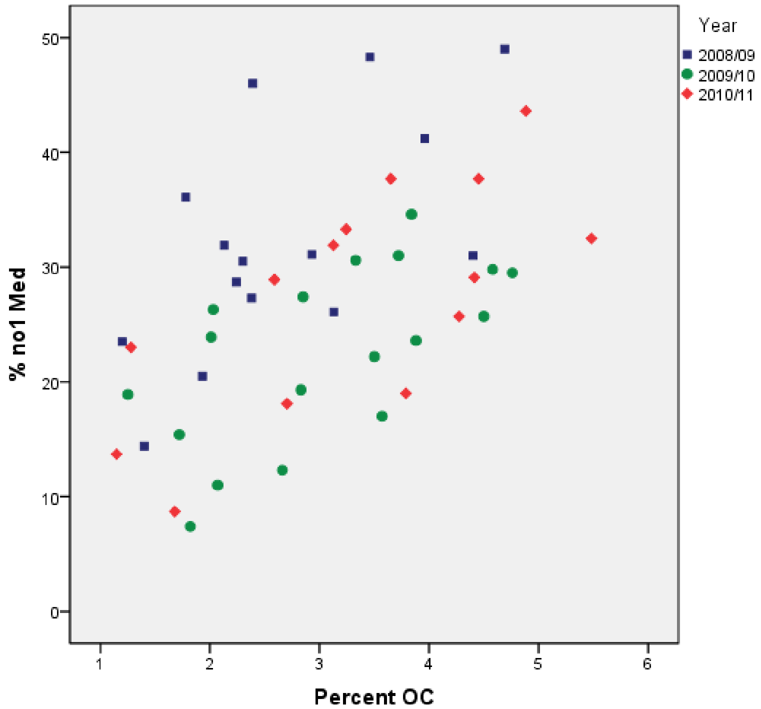


Figure 1. Relationship between soil organic carbon and potato packout over the three seasons. In2008/09 there was a correlation of 0.63 with a p-value 0.05. The correlations for 2009/10 and 2010/11 were 0.62 and 0.7 respectively with a p-value of 0.01.

Source	df	Sum of Squares	Mean Square	F	Sig.
%OC	1	1546	1545.94	29.5	0.000
Year	2	57	28.45	0.5	0.6
Year*%OC	2	21	10.36	0.2	0.8
Error	41	2146	52.34		

Table1. Analysis of variance for comparison of linear regression equations between packout and Organic Carbon across the years, showing the consistent relationship between soil organic carbon and potato packout over the 3 seasons.

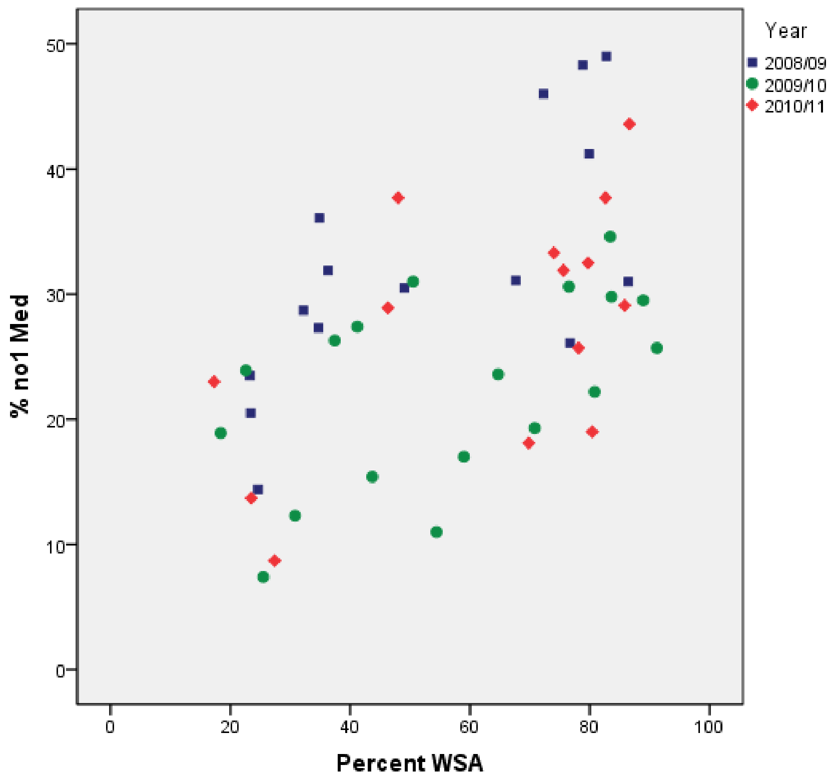


Figure2. Relationship between water stable aggregates and potato packout over the three seasons. In2008/09 there was a correlation of 0.7 with a p-value 0.01. The correlations for 2009/10 and 2010/11 were 0.54 and 0.57 respectively with a p-value of 0.05.

Source	df	Sum of Squares	Mean Square	F	Sig.
%WSA	1	1367	1367.38	24.2	0.000
Year	2	26	12.99	0.2	0.8
Year*%WSA	2	63	31.32	0.6	0.6
Error	41	2318	56.53		

Table2. Analysis of variance for comparison of linear regression equations between packout and aggregate stability across the years, showing the consistent relationship between soil aggregate stability and potato packout over the 3 seasons.

Year	Ferrosol	Non-Ferrosol
2008/09	40.3	26.7
2009/10	25.6	20.1
2010/11	30.7	15.1

Table 3. Mean Values for % potato packout and soil type. In each season the average potato packout was higher for the potatoes produced on Ferrosols compared to those produced on non-ferrosol soils.

Source	df	Sum of Squares	Mean Square	F	Sig.
Soil Type	1	10.441	10.441	3.1	0.09
Year	2	20.245	10.123	3.0	0.07
Soil Type*Year	2	4.047	2.023	0.6	0.56
Error	26	88.187	3.392		

Table 4. Analysis of variance results for potato packout and soil types across the years, showing the significant difference between potato packouts from the different soil types is significant. Note though the relationship varies from year to year with an f-value of 3.0.

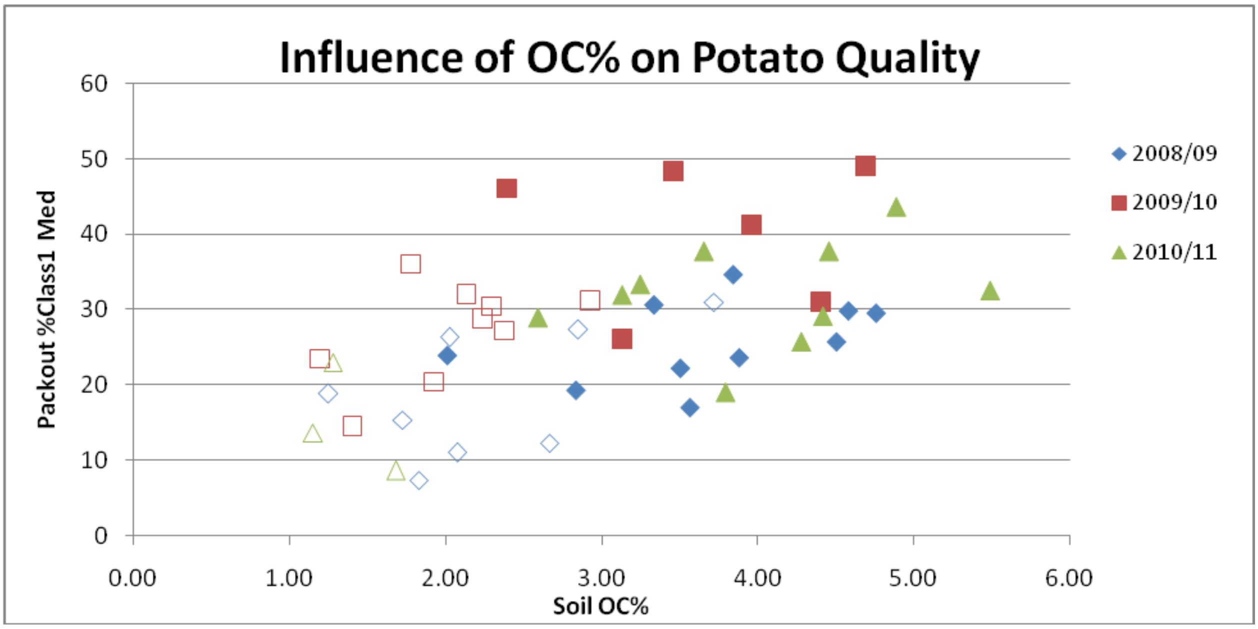


Figure3. Relationship between organic carbon and potato packout, separated by soil types. The Ferrosol soils are shown as the solid markers, whereas the hollow markers are the non ferrosols.

During the second year of the project, soil PCR testing for the potato diseases *Rhizoctonia solani* strains AG2.1 and AG3, powdery scab, common scab and *Colletotrichum coccodes* (black dot) became available as a result of the work completed as part of the Australia Potato Research Program. The use of this technology was added into the project, with all potato paddocks being tested during the 2010/11 season. Due to the small sample size (total of 17 paddocks), and a large portion of the crop still being in storage statistical analysis has not been undertaken on this data. However, initial assessments are promising, showing that this may be a very useful tool for predicting the disease risk for potatoes, particularly for powdery scab and black dot, where there was a good correlation between levels of soil DNA and expression of disease on the washed tubers. The common scab results however seem to be less useful, with some paddocks that tested no or low risk for common scab having significant commercial losses due to this disease.

None of the other variables were found to have a significant consistent association with potato performance (see Appendix 4).

Carrots

No consistent relationships were found between the factors measured and crop performance by carrots across all three seasons (Table 5, Appendix 3). However, the 2010/11 season was uncharacteristic and it is likely the magnitude of weather events masked any effects due to soil factors. The 2010/11 season had above average rainfalls through the summer and cooler than average day time temperatures. Many sites in Northern Tasmania had the highest summer rainfall on record, with rainfall totals twice their typical summer values across all sites (BOM, 2011). In 2010/11 crops harvested after February received less heat units than in previous years (Figure 4). A separate analysis as part of the company's review of the season showed that the weather accounted for a 23% drop in carrot production.

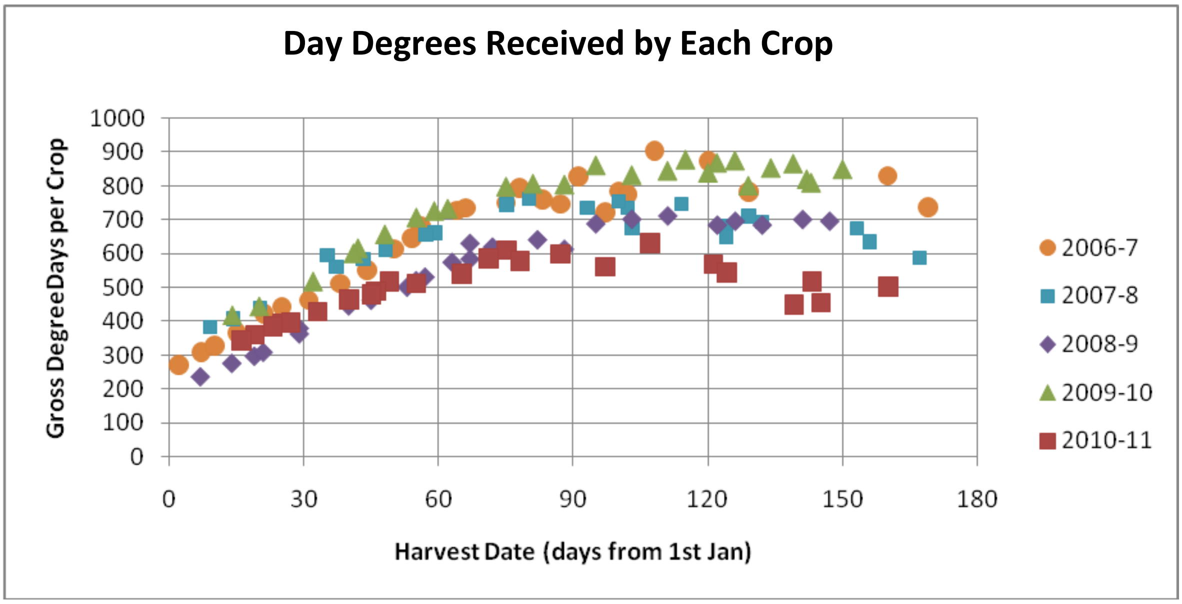


Figure 4. Day Degrees received by each crop over past 5 years. Day degrees is the sum of the mean daily temperatures above 10°C. The plot demonstrates that the crops harvested from March onwards received less heat units than the previous seasons.

Over the 2008/9 and 2009/10 seasons, significant relationships were found between carrot planting date, day degrees and days to harvest (table 5). Historic data going back to the 2003/4 season was available for these variables and they too were analysed. With the exception of the 2010/11 season, negative relationships were found each year between carrot packout and degree days, with crop quality declining as heat units increase (Figure 5). Similarly, in all years with the exception of the 2010/11 season, there was a significant decrease in carrot quality over the course of the season, although the extent of the effect varied between seasons (Figure 6). Days to harvest were found to have a significant negative effect on carrot quality in four of the past seven seasons (Figure 7). Day degrees and planting date are not independent, however it is difficult to be precise as to what it is that these two attributes are influencing that is having an effect upon carrot performance.

	Class1 Yield t/ac			%Class1 med med/lrg			%Waste		
	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11
Days to Harvest	.2	-.6	.2	.1	-.7	.2	.2	.6	.2
Days from 1/8	-.1	-.6	.3	-.5	-.7	.0	.8	.8	.0
Length:weight med		.4	-.3		-.6	.0		.8	.1
NO3 (ppm)	-.3	-.5	-.2	-.7	-.5	-.1	.4	.3	.0
NO3:Ca	-.5	-.4	-.3	-.6	-.4	-.2	.7	.3	-.3
NO3-N(mg/kg)	-.1	-.4	-.2	-.3	-.6	-.4	.4	.4	.3
Compaction	.1	-.5	-.6	-.3	-.6	-.5	.6	.7	.6
Day Degrees	.0	-.5	.5	-.5	-.7	.2	.7	.5	-.1

Table 5. Correlations found between the carrot performance variables and the measured variables over the three seasons. The highlighted figures are significant to a P value of 0.01.

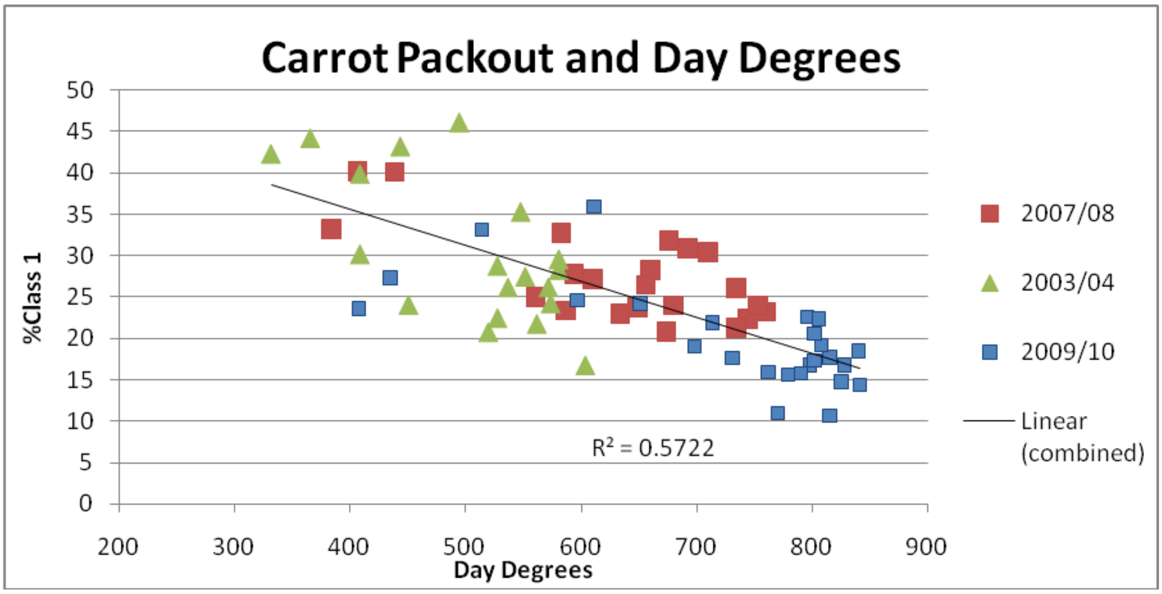


Figure 5.Carrot packout decreases as the heat units received by each crop increases. The extent of this effect varied year to year, the relationship was found in all seasons back to 2003/4, with the exception of the 2010/11 season. Only three seasons are shown for clarity, complete data is in Appendix 3.

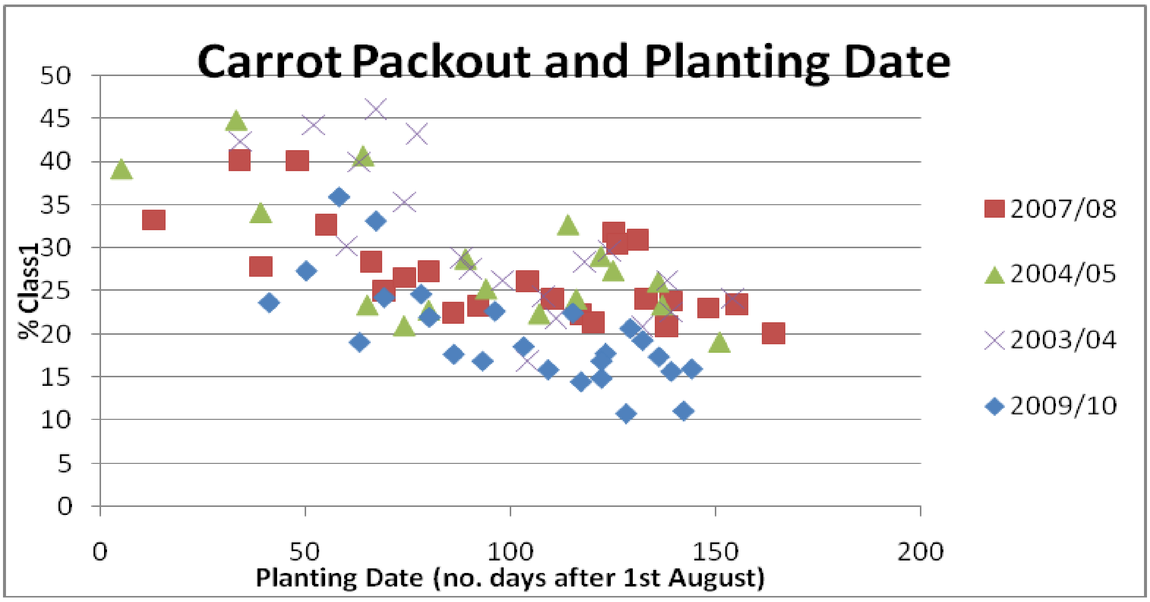


Figure 6.Carrot packout decreases as crops are planted later into the season., The extent of this effect varied year to year, the relationship was found in all seasons back to 2003/4, with the exception of the 2010/11 season. See Appendix 3 for remaining years.

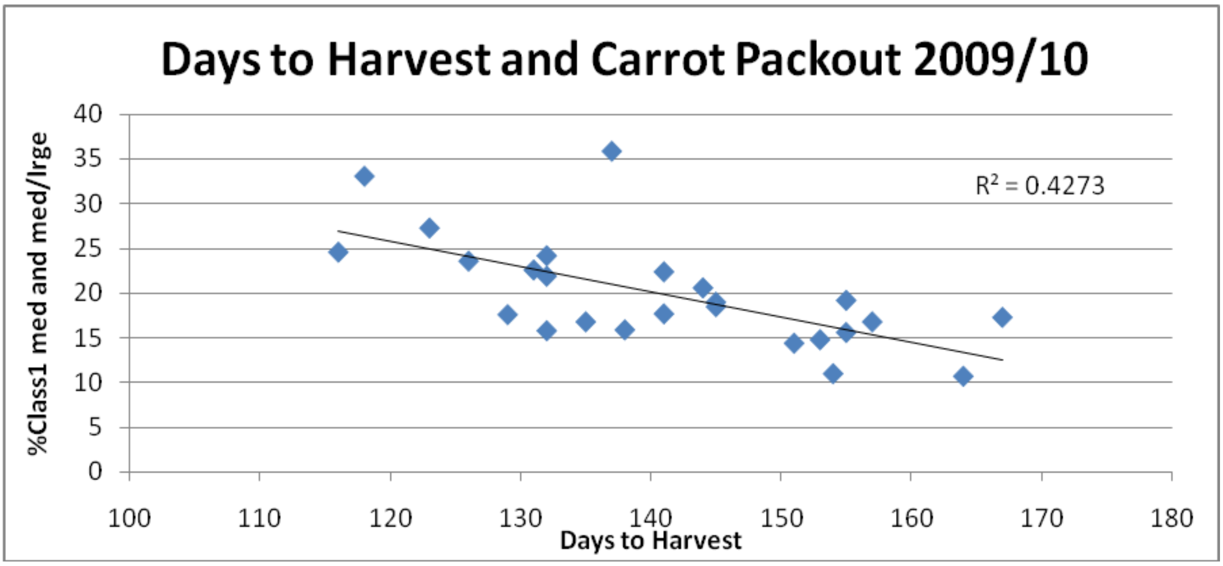


Figure 7.The relationship between carrot packout and days to harvest. Only the 2009/10 data shown, the remaining years relationships are in Appendix 3.

Plant and soil nitrogen content were found to have a significant relationship with carrot performance (Table 5). In the 2008/9 and the 2009/10 seasons, carrot packouts were found to decline as the nitrate levels in the plant sap and soil increased (Figure 8). However this relationship may not be independent, with strong associations between planting date and day degrees (Appendix 2) and may reflect increased nitrification as the soil warms. Nitrate levels were found to increase as the season developed and temperatures increased (Figures 9&10).

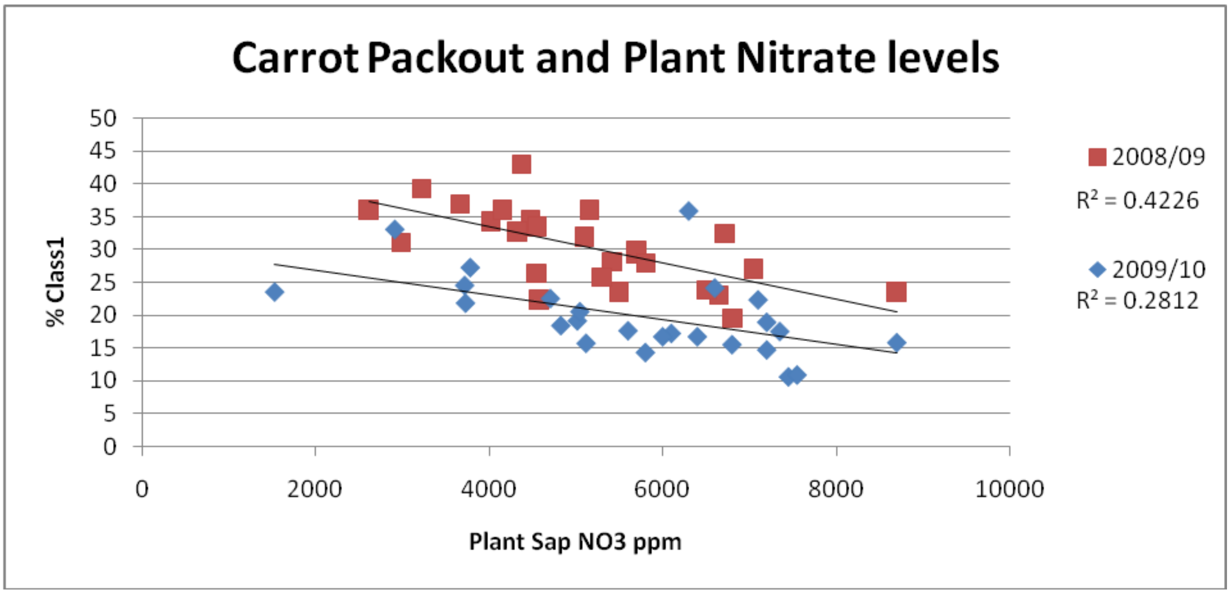


Figure 8. Decrease in carrot quality with increasing levels of nitrate in the plant sap.

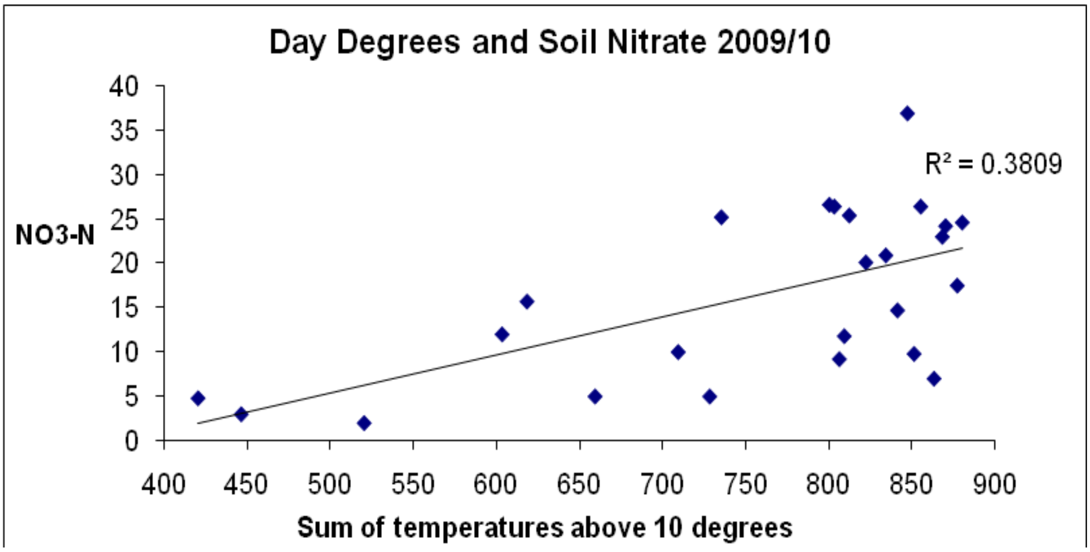


Figure 9. Showing increase in soil nitrate levels with increasing temperatures.

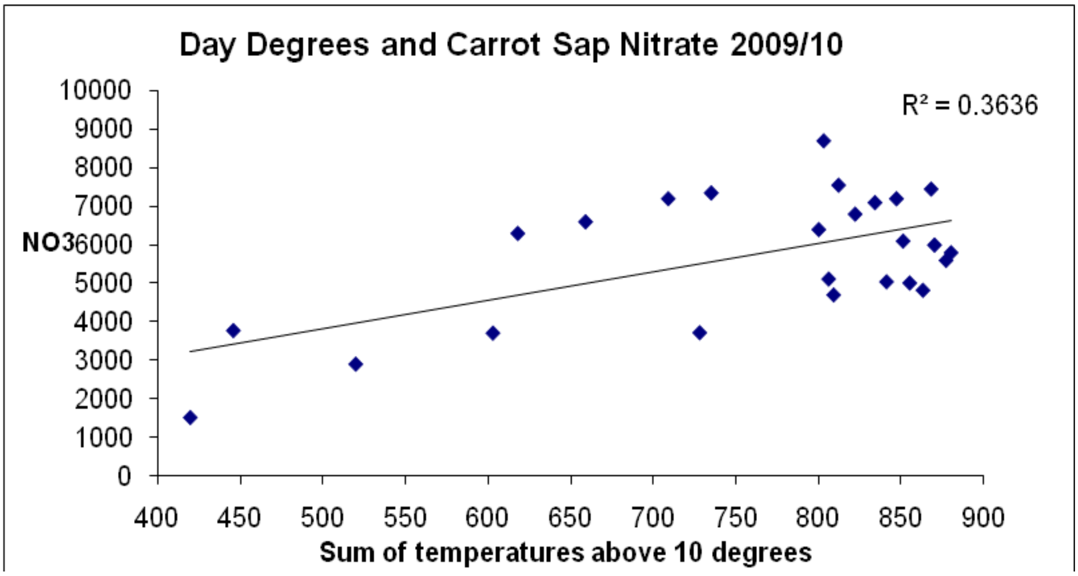


Figure10. Plant sap nitrate levels increase in the carrots as the temperatures increase.

Soil resistance or compaction at planting was also found to have significant relationship with carrot performance in the 2008/9 and 2009/10 seasons (Table 5). The percentage of waste and lower grade carrots increased as the levels of compaction in the soil increased. In 2010/11 the wetter season and soils probably mitigated against any effects of compaction. Soils were often so moist that measurements were difficult to make. In the first two seasons the levels of soil resistance at planting increased as the crops were planted later in the season (Figure 11).

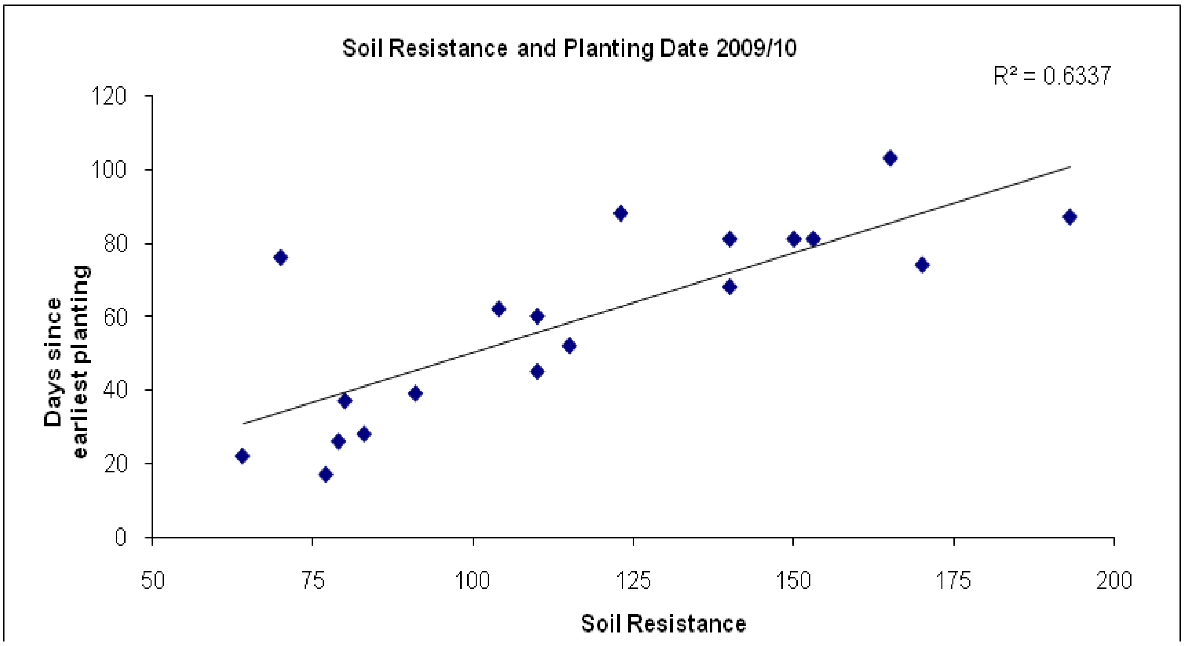


Figure 11. Soil resistance (compaction) at planting increases in the paddocks as the season continues. Paddocks planted later in the season had increased levels of compaction.

DISCUSSION

Potatoes

The results from the potato analysis show that potato packouts and grower returns can be potentially improved through better paddock selection. The data showed that Ferrosols produce a better quality potato than the other soil types. However the other soil types may have the potential to also produce higher quality potatoes where they have a higher organic carbon and aggregate stability levels. This suggests that financial benefits can be achieved through implementing strategies to improve soil health on non-ferrosol soils for potato production. In both 2008/09 and 2009/10 the crops grown in non-ferrosol soils achieved results comparable to those from ferrosol soils where the organic carbon levels were 3% or higher. In contrast, there is little evidence from this data to suggest that, within the range measured, increasing the soils OC or WSA in a Ferrosol will lead to commercial benefits for potato production. In this study the Ferrosols all had an organic carbon level above 2% and the majority of paddocks were over 3%.

Preliminary analysis from PCR testing for potato diseases has shown a strong ability to predict the risk of the diseases powdery scab and black dot prior to planting. Both these diseases can cause significant economic loss in Tasmania, particularly for washed potatoes. Harvest Moon is adopting this testing prior to commercial plantings as a means to assess disease risk and paddock suitability for potato production.

Carrots

The results from the carrot analysis unexpectedly showed that none of the soil health or management practices that were measured had a significant or consistent influence on carrot quality and grower returns over three years. As mentioned earlier it is believed that the weather conditions experienced in 2010/11 were largely responsible. Almost all the carrot data was collected from a single soil type (ferrosols) and hence it is likely that differences between paddocks would be harder to find and easier to mask by external events. Ferrosol soils are known to have a strong buffering capacity (Sparrow *et al*., 2011).

The correlations found between carrot packout and soil and sap nitrate require further investigation in order to determine their importance, as soil and sap nitrate increased in crops planted later in the season (as day degrees increased), it has not been determined which variable is primarily responsible for the reduction seen in carrot packouts.

The correlations between carrot packout and soil resistance at planting also require further investigation, as this relationship also correlated to planting date. Carrots planted earlier in the season (during August and September) are bedded up and planted within a short period, whereas carrots planted later in the season are bedded up for a longer period prior to planting to allow for the benefits of a stale seed bed (for weed control purposes). The longer the soil is bedded up the more the soil in the beds will consolidate. It is likely that this is the reason why soil resistance increased at planting as the season developed. The looser soil in earlier paddocks may allow for improved tap root development during the early stages of the crop, giving improved carrot shape, however once the soil has settled the effect maybe the reverse. This suggests that tillage practices maybe an area for further investigation. Less tillage may in fact be a better option for carrot production.

The strong but inconsistent relationship that was found in a number of the years between days to harvest and carrot quality is considered to be associated with crop maturity. This led to further work and the development of a protocol to predict and assess carrot maturity and ideal time for harvest. These protocols will be fully implemented into the Harvest Moon carrot production program during the 2011/12 season and will improve harvest timing decision in order to achieve the best outcome for each crop.

Additional Findings

In addition to comparing crop performance, the project collected a large amount of soil data. In total over 200 soil samples were collected. Strong correlations were found between the physical soil attributes such as aggregate stability, bulk density, water infiltrability and also carbon, a chemical attribute. However these relationships were weaker in the Ferrosol (Figure 12, Appendix 5).

