Mechanical Citrus Harvester; improvement modifications for commercialisation purposes

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MECHANICAL CITRUS HARVESTER: IMPROVEMENT MODIFICATIONS FOR COMMERCIALISATION PURPOSES

Horticulture Australia Project Number: CTO8027 (September 2009)

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This final report describes the engineering development of a 24-hour, all-weather mechanical citrus harvester that has increased harvest productivity to 5 tonnes/hour for a full season on medium sized crops. The harvester cost growers $80/tonne during this season which is the same rate as hand labour. Further modifications are expected to follow in coming years.

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September 2009

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MEDIA SUMMARY

The Australian Citrus Industry has been seeking a satisfactory mechanical harvester since at least the 1980s. It is perhaps therefore no surprise that when a machine comes along that is clearly a big step in the right direction, there is considerable interest in its performance.

Nelson Harvesters Pty Ltd (**Nelson**) had already designed and built a prototype mechanical harvester, which was originally trialled and used commercially in the olive industry. Nelson's decision to develop the machine for orange harvesting was encouraged by leaders in the citrus industry. In 2008 (prior to this project's commencement), the Nelson Harvester (the **machine**) was trialled commercially on several varieties of juicing oranges in the Riverina district of NSW. In October of that year it was demonstrated at the 2008 Australian Citrus Industry Conference and viewed by 150 growers, representatives of juicing companies and other interested parties.

In order to keep up with and meet the needs of Australia's rapidly expanding Citrus Industry – specifically for the orange juice industry - modifications were required on the 2008 model of Nelson Mechanical Citrus harvester before being able to consider manufacture or even consider tackling a full season harvest. The modifications aimed to achieve 24 hour harvesting by undertaking the following:

1) Split the conveyor system to allow for quick clearing of blockages
2) Build an overhead conveyor to pass fruit across the adjacent tree row so that the ferry bin trailer need not be located in the same tree row as the harvester as is the present arrangement
3) Replace existing overhead conveyor with one of greater capacity
4) Install a weather proof camera system to monitor discharge system
5) Install longer fishplates to minimise fruit loss
6) Fit a size grading mechanism so as to separate any immature fruit
7) Fit a de-stemmer to overhead conveyor so as processing plant does not need to deal with stems
8) Strengthen elements of the frame where necessary
9) Modify blower system to better remove dead twigs and branch material
10) Replace floor conveyor system with more suitable components with no sharp edges
11) Build new trailer conveyor
12) Install and plumb new hydraulics

The 2009 trials successfully demonstrated that 90% of fruit was collected using the modified Nelson citrus harvester. In this project, a total of 1155 tonne of fruit was harvested with this modified harvester with a daily average of 29.7 tonne, with an average day consisting of 8.6 hr of harvesting time (which equated to a total of 12 hours

actually in the orchard). Assuming a second tractor and chaser bin are added in the 2010 season to the harvesting operation, with no further modifications, Nelson harvesters predict the harvest total to increase by an additional 30