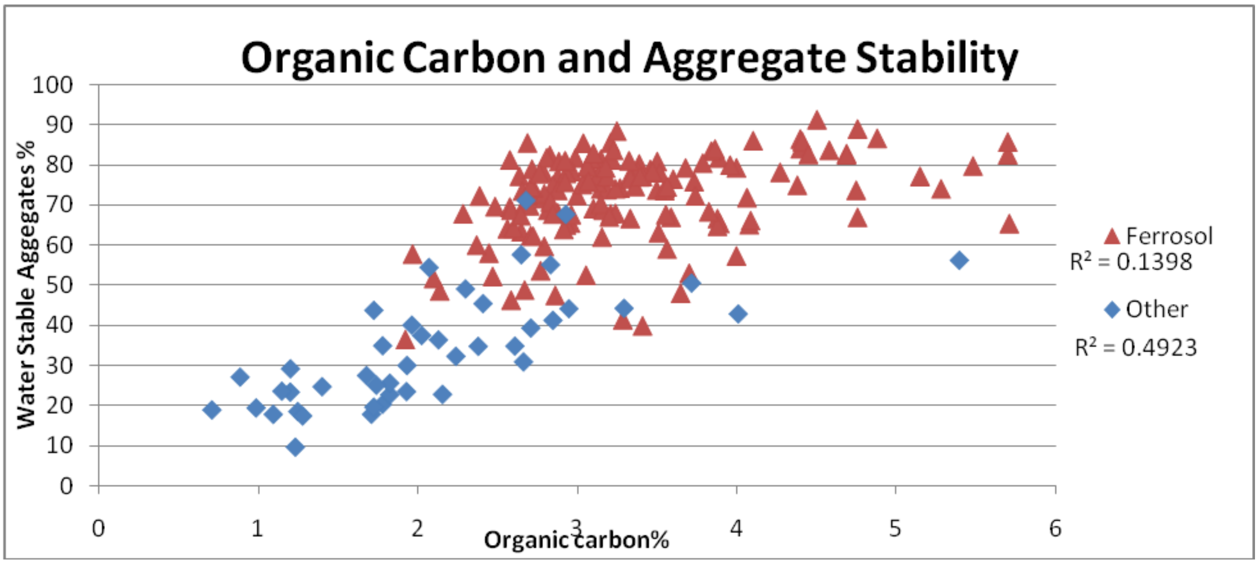


Figure 12. Plot of soil test results collected over the three seasons, showing the relationship between organic carbon and aggregate stability. The relationship is stronger in the non-ferrosols. Only a weak relationship was present in the Ferrosols across the ranges measured.

There were no strong or consistent correlations between the soil microbial indicator tests (SMI) and any of the performance variables or the other soil health measures. Only weak relationships were identified during the first year between total bacteria and potato packout and Azotobacter and carrot packouts (Appendix 6). These results were not found in the 2009/10 season. Similarly the bean root bio-assays and labile carbon tests also failed to correlate to any of the performance variables or other soil health measures. Whilst soil biology is known to be an important aspect of the soils health, these results suggest that these methods for measuring soil microbiology are of limited use for providing information on soil health and the impact this may have upon commercial crop performance.

OUTCOMES

Despite failing to provide a strong predictive measure for carrot performance, the project nonetheless produced a number of significant findings which have already been integrated into Harvest Moon's cropping program. It also indicated that some attributes which were thought to be important such as fine seed beds may have little effect upon carrot performance.

It is clear that non-ferrosol soils will respond to organic matter addition with improvement in potato quality, at least up to a level of 3%. It is also worth noting that Ferrosols may show no such affect thus it is important to be clear as to the reason for organic amendments in such soils.

Testing will continue to see if disease levels may be an indicator of soil health for carrots whilst all potato paddocks are now routinely being assessed with PCR testing prior to planting.

Work will also continue to monitor nitrate levels and carrot performance to see if the data from the first two seasons is valid.

Harvest Moon has a large grower base for its cropping program and produces nearly 10% of Australia's table carrot production. The Company has a grower base of over 120 and most of these growers produce crops for a range of other companies. Implementation of these results will clearly have flow through effects into the broader growing community.

The soil health data from the project was also presented at the Soils R&D Presentation Day for the Tasmanian Branch of the Australian Society of Soil Science, in Launceston on the 30th June 2011. This forum was an opportunity to share this work with others involved in soil research in Tasmania. Through the sharing of research work, better emphasis can be placed onto allocating which areas require further research.

ACKNOWLEDGEMENTS

I would like to thank Dr. Doris Blaesing for her assistance with project planning and result interpretation.

Harvest Moon's potato and carrot contract growers for allowing me to undertake sampling in their crops and for providing crop management information.

REFERENCES

BOM, 2011. www.bom.gov.au/climate/current/season/tas/archive/201102.summary.shtml

Cotching WE (1997) Krasnozem topsoil structure. Australian Institute of Agricultural Science and Department of Primary Industry and Fisheries, Tasmania

Cotching, W.E. and Belbin, K.C. 2007. "Assessment of the influence of soil structure on soil strength/soil wetness relationships on Red Ferrosols in north-west Tasmania." AUSTRALIAN JOURNAL OF EXPERIMENTAL AGRICULTURE. Volume: 44**,** Issue:12**,** Pages: 1241-1249.

Gugino, B.K., Idowu, O.J., Schindelbeck, R.R., van Es, H.M., Wolfe, D.W., Moebius, B.N., Thies, J.E. and Abawi, G.S. 2007. Cornell Soil Health Assessment Training Manual, Edition 1.2.2, Cornell University, Geneva, NY.

Ophelkeller, K., SARDI, Storey, M., 2009. Diagnostic tests for soil borne pathogens, International Collaboration. HAL Project PT08048

Rayment, G.E. and Lyons, D.J. 2010. Soil chemical methods: Australasia

Sparrow, L.A., Cotching, W.E., Parry-Jones, J., Oliver, G., White, E., Doyle, R.B. 2011. Changes in carbon and Soil Fertility in Tasmanian Ferrosols. Current activities n Tasmanian Soil Science, Australian Society of Soil Science Inc. Forum June 2011. Newnham, Launceston, Tasmania

Appendix 1

Table listing methods used for soil analysis.

Element/Test	Method/code	Undertaken by:
Soil Tests		
Nitrate	4500-NO3F	AgVita*
Ammonium	QC10-107-06-5-E	AgVita
Chloride	5A2	AgVita
Phosphorus	ICPES Mehlich extract	AgVita
Potassium	ICPES Mehlich extract	AgVita
Calcium	ICPES Mehlich extract	AgVita
Magnesium	ICPES Mehlich extract	AgVita
Sodium	ICPES Mehlich extract	AgVita
Sulphur	ICPES Mehlich extract	AgVita
Boron	ICPES Mehlich extract	AgVita
Copper	ICPES Mehlich extract	AgVita
Zinc	ICPES Mehlich extract	AgVita
Manganese	ICPES Mehlich extract	AgVita
Iron	ICPES Mehlich extract	AgVita
Molybdenum	ICPES Mehlich extract	AgVita
Selenium	ICPES Mehlich extract	AgVita
Cobalt	ICPES Mehlich extract	AgVita
Aluminium	ICPES Mehlich extract	AgVita
pH	pH 4B3 in water	AgVita
pH	pH 4A2 in CaCl	AgVita
Total Carbon	ISO-10695 Combustion	AgVita
Total Nitrogen	ANC300305E Combustion	AgVita
Organic Carbon	Walkley & Black	AgVita
Organic Matter	Calculated	AgVita
Phosphorus Saturation ratio	M3-PSR Calculated	AgVita
Phosphorus Buffer Index	PBI 9I4	AgVita
Water Stable Aggregates	Cornell University	AgVita
Labile Carbon	Potassium Permanaganate Extraction	AgVita
Soil Microbial Indicator	Agar plating	DHM Labs NZ
Potato Diseases	PCR	SARDI
Soil Resistance	In-field Penetrometer	Project Officer
Bulk Density	12.5cm diameter, 7cm depth cores	Project Officer
Water infiltration	Cornell University Infiltrometer	Project Officer
Bio-assay	Cornell University Bean root method	Project Officer
Structure Score	Bill Cotching	Project Officer
Plant Tissue Nutrient Analysis	ICP and flow injection analysis	Agvita

*AgVita Analytical Pty Ltd, Devonport,Tasmania, Australia, Ph: 03 64209600

Appendix 2

Factors affecting paddock performance of carrots. August 2010

Statistical Report by Glen McPherson Consultancy

16a Maning Avenue

Sandy Bay 7005

Tasmania

Australia

Glen McPherson Consultancy

Data Management

Phone: (03) 6225 3162

Mobile: 0419 001 612

Email: mcpconsult@gmail.com

Factors affecting paddock performance of carrots

for Harvest Moon

August 2010

Objectives

1. Using data from the 2009/10 season, to seek associations between paddock performance in carrots as measured by ‘Class 1 yield', '% Class 1 large and medium large' and '% waste', with a selection of variables that are considered to have potential as explanatory variables. These variables provide data from four main areas of paddock composition – dates of planting and harvesting, physical, chemical, and environmental variables.
2. To determine if there is evidence of a change in the relations between the three response variables and planting date across a number of years, and if so, to seek to explain the variation through variations in climate.

Principal findings

2009/2010 SEASON

Planting date and days to harvest

- For all response variables, namely Class 1 yield, Percent waste, and Percent Class 1 large and medium large, the strongest relationship is with planting date.
- Planting date is highly correlated with days to harvest. Hence the strong relation is also found with days to harvest.
- Given the predictive information contained in planting data, there is generally no useful predictive information in any of the other variables in the set of explanatory variables employed in the study. The only exception is that Compaction provides additional predictive information for Percent waste and Percent Class 1 large and medium large.

Other predictive variables

If it is assumed that planting date is dictated by factors that are not easily controlled, then the following findings become important:

- For Class 1 yield:. Compaction is a substantial predictor.
- Percent waste: Compaction is a strong predictor.
- Percent Class 1 large and medium large: Three nutrient variables with substantial predictive power (Total nutrients, NO3, and NO3-N). These variables are strongly correlated. Hence they contain similar information.

INTERPRETING INTERRELATIONS

The points made above cover direct relations between predictors and response variables. There has also been exploration of relations among predictors to aid the search for an understanding of the cause-effect structure that is operating.

Weather variable

- The weather variable defined as the sum of temperatures for days with average temperatures above ten degrees is strongly correlated with planting date for earlier planting dates (which corresponds with low sums) but the relation is weak for later planting dates. What is significant is that the weather variable correlates well with the three response variables when sums are higher but not when the sums are lower. The implication is that variables that correlate well with the weather variable are likely to also be important as predictors for performance for later planted crops although not necessarily for earlier planted crops.
- Predictors that are indicated as having value with respect to later planted crops are NO_3, NO_3-N, total nutrients and compaction.
- On the basis of the findings the possibility that later planted crops have poorer performance could be associated with either the longer exposure to warm weather or to increased nitrogen levels.

Days to harvest

- Low nitrogen levels are associated with shorter days to harvest.
- There is no relation between days to harvest and planting date for crops planted within 60 days of the earliest planting date. There is strong positive relation between the variables for later planting dates.

Compaction

Compaction is identified in several analyses as a predictor for performance. While it correlates with other potential predictors, the relation is not strong. This suggests that the contribution from compaction possibly takes a different from that provided by other variables.

COMPARISONS ACROSS SEASONS

- There is strong evidence that the relation between all response variables and planting date varies across years from the 2003/04 season to the 2009/10 season.
- There is no explanation for the variation in terms of monthly rainfall data or monthly temperature data.

RELATIONS BETWEEN PLANTING DATE AND OTHER VARIABLES

Based on the data from the 2009/10 season:

- There is a strong positive relation between planting date and the sum of temperatures for days with temperatures above ten degrees, although the relation is lost when the sum is high.
- Compaction has a strong relation with planting date, with higher compaction associated with later planting date.
- Several nutrient variables and boron have a moderate relation with planting date.

Additionally:

- Of the variables for which data are available, only boron shows a difference in pattern between the 2008/09 season and the 2009/10 season. However, the existence of this difference is dependent on a low reading from a single paddock.

Data

2009/10 DATA

Data are provided from 25 paddocks in the 2009/2010 season for each of three paddock performance variables, namely ‘Class 1 yield', '% Class 1 large and medium large' and '% waste' and for 26 potential explanatory variables.

The explanatory variables are listed below.

Some variables have missing values.

Table 1. Potential explanatory variables used in the analysis.

Group	Variable	Number of values
Dates	Days since earliest planting date*	25
	Days to Harvest	25
Nu-Test	NO_3 (ppm)	25
	NO3 to Ca	25
	Boron	25
	Total nutrients	25
N- Check	NO_3-N(mg/kg)	25
	NH_4-N(mg/kg)	24
Express Soil	OC (%)	25
	WSA (%)	25
Field Assessment	Compaction	19
	Density	25
SMI Data	Total Microbial:	24
	Bacteria	24
	Fungi	23
	Yeast	24
	Anaerobic	24
	Azotobacter	24
	Actinomycetes	24
	Fungi: to Bacteria	23
	Fungi to Yeast	23
	Viable Count	24
Additional variables	Ploughed	25
	Workability**	25
	Infiltration	21
	Bulk density	24
	Labile carbon	25
	Sum av temp above 10 deg	25

* For purpose of analysis, 'planting date' was replaced by Days since earliest planting date. The date 11/9/2009 became day 0.

** For purpose of analysis, the three classes of workability, 1, 2 and 3 were replaced by two classes, 1 and 'greater than 1' because there were too few paddocks with class 3 for reliable analysis.

DATA FROM STUDIES BETWEEN 2003 AND 2010

Data on the three response variables and planting date were provided for all years from 2003/04 to 2009/10 except for 2005/06.

The variable 'Days since earliest planting date' was constructed from planting date data using the earliest planting date across all years (6 August) as the common zero date.

WEATHER DATA

For the search for an explanation for changes in relations between response variables and the Days since earliest planting date, data were obtained on average monthly temperature and average monthly rainfall for the years and months of the growing season.

The weather data obtained, and the sites to which it applies, are presented in Table 2.

From the data provided, additional variables were computed to provide averages over extended periods (Table 2).

Table 2. Monthly rainfall and temperature data for the region over the study period.

TOTAL RAINFALL (FORTHSIDE R/S)

Year	Aug	Sep	Oct	Nov	Dec	Jan	Aug+Sep	Aug to Oct	Aug to Nov
2003/04	159.4	117.8	30	21.6	73.6	148.8	277.2	307.2	328.8
2004/05	85.4	32.8	58.8	86.6	41.8	16	118.2	177	263.6
2006/07	*25.4*	54	13.2	*13.4*	23.6	74.2	79.4	92.6	106
2007/08	122.8	85.8	39.8	23.8	123.8	13.4	208.6	248.4	272.2
2008/09	*66.6*	76.6	9.4	88.4	58.2	9.4	143.2	152.6	241
2009/10	186.4	110.2	48	*74.8*	*23.4*	*4.6*	296.6	344.6	419.4

MEAN MAXIMUM TEMPERATURE (DEVONPORT AIRPORT)

	Aug	Sep	Oct	Nov	Dec	Jan	Aug to Sep	Aug to Oct	Aug to Nov
2003/04	12.8	13.2	14.5	17.7	20.6	19.8	13.0	13.5	14.6
2004/05	12.6	14.3	16.1	17.4	20.6	21.3	13.5	14.3	15.1
2006/07	13.2	13.9	15.7	18.2	19.6	21.9	13.6	14.3	15.3
2007/08	13.4	14.5	15.5	19.1	20.4	22.5	14.0	14.5	15.6
2008/09	12.9	14	16.7	17.8	18.8	21.5	13.5	14.5	15.4
2009/10	13.8	14.7	16.1	19.5	20	23.1	14.3	14.9	16.0

Statistical approach

Initially the contribution of individual explanatory variables was considered in accounting for variation in responses for the individual paddock performance variables.

Where there was evidence of a contribution from a variable, there was further exploration to determine if additional information could be obtained from any other variables.

The method employed is linear regression analysis except in the case of the categorical explanatory variables 'Ploughing' and 'Workability'. In respect of these binary variables, t-tests were employed to compare mean responses.

Standard model and data checking were applied to determine if there was any evidence against the assumption of a linear additive model with constant variance, or if there were any responses that suggested data errors. There was no evidence against the model assumptions and no evidence of data errors.

INTERPRETING RESULTS OF STEPWISE REGRESSION ANALYSIS

The process of fitting statistical models proceeds in stages.

At the first stage, each potential explanatory variable is included in a simple linear equation on the assumption that portion of the observed variation in the values of the response variable can be explained by variation in the explanatory variable.

Assuming there is at least one explanatory variable that has predictive value, the percentage of variation in the response variable explained by the variable identified as having the most predictive power is included in the regression equation.

Then tests are performed by including, successively, each other potential regression equation.

If at this second stage, there is an explanatory variable that adds additional predictive information, it is included.

The process is continued with the test for additional information from a third explanatory variable, and so on.

Relations among nutrient variables

If two explanatory variables are closely related, it follows that any predictive power one variable may have in respect of a response variable will also be contained in the other variable. In the current study, this is the case for several nutrient variables.

The levels of 'NO_3' and 'Total nutrients' is an example of two variables that are highly correlated (Table 3).

In the context of stepwise regression, the consequence of this close association is that the selection of one of these variables are a predictor will automatically exclude the inclusion of the other since there is no additional predictive information in the second variable.

Table 3. Correlations among nutrient variables.

	NO_3 ppm	Total nutrients
Total nutrients	0.96	
NO_3-N mg per kg	0.68	0.62

It is important to appreciate that the failure to select the second variable is not an indication it has no predictive power.

Generally this carries the practical consequence that in a case where cause and effect is known to apply, it is not possible to determine the extent to which one or other of the explanatory variables is the causal variable.

CORRELATIONS AMONG RESPONSE VARIABLES

There are strong relations between the three response variables (Table 4) which carries the implication that predictive relationships can be expected to be similar.

Table 4. Correlations among response variables.

	% Class 1 large and medium large	%Waste
Class1 Yield	.90	-.75
% Class 1 large and, medium large		-.744

Results from the 2009/10 trial

RELATIONSHIPS BETWEEN PLANTING DATES AND OTHER EXPLANATORTY VARIABLES

The sum of temperatures for days with average temperatures above ten degrees is strongly related to planting date. This raises the possibility that planting date might be, in part, dependent on these other variables. Whether this is the case or not, is not a question that cannot be assessed by statistical analysis.

CLASS 1 YIELD

Findings are summarised in Table 5

The strong predictive relationships are with the two date variables, namely ‘Days since earliest planting date’ and ‘Days to harvest’, with ‘Days since earliest planting date’ accounting being the stronger predictor and accounting for about 40% of the total variation in Class 1 yield.

A plot of Class 1 yield versus Days since earliest planting is displayed in Figure 2 and a plot versus Days to harvest is provided in Figure 3.

With either of these variables included as a predictor, there is no additional information available in any of the other potential explanatory variables.

If date variables are excluded as potential predictors, the best predictor is Total nutrients which accounts for 19% of variation in Class 1 yield.

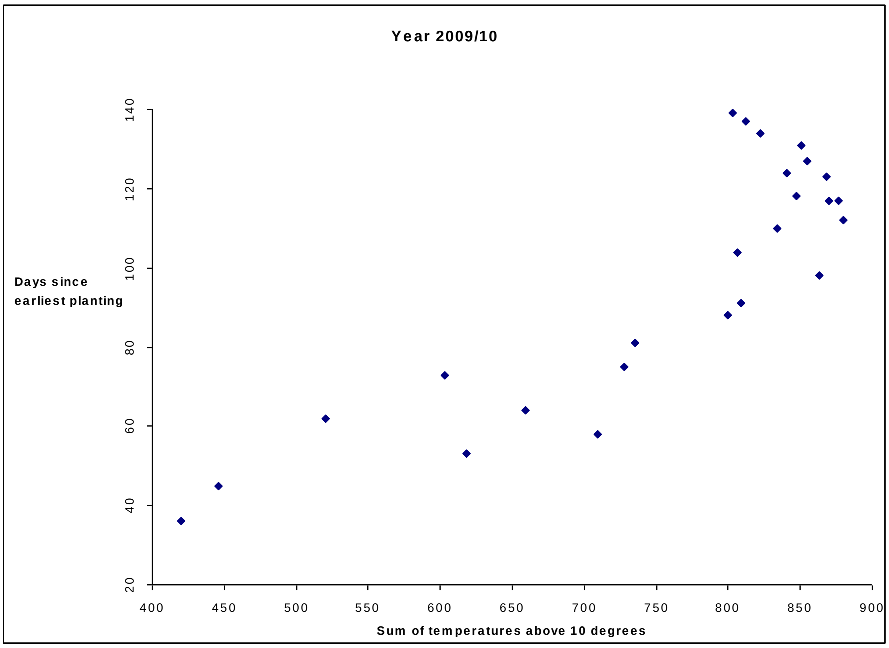


Figure 1. Relation between planting date and The sum of temperatures for days with average temperature above 10 degrees.

Table 5. Class 1 yield. Correlations with potential predictors and results of regression analyses.

	Correlation				**Regression (R^2)**	
					Single variables	
Class 1 yield with	Correlation with Yield	Sig. (p)		Number of missing values	Best single variable	Exc date variables
Days since earliest plant date	**-.642**	0.00	***		41%	
Days to Harvest	**-.573**	0.00	***			
NO3 ppm	-.468	0.02	**			
NO3 to Ca	-.314	0.13				
Boron	.149	0.48				
Total nutrients	-.482	0.01	**			19%
NO3-N mg per kg	-.359	0.08				
NH4-N mg per kg	.004	0.99		1		
OC Perc	.210	0.31				
WSA Perc	-.165	0.43				
Compaction	-.464	0.05	**	6		
Density	-.030	0.89				
Total Microbial	-.088	0.68		1		
Bacteria	-.217	0.31		1		
Fungi	.249	0.25		2		
Yeast	-.016	0.94		1		
Anaerobic	.323	0.12		1		
Azotobacter	-.105	0.63		1		
Actinomycetes	.335	0.11		1		
Fungi to Bacteria	.371	0.08		2		
Fungi to Yeast	.277	0.20		2		
Viable Count	.043	0.84		1		
Sum temp days above 10 deg	-0.458	0.02	**			
Infiltration	**-0.038**	0.87				
Bulk density	-.189	0.38				
Labile carbon	0.140	0.50				
Number of observations					25	25

*** $P<0.01$
** $p<0.05$
* $p<0.1$

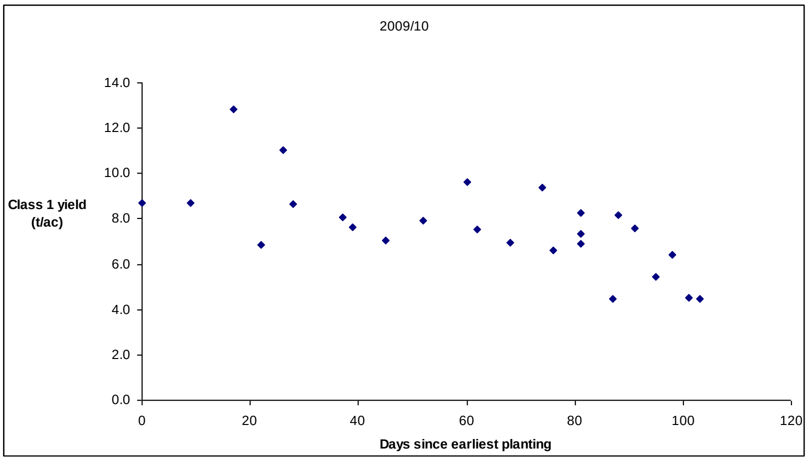


Figure 2. The relation between Class 1 yield and Days since earliest planting in the 2009/10 season.

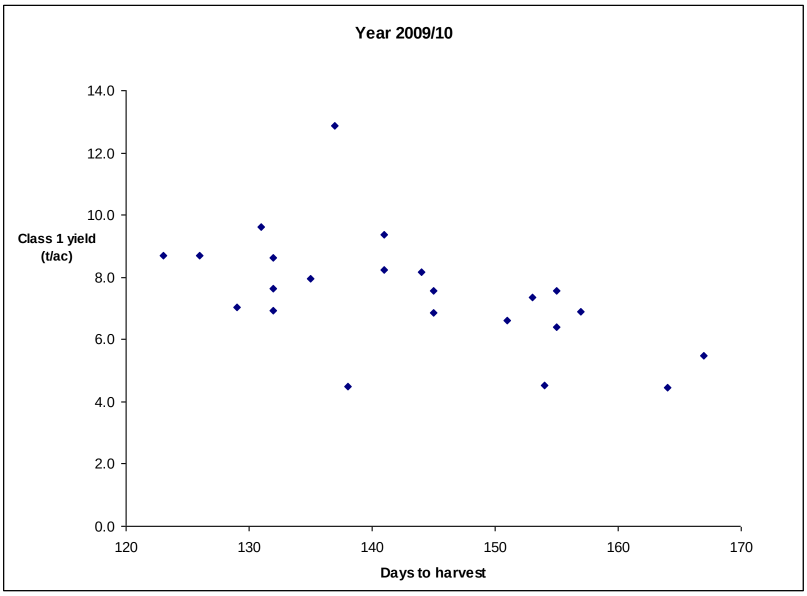


Figure 3. The relation between Class 1 yield and Days to harvest in the 2009/10 season

PERCENT WASTE

Findings are summarised in Table 6.

The strong predictive relationships are with the two date variables, namely 'Days since earliest planting date' and 'Days to harvest', with Days since first planting being the stronger predictor and accounting for 64% of the total variation in Class 1 yield.

A plot of Percent waste versus Days since earliest planting is displayed in Figure 4.

With Days since earliest planting date included as a predictor, Compaction provides additional predictive power that increases the percentage prediction to 71%.

If date variables are excluded as potential predictors, Compaction is included as a strong predictor, accounting for 53% of variation in Percent waste.

The sum of temperatures where the average temperature is above ten degrees is also identified as a predictor and accounts for 37% of variation in Percent waste.

No other potential explanatory variable is identified as having a relation with Percent waste.

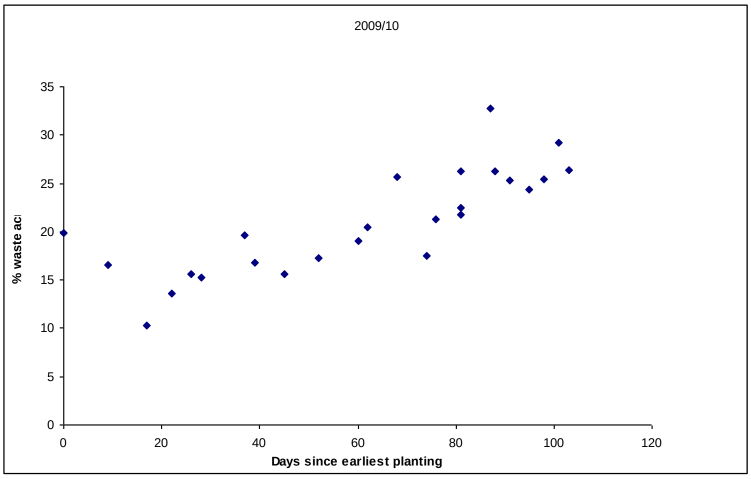


Figure 4. The relation between Percent waste and Days since earliest planting in the 2009/10 season.

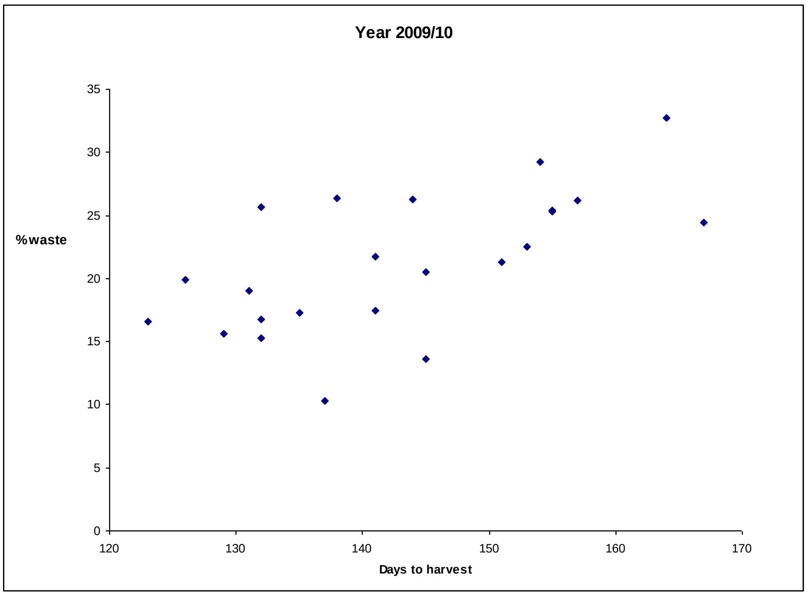


Figure 5. The relation between Percent waste and Days to harvest in the 2009/10 season

Table 6. Percent waste. Correlations with potential predictors and results of regression analyses.

	Correlation				Regression (R^2)		
					Single variables		Stepwise
% waste with	Correlation with Waste	Sig. (p)		Number of missing	Best single variable	Compaction	Plant date, compaction
Days since earliest plant date	**.801**	0.00	***		0.64		0.71*
Days to Harvest	**.624**	0.00	***				
NO3 ppm	.242	0.24					
NO3 to Ca	.279	0.18					
Boron	-.280	0.17					
Total nutrients	.247	0.23					
NO3-N mg per kg	.386	0.06	*				
NH4-N mg per kg	.137	0.52		1			
OC Perc	-.188	0.37					
WSA Perc	.078	0.71					
Compaction	**.726**	0.00	***	6		53%	
Density	-.029	0.89					
Total Microbial	-.177	0.41		1			
Bacteria	.246	0.25		1			
Fungi	-.213	0.33		2			
Yeast	-.058	0.79		1			
Anaerobic	-.226	0.29		1			
Azotobacter	.337	0.11		1			
Actinomycetes	-.093	0.67		1			
Fungi to Bacteria	-.362	0.09	*	2			
Fungi to Yeast	-.201	0.36		2			
Viable Count	.136	0.525		1			
Sum temp days above 10 deg	**-0.606**	0.00	***				
Infiltration	-.141	0.54	*				
Bulk density	.131	0.54					
Labile carbon	-0.233	0.26					
Number of observations					25	19	19

***	P<0.01
**	p<0.05
*	p<0.1

Note: * The fact that there are 6 missing values for compaction means that stepwise regression analysis that includes this variable can only be applied to data from19 of the 25 paddocks. A consequence is that the proportion of variable explained by Days since earliest harvest is different when this variable is fitted together with compaction than when it is fitted alone.

PERCENT CLASS 1 LARGE AND MEDIUM LARGE

Findings are summarised in Table 7.

The strongest predictive relationship is with the date variable 'Days since earliest planting date' which accounts for 53% of the total variation in Percent class 1 large and medium large.

A plot of Percent waste versus Days since earliest planting is displayed in

Figure 6.

Additional information is contained in Compaction. Including this variable raises the percentage explained to 59%.

If date variables are excluded as potential predictors:

- The variable Sum of temperatures for days with average temperatures above ten degrees is identified as a predictor and accounts for 37% of the variation in Percent class 1 large and medium large.
- Three nutrient variables (Total nutrients, NO_3, NO_3-N) are identified as each having a relation to Percent Class 1, accounting for between 26% and 31% of variation in Percent Class 1 large and medium large. As expected from the strong relationships between these variables (Table 3), if any one of these variables is included as a predictor, there is no additional predictive information contained in the other variables.

With any of these variables included as a predictor, there is no additional information available in any of the other potential explanatory variables.

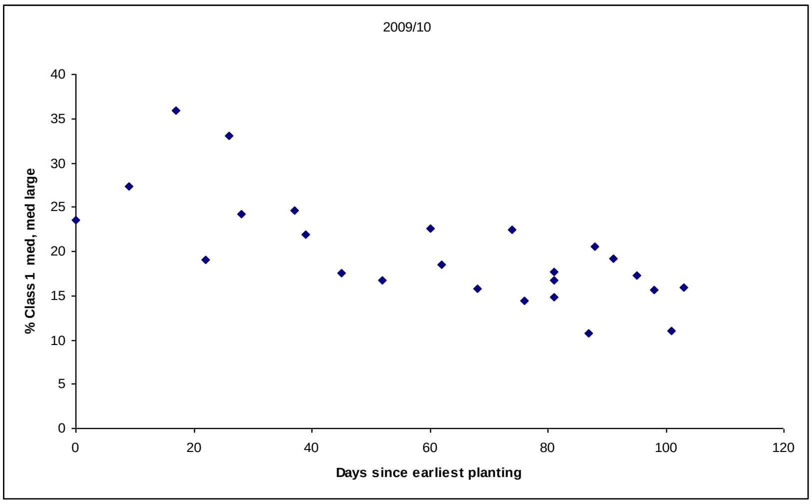


Figure 6. The relation between % Class 1 large and medium large and Days since earliest planting in the 2009/10 season.

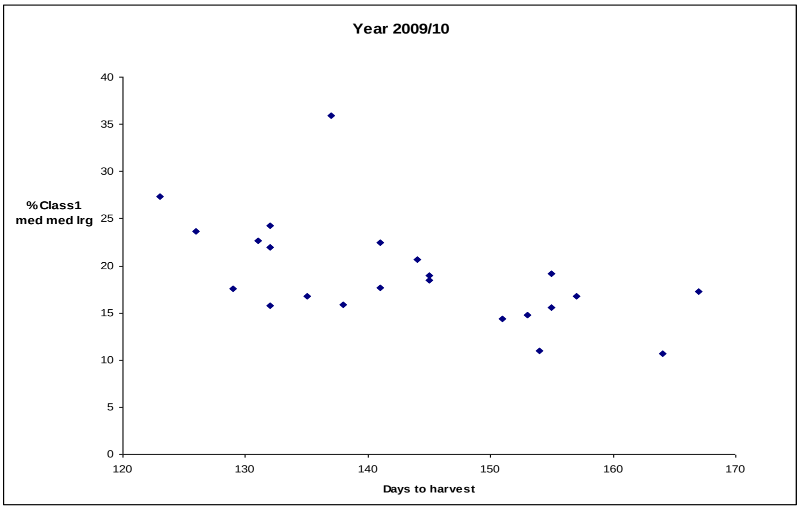


Figure 7. The relation between % Class 1 large and medium large and Days to harvest in the 2009/10 season.

Table 7. Percent Class 1 large and medium large. Correlations with potential predictors and results of regression analyses.

% Class 1 large and medium large with	Correlation with % Class 1	Sig. (p)		Number of missing values	Regression (R^2) Single variables: Best single variable	Exc date variables	Stepwise: Plant date, compaction
Days since earliest plant date	**-.727**	0.00	***		53%		59%
Days to Harvest	**-.654**	0.00	***				
NO3 ppm	**-.514**	0.01	***				
NO3 to Ca	-.347	0.09	*				
Boron	.287	0.16					
Total nutrients	**-.521**	0.01	***				
NO3-N mg per kg	**-.559**	0.00	***				
NH4-N mg per kg	.005	0.98		1			
OC Perc	.246	0.24					
WSA Perc	-.249	0.23					
Compaction	-.557	0.01	**	6			
Density	-.112	0.59					
Total Microbial	-.068	0.75		1			
Bacteria	.005	0.98		1			
Fungi	.139	0.53		2			
Yeast	.091	0.67		1			
Anaerobic	.486	0.02	**	1			
Azotobacter	-.129	0.55		1			
Actinomycetes	.169	0.43		1			
Fungi to Bacteria	.178	0.42		2			
Fungi to Yeast	.188	0.39		2			
Viable Count	.139	0.52		1			
Sum temp days above 10 deg	**-0.605**	0.00	***			37%	
Infiltration	-.106	0.65	**				
Bulk density	-.169	0.43					
Labile carbon	0.281	0.17					
Number of observations					25	25	25

*** P<0.01

** p<0.05

* p<0.1

Note: * The fact that there are 6 missing values for compaction means that stepwise regression analysis that includes this variable can only be applied to data from19 of the 25 paddocks. A consequence is that the proportion of variable explained by Days since earliest harvest is different when this variable is fitted together with compaction than when it is fitted alone.

Relations between response variables and Ploughing and Workability

None of the response variables show evidence of a relation with either ploughing or workability.

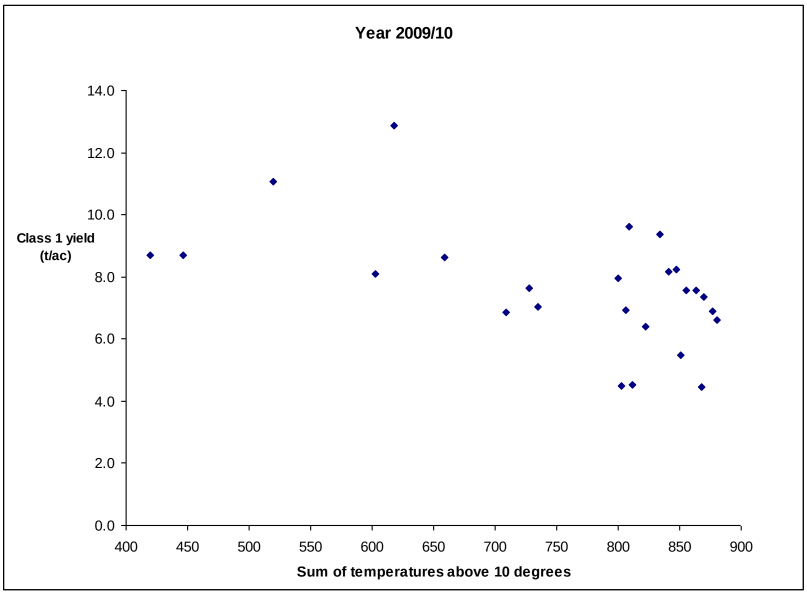
Relations between response variables and the sum of temperatures for days with an average temperature above ten degrees

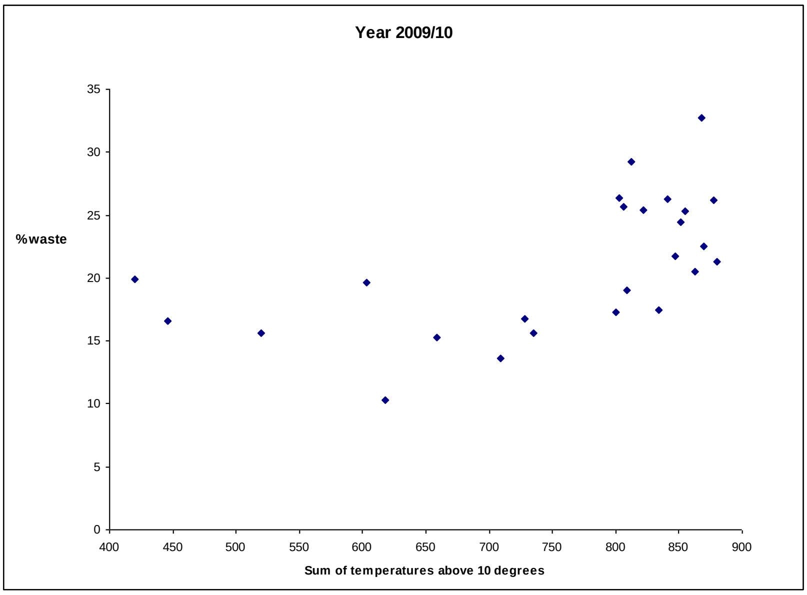
Plots of the relation between the three response variables and The sum of temperatures for days with an average temperature above ten degrees are displayed in Figure 8.

For all variables, there is no evidence of a relationship if The sum of the temperatures is below 600.

Above that level:

- Class 1 yield declines (correlation = -0.62)
- Percent class 1 large and medium large shows a constant rate of decline (correlation = -0.74).
- Percent waste shows a constant rate of increase (correlation = 0.72).





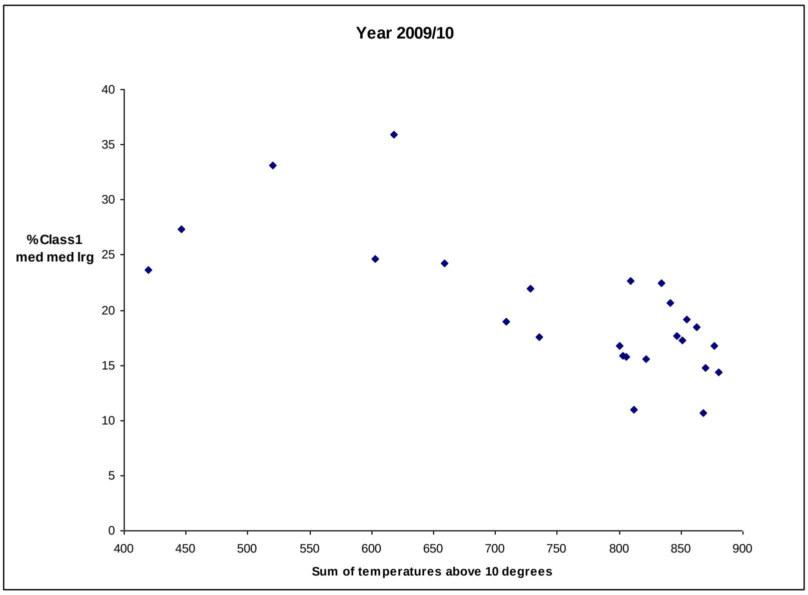


Figure 8. The relation between the three response variables and The sum of temperatures for days with an average temperature above ten degrees.

VARIABLES RELATED TO PLANTING DATE

Based on the results presented in Table 8,

- Planting date is strongly correlated with a number of nutrient variables plus Boron, Compaction and The sum of temperatures for days with average temperature above ten degrees.
- The strongest correlation is with The sum of temperatures for days with average temperature above ten degrees which can account for 76% of variation in planting date.
- The only variable that provides additional predictive value is Compaction, which increases the percentage explained to 81%.
- For all other variables, the association they have with planting date is contained in the information provided by The sum of temperatures for days with average temperature above ten degrees.
- There is no relation between planting date and either ploughing or workability.

Examining the relation between Days since earliest planting and The sum of temperatures for days with average temperature above ten degrees (Figure 9), it is apparent that the relation is very strong until the sum is above 800.

The lack of correlation at high sums is of importance because it has been established (see Figure 8) that The sum of temperatures for days with average temperatures above ten degrees correlates strongly with all response variables when the sum is high. The implication is that planting date is not so critical when it is above about 60 days and we should be looking to variables that correlate well with the temperature sum variable.

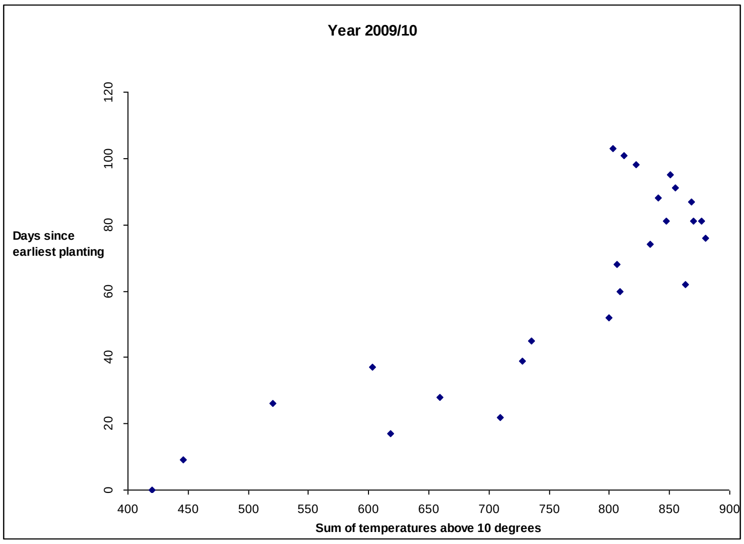


Figure 9. The relation between Days since earliest planting date and The sum of temperatures for days with average temperatures above ten degrees.

Compaction shows a relation during earlier planting dates but not later dates. This offers an explanation for the additional information provided about % Class 1 large and medium large by Compaction over and above that provided by planting date.

The relation with Boron does not look to be of value.

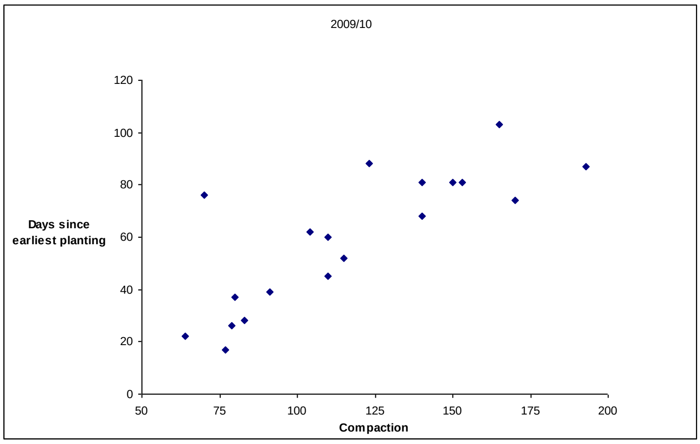


Figure 10. Plot of Days since earliest planting date versus Compaction

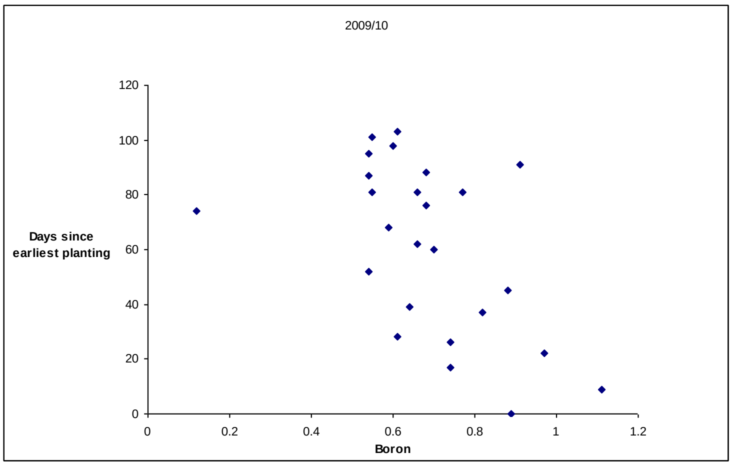


Figure 11. Plot of Days since earliest planting date versus Boron

Table 8. Planting date: Correlations with potential predictors and results of regression analyses.

	Correlation				**Regression (R^2)**	
					Single variables	Stepwise
Days since earliest plant date with	Correlation with Yield	Sig. (p)		Number of missing values	Best single variable	Sum temp, compaction
NO3 ppm	0.562	0.00	***			
NO3 to Ca	0.564	0.00	***			
Boron	-0.525	0.00	***			
Total nutrients	0.544	0.00	***			
NO3-N mg per kg	0.639	0.00	***			
NH4-N mg per kg	-0.046	0.83		1		
OC Perc	-0.145	0.49				
WSA Perc	0.366	0.07				
Compaction	0.796	0.00	***	6		
Density	0.145	0.49				
Total Microbial	-0.196	0.36		1		
Bacteria	0.080	0.71		1		
Fungi	-0.151	0.49		2		
Yeast	-0.191	0.37		1		
Anaerobic	-0.122	0.57		1		
Azotobacter	0.194	0.36		1		
Actinomycetes	-0.056	0.79		1		
Fungi to Bacteria	-0.235	0.28	*	2		
Fungi to Yeast	-0.113	0.61		2		
Viable Count	0.054	0.80		1		
Sum temp days above 10 deg	0.875	0.00	***		76%	81%
Infiltration	**0.067**	0.81				
Bulk density	0.092	0.73				
Labile carbon	-0.215	0.30				
Number of observations					25	19

*** P<0.01
** p<0.05
* p<0.1

VARIABLES RELATED TO DAYS TO HARVEST

Days to harvest correlates with the variables listed in Table 9.

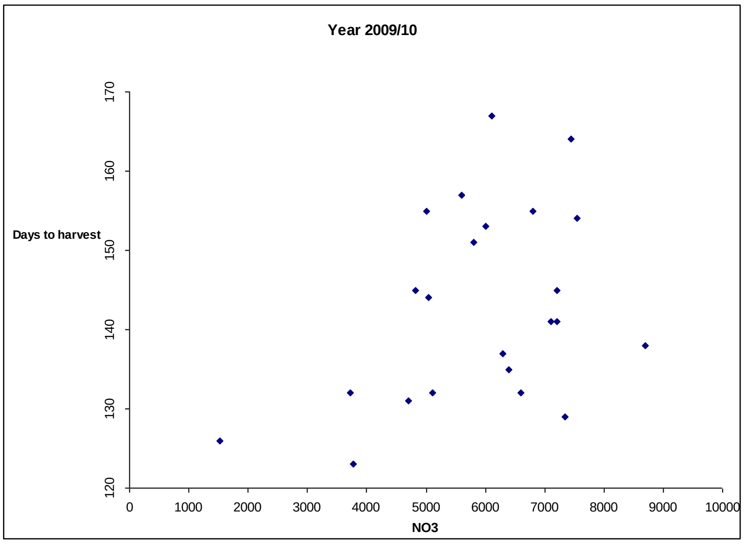
With respect to the nitrogen variables, it can be seen in Figure 12, that nitrogen levels are low when the Days to harvest is short, but at higher nitrogen levels there is little relationship.

With respect to Compaction, as can be seen in Figure 13, there is a tendency to higher levels of compaction tending to be associated with longer days to harvest.

With respect to The sum of temperatures of days with average temperature above ten degrees, as the sum increases, there is an ever increasing lengthening of Days to harvest (Figure 14). The same is true with respect to planting date (Figure 15)

Table 9. Variables with a correlation of less than 0.05 with Days to harvest.

NO_3	NO_3:Ca	NO_3-N	Compaction	Sum temp days over 10 deg
0.513	0.447	0.446	0.495	0.638



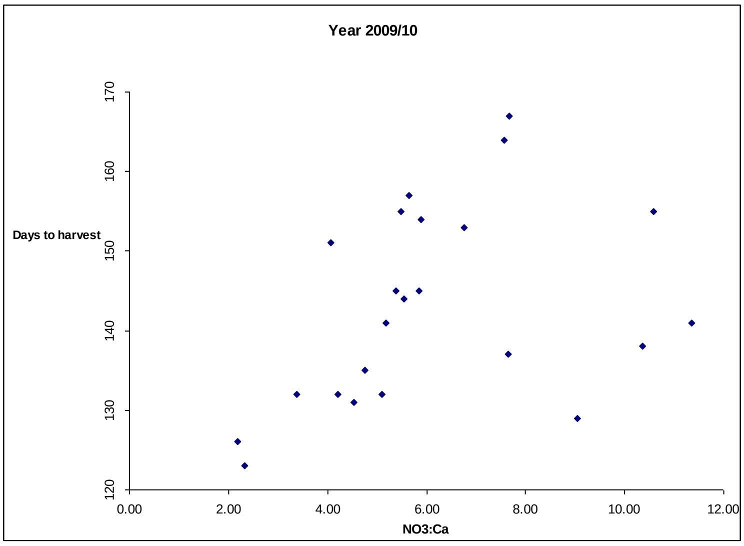


Figure 12. Plot of Days to harvest versus selected nitrogen variables.

Figure 13. Plot of Days to harvest versus compaction.

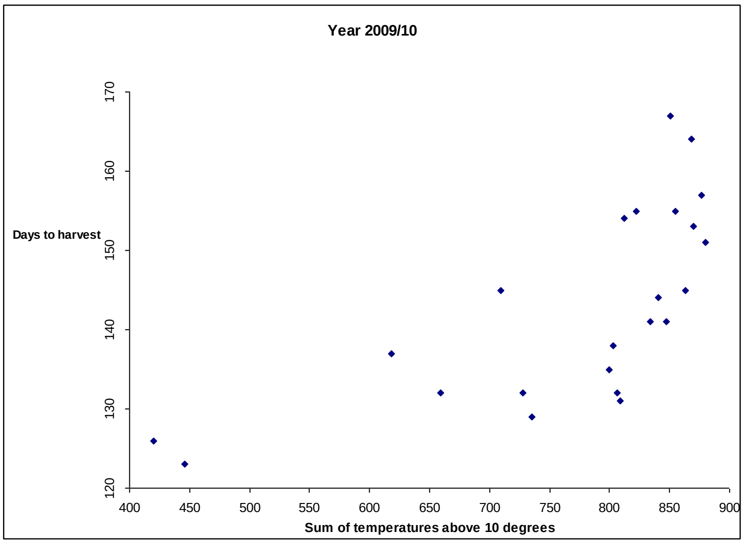


Figure 14. Plot of Days to harvest versus Sum of temperature for days above ten degrees.

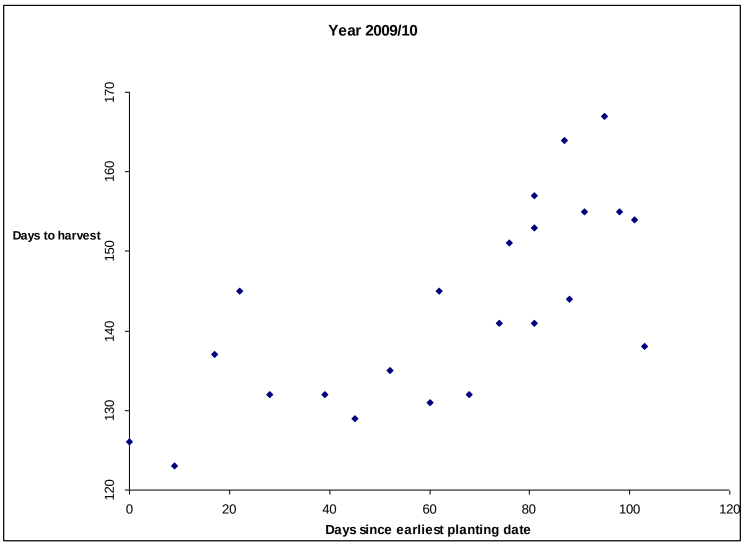


Figure 15. Plot of days to harvest versus Days since earliest planting date

VARIABLES RELATED TO THE SUM OF TEMPERATURES FOR DAYS ABOVE TEN DEGREES

The sum of temperatures for days above ten degrees correlates strongly with the variables listed in Table 10.

The application of stepwise regression using The sum of temperatures for days above ten degrees as the response variable results in only Compaction being included. The implication is that all variables in Table 10 show a similar pattern of change as The sum of temperatures for days above ten degrees varies.

Table 10. Variables correlated with the sum of temperatures for days above ten degrees where the p-value is less than0.05.

NO_3	Boron	Total nutrients	NO_3-N	Compaction
0.588	-0.578	0.579	0.576	0.638

There is generally an increase in nitrogen and total nutrients with an increasing sum ((Figure 16, Figure 17 and Figure 18).

For low sums, compaction is low. There is little relation when the sum is higher.

Boron levels decline with increasing sum.

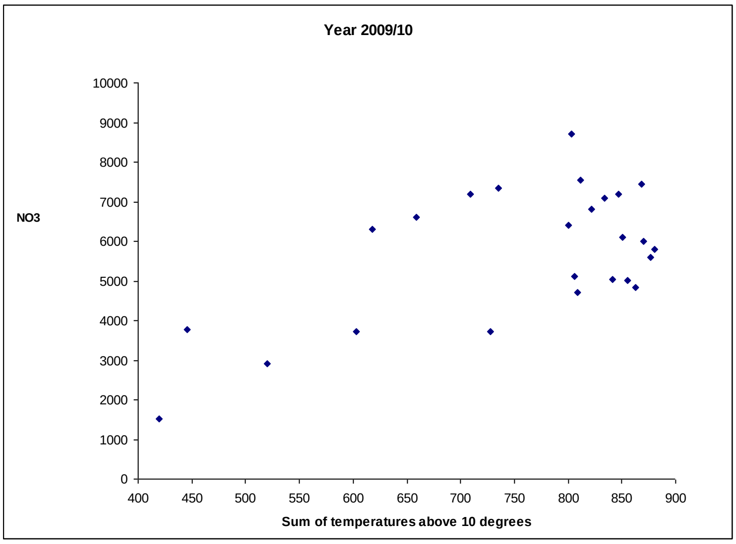


Figure 16. Plot of NO_3 versus Sum of temperatures for days with average temperature above ten degrees.

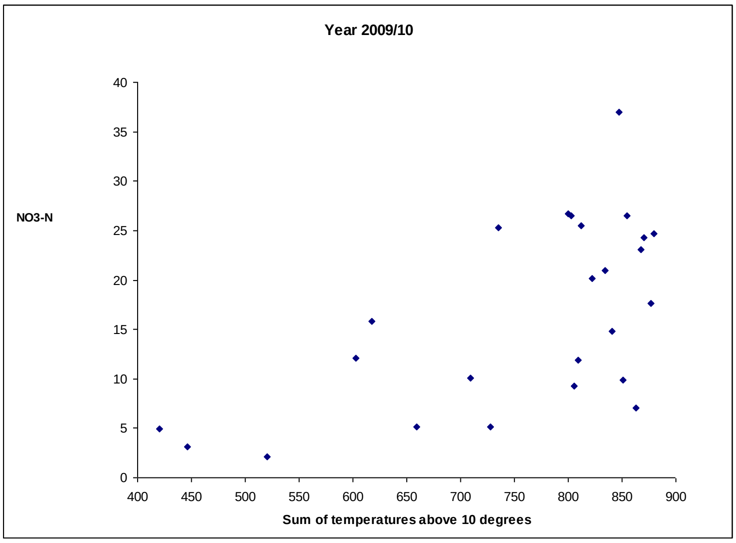


Figure 17. Plot of $N0_3$-N versus Sum of temperatures for days with average temperature above ten degrees.

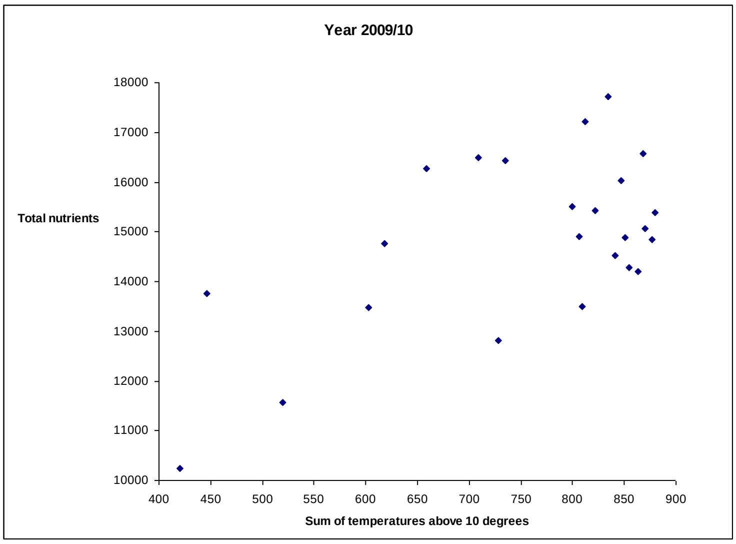


Figure 18. Plot of Total nutrients versus Sum of temperatures for days with average temperature above ten degrees.

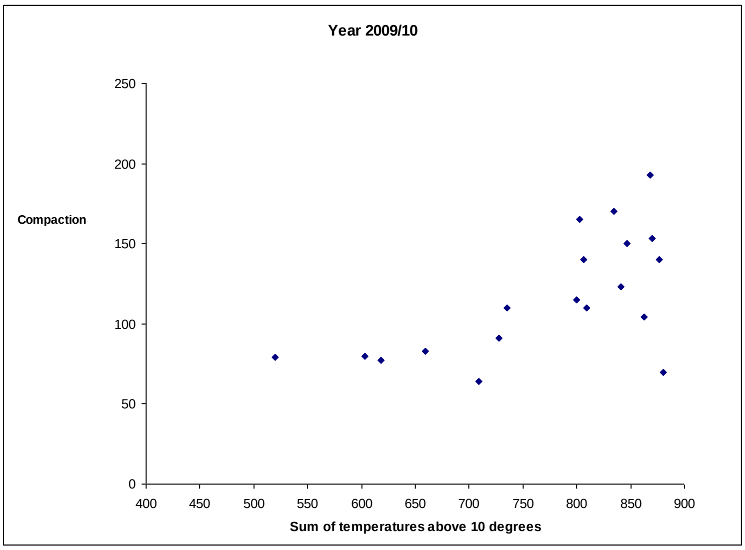


Figure 19. Plot of Compaction versus Sum of temperatures for days with average temperature above ten degrees

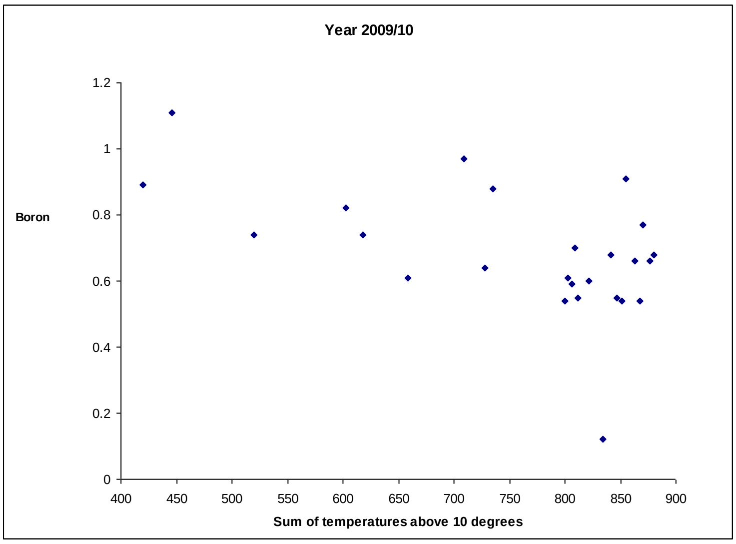


Figure 20. Plot of Boron versus Sum of temperatures for days with average temperature above ten degrees.

VARIABLES RELATED TO COMPACTION

Compaction is identified as a useful predictor. This seen in the graphs in Figure 21.

The variables it correlates with are listed in Table 11.

From an examination of the graphs in Figure 22 to Figure 24, it can be seen that the relation does not appear to be strong except with Boron.

Table 11. Variables correlated with compaction where the p-value is less than0.05.

NO_3	NO_3:Ca	Total nutrients	NO_3-N	Boron	Azotobacter
0.479	-0.489	0.503	0.543	-0.594	0.561

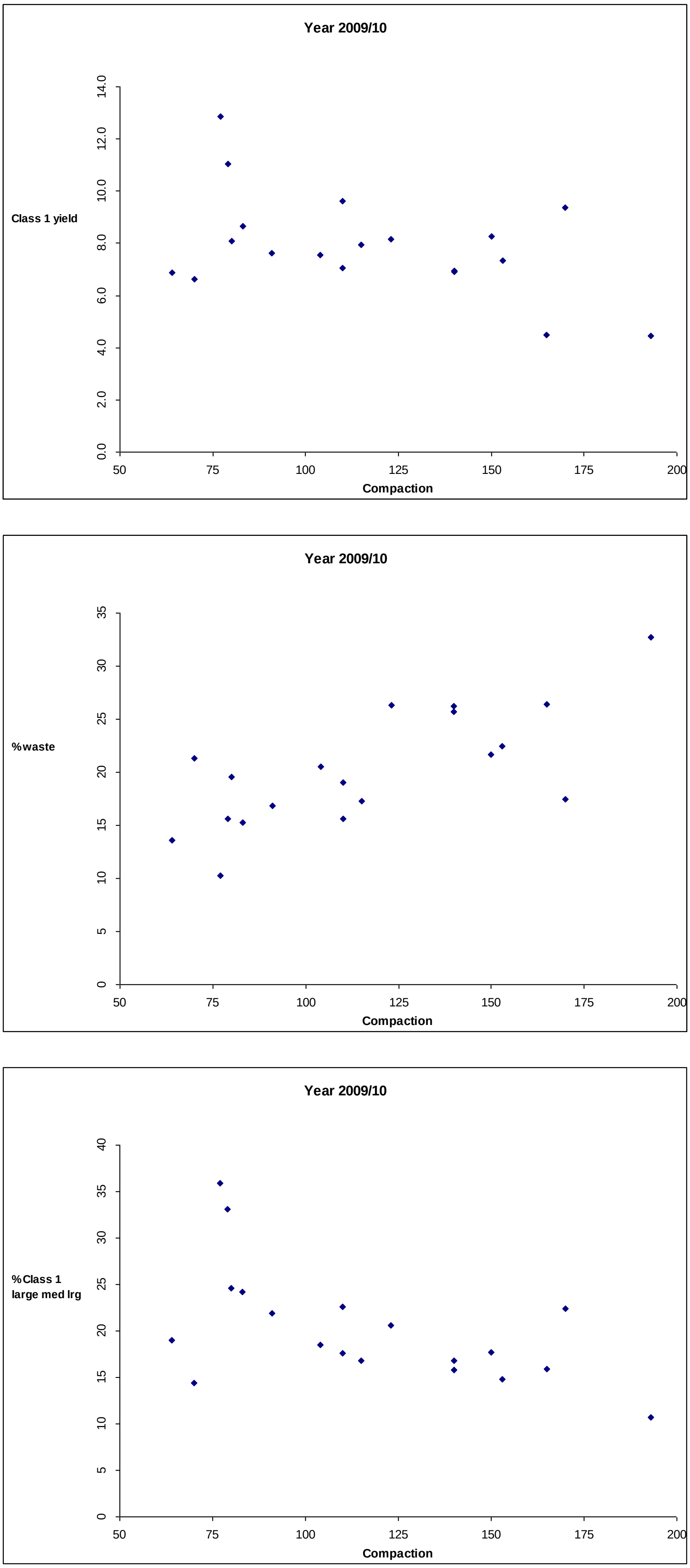
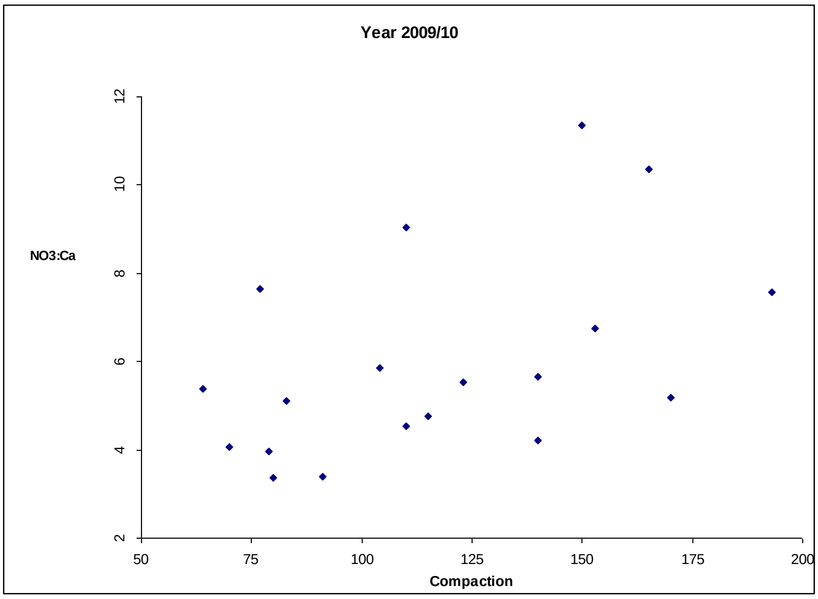
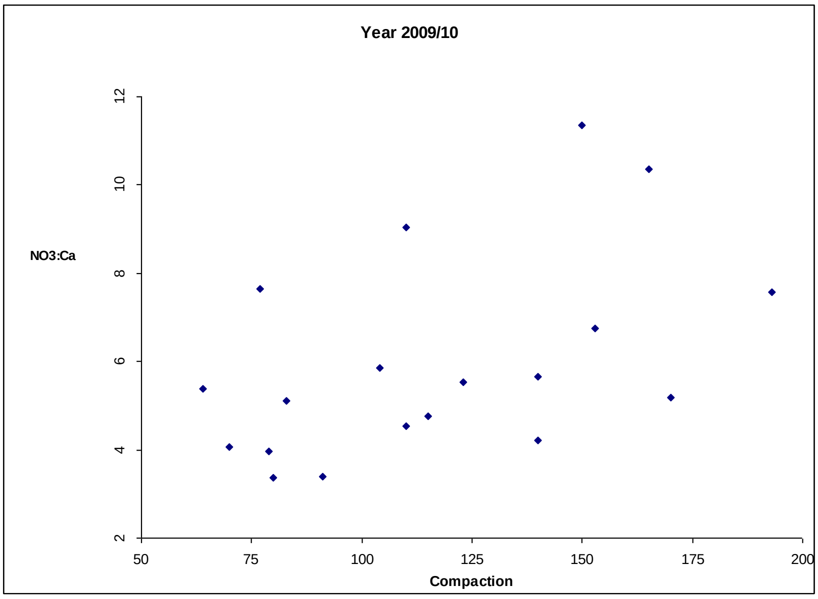


Figure 21. Plots of response variables versus compaction.





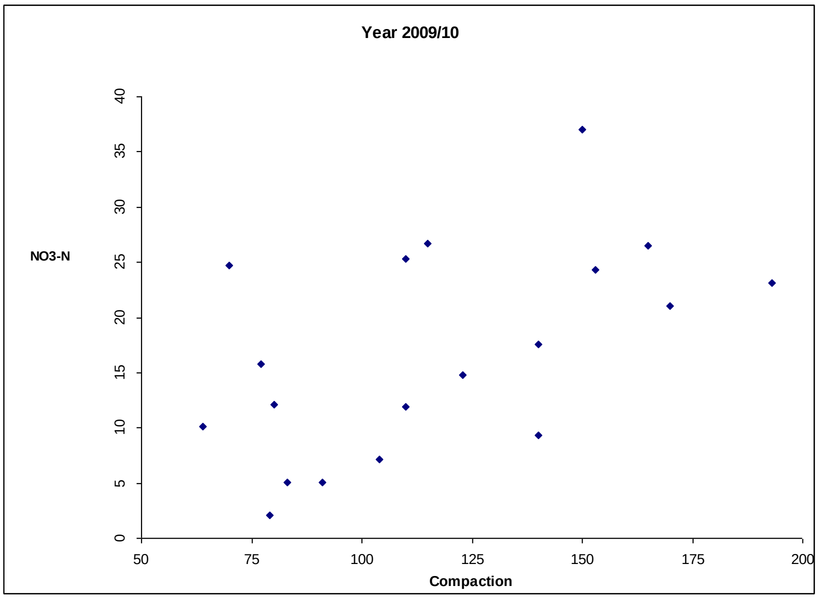


Figure 22. Plots of nitrogen variables versus compaction.

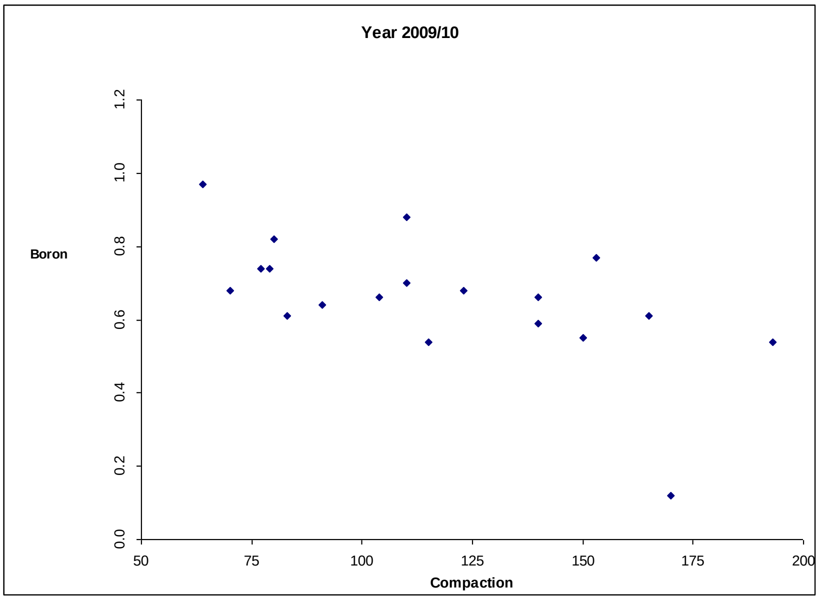


Figure 23. Plot of Boron versus compaction.

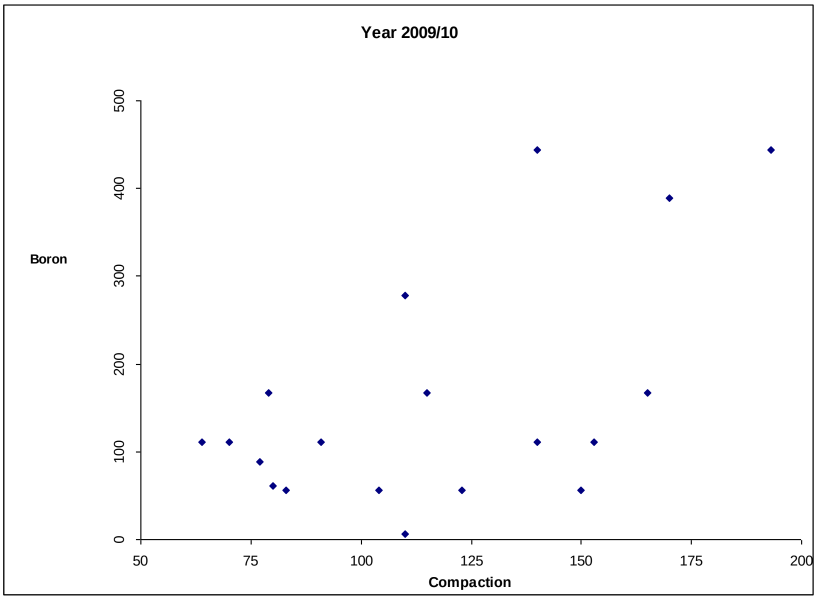


Figure 24. Plot of azotobacter versus compaction.

Comparisons across years 2003/04 to 2009/10

The relation between each of the response variables and Days since earliest planting date was analysed to determine if there was evidence that the relation varied among years.

Based on the results presented in Table 12, there is strong evidence for all variables that

- there is a relation with Days since earliest planting (p-value for Days since earliest planting),
- the average response varies from year to year (p-value for Year), and
- the rate of change per day varies from year to year (p-value for Years * Days since earliest planting date).

The nature of the change in the relation from year to year can be seen in Figure 25, Figure 26 and Figure 27.

Table 12. Analysis of variance tables in the comparison of relations between response variables and Days since earliest planting across years.

CLASS 1 YIELD

Source	df	Sum of squares	Mean Square	F	Sig.
Days since first planting date	1	269.2	269.242	43.5	.000
Year	5	126.5	25.298	4.1	.002
Years*Days since first planting date	5	128.2	25.636	4.1	.002
Residual	123	762.0	6.195		

PERCENT WASTE

Source	df	Sum of squares	Mean Square	F	Sig.
Days since first planting date	1	649.9	649.877	56.1	.000
Year	5	312.1	62.423	5.4	.000
Years*Days since first planting date	5	652.1	130.427	11.3	.000
Residual	125	1447.0	11.576		

PERCENT CLASS 1 LARGE AND MEDIUM LAREGE

Source	df	Sum of squares	Mean Square	F	Sig.
Days since first planting date	1	2104.0	2103.975	79.5	.000
Year	5	847.2	169.443	6.4	.000
Years*Days since first planting date	5	566.0	113.198	4.3	.001
Residual	125	3306.7	26.454		

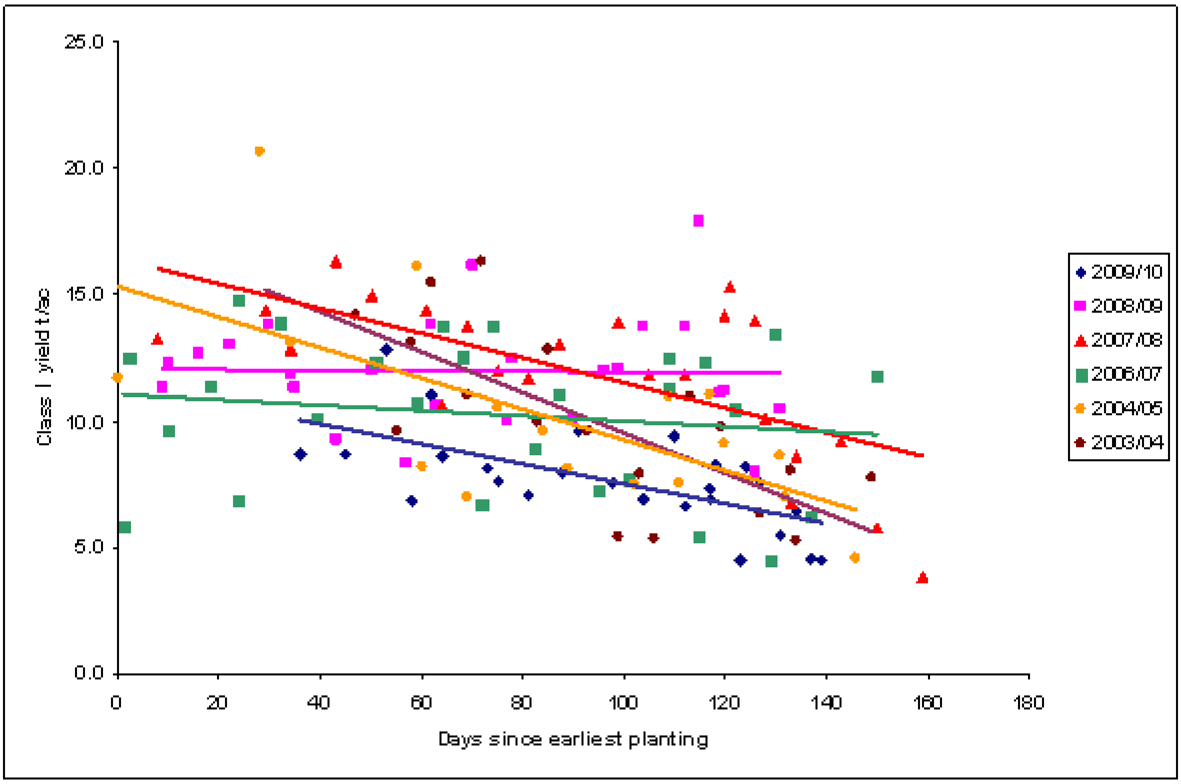


Figure 25. Relation between Class 1 yield and Days since earliest planting for a selection of years with the linear trend for each year displayed.

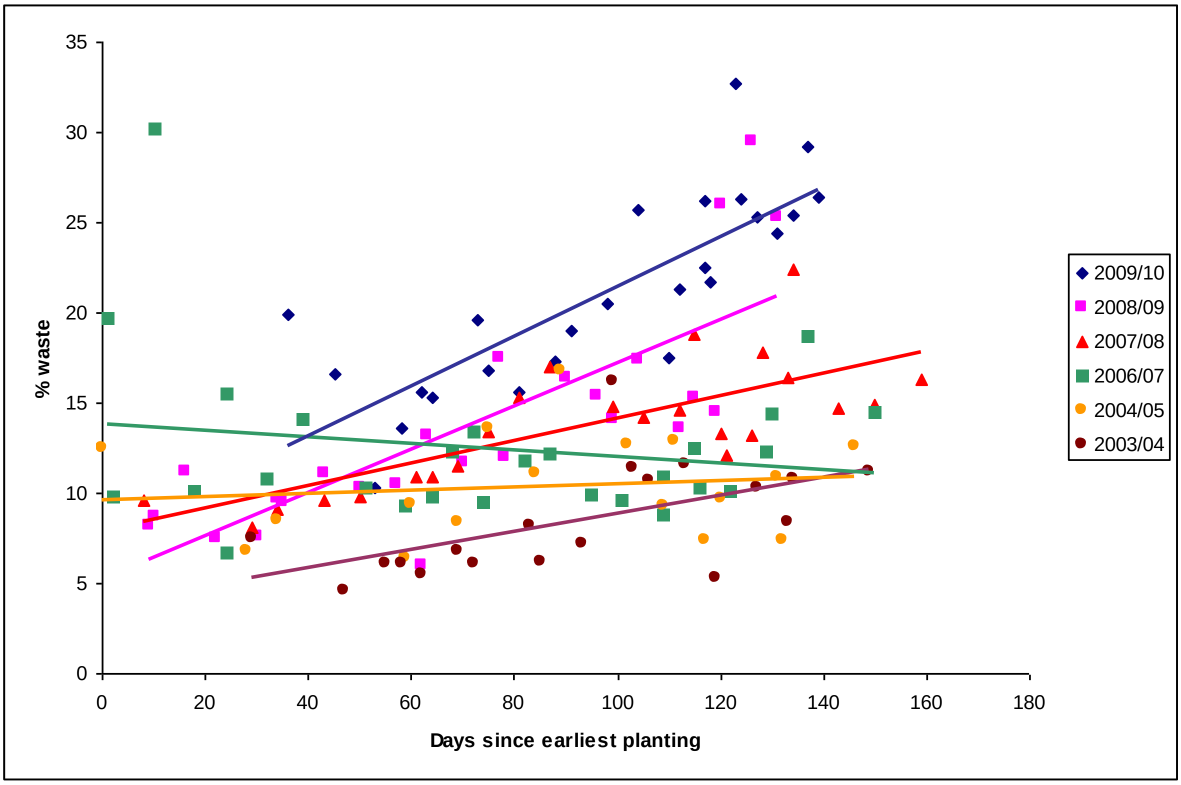


Figure 26. Relation between Class 1 yield and Days since earliest planting for a selection of years with the linear trend for each year displayed

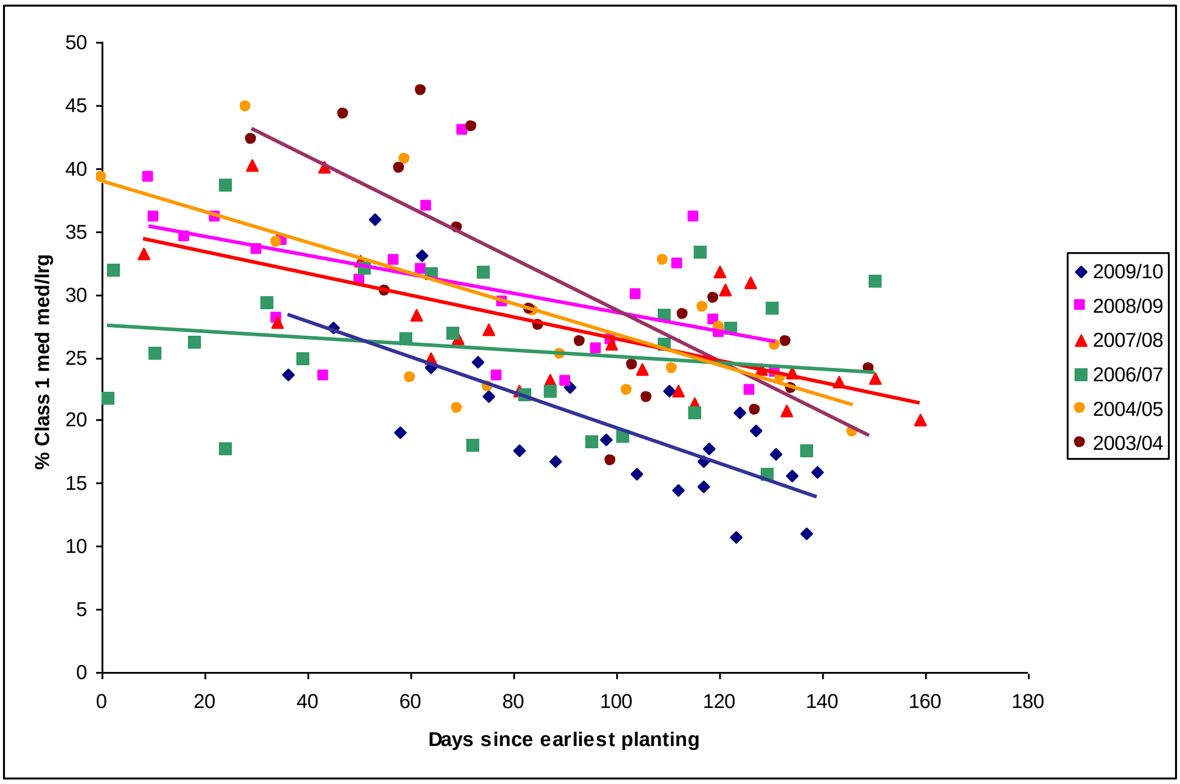


Figure 27. Relation between % Class 1 large and medium large and Days since earliest planting for a selection of years with the linear trend for each year displayed

EXPLAINING YEAR TO YEAR VARIATIONS IN THE RELATION BETWEEN RESPONSE VARIABLES AND DAYS SINCE EARLIEST PLANTING

The possibility was considered that year to year variations in the relationship between the response variables and Days since earliest planting might be explained by variations in weather conditions during the growing season.

For each of the response variables, the intercept and slope from yearly fits of linear regression equations were computed. The values obtained are presented inTable 13.

Stepwise regression analysis was then employed using each of intercept and slope as response variable and Year as the explanatory variable.

There was no evidence that the rainfall data from any month could assist in explaining the variation in the relations that are observed in Figure 25 to Figure 27.

The same conclusion was reached with respect to the temperature data.

Table 13. Intercepts and slopes from the fit of linear regression relations between response variables and Days since earliest planting date for selected years.

	%Class1 med, med lrg		**Waste**		**Class 1 yield**	
Year	Intercept	Slope	Intercept	Slope	Intercept	Slope
2003/04	49.0	-0.203	3.8	0.051	17.5	-0.079
2004/05	38.9	-0.122	9.6	0.009	15.3	-0.060
2006/07	27.6	-0.025	13.9	-0.018	11.1	-0.011
2007/08	35.1	-0.086	7.9	0.062	16.4	-0.049
2008/09	36.0	-0.075	5.2	0.120	12.1	-0.001
2009/10	33.4	-0.140	7.7	0.138	11.5	-0.040

Comparisons between 2009/10 and 2008/09 findings

The relationships between the three response variables, Class 1 yield, % Class 1 large and medium large and % waste and selected variables were compared between the 2008/09 and the 2009/10 seasons. In all cases a linear regression relation was assumed.

The predictive variables included are Days since earliest planting, NO_3, ratio NO_3 to Ca, Total nutrients, Ratio NO_3 to N, Ratio $NH_4$to N, Compaction, Boron and The sum of temperatures for days with average temperature over ten degrees.

Between the two seasons, the relation may vary in either of the two parameters, average level of response or rate of change in response per unit increase in explanatory variable.

Table 14 presents the cases where there are differences.

It is apparent that while there is broad evidence of difference in average responses, there is little evidence that the rate of change in response per unit change in explanatory variable varies between the seasons. In the cases where there is a difference in rate,

- For the relation between Percent waste and Compaction, the rate of change increases from 0.04 in 2008/09 to 0.11 in 2009/10.
- For the relation between % Class1 large and medium large and ratio $NH_4$to N, the rate was 12 in 2008/09 and 0 in 2009/10.

Where there are average differences,

- For Class 1 yield, levels were higher in 2008/09 for all variables.
- For Percent waste, levels were higher in 2009/10 for all variables.
- For Percent Class 1 large and medium large, levels were higher in 2008/09 for all variables.

Table 14. Results of tests for evidence of seasonal difference in average response and in rate of change across levels of explanatory variables. Values are presented as p-values from tests undertaken using analysis of variance in the comparison of linear regression equations between the 2008/9 season and the 2009-10 seasons. P-values are only provided where they are less than 0.05.

CLASS 1 YIELD LARGE AND MEDIUM LARGE

	Diff in average response	Diff in rate of change
Ratio NO_3 to Ca	<0.01	
Ratio NO_3 to N	<0.01	
Boron	0.02	

PERCENT WASTE

	Diff in average response	Diff in rate of change
Days since earliest planting	<0.01	
Ratio NO_3 to Ca	<0.01	
Ratio NO_3 to N	0.02	
Compaction		0.02

PERCENT CLASS 1 LARGE AND MEDIUM LARGE

	Diff in average response	Diff in rate of change
Days since earliest planting	0.01	
NO_3	<0.01	
Ratio NO_3 to N	0.02	
Ratio NH_4 to N		0.04

Appendix 3

Factors affecting paddock performance of carrots. August 2011

Statistical report by Glen McPherson Consultancy

16a Maning Avenue

Sandy Bay 7005

Tasmania

Australia

Glen McPherson Consultancy

Data Management

Phone: (03) 6225 3162

Mobile: 0419 001 612

Email: mcpconsult@gmail.com

Factors affecting paddock performance of carrots

for Harvest Moon

August 2011

Objectives

3. Using data from the 2010/11 season, to seek associations between paddock performance in carrots as measured by 'Class yield', '% class medium to medium large', % waste', 'Medium' and 'Medium large' with a selection of variables that are considered to have potential as explanatory variables.
4. To determine if there is evidence of a change in the relations between the response variables and selected explanatory variables between the 2010/11, 2009/10 and 2008/09 seasons and provide details of such relationships.
5. Based on the data set that contains data back to the 2003/04 season to determine if there is evidence of a change in the relations between the response variables and selected explanatory variables over the six year period.

Principal findings

RELATIONS AMONG RESPONSE VARIABLES

- Class 1 yield and % Class 1 medium to medium large are strongly correlated across all years (Table 15,
-
-
- Figure 28).
- There is a lesser correlation of these two variables with Percent waste (Table 15,
-
-
- Figure 29,
-
-
- Figure 30).

RELATIONS WITH POTENTIAL EXPLANATORY VARIABLES IN THE 2010/11 SEASON

Class 1 yield

- This variable shows no relation to any of the explanatory variables in the 2010/11 season (Table 20).

% Class 1 medium to medium large

- This variable shows no relation to any of the explanatory variables in the 2010/11 season (Table 20) despite the fact that it showed a correlation with eight variables in the previous season.

Percent waste

- This variable shows no relation to any of the explanatory variables in the 2010/11 season (Table 20) despite the fact that it showed a correlation with five variables in the previous season.

COMPARISONS ACROSS SEASONS 2008/09 TO 2010/11

Class 1 yield

- Class 1 yield shows little relation with any variables across the three years (Table 20).

% Class 1 medium to medium large

- Strong correlations with Days since August 1st , NO_3 and Total nutrients in the 2008/09 and 2009/10 seasons are not present in the 2010/11 season (Table 20).

% waste

- Strong correlations with Days since August 1st and Compaction in the 2008/09 and 2009/10 seasons are not present in the 2010/11 season (Table 20).

Comparisons across seasons 2003/04 to 2010/11

% Class 1 medium to medium large

Days to harvest

- There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 22). For four of the seven years, the relation is negative (Figure 31).

Degree days

- There is strong evidence the relationship varies across the years (p-value for Year*Days to harvest in Table 23). As can be seen in Figure 32, the relationship is negative for all years except 2010/11.

Days since August 1st

- There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 24). The relationship is negative in all years with the difference being in the rate of change (
-
-
- Figure 33).

% waste

Days to harvest

- While there is evidence of a relation between % waste and Days to harvest, a common line may fit all years (p-values in Table 25).
-
-
- Figure 34 shows the plot with the regression line fitted. As can be seen, % waste increases with increasing days to harvest although there is a lot of individual variation.

Degree days

- There is strong evidence of differences in the relationship among years (p-value for Year * Degree days in Table 26).
-
-
- Figure 35 indicates that the negative correlation in the 2006/07 and 2010/11 seasons is inconsistent with other years.

Days since August 1st

- There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 27). The relationship shows substantial variation across the seasons (
-
-
- Figure 36)

Class 1 yield

Days to harvest

- There is some evidence of differences in the relationship among years (p-value for Year * Days to harvest in Table 28). The differences can be seen in
-
-
- Figure 37. However, as can be seen in the figure, there is no general trend either up or down.

Degree days

- There is evidence of differences in the relationship among years (p-value for Year * Degree days in Table 29). There is substantial variation in the relationship across seasons (
-
-
- Figure 38).

Days since August 1st

- There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 30). The relationship shows substantial variation across the seasons (
-
-
- Figure 39).

Data

DATA AVAILABLE IN THE 2008/09, 2009/10 AND 2010/11 SEASONS

Data are provided from years 2008/09, 2009/10 and 2010/11. The response variables and the number of samples per year are provided in Table 15.

Table 15. Response variables used in the analysis and the number of paddocks supplying data by year.

	2008/09	2009/10	2010/11
Class1 Yield t/ac	26	25	18
%Class1 med med/lrg	26	25	18
%Waste	26	25	18

The explanatory variables for which data are provided are listed in Table 1.

The variables Workability, Bulk density and Labile carbon are not analysed because they provide no data in the 2010/11 season. Note that no data are provided for the length:weight variables in 2008/09.

Table 16. Potential explanatory variables used in the analysis and the number of paddocks supplying data by year.

Group	Variable	2008/09	2009/10	2010/11
	Days from August 1st	26	25	18
Lerngth:weight	medium	0	18	13
	Medium/large	0	18	13
Nu test	NO3 (ppm)	26	25	17
	NO3:Ca	26	25	17
	Boron	26	25	17
	Total nutients	26	25	17
N-check	NO3-N(mg/kg)	26	25	18
	NH4-N(mg/kg)	26	24	18
Express soil	OC (%)	26	25	17
	WSA (%)	26	25	17
Field asessment	Compaction**	26	19	9
	Days to Harvest	26	19	9
	Density	26	25	18
	Workability	0	25	18
	Infiltration	7	21	0
	Bulk Density	7	24	0
	Labile Carbon	0	25	0
	Degree Days	25	25	18

DATA AVAILABLE FROM SEASON 2003/04 TO SEASON 2010/11

Data are provided over the six seasons from 2003/04 to 2009/10 seasons.

Table 17. Response variables used in the analysis and the number of paddocks supplying data by year.

	2003/04	2004/05	2006/07	2007/08	2008/09	2009/10
% Class 1 med to med/lrg	19	17	27	24	25	25
%Waste	19	17	27	24	25	25
Class 1 yield	18	17	27	23	25	25

Table 18. Potential explanatory variables used in the analysis and the number of paddocks supplying data by year.

	2003/04	2004/05	2006/07	2007/08	2008/09	2009/10
Days from August 1	19	17	27	24	25	25
Day To Harvest	19	17	27	24	25	25
Day Degree	19	17	27	23	25	25

Results

CORRELATIONS AMONG RESPONSE VARIABLES

Correlations among response variables are shown by year in Table 19.

In general, there is consistency of the relationships across the years, and with the exception of Percent waste, there is good correlation among the response variables.

Figure 28 to

Figure 30 show the relations between variables across the years.

Table 19. Correlations between pairs of response variables by year. Correlations with p-values less than 0.05 are shown bolded.

		Correlations			Sample size		
Class1 Yield		2008/09	2009/10	2010/11	2008/09	2009/10	2010/11
with	%Class1 med med/lrg	**.66**	**.90**	**.85**	26	25	18
	% waste	-.41	**-.75**	-.44	26	25	18
%Class1 med med/lrg							
with	% waste	**-.64**	**-.74**	**-.52**	26	25	18

The following points are noted:

- Class 1 yield and % class 1 med/med lrg are closely related across all years.
- The relation between Class1 yield and % waste is strong only in the 2009/10 season.
- % class 1 med/med lrg has a moderate correlation with % waste across all years.

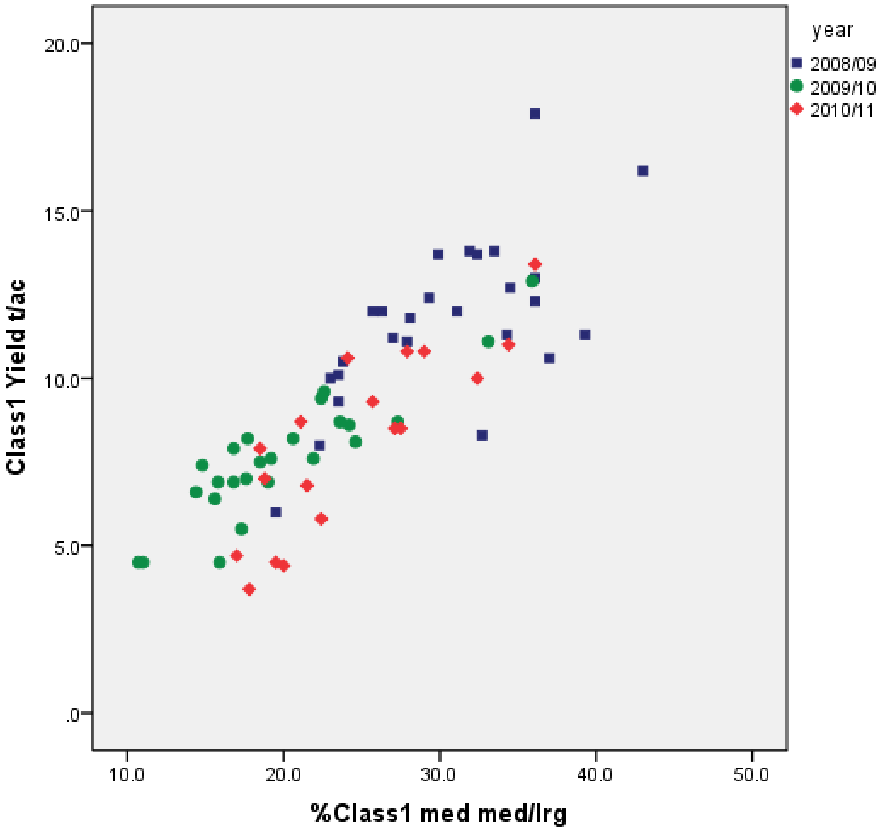


Figure 28. Plot of Class 1 yield versus % class 1 med med/lrg across years.

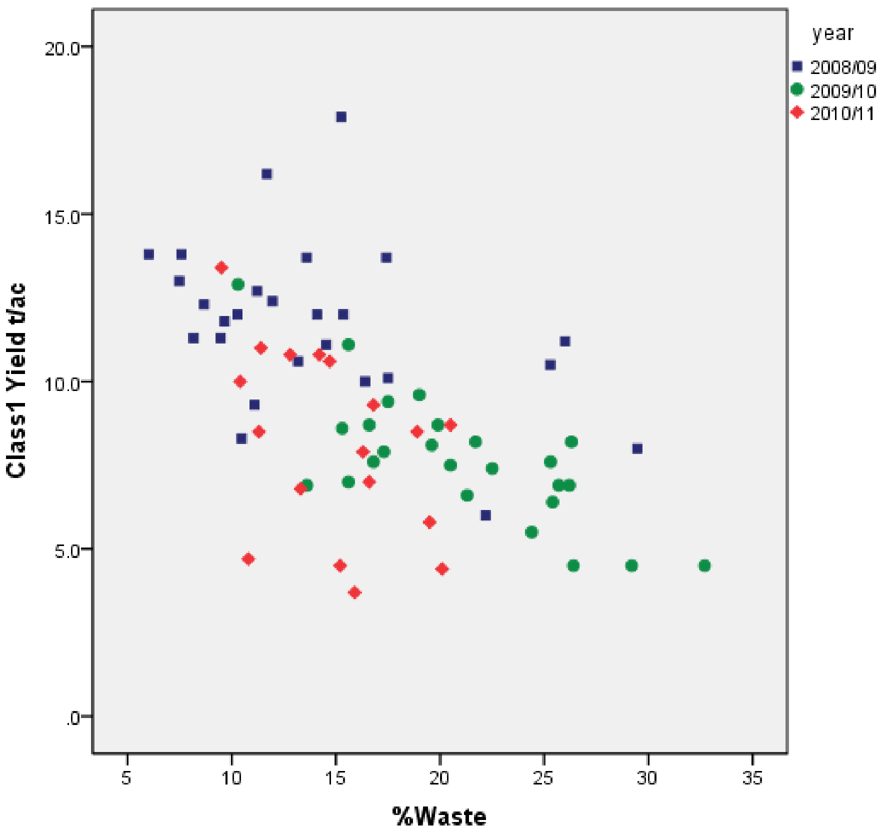


Figure 29. Plot of Class 1 yield versus % Waste across years.

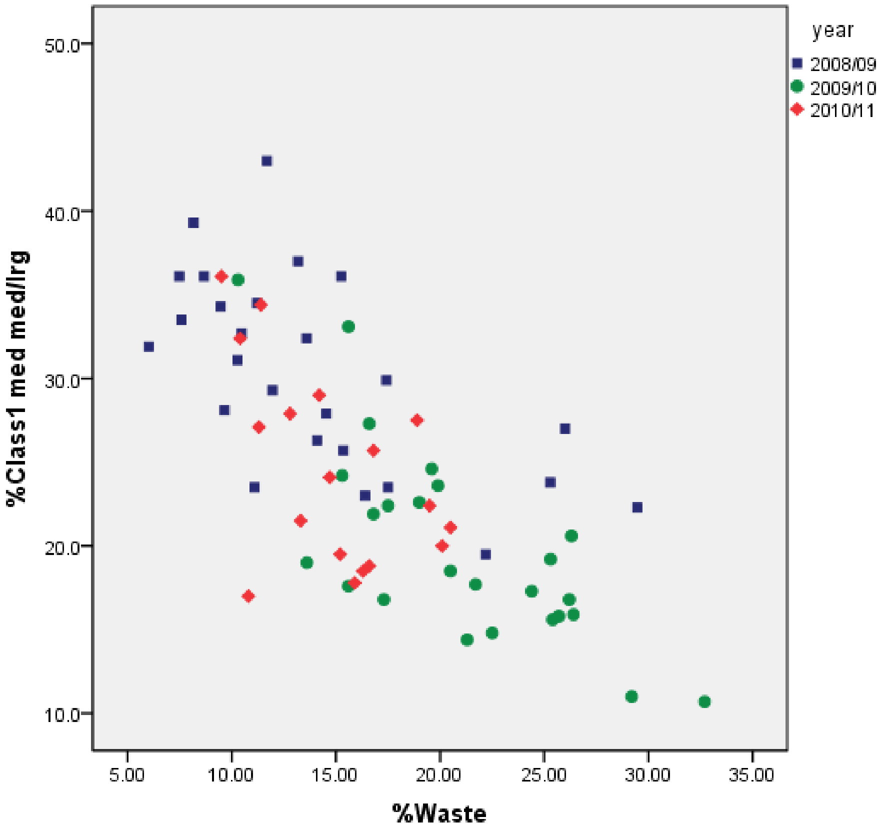


Figure 30. Plot of % class 1 med med/lrg versus %Waste across years.

CORRELATIONS BETWEEN RESPONSE VARIABLES AND POTENTIAL SCALED EXPLANATORY VARIABLES

Correlations between the response variables and the set of explanatory variables are displayed in Table 20 for each year. The variables ‘length:weight med’ and ‘length:weight med lrg’ were not observed in 2008/09.

Note that the recording of correlations as ‘moderate’ or ‘strong’ is based on a statistical test, with ‘moderate’ indicated when the p-value is below 0.01 and strong when the p-value is below 0.001. These tests are dependent on sample size (provided in Table 21), the larger the sample size the smaller the correlation required for significance. Thus it is possible for two correlations of the same value to be recorded a different strength status.

Table 20. Correlations between response variables and explanatory variables within years. Evidence of correlation is indicated by colouring a cell - yellow for moderate and orange for strong.

	Class1 Yield t/ac			%Class1 med med/lrg			%Waste		
	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11
Days to Harvest	.2	-.6	.2	.1	-.7	.2	.2	.6	.2
Days from 1/8	-.1	-.6	.3	-.5	-.7	.0	.8	.8	.0
Length:weight med		.4	-.3		.6	.0		-.8	.1
Length:weight med lrg		.7	-.4		.8	.0		-.6	.1
NO3 (ppm)	-.3	-.5	-.2	-.7	-.5	-.1	.4	.3	.0
NO3:Ca	-.5	-.4	-.3	-.6	-.4	-.2	.7	.3	-.3
Boron	-.1	.2	-.6	.2	.3	-.5	-.1	-.3	.6
Total nutrients	-.3	-.5	-.3	-.5	-.5	-.2	.3	.3	.1
NO3-N(mg/kg)	-.1	-.4	-.2	-.3	-.6	-.4	.4	.4	.3
NH4-N(mg/kg)	.1	.0	-.3	.4	.0	-.2	-.3	.1	.3
OC (%)	-.1	.2	-.4	.0	.2	-.2	.2	-.2	.5
WSA (%)	.2	-.1	.2	.3	-.2	.2	-.4	.1	.0
Compaction	.1	-.5	-.6	-.3	-.6	-.5	.6	.7	.6
Density	.2	.0	.2	.0	-.1	-.1	.1	.0	.0
Workability		-.2	-.1		-.1	.0		.1	-.1
Day Degrees	.0	-.5	.5	-.5	-.7	.2	.7	.5	-.1

Table 21. Sample sizes for data employed in the computations of correlations between response variables and explanatory variables.

	Class1 Yield t/ac			%Class1 med med/lrg			%Waste		
	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11	2008/09	2009/10	2010/11
Days to Harvest	26	25	18	26	25	18	26	25	18
Days from 1/8	26	25	18	26	25	18	26	25	18
Length:weight med	0	18	13	0	18	13	0	18	13
Length:weight med lrg	0	18	13	0	18	13	0	18	13
NO3 (ppm)	26	25	17	26	25	17	26	25	17
NO3:Ca	26	25	17	26	25	17	26	25	17
Boron	26	25	17	26	25	17	26	25	17
Total nutrients	26	25	17	26	25	17	26	25	17
NO3-N(mg/kg)	26	25	18	26	25	18	26	25	18
NH4-N(mg/kg)	26	24	18	26	24	18	26	24	18
OC (%)	26	25	17	26	25	17	26	25	17
WSA (%)	26	25	17	26	25	17	26	25	17
Compaction	26	19	9	26	19	9	26	19	9
Density	16	25	18	16	25	18	16	25	18
Workability	0	25	18	0	25	18	0	25	18
Degree Days	25	25	18	25	25	18	25	25	18

2010/11 RESULTS

The variables Class 1 yield, % class1 med med/lrg and % waste display no relationships with any explanatory variables.

COMPARISONS ACROSS SEASONS 2008/09 TO 2010/11

Class 1 yield

Class 1 yield shows little relation with any variables across the three years (Table 20).

% Class 1 medium to medium large

Strong correlations with Days since August 1st , NO_3 and Total nutrients in the 2008/09 and 2009/10 seasons are not present in the 2010/11 season (Table 20).

% waste

Strong correlations with Days since August 1st and Compaction in the 2008/09 and 2009/10 seasons are not present in the 2010/11 season (Table 20).

Comparisons across seasons 2003/04 to 2010/11

% Class 1 medium to medium large

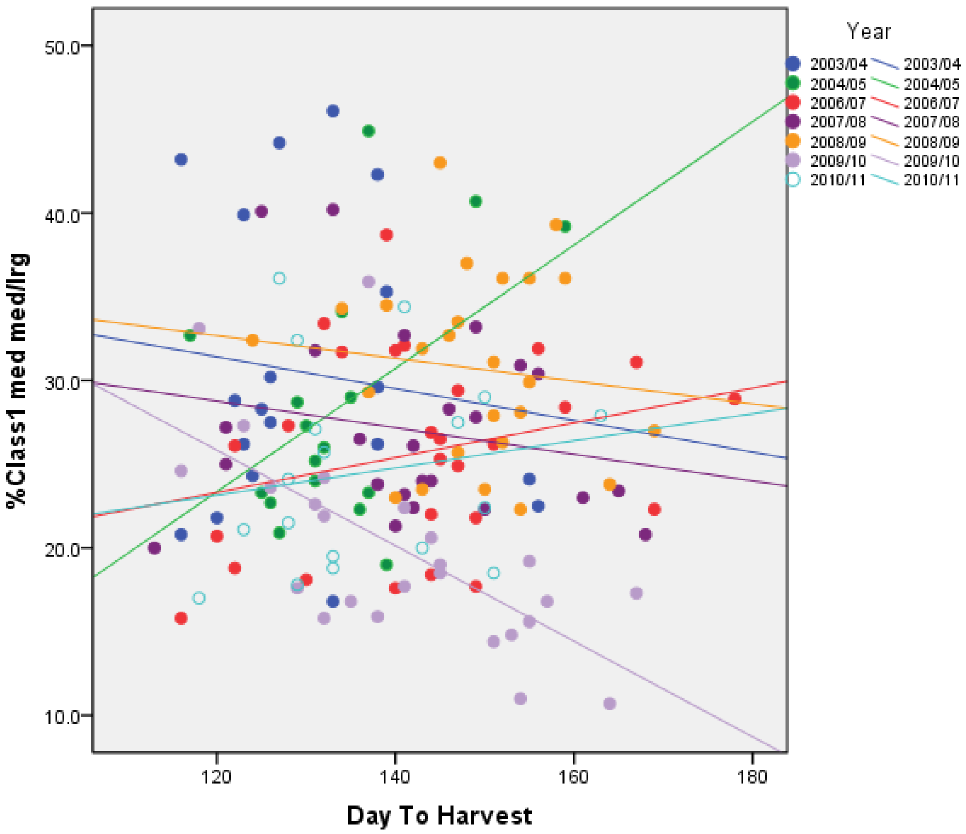
Days to harvest

There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 22). For four of the seven years, the relation is negative (Figure 31).

Table 22. Analysis of variance tables from a fit of % class 1 medium to medium large on Days to harvest across seven years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Days To Harvest	1	.26	.26	.0	.935
Year	6	601.59	100.26	2.6	.019
Year * Days To Harvest	6	684.37	114.06	3.0	.009
Error	141	5400.46	38.30		

Figure 31. Plot of % Class 1 medium to medium large versus Days to harvest with best fitting linear regression lines for individual years.



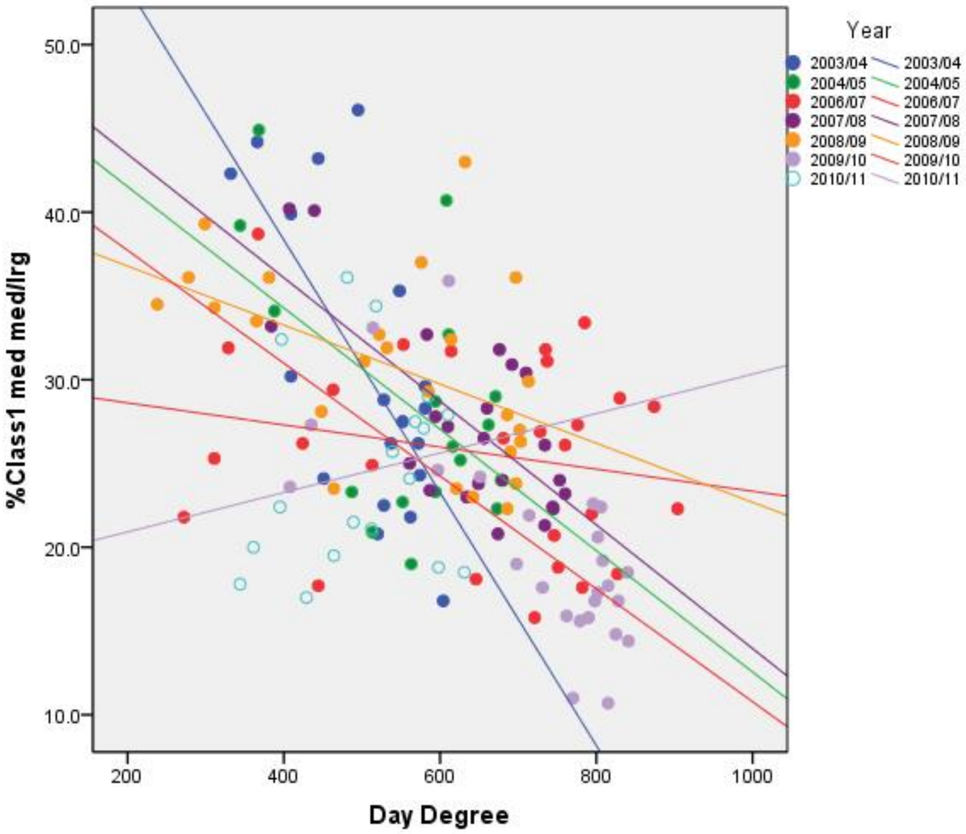
Degree days

There is strong evidence the relationship varies across the years (p-value for Year*Days to harvest in Table 23). As can be seen in Figure 32, the relationship is negative for all years except 2010/11.

Table 23. Analysis of variance tables from a fit of % class 1 medium to medium large on Degree days across seven years

Source	df	Sum of Squares	Mean Square	F	Sig.
Day Degrees	1	1221.96	1221.96	41.2	.000
Year	6	926.49	154.41	5.2	.000
Year * Day Degrees	6	845.27	140.88	4.8	.000
Error	140	4152.04	29.66		

Figure 32. Plot of % Class 1 medium to medium large versus Degree days with best fitting linear regression lines for individual years.



Days since August 1st

There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 24). The relationship is negative in all years with the difference being in the rate of change (

Figure 33).

Table 24. Analysis of variance tables from a fit of % class 1 medium to medium large on Number of days since August 1 across seven years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Days Since August1	1	1554.76	1554.76	56.3	.000
Year	6	1059.48	176.58	6.4	.000
Year * Days Since August 1	6	678.34	113.06	4.1	.001
Error	141	3890.71	27.59		

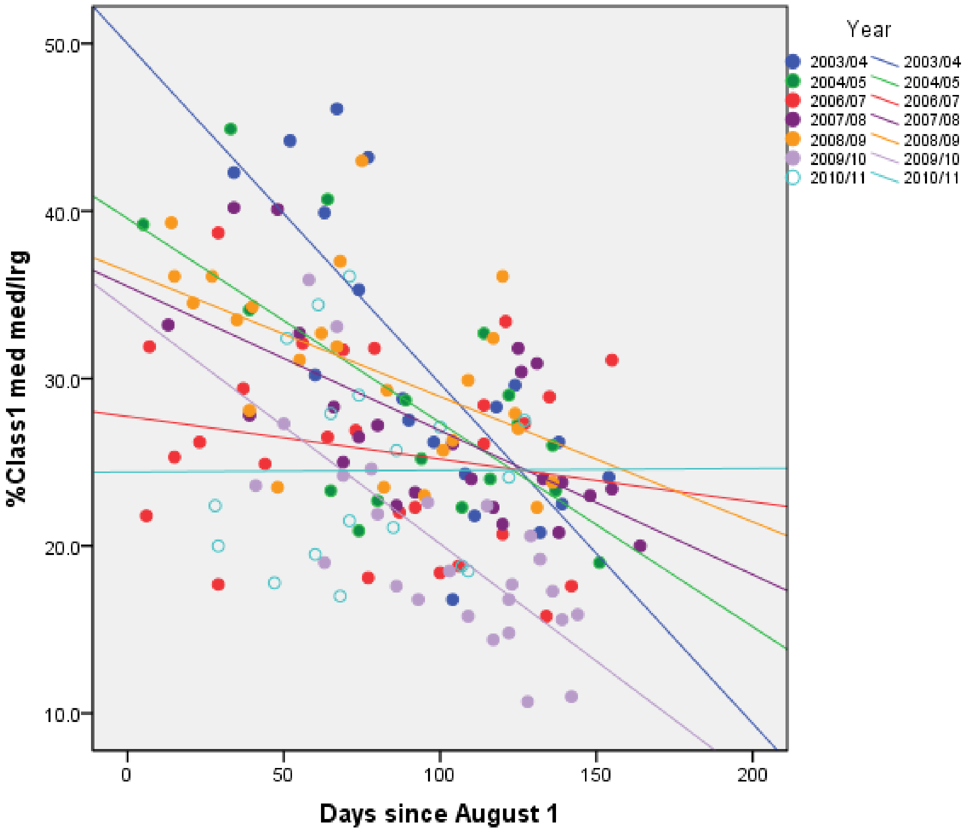


Figure 33. Plot of % Class 1 medium to medium large versus Number of days since August 1 with best fitting linear regression lines for individual years.

% Waste and Days to harvest

While there is evidence of a relation between % waste and Days to harvest, a common line may fit all years (p-values in Table 25).

Figure 34 shows the plot with the regression line fitted. As can be seen, % waste increases with increasing days to harvest although there is a lot of individual variation.

Table 25. Analysis of variance tables from a fit of % waste on Days to harvest across six years

Source	df	Sum of Squares	Mean Square	F	Sig.
DayToHarvest	1	173.53	173.53	10.2	.002
Year	6	134.98	22.50	1.3	.254
Year * DayToHarvest	6	202.71	33.78	2.0	.073
Error	141	2409.22	17.09		

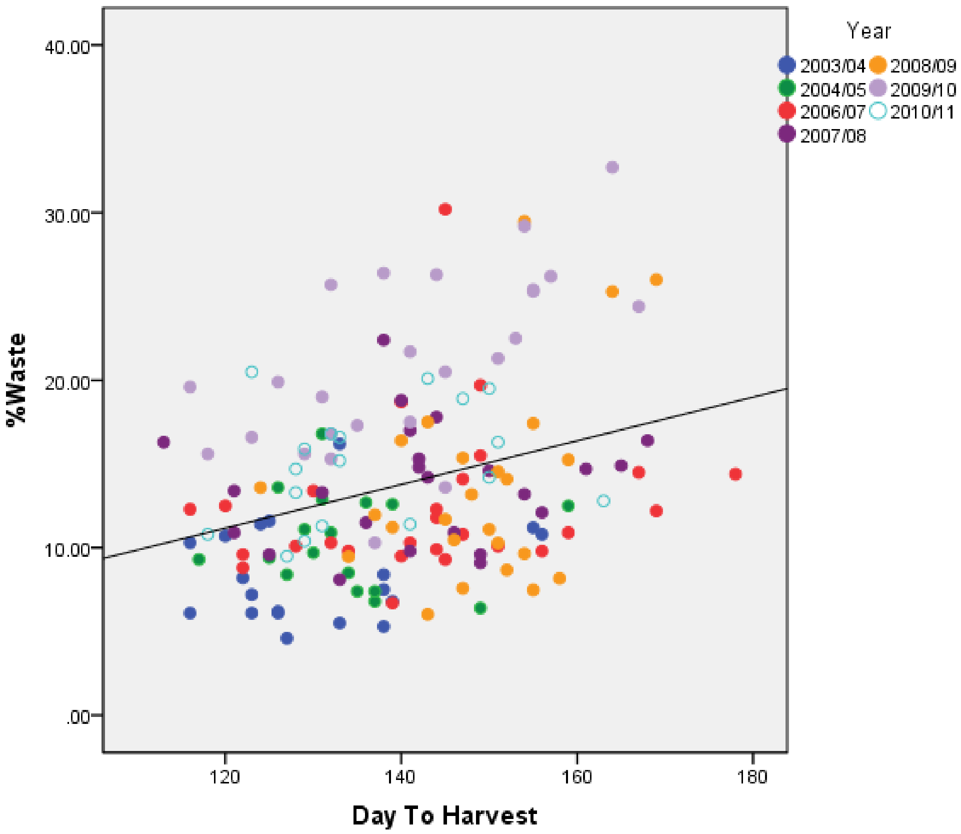


Figure 34. Plot of % waste versus Days to harvest with best fitting linear regression line

Degree days

There is strong evidence of differences in the relationship among years (p-value for Year * Degree days in Table 26).

Figure 35 indicates that the negative correlation in the 2006/07 and 2010/11 seasons is inconsistent with other years.

Table 26. Analysis of variance tables from a fit of % waste on Degree days across six years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Degree days	1	209.17	209.17	14.1	.000
Year	6	425.47	70.91	4.8	.000
Year * Degree days	6	550.33	91.72	6.2	.000
Error	140	2077.44	14.84		

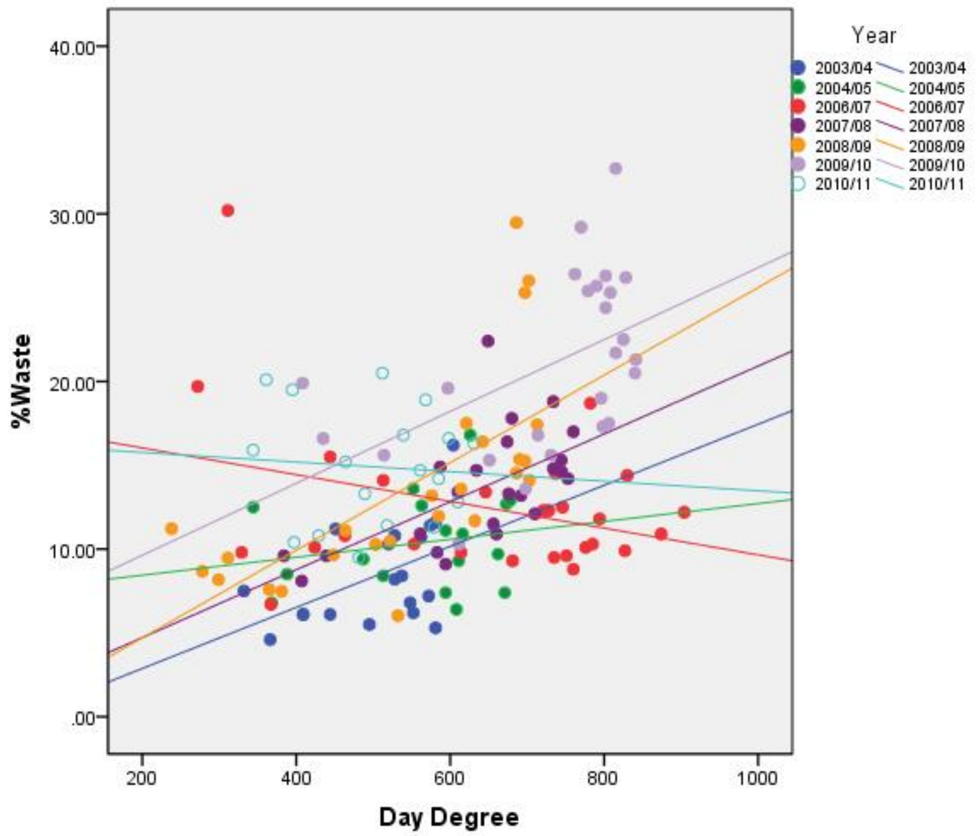


Figure 35. Plot of % waste versus Degree days with best fitting linear regression lines for individual years.

Days since August 1st

There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 27). The relationship shows substantial variation across the seasons (

Figure 36).

Table 27. Analysis of variance tables from a fit of % waste on Number of days since August 1 across seven years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Days Since August1	1	488.36	488.36	41.7	.000
Year	6	397.98	66.33	5.7	.000
Year * Days Since August 1	6	685.50	114.25	9.8	.000
Error	141	1651.04	11.71		

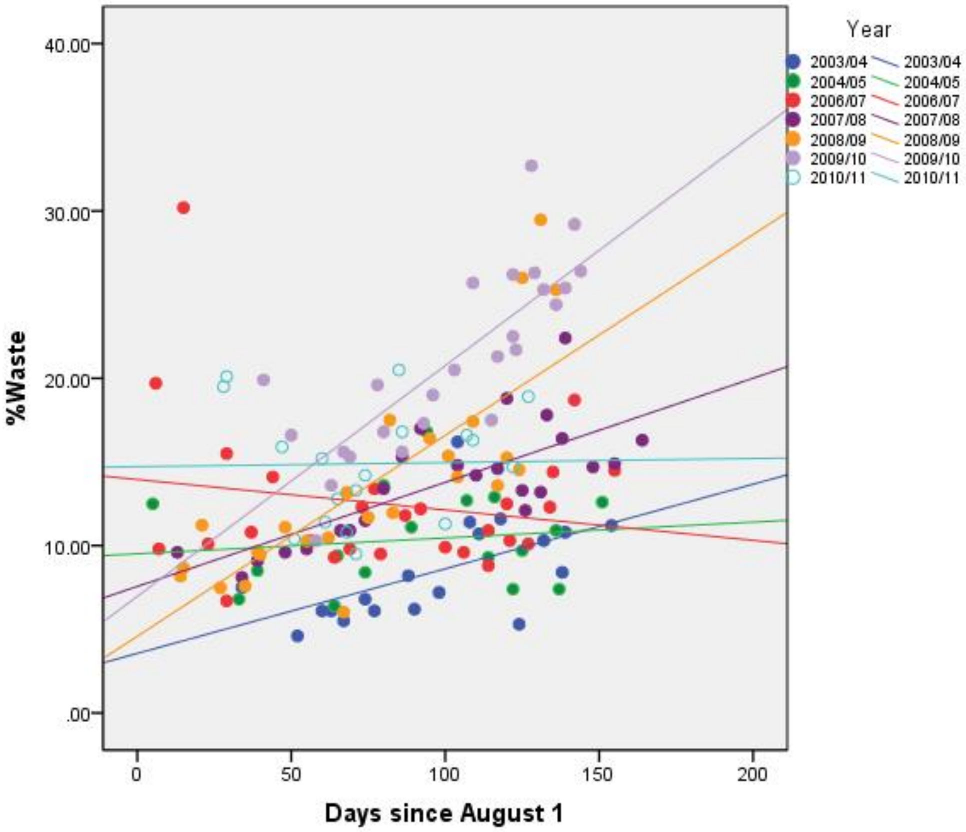


Figure 36. Plot of % waste versus Number of days since August 1 with best fitting linear regression lines for individual years.

Class 1 yield

Days to harvest

There is some evidence of differences in the relationship among years (p-value for Year * Days to harvest in Table 28). The differences can be seen in

Figure 37. However, as can be seen in the figure, there is no general trend either up or down.

Table 28. Analysis of variance tables from a fit of Class 1 yield on Days to harvest across six years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Days To Harvest	1	.24	.239	.0	.863
Year	6	104.34	17.391	2.2	.050
Year * Days To Harvest	6	111.11	18.518	2.3	.037
Error	139	1115.81	8.027		

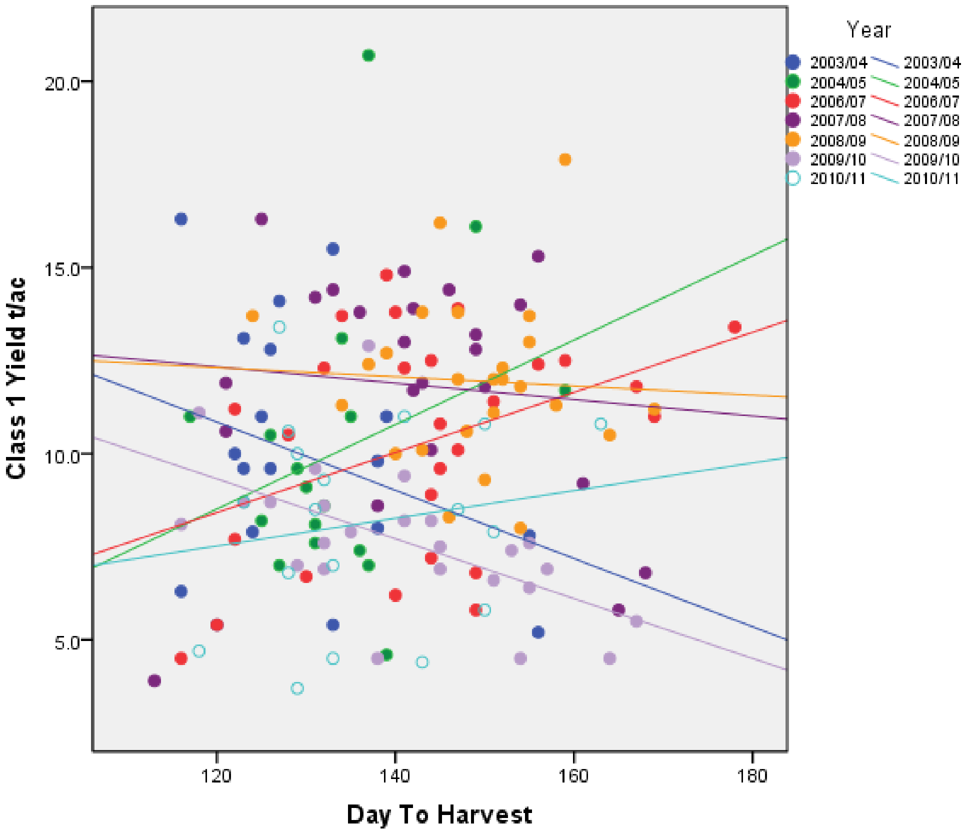


Figure 37. Plot of Class 1 yield versus Days to harvest with best fitting linear regression lines for individual years.

Degree days

There is evidence of differences in the relationship among years (p-value for Year * Degree days in Table 29). There is substantial variation in the relationship across seasons (

Figure 38).

Table 29. Analysis of variance tables from a fit of Class 1 yield on Degree days across six years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Degree days	1	40.22	40.222	5.6	.019
Year	6	154.92	25.819	3.6	.002
Year * Degree days	6	146.46	24.410	3.4	.004
Error	138	992.81	7.194		

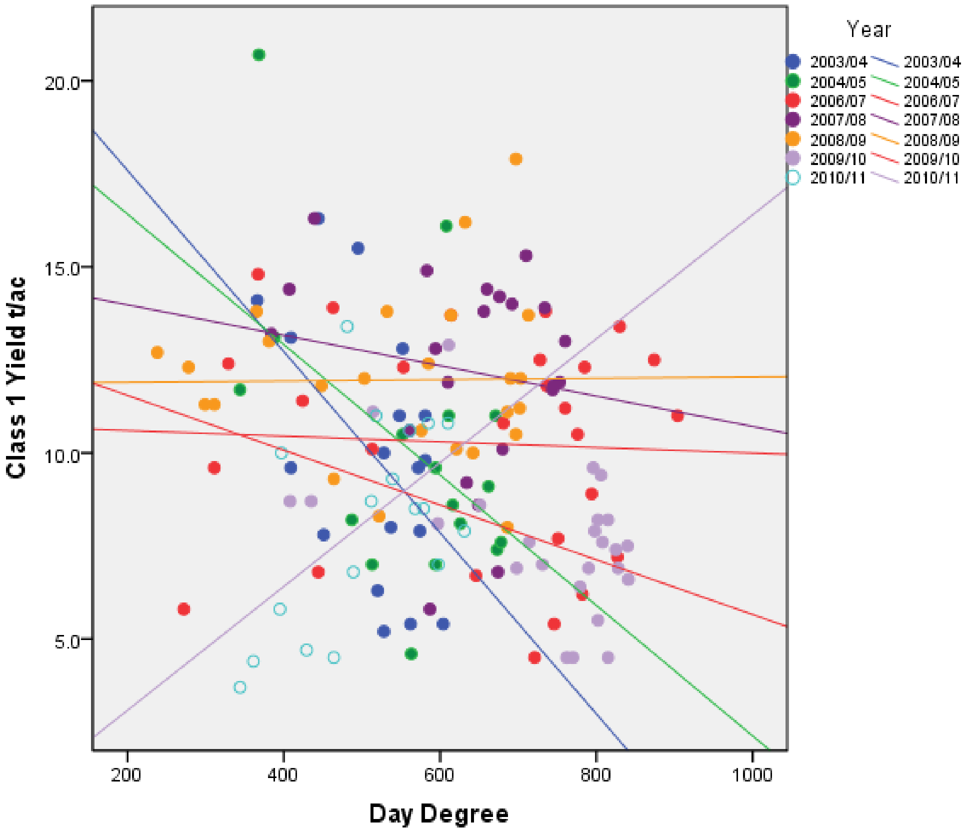


Figure 38. Plot of Class 1 yield versus Degree days with best fitting linear regression lines for individual years

Days since August 1st

There is strong evidence the relationship varies among the years (p-value for Year*Days to harvest in Table 30). The relationship shows substantial variation across the seasons (

Figure 39).

Table 30. Analysis of variance tables from a fit of Class 1 yield on Number of days since August 1 across seven years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Days Since August1	1	149.63	149.634	23.7	.000
Year	6	244.14	40.691	6.4	.000
Year * Days Since August 1	6	185.42	30.903	4.9	.000
Error	139	877.32	6.312		

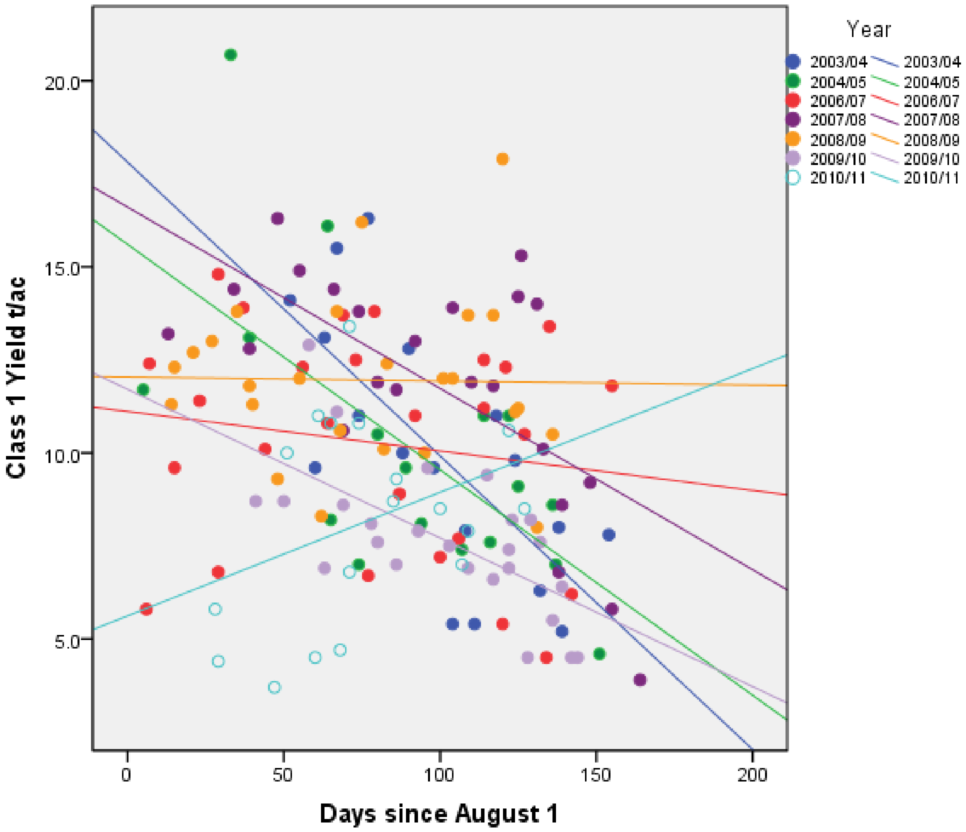


Figure 39. Plot of Class 1 yield versus Number of days since August 1 with best fitting linear regression lines for individual years.

Appendix 4

Factors affecting paddock performance of potatoes. August 2011
Statistical report by Glen McPherson Consultancy

16a Maning Avenue

Sandy Bay 7005

Tasmania

Australia

Glen McPherson Consultancy

Data Management

Phone: (03) 6225 3162

Mobile: 0419 001 612

Email: mcpconsult@gmail.com

Factors affecting paddock performance of potatoes

for Harvest Moon

August 2011

Objectives

6. Using data from the 2010/11 season, to seek associations between paddock performance in potatoes as measured by '% No 1 medium', 'No 1 medium yield', 'Dollars per acre return' and '% waste' with a selection of variables that are considered to have potential as explanatory variables.
7. To determine if there is evidence of a change in the relations between the response variables and selected explanatory variables between the 2010/11, 2009/10 and 2008/09 seasons and provide details of such relationships.

Principal findings

DATA ISSUES

- For the 2010/11/ season the number of values for the response variables No 1 medium yield and Dollars per acre return are small, namely 6 or 7 responses (Table 15). Consequently the reliability of findings for these variables in the year 2010/11 is low.
- There are no readings for stem density in 2008/09 (Table 1).
- There are only 8 readings for bulk density in 2010/11 (Table 1).
- There is too little repetition of the different crops for 'Previous crops' to be analyzable (Table 33).
- Only 'clay' and 'loam' have sufficient numbers for use in soil type analysis. Note also that loam has only 3 readings in 2010/11 (Table 34).

RELATIONS BETWEEN RESPONSE VARIABLES

- Across the years, there is generally at least a moderate correlation between the response variables (Figure 40 to Figure 45). The exception is the relation between Dollar per acre return and Percent waste which is low in the 2008/09 and 2009/10 seasons.

RESULTS FOR 2010/11 SEASON

% No 1 medium

- The only correlations are with Percent OC (Table 20 and Figure 46) and Percent WSA (Table 20 and Figure 47)
- The mean level in clay soils is higher than that in loam soils (Table 37 and Table 38).

No 1 medium yield

- The only correlation is with NO_3 (Table 20 and Figure 48). Note however, the result comes from only six observations.

Dollars per acre return

- No explanatory variables correlated with Dollars per acre return. Note however, the number of data values was small. Hence the reliability of this finding is low.

Percent waste

- The only correlations are with NO_3 (Table 20 and Figure 49)
- The mean level in clay soils is higher than that in loam soils (Table 37 and Table 38).

COMPARISONS ACROSS YEARS

% No 1 medium

- There is a linear relation with both Percent OC and WSA that is consistent across the three years (Table 45, Table 46).
- Clay soils have consistently produced higher values than loam soils across the years (Table 38, Table 47).

No 1 Medium yield

- For no variable is there a relation with No 1 medium yield across the three years (Table 20).
- There is no evidence of differences between clay and loam soils.

Dollars per acre return

- There is no evidence of a correlation between Dollar per acre return and any of the potential explanatory variables across the three years (Table 20).
- There is no evidence of differences between clay and loam soils.

Percent waste

- For no variable is there a relation with Percent waste across the three years (Table 20).
- There is evidence of a difference in levels of Percent waste between clay soils (p-value of Soil in Table 50), with loam soils having lower Percent waste (Table 44), that is consistent across the years (p-value for Soil * Year in Table 50).

Data

Data are provided from years 2008/09, 2009/10 and 2010/11. The response variables and the number of samples per year are provided in Table 15.

Table 31. Response variables used in the analysis and the number of paddocks supplying data by year.

	Number of values		
Variable	2008/09	20009/10	2010/11
% no1 Med	15	18	14
No1 Med yield (t/ac)	13	17	6
Dollars per acre return	13	17	7
%waste	15	18	14

The explanatory variables for which data are provided are listed in Table 1.

Stem density, Previous crops and Bulk density have missing values.

Table 32. Potential explanatory variables used in the analysis and the number of paddocks supplying data by year.

		Number of values		
Group	Variable	2008/09	2009/10	2010/11
Field assessment	Soil type*	15	18	14
	Stem density	0	18	10
	Previous crop**	12	18	14
Nu test	**NO_3 (ppm)**	15	18	14
	P (ppm)	15	18	14
	K (ppm)	15	18	14
	Ca (ppm)	15	18	14
	Mg (ppm)	15	18	14
	NO3:Ca	15	18	14
Soil test	**OC (%)**	15	18	14
	WSA (%)	15	18	14
	Bulk Density	6	18	8

Previous crop

There is too little repetition of previous crop to be analyzable (Table 33).

Table 33. Number of paddocks with specified previous crops by year.

Previous Crop	2008/09	2009/10	2010/11
brassica	1	4	2
celery		1	
cereal	2		
legume	1	1	
lettuce	2	1	
onions			2
pasture	4	9	6
pasture		1	
poppies	2	1	2
cereal			2
(blank)	3		

Soil type

Only clay and loam are present in sufficient numbers to allow a comparison (Table 34). Note that loam is present in only three paddocks in 2010/11.

Table 34. Number of paddocks with specified soil types by year.

Soil Type	2008/09	2009/10	2010/11
clay	6	10	11
loam	8	6	3
sand	1	2	

Results

CORRELATIONS AMONG RESPONSE VARIABLES

Correlations among response variables are shown by year in Table 19. Note that the sample sizes in 2010/11 are low. Hence the reliability of the correlations from this period is lower than that in earlier years. In particular, high correlations are required to establish evidence of correlation.

In general, there is consistency of the relationships across the years, and with the exception of Percent waste, there is good correlation among the response variables. Figure 40 to Figure 45 show the similarity in relations between variables across the years.

Table 35. Correlations between pairs of response variables by year. Correlations with p-values less than 0.05 are shown bolded.

Variable		Correlation			Sample size		
		2008/09	2009/10	2010/11	2008/09	2009/10	2010/11
% no1 Med							
with	No1 Med yield	**0.7**	**0.7**	0.8	13	17	6
	Dollar per acre return	**0.6**	**0.6**	**0.8**	13	17	7
	Percent waste	-0.5	**-0.9**	**-0.6**	15	18	14
No1 Med yield							
with	Dollar per acre return	**0.9**	**0.9**	**0.9**	13	17	6
	Percent waste	-0.4	**-0.6**	**-0.9**	13	17	6
Dollar per acre return							
with	Percent waste	-0.3	-0.5	**-0.8**	13	17	7

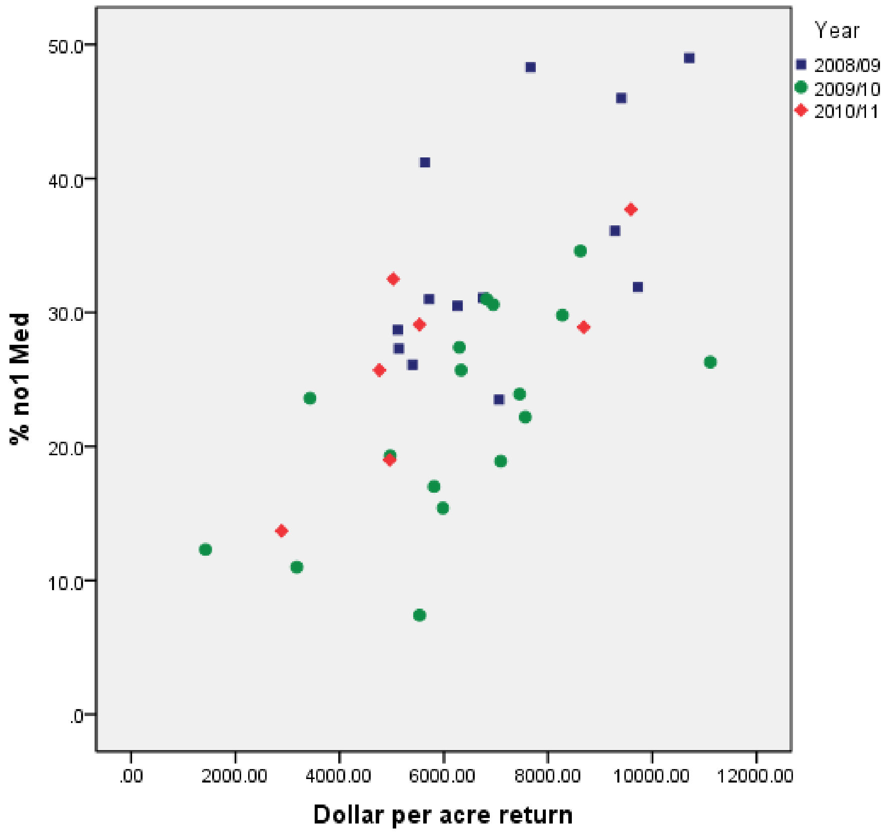


Figure 40. Scatter plot of % no1 Med vs Dollar per acre return for different years

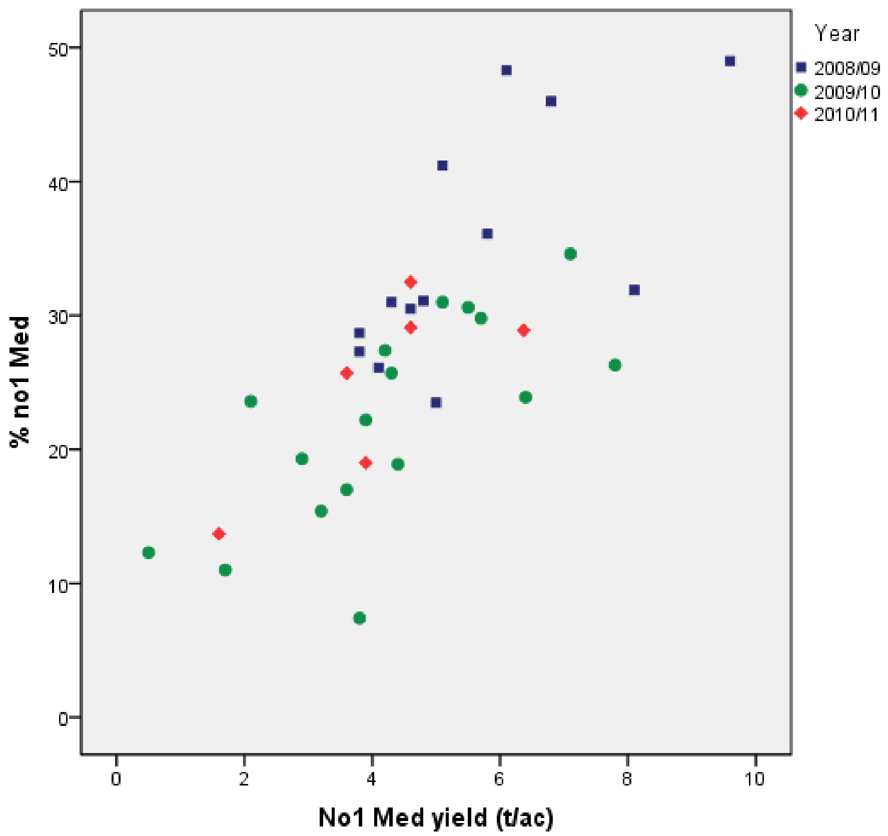


Figure 41. Scatter plot of % no1 Med vs No1 Med yield for different years

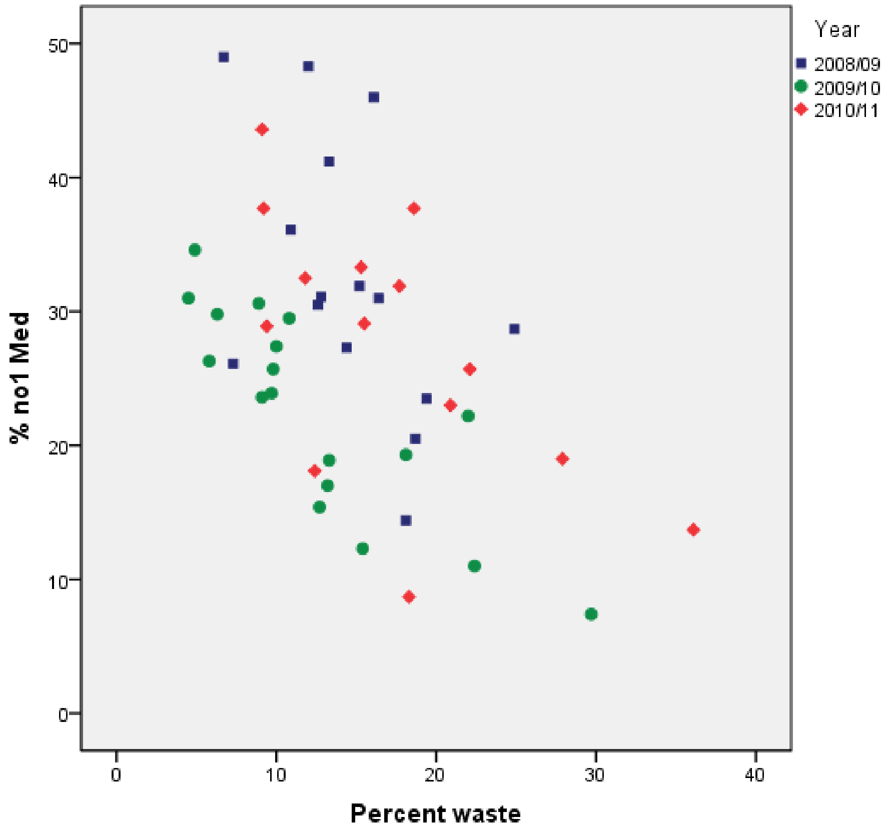


Figure 42. Scatter plot of % no1 Med vs Percent waste for different years

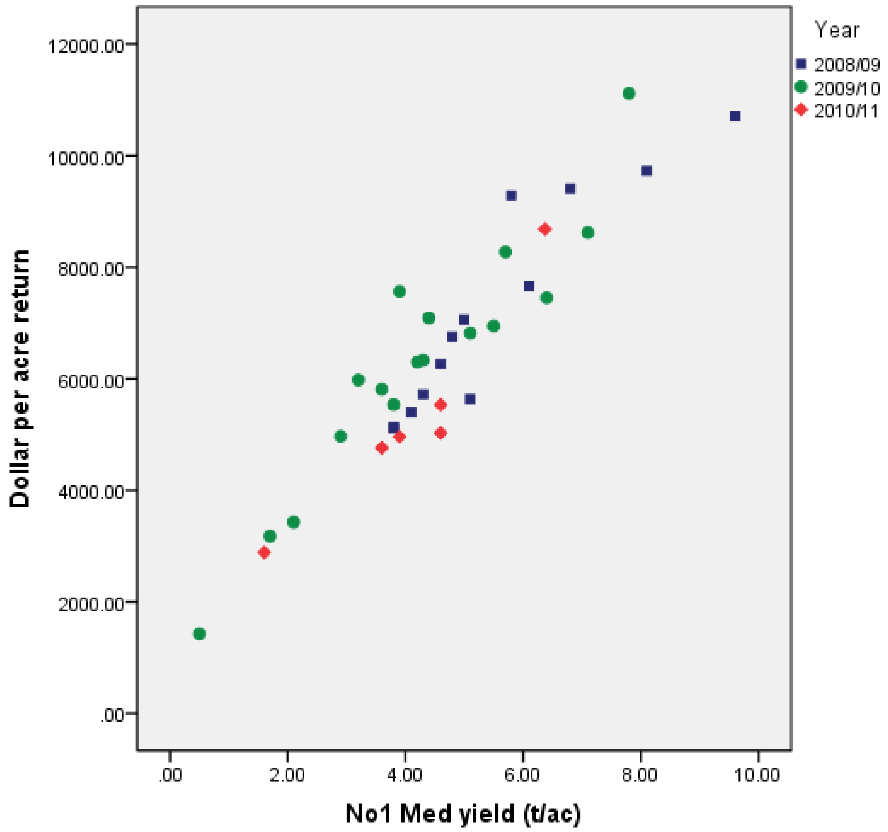


Figure 43. Scatter plot of Dollar per acre return vs No1 Med yield for different years

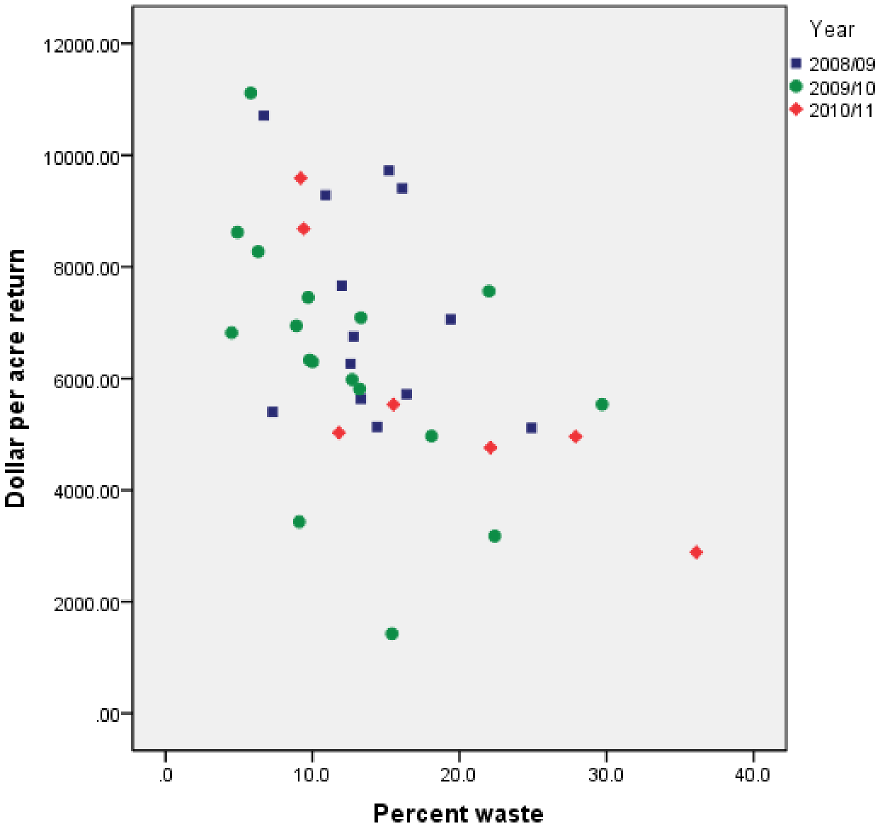


Figure 44. Scatter plot of Dollar per acre return vs Percent waste for different years

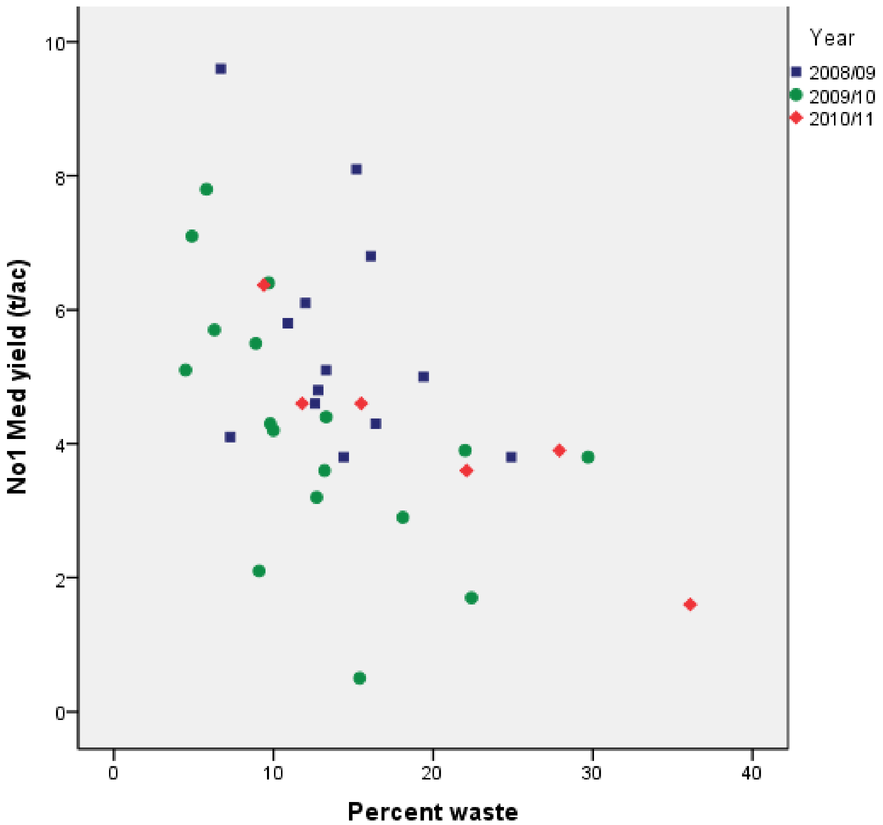


Figure 45. Scatter plot of No1 Med yield vs Percent waste for different years

Correlations between response variables and potential scaled explanatory variables

Correlations between the four response variables and the set of explanatory variables are displayed in Table 20 for each year. Of note is that

- NO_3 shows strongly for two of the four response variables in 2010/11, but weaker or no correlation in previous years.
- % OC and % WPA are closely related to % No1 Med but not to other response variables.

Table 36. Correlations between response variables and explanatory variables within years. Evidence of correlation is indicated by colouring a cell - yellow for moderate and orange for strong.

		2010/11				2009/10				2008/09			
		% no1 Med	No1 Med yield (t/ac)	Dollar per acre return	% waste	% no1 Med	No1 Med yield (t/ac)	Dollar per acre return	% waste	% no1 Med	No1 Med yield (t/ac)	Dollar per acre return	% waste
Stem Density		-.5	-.77	-.28	.38	.06	.03	.08	-.10				
	N	10	6	7	10	18	17	17	18				
NO3 ppm		.13	.94	.71	-.71	.46	.62	.59	-.36	.41	.23	.20	.33
	N	14	6	7	14	18	17	17	18	15	13	13	15
P ppm		-.16	.25	.04	.04	-.36	-.07	-.04	.18	.12	.34	.56	-.13
	N	14	6	7	14	18	17	17	18	15	13	13	15
K ppm		.02	-.02	.35	.01	.14	.04	.01	-.06	.18	.41	.43	.13
	N	14	6	7	14	18	17	17	18	15	13	13	15
Ca ppm		-.25	.15	.03	.01	-.01	.07	.18	-.03	-.04	-.19	-.16	-.08
	N	14	6	7	14	18	17	17	18	15	13	13	15
Mg ppm		.03	-.43	-.01	.21	-.58	-.60	-.49	.32	-.31	-.20	-.17	.00
	N	14	6	7	14	18	17	17	18	15	13	13	15
NO3 to Ca		.33	.59	.47	-.52	.29	.24	.12	-.23	.73	.30	.22	-.01
	N	14	6	7	14	18	17	17	18	15	13	13	15
Percent OC		.70	.40	.24	-.50	.62	.11	.07	-.42	.63	.25	.00	-.52
	N	14	6	7	14	18	17	17	18	15	13	13	15
Percent WSA		.57	.36	.26	-.45	.54	.10	.13	-.24	.70	.21	.05	-.59
	N	14	6	7	14	18	17	17	18	15	13	13	15
Bulk Density		-.61	-.39	-.26	.56	-.41	.16	.09	.33	-.59	.18	.69	.43
	N	8	4	5	8	18	17	17	18	6	5	5	6

2010/11 RESULTS

% No 1 medium

Correlations with potential scaled explanatory variables

The only scaled explanatory variables that show an association with No 1 medium are Percent OC and Percent WSA (Table 20). Plots of the relationships are shown in Figure 46 and Figure 47.

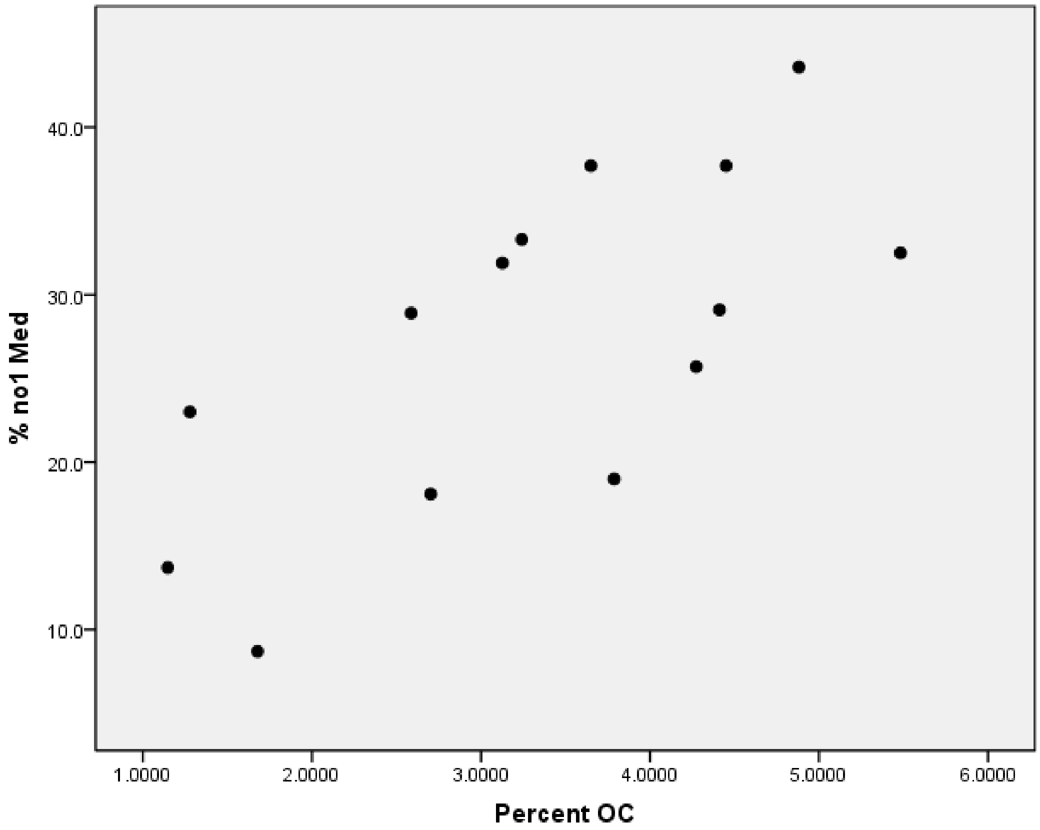


Figure 46. Plot of % No 1 medium versus Percent OC for 2010/2011 data.

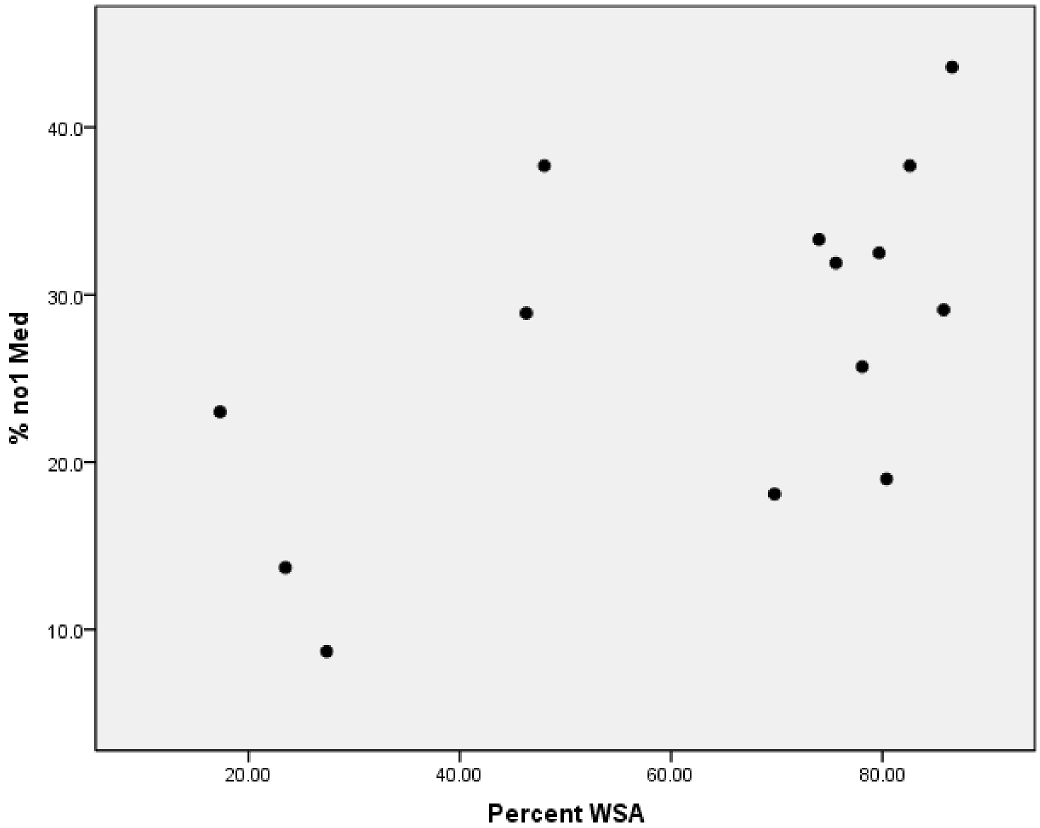


Figure 47. Plot of % No 1 medium versus Percent WSA for 2010/2011 data.

% No 1 medium for different soil types

There is strong evidence of a difference in % No 1 medium between clay and loam soils (Table 37).

Yields are higher in clay soils (Table 38).

Table 37. Analysis of variance results for comparison of % No 1 medium between clay and loam soils for year 2010/11.

Source	df	Sum of Squares	Mean Square	F	Sig.
SoilType	1	569.852	569.852	9.7	.009
Error	12	707.623	58.969		

Table 38. Mean values for % No 1 medium under different soil conditions across years.

Year	clay	loam
2008/09	40.3	26.7
2009/10	25.6	20.1
2010/11	30.7	15.1

No 1 Medium yield

Correlations with potential scaled explanatory variables

The only variable that associates with No 1 Med yield in the 2010/11 season is NO_3 (Table 20). There is a strong correlation as shown in Figure 48. The fact that this plot is based on only six observations, and the relation is not observed in other years, suggests the relation may be a chance effect.

Observed mean responses are provided in Table 40.

No 1 medium yield for different soil types

The differences in mean yield could be explained as chance variation (Table 39). Note that the small sample size reduces the reliability of this finding.

Table 39. Analysis of variance results for comparison of No 1 medium yield between clay and loam soils for year 2010/11.

Source	df	Sum of Squares	Mean Square	F	Sig.
SoilType	1	7.570	7.570	6.6	.06
Error	4	4.622	1.155		

Table 40. Mean values for No 1 medium yield under different soil conditions across years.

Year	clay	loam
2008/09	6.0	5.2
2009/10	4.6	4.0
2010/11	4.6	1.6

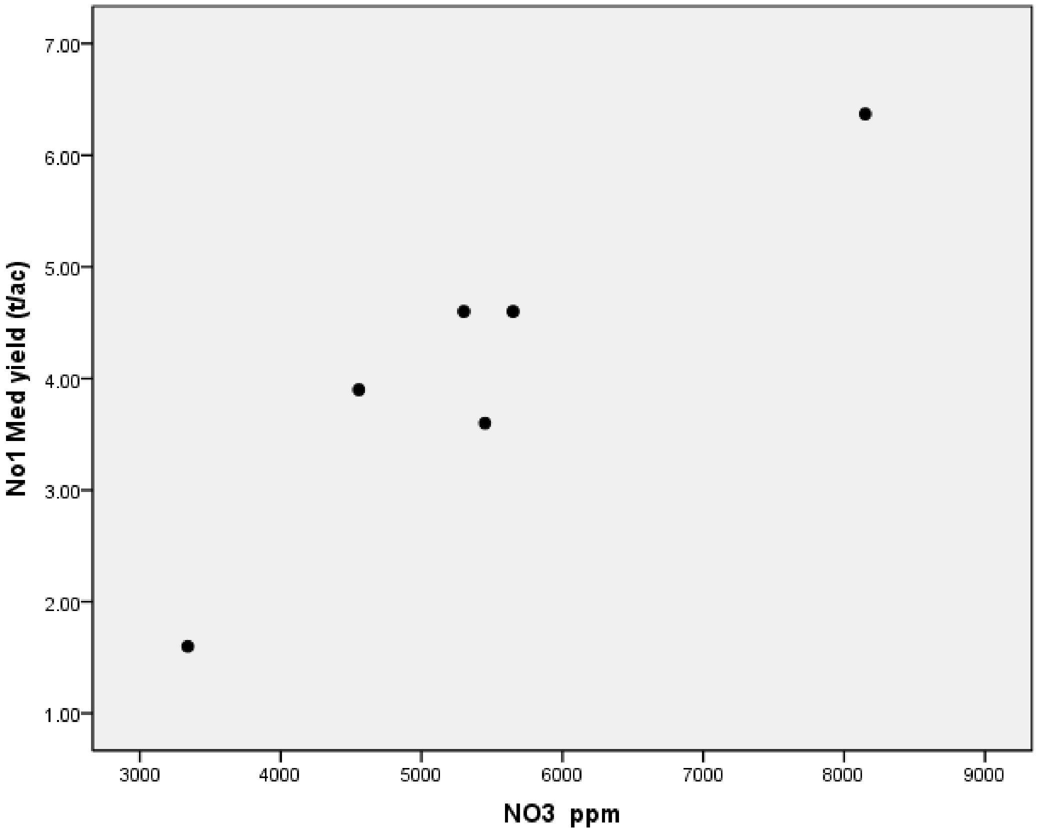


Figure 48. Plot of No 1 medium yield versus NO3 for 2010.11 data

Dollars per acre return

Correlations with potential scaled explanatory variables

There is no evidence of a correlation between Dollars per acre return and any of the potential explanatory variables (Table 20). Note however, this result is determined from only seven observations (Table 15).

Dollars per acre return for different soil types

The differences in mean yield could be explained as chance variation (Table 41). Note that the small sample size (Table 15) reduces the reliability of this finding.

Observed mean responses are provided in Table 42.

Table 41. Analysis of variance results for comparison of Dollars per acre return between clay and loam soils for year 2010/11.

Source	df	Sum of Squares	Mean Square	F	Sig.
SoilType	1	10738641	10738641	2.36	.19
Error	5	22772734	4554547		

Table 42. Mean values for Dollars per acre return under different soil conditions across years.

Year	clay	loam
2008/09	7423	7180
2009/10	6600	6383
2010/11	6427	2887

Percent waste

Correlations with potential scaled explanatory variables

The only variable that associates with Percent waste in the 2010/11 season is NO_3. (Table 20). There is a strong correlation as shown in Figure 49.

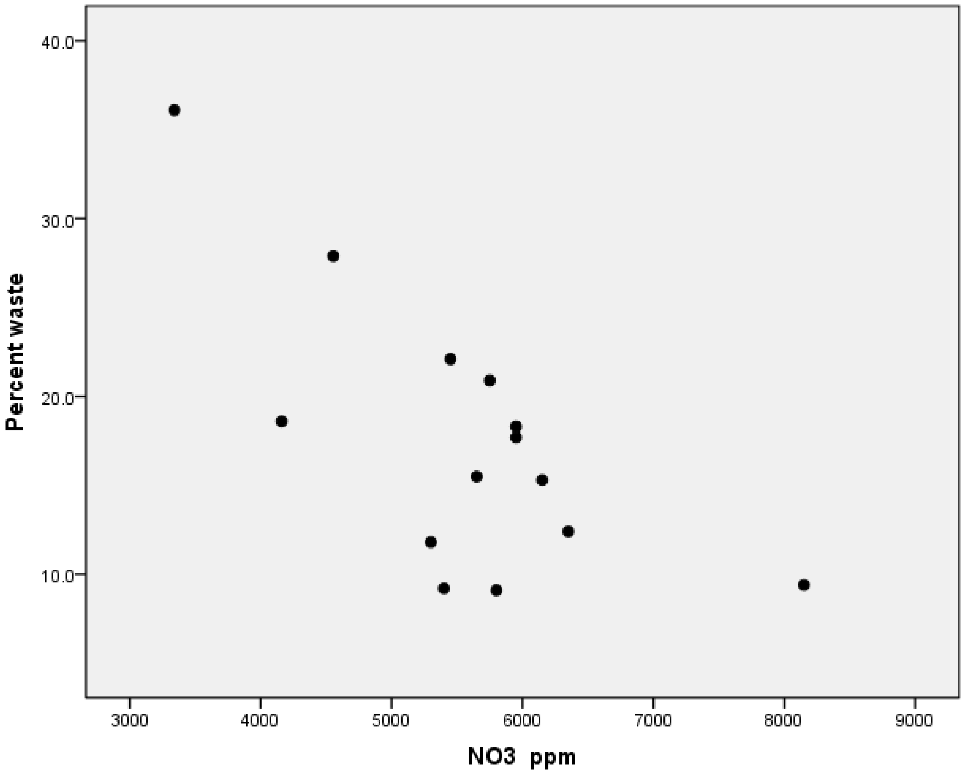


Figure 49. Plot of Percent waste versus NO3 for 2010/11 data

Percent waste for different soil types

There is weak evidence of differences in Percent waste for clay and loam soils (Table 43) with loam soils being associated with higher waste (Table 44).

Table 43. Analysis of variance results for comparison of Percent waste between clay and loam soils for year 2010/11.

Source	df	Sum of Squares	Mean Square	F	Sig.
Soil Type	1	223.45	223.45	5.0	.045
Error	12	537.65	44.80		

Table 44. Mean values for Percent waste under different soil conditions across years.

Year	clay	loam
2008/09	12.0	16.8
2009/10	11.3	11.4
2010/11	15.4	25.1

COMPARISONS ACROSS YEARS

Correlations with potential explanatory variables

% No 1 medium

The two variables that show an association with No 1 Medium across the years are Percent OC and Percent WSA (Table 20). For both variables, the results of the analyses reported in Table 45 and Table 46 indicate that the relationship is consistent across the three years.

The nature of the relation is shown in Figure 50 and Figure 51. As can be seen from the figures there is a moderate positive correlation between the variables for all years.

Table 45. Analysis of variance for comparison of linear regression equations between % No 1 medium and Percent OC across years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Percent OC	1	1546	1545.94	29.5	.000
Year	2	57	28.45	.5	.6
Year * Percent OC	2	21	10.36	.2	.8
Error	41	2146	52.34		

Table 46. Analysis of variance for comparison of linear regression equations between % No 1 medium and Percent WSA across years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Percent WSA	1	1367	1367.38	24.2	.000
Year	2	26	12.99	.2	.8
Year * Percent WSA	2	63	31.32	.6	.6
Error	41	2318	56.53		

No 1 Medium yield

There are few correlations with explanatory variables, and where correlations are found, there is no consistency across years (Table 20) Those correlations that are found are,

- a strong correlation with NO_3 in 2010/11 which does not show in earlier years. Note however, that the 2010/11 results are based on only six observations, and
- a moderate correlation with Magnesium in 2009/10 which is not found in the other years.

Dollar per acre return

The few correlations that are found with explanatory variables are not consistent across years. As shown in Table 20,

- there is a moderate correlation with NO_3 and with Mg in 2009/10 which is found in other years, and
- there is a moderate correlation with P in 2008/09 that is not found in other years.

Percent waste

Only one correlation is found with explanatory variables, namely a strong correlation with NO_3 in 2010/11 (Table 20).

Figure 50. Plot of % No 1 Med versus Percent OC across years.

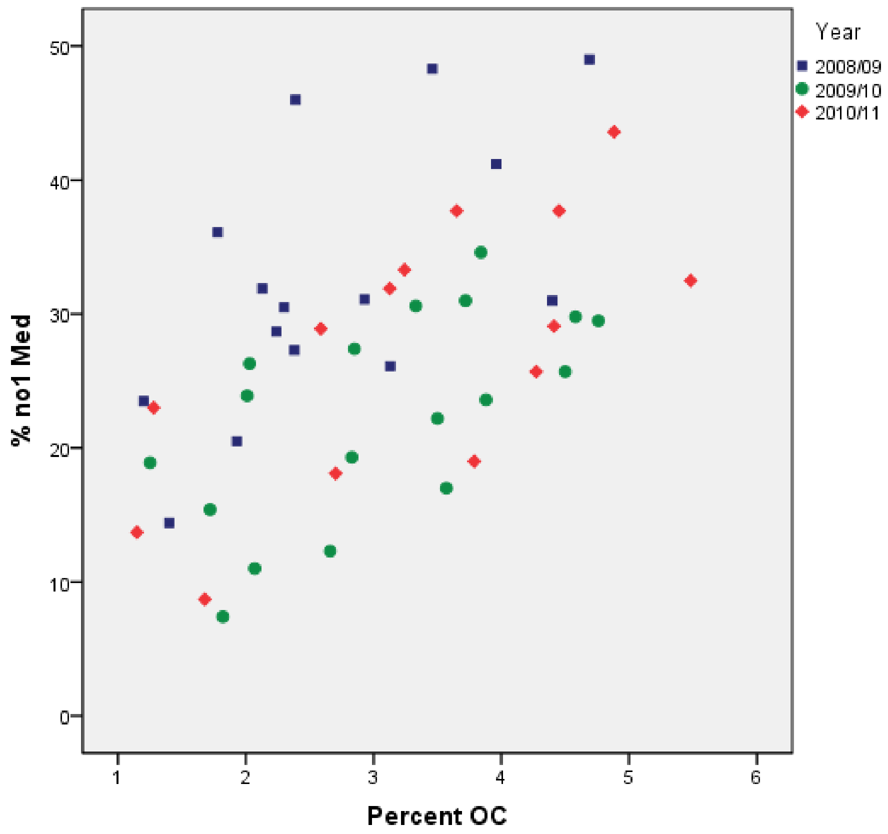
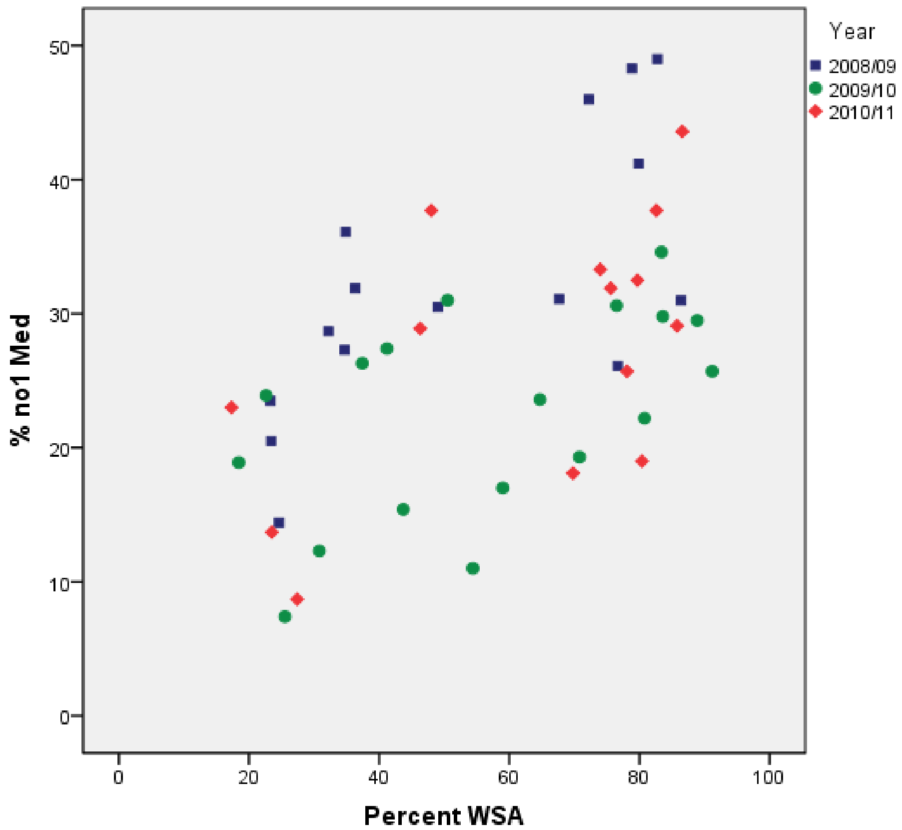


Figure 51. Plot of % No 1 Med versus Percent WSA across years.



Variations in mean differences between soil types across years

% No 1 Medium

There is evidence that % No 1 medium varies between clay and loam soil types (p-value for Soil type in Table 47) and the difference is consistent across years (p-value for Soil type * Year in Table 47). As seen in Table 38, clay soils consistently have higher values than do loam soils.

Table 47. Analysis of variance results for % No 1 Medium by soil type and years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Soil Type	1	1184.39	1184.39	22.4	.000
Year	2	963.25	481.63	9.1	.001
Soil Type * Year	2	169.99	85.00	1.6	.214
Error	37	1954.87	52.83		

No 1 Medium yield

There is no evidence that differences in mean responses between clay and loam soils varied across the three years (p-value for Soil type * Year in Table 48 .

Mean responses for the two soil types over the three years are provided in Table 40.

Table 48. Analysis of variance results for No 1 medium yield by soil type and years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Soil Type	1	10.441	10.441	3.1	.09
Year	2	20.245	10.123	3.0	.07
Soil Type * Year	2	4.047	2.023	.6	.56
Error	26	88.187	3.392		

Dollar per acre return

There is no evidence that differences in mean responses between clay and loam soils varied across the three years (p-value for Soil type * Year in Table 49).

Mean responses for the two soil types over the three years are provided in Table 42.

Table 49. Analysis of variance results for Dollar per acre return by soil type and years.

Source	df	Sum of Squares	Mean Square	F	Sig.
SoilType	1	8835861	8835861	1.7	.20
Year	2	18990650	9495325	1.9	.17
SoilType * Year	2	8251627	4125813	.8	.45
Error	27	137049043	5075890		

Percent waste

There is no evidence that differences in mean responses between clay and loam soils varied across the three years (p-value for Soil type * Year in Table 50. However, there is strong evidence that mean responses varied between the soil types and varied across the years.

Mean responses for the two soil types over the three years are provided in Table 44.

Table 50. Analysis of variance results for Percent waste by soil type and years.

Source	df	Sum of Squares	Mean Square	F	Sig.
Soil Type	1	213.6	213.57	7.4	.010
Year	2	438.3	219.17	7.6	.002
Soil Type * Year	2	127.7	63.85	2.2	.123
Error	37	1063.0	28.73		

Appendix 5

Soil Analysis. August 2011

Statistical report by Glen McPherson Consultancy

Soil analysis

Objective

To examine the correlation between organic carbon (OC) and aggregate stability (WSA) within each year/soil type classification.

Data

Data are available from the seasons 2008/09, 2009/10 and 2010/11 for variables OC and WSA. The sample sizes are shown in

Table 51. Sample sizes for soil data by year and soil type

	year		
Soil Type	2008/09	2009/10	2010/11
Ferrosol	49	44	63
other	16	17	12

Results

Correlations are displayed in Table 52. Correlations are consistently higher for ‘other’ soils compared with ‘Ferrosol’ soils.

Note that samples sizes for ‘other’ soils are considerably smaller than those for Ferrosol. Hence higher correlations are required to achieve the same p-value.

Table 52. Correlations between OC and WSA within year/soil type classifications. Figures in cells shaded in orange have p-values less than 0.01. The figure shaded yellow has a p-value in the range 0.01 to 0.05

	year		
Soil Type	2008/09	2009/10	2010/11
Ferrosol	0.25	0.50	0.41
other	0.52	0.75	0.79

The relations between OC and WSA are displayed for Ferrosol soils in Figure 52, and for ‘Other’ soils in Figure 53. Agreement across years is greater for Ferrosol soils.

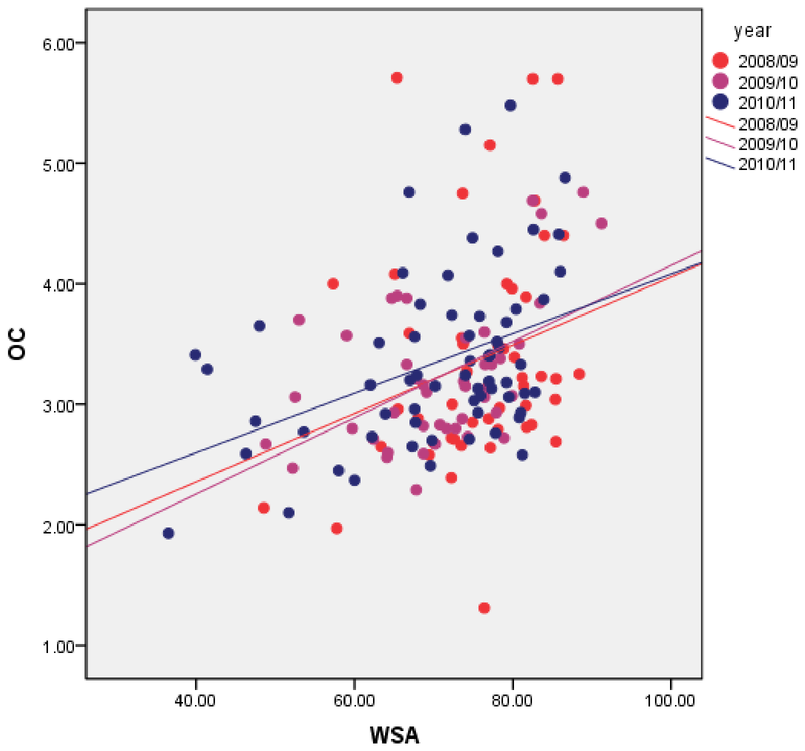


Figure 52. Ferrosol soils: Plot of OC versus WSA with best fitting regression lines for individual seasons included.

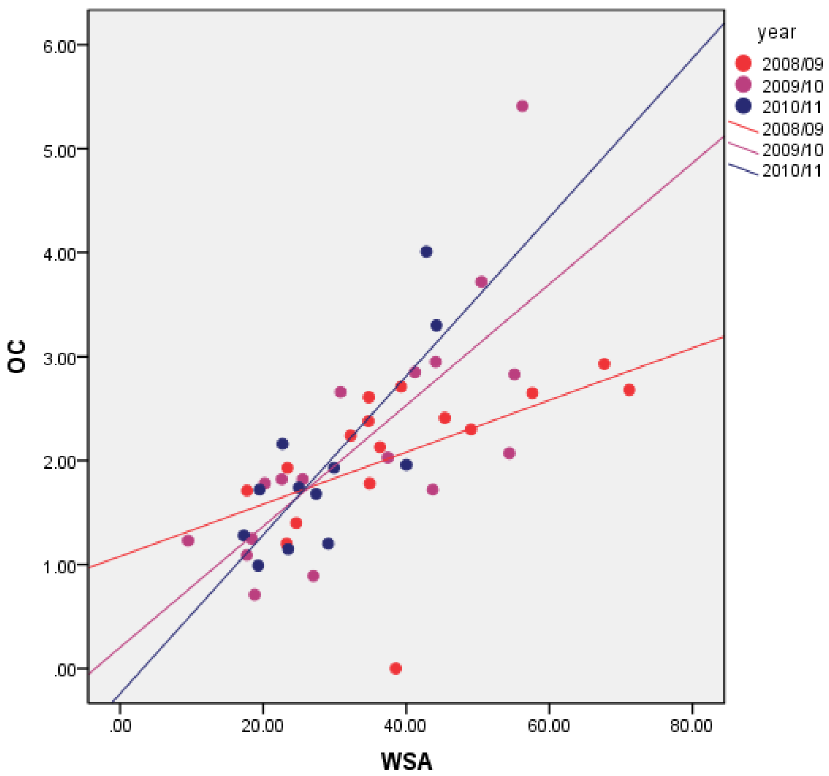


Figure 53. 'Other' soils: Plot of OC versus WSA with best fitting regression lines for individual seasons included.

Appendix 6

Factors affecting paddock performance of selected crops. September 2009.
Statistical report by Glen McPherson Consultancy

16a Maning Avenue

Sandy Bay 7005

Tasmania

Australia

Glen McPherson Consultancy

Data Management

Phone: (03) 6225 3162

Mobile: 0419 001 612

Email: mcpconsult@gmail.com

Factors affecting paddock performance of selected crops

for Harvest Moon

Revised 24 September 2009

Objectives

To seek associations between paddock performance in carrots, onions and potatoes, as measured by 'dollar per acre', '% Class 1 medium to medium large' and '% waste', with a selection of variables that are considered to have potential as explanatory variables. These variables provide data from four main areas of paddock composition – physical, chemical, and environmental variables.

Data

Carrots

Data are provided from 32 paddocks for each of the three paddock performance variables and for 26 potential explanatory variables.

Two varieties were represented, variety 1 in 26 paddocks and variety 2 in 6 paddocks.

Twenty five potential explanatory variables provided data for the analysis.

Potatoes

Data are provided from 15 paddocks.

There are three paddock performance variables that provide data from all paddocks.

Twenty six potential explanatory variables provided data for the analysis.

Note that of the 15 paddocks providing complete data on the explanatory variables, only six provide data for the paddock performance variables '% disease' and '% damage'. This is too few for a meaningful statistical analysis.

The explanatory variable 'Fallow period' has been excluded because it has too many missing values.

Results

Caution: The results for carrots presented below are obtained from data on only 32 paddocks where both varieties are included or 26 paddocks where only variety 1 is considered. For potatoes, the number of paddocks with complete results is only 15.

The small sample size raises concerns that results may only reflect relationships in these paddocks and not the farming region as a whole. To have confidence that findings are likely to be stable across the whole region, my rule-of-thumb is that there needs to be ten paddocks for every explanatory variable employed. Given that 25 explanatory variables are employed in the analysis, this suggests that 250 paddocks would be required. The fact that such a large sample size is not feasible, does not invalidate the findings of this study. However, the small sample size does suggest that the findings should not be given a status beyond the use as an indicator of where additional resources might be directed for further investigation.

CARROTS

The findings are summarized in Table 54 for the combined data from both varieties, and in Table 56 based on variety 1 data only.

Visual pictures of the relationships and their strengths are presented in Figure 55 to Figure 57.

Scatter plots displaying relations between response variables and selected explanatory variables are provided in Figure 60 to Figure 65.

For all response variables there is evidence of a strong relation between the response and at least one explanatory variable.

Relations between response variables

Scatter plots displaying the relations between the three response variables are provided in Figure 58.

There is a strong relation between dollars per acre and % Class 1 medium to medium large. The relation between these variables and % waste is weaker.

Relation between explanatory variables

It is noted that where the ratio of NO_3 to Ca is excluded from the list of potential input variables, its place tends to be taken by the ratio of NO_3 to Mg. As can be seen in Figure 59, there is a strong relation between Ca and Mg. However, it is dependent on data from only two paddocks.

Correlations between response variables and explanatory variables

The correlation between paddock performance variables and potential explanatory variables are displayed in Table 53

Table 53. Correlations between paddock performance variables and potential explanatory variables.

	Both varieties			Variety 1		
	Dollars per acre	% Class 1 medium to medium large	Percent waste	Dollars per acre	% Class 1 medium to medium large	Percent waste
Dollars per acre		.664**	-.502**		.660**	-.654**
% Class 1 medium to medium large	.664**		-.600**	.660**		-.637**
Percent waste	-.502**	-.600**		-.654**	-.637**	
NO3 (ppm)	-0.314	-.562**	.408*	-0.337	-.650**	.404*
Ratio NO3 to K	-.357*	-.493**	0.34	-0.245	-.557**	0.365
Ratio NO3 to Ca	-.474**	-.531**	.600**	-.547**	-.631**	.684**
Ratio NO3 to Mg	-.448*	-.418*	.421*	-0.277	-.564**	.626**
K (ppm)	0.144	-0.081	0.068	-0.185	-0.237	0.069
Ca (ppm)	0.145	0.291	-0.153	0.106	0.326	-0.214
Mg (ppm)	0.13	0.316	-0.192	-0.037	0.367	-0.257
Total Cations	0.214	0.108	-0.037	-0.111	0.027	-0.097
Total nutients	-0.143	-.388*	0.304	-0.344	-.515**	0.28
NO3-N(mg/kg)	-0.292	-0.27	.398*	-0.24	-0.269	.394*
NH4-N(mg/kg)	0.306	.519**	-0.283	0.09	.426*	-0.268
OC (%)	0.147	0.141	0.129	0.076	-0.035	0.167
WSA (%)	.455**	.500**	-.362*	0.282	0.319	-.429*
Soil resistance (KPa)	-0.265	-0.26	.479**	-0.09	-0.322	.592**
Days to Harvest	0.305	0.29	0.149	0.156	0.103	0.18
Total Microbial:	0.082	0.174	-0.004	-0.181	0.034	0.027
Bacteria	-0.114	0.052	0.189	-.444*	-0.117	0.245
Fungi	0.124	0.22	-0.147	0.013	0.17	-0.112
Yeast	0.136	0.046	0.005	0.014	-0.041	-0.03
Anaerobic	0.02	0.087	0.133	-0.059	0.031	0.15
Anaerobic Desired	-0.114	0.052	0.189	-.444*	-0.117	0.245
Azotobacter	-0.044	0.066	-0.194	0.351	.514**	-.413*
Actinomycetes	0.134	0.046	-0.176	-0.042	0.052	-0.256
Fungi to Bacteria	0.208	0.115	-0.234	0.298	0.171	-0.26
Fungi to Yeast	0.086	0.173	-0.169	0.046	0.16	-0.155

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 54. Both varieties: Results from linear regression analysis for carrot data. The primary explanatory variable is a variable that is fitted independently of associatinos with other variables. A secondary or subsequent y explanatory variabvle is one that ise fitted to responses after adjustment for influence from the preceding variable or variables.

BOTH VARIETIES

Paddock performance variable	Primary explanatory	Secondary explanatory	Tertiary explanatory	Percentage explained
Dollars per acre				
All variables	NO_3/Ca			23%
	NO_3/Ca	WSA %		33%
Exclude NO_3/Ca	WSA %			21%
	NO_3/Mg			20%
	NO_3/K			13%
% Class 1 medium to medium large				
All variables	NO_3			32%
	NO_3	WSA %		48%
	NO_3	WSA %	Azotobacter	55%
Exclude NO_3 and WSA%	NO_3/Ca	NH_4-N		28%
	NO_3/Ca	NH_4-N		45%
% waste				
All variables	NO_3/Ca			36%
	NO_3/Ca	Ca		48%
Exclude NO_3/Ca	Soil resistance			23%

Table 55. Variety 1: Results from linear regression analysis for carrot data. The primary explanatory variable is a variable that is fitted independently of associations with other variables. A secondary or subsequent y explanatory variable is one that is added after the preceding variable.

VARIETY 1

Paddock performance variable	Primary explanatory	Secondary explanatory	Tertiary explanatory	Quaternary explanatory	Percentage explained
Dollars per acre	NO_3/Ca				30%
All variables	NO_3/Ca	Mg			44%
	NO_3/Ca	Mg	OC %		55%
	NO_3/Ca	Mg	OC %	Fungi to yeast	65%
	Bacteria				20%
Exclude NO_3/Ca	Bacteria	NO_3/Mg			36%
	Bacteria	NO_3/Mg	K		48%
	Anaerobic Desired				20%
Exclude NO_3/Ca and Bacteria	Anaerobic Desired	NO_3/Mg			36%
	Anaerobic Desired	NO_3/Mg	K		48%
% Class 1 medium to medium large	NO_3				42%
All variables	NO_3	Azotobacter			71%
	NO_3	Azotobacter	Ca		78%
	NO_3/Ca				40%
Exclude NO_3	NO_3/Ca	Total nutrients			57%
	NO_3/Ca	Total nutrients	Azotobacter		74%
	NO_3/Mg				32%
Exclude NO_3 and NO_3/Ca	NO_3/Mg	Azotobacter			58%
	NO_3/Mg	Azotobacter	Total nutrients		71%
	NO_3/Mg	Azotobacter	Total nutrients	Ca	76%
% waste	NO_3/Ca				47%
All variables	NO_3/Ca	Ca			58%
	NO_3/Mg				39%
Exclude NO_3/Ca	NO_3/Mg	Bacteria			56%
	NO_3/Mg	Bacteria	Azotobacter		67%

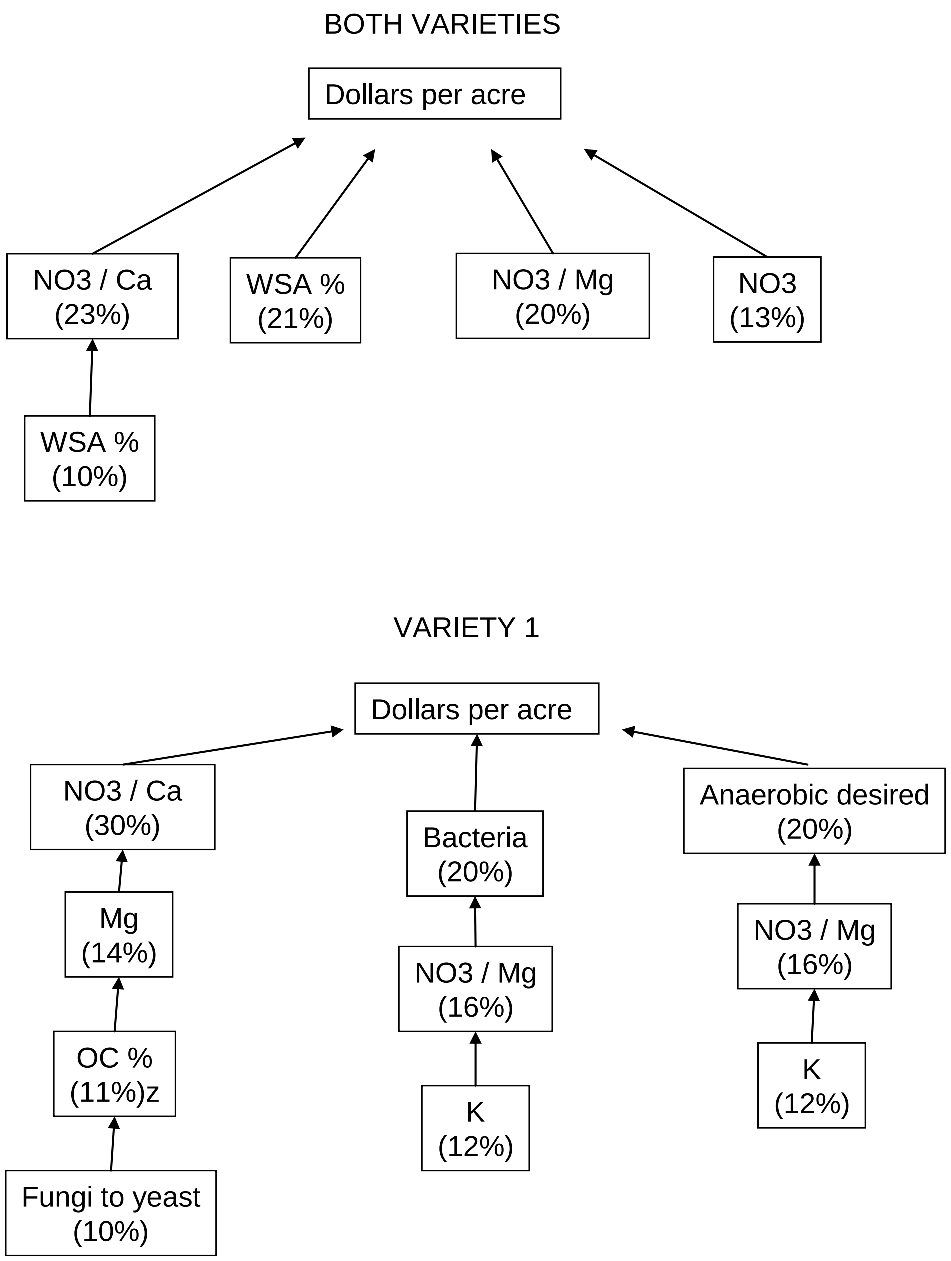


Figure 54. The percentage of variation in dollars per acre values explained by different input variables based on linear regression models. Stepwise fitting was employed. The percentages indicated for secondary variables represent the additional percentage explained.

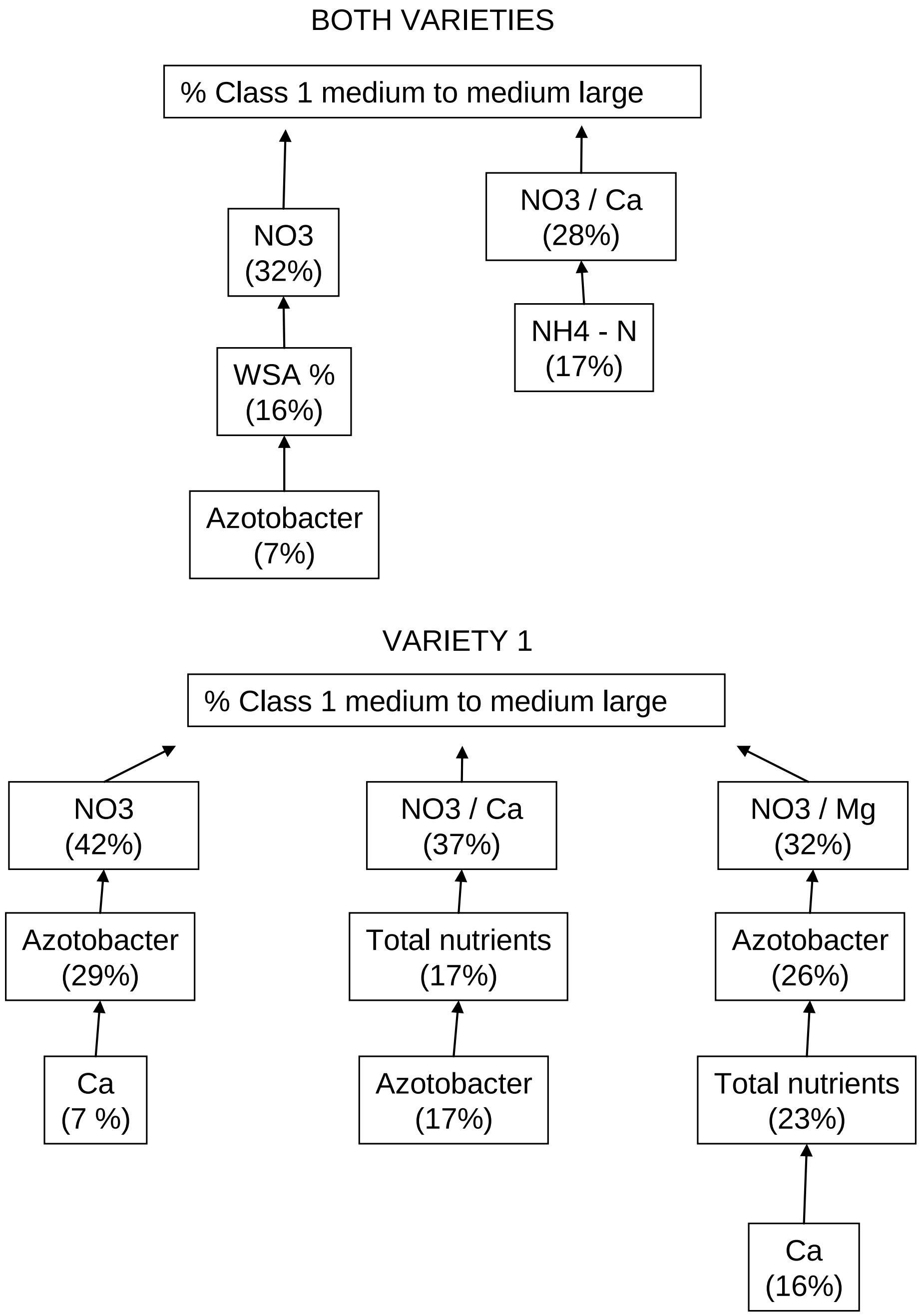


Figure 55. The percentage of variation in % class 1 medium to medium large values explained by different input variables based on linear regression models. Stepwise fitting was employed. The percentages indicated for secondary variables represent the additional percentage explained.

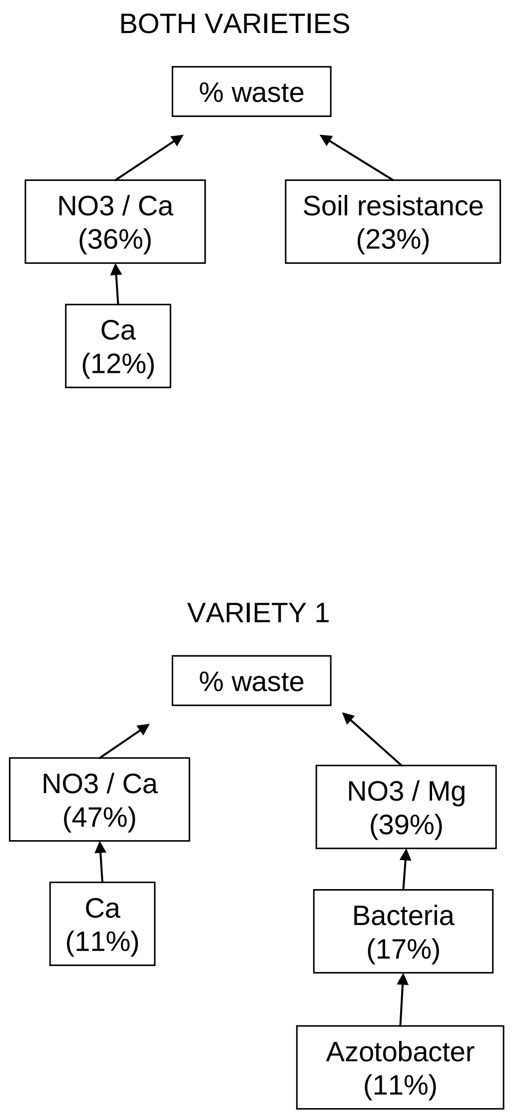


Figure 56. The percentage of variation in % waste values explained by different input variables based on linear regression models. Stepwise fitting was employed. The percentages indicated for secondary variables represents the additional percentage explained.

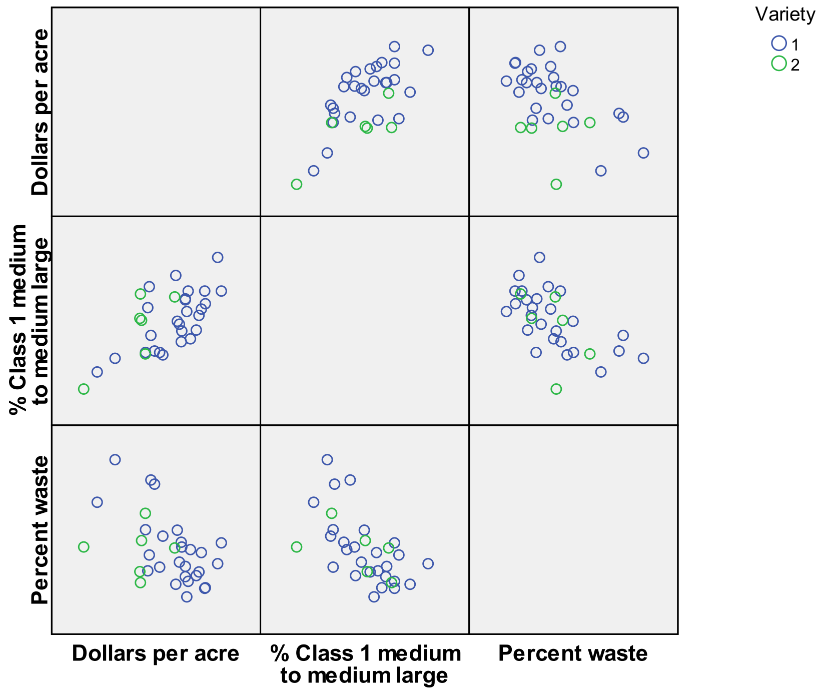


Figure 57. Scatter plots displaying relations between the three response variables.

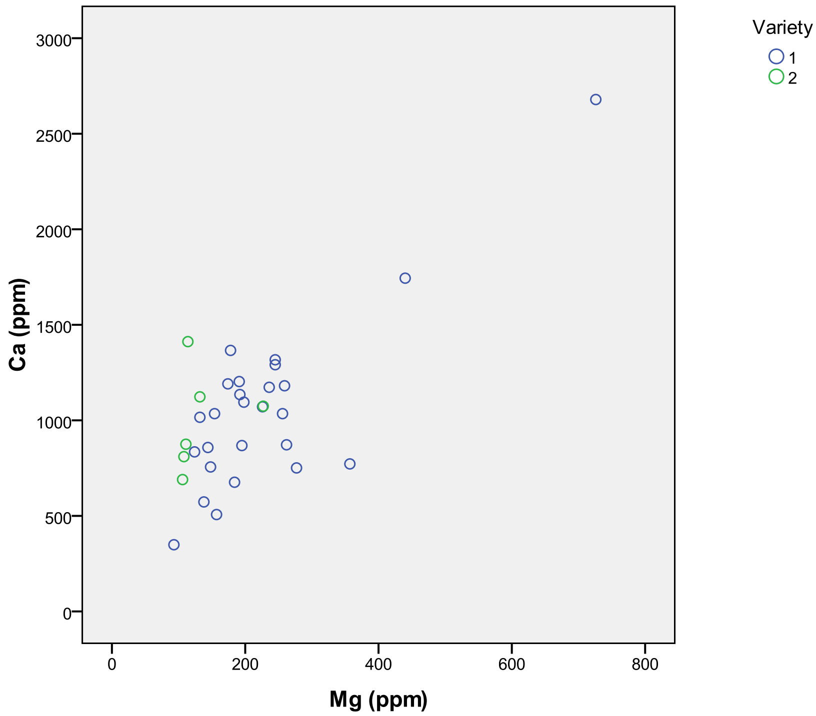


Figure 58. Relation between Ca and Mg levels.

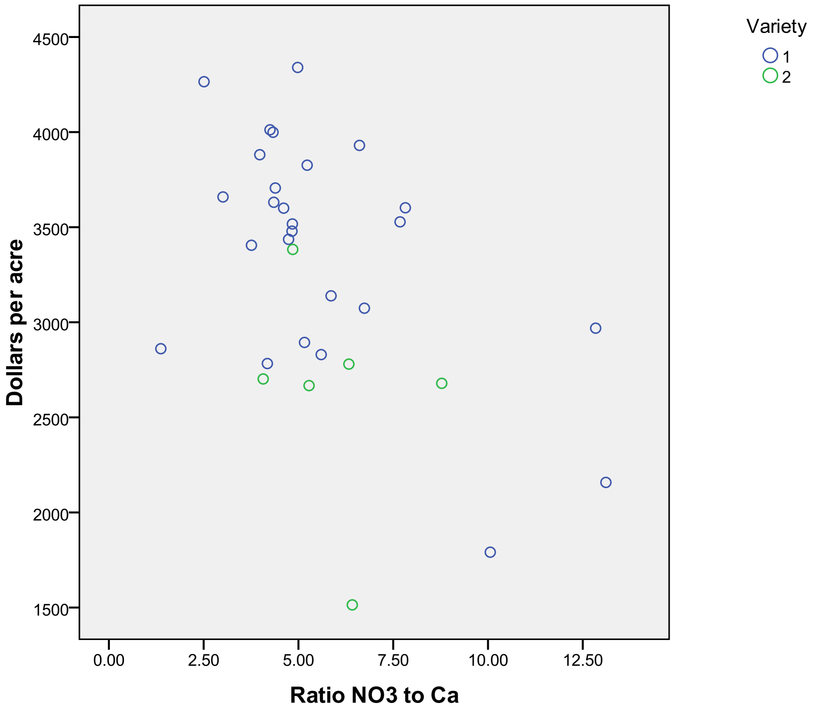


Figure 59. Scatter plot displaying the relation between dollars per acre and the ratio of NO_3 to Ca.

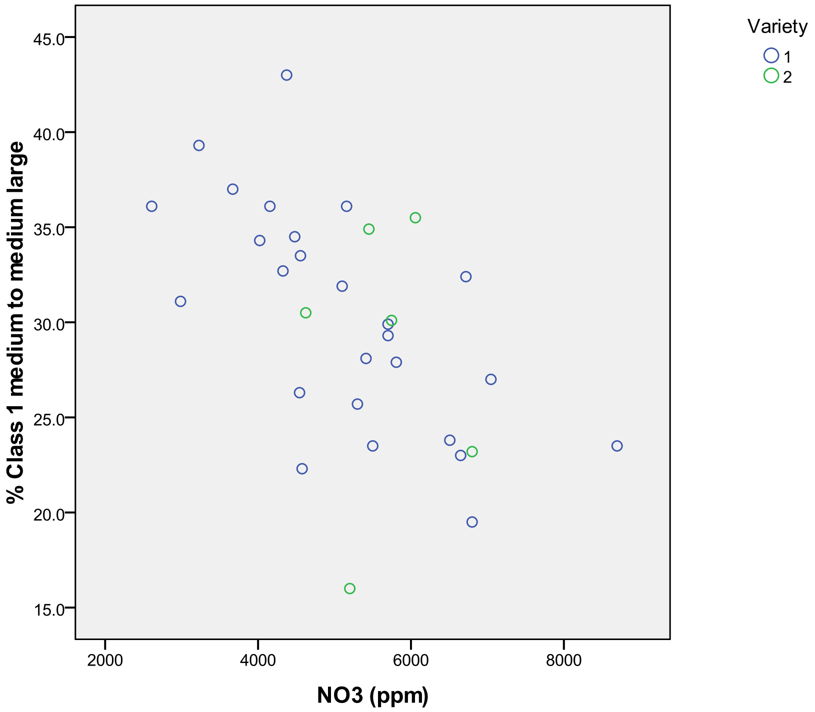


Figure 60. Scatter plot displaying the relation between % Class 1 medium to medium large and NO_3.

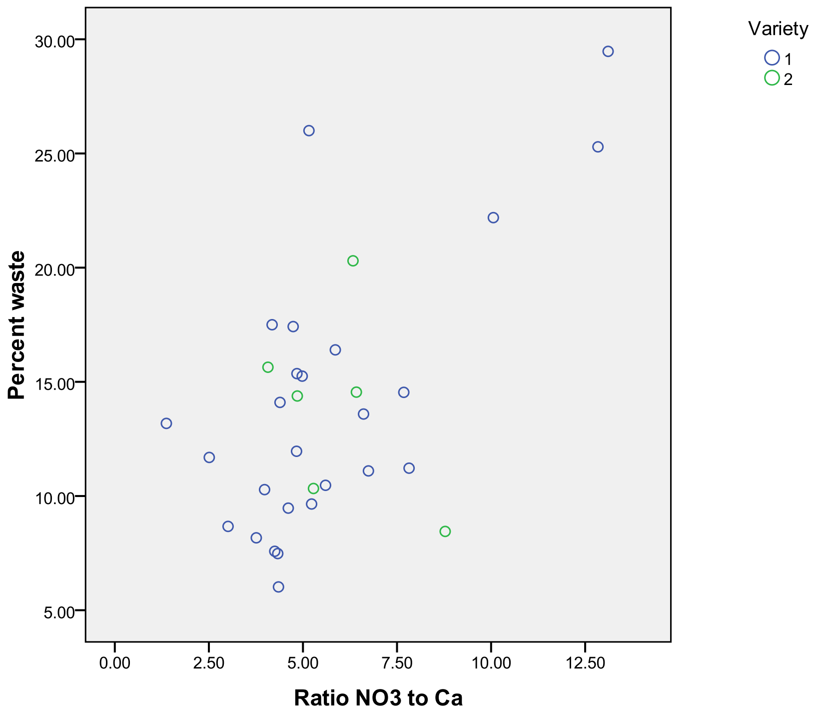


Figure 61. Scatter plot displaying the relation between % waste and the ratio of NO_3 to Ca.

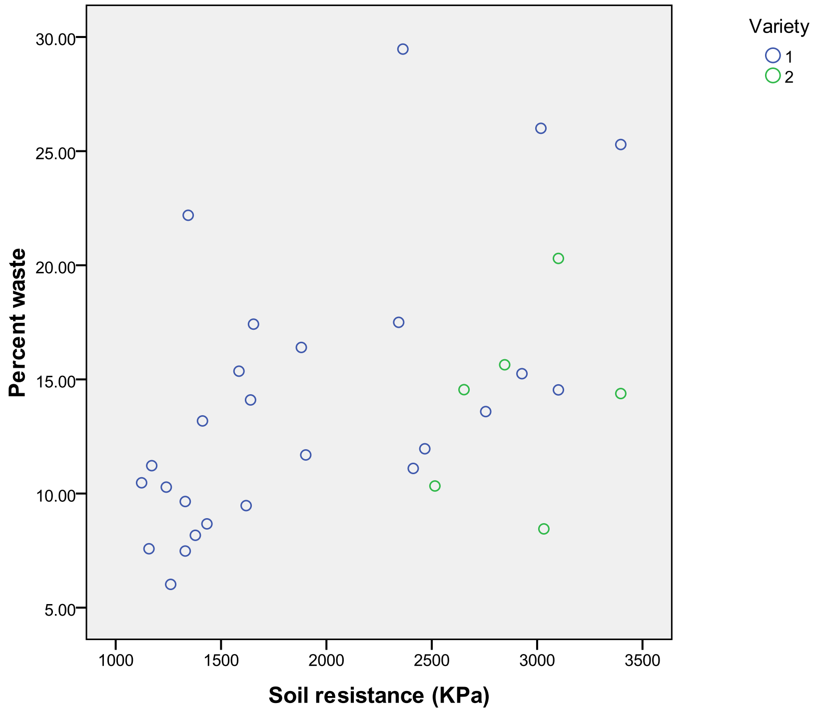


Figure 62. Scatter plot displaying the relation between % waste and soil resistance.

POTATOES

The findings are summarised in Table 56.

Visual pictures of the relationships and theire strengths are presented in Figure 66.

Scatter plots displaying relations between response variables and selected explanatory variables are provided in Figure 60 to Figure 65.

For all response variables there is evidence of a strong relation between the response and at least one explanatory variable.

Interpreting findings

Given the small number of paddocks providing data and the large number of potential explanatory variables, it is recommended that only relations that have a sound biological or physical meaning should be considered as reliably indicators of relationships.

Table 56. Results from linear regression analysis for the potato data. The primary explanatory variable is a variable that is fitted independently of associations with other variables. A secondary or subsequent y explanatory variable is one that is added after the

Paddock performance variable	Primary explanatory	Secondary explanatory	Tertiary explanatory	Quaternary explanatory	Percentage explained
% No1 med	OC %				40%
All variables	WSA %				34%
Exclude OC %	NO_3/Ca				30%
Exclude OC % and WSA %					
% large	Soil resistance				42%
All variables	Bulk density				29%
Exclude Soil resistance	OC %				28%
Exclude Soil resistance and bulk density					
% waste	WSA %				35%
All variables	WSA %	NO_3			55%
	WSA %	NO_3	NH_4-N		73%
	WSA %	NO_3	NH_4-N	P	87%
	Soil resistance				34%
Exclude WSA %	Soil resistance	Bacteria			55%
	OC %				27%
Exclude WSA % and soil resistance	OC %	S			54%

Correlations between paddock performance variables and explanatory variables.

Table 57 displays correlations between paddock performance variables and explanatory variables.

Correlations among paddock performance variables

Table 57 displays correlations among paddock performance variables.

It is noted that none of the correlations are statistically significant.

Table 57. Correlations between paddock performance variables and potential explanatory variables. Correlations that are statistically significant are highlighted.

	% no1 Med	%Large	%waste
% no1 Med		0.11	-0.39
%Large	0.11		-0.40
%waste	-0.39	-0.40	
NO3 (ppm)	0.14	-0.03	0.33
P (ppm)	-0.12	-0.29	-0.13
K (ppm)	0.13	-0.21	0.13
Ca (ppm)	-0.09	-0.05	-0.08
Mg (ppm)	-0.26	-0.22	0.00
NO3:Ca	.546*	0.26	-0.01
Total Cations	0.09	-0.36	0.15
Total Nutrients	0.13	-0.16	0.29
NO3-N(mg/kg)	0.42	-0.15	-0.02
NH4-N(mg/kg)	0.01	-0.09	0.00
pH (1:5 CaCl2)	-0.02	-0.07	0.13
S (mg/kg)	0.09	-0.13	0.39
Bulk Density (g cm-3)	-0.29	-.534*	0.48
OC (%)	.633*	.524*	-.520*
WSA (%)	.584*	0.50	-.590*
Soil resistance (MPa)	-0.01	.651**	-.585*
Total Microbial:	0.07	-0.14	0.18
Bacteria	0.02	-0.08	-0.18
Fungi	0.06	0.03	0.26
Yeast	-0.02	-0.32	0.30
Anaerobic	0.01	-0.05	0.45
Anaerobic Desired	-0.11	-0.20	-0.03
Azotobacter	0.11	-0.02	0.10
Actinomycetes	-0.13	-0.37	0.08
Fungi:Bacteria	0.18	-0.18	0.40
Fungi:Yeast	0.14	0.31	0.10

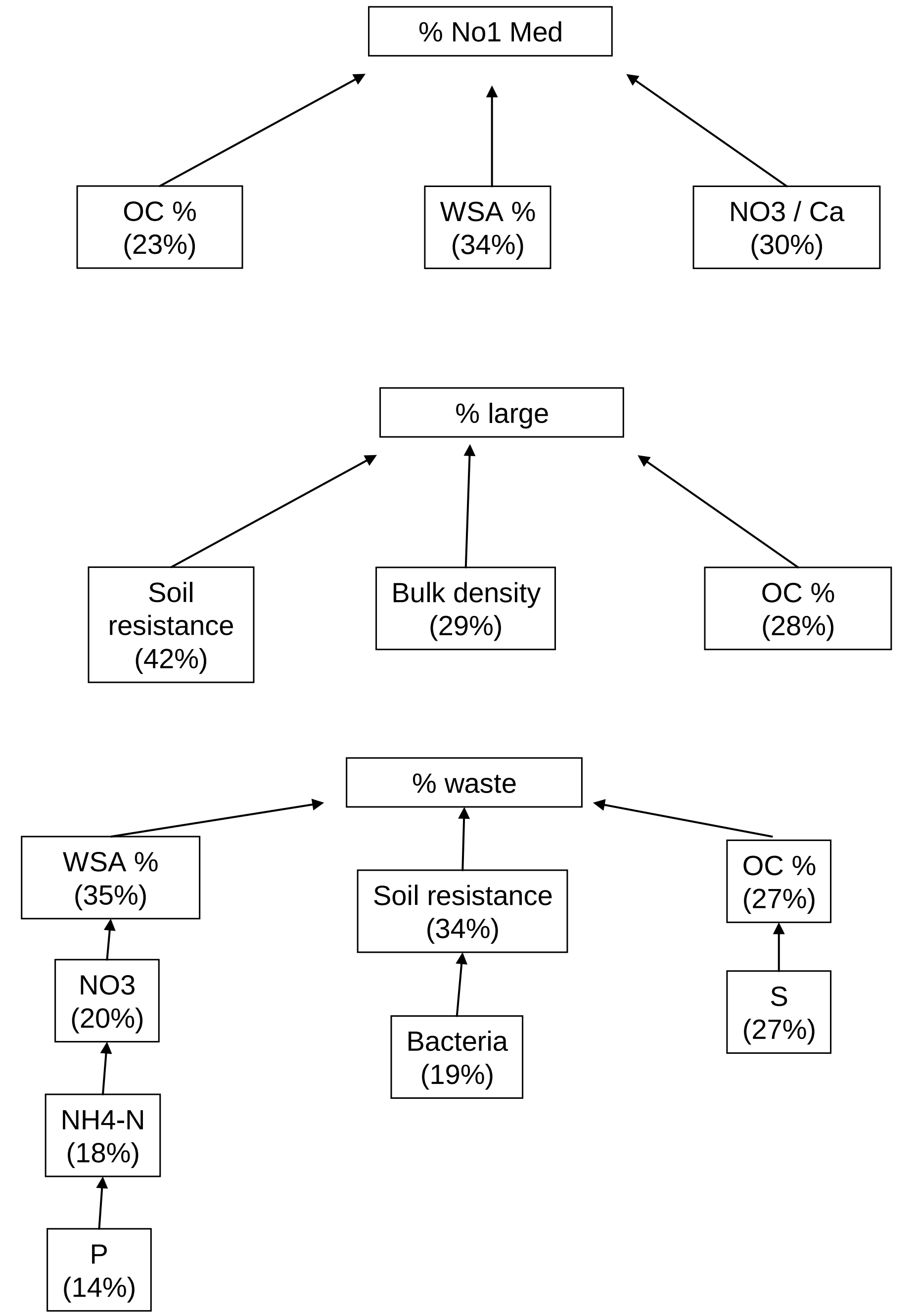


Figure 63. The percentage of variation in each of the paddock performance variables explained by different input variables based on linear regression models. Stepwise fitting was employed. The percentages indicated for secondary variables represent the additional p

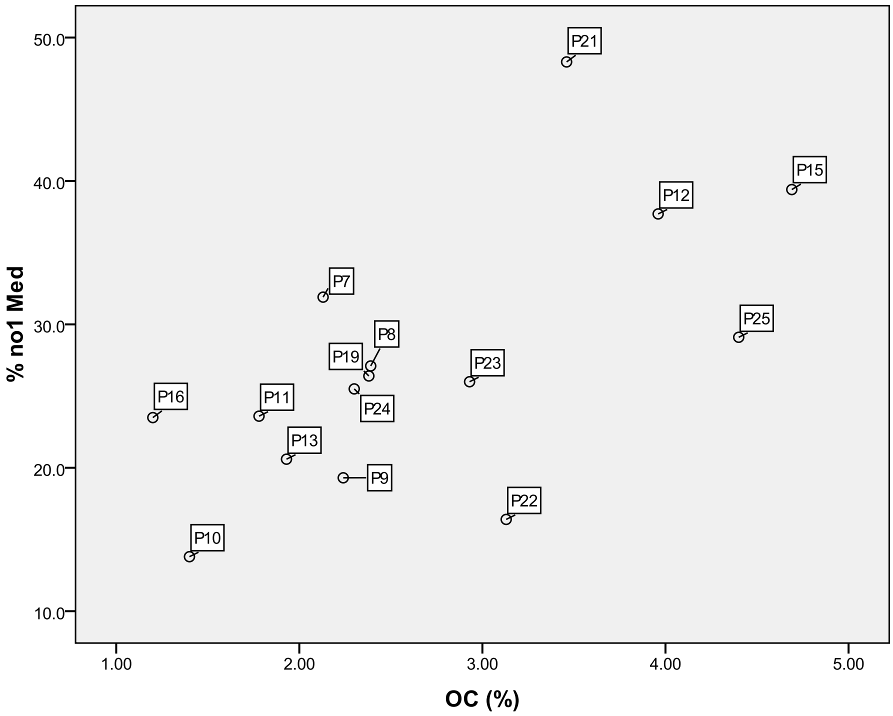


Figure 64. Scatter plot displaying the relation between % No1 Med and OC %.

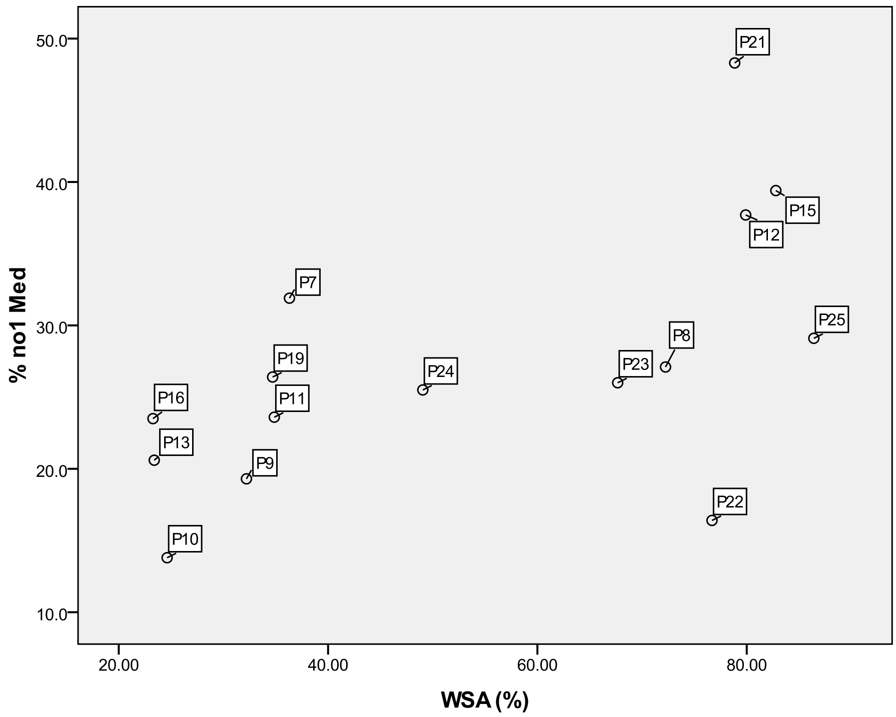


Figure 65. Scatter plot displaying the relation between % No 1 Med and WSA %.

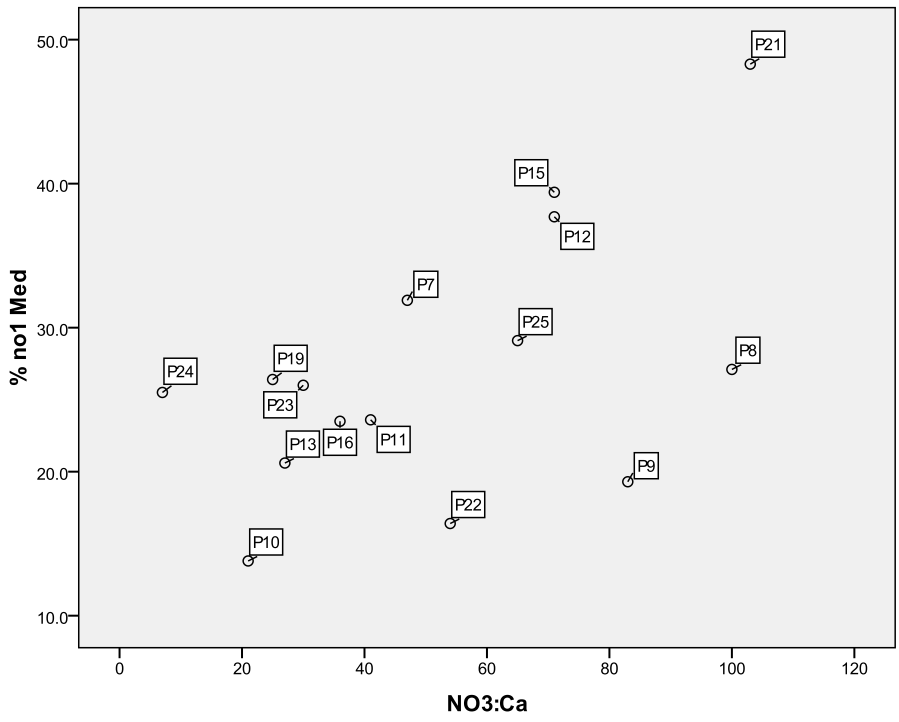


Figure 66. Scatter plot displaying the relation between % No 1 Med and the NO_3 to Ca ratio

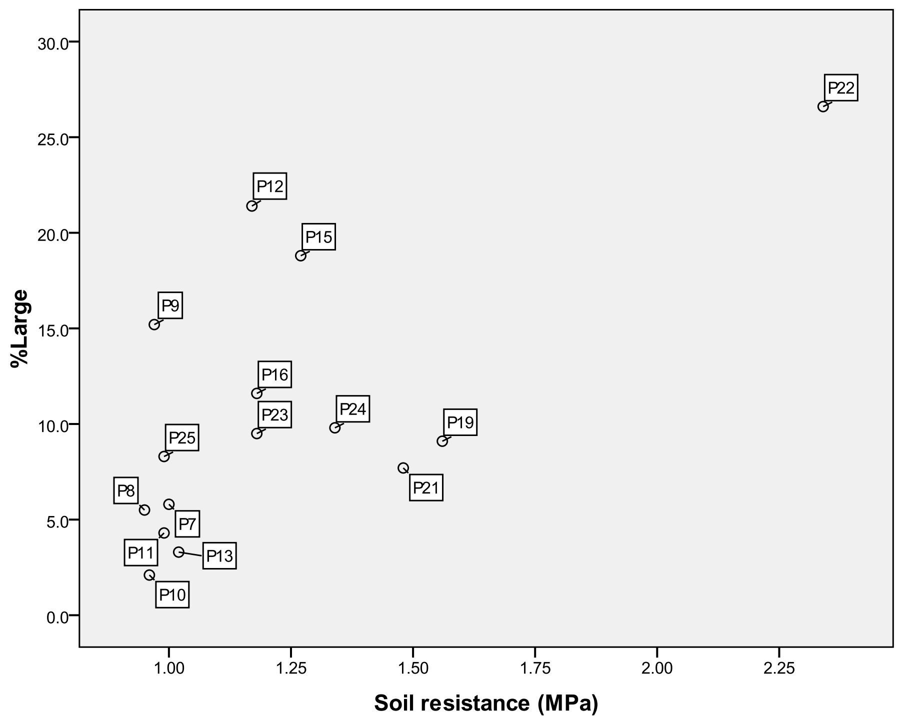


Figure 67. Scatter plot displaying the relation between % large and soil resistance.

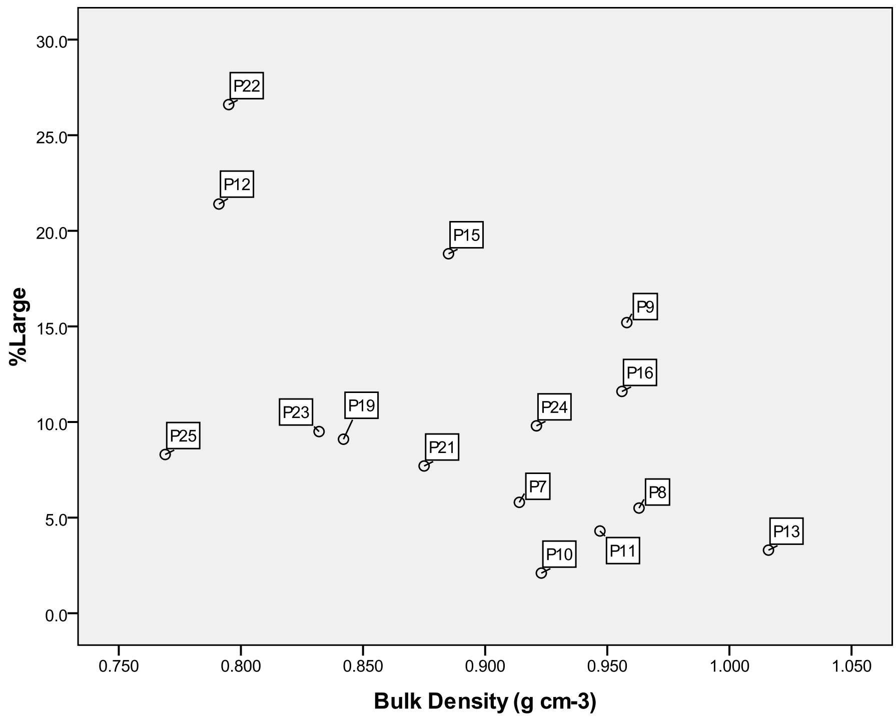


Figure 69. Scatter plot displaying relation between % large and Bulk density

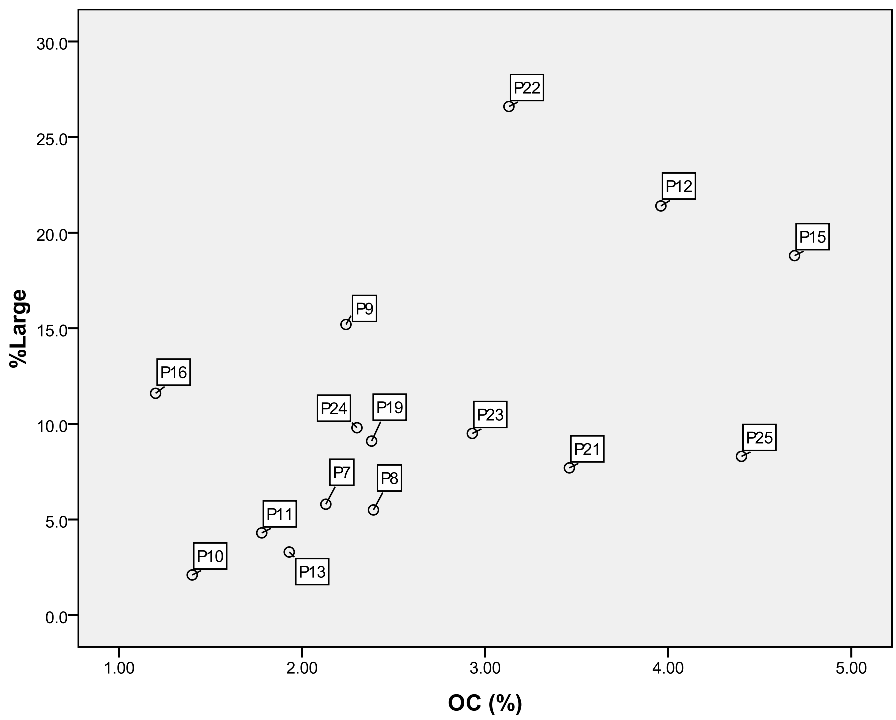


Figure 68. Scatter plot displaying relation between % large and OC %.

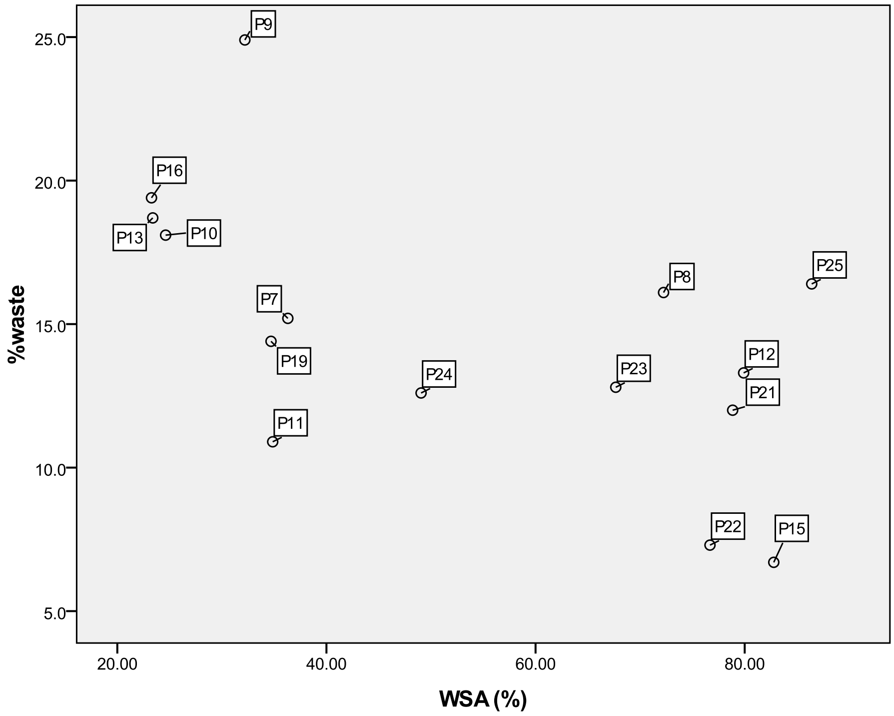


Figure 70. Scatter plot displaying relation between % waste and WSA %.

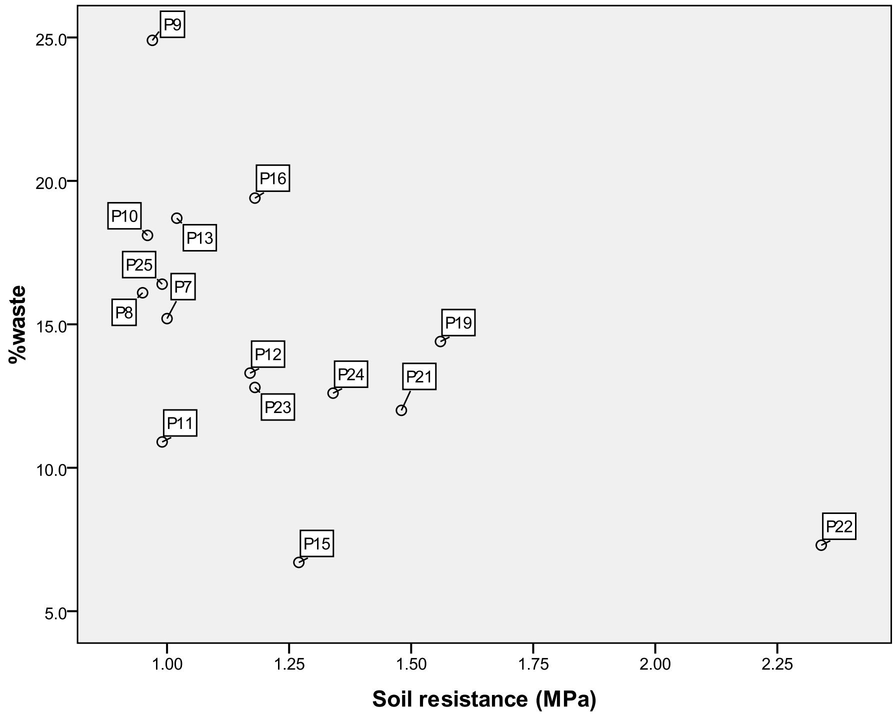


Figure 71. Scatter plot displaying the relation between % waste and soil resistance.

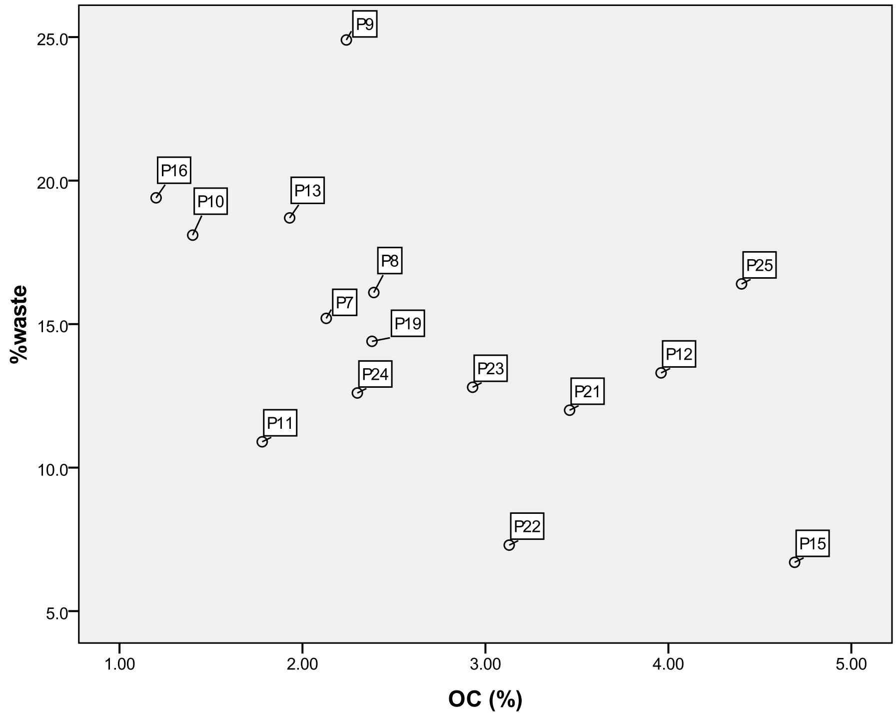


Figure 72. Scatter plot displaying the relation between % waste and OC %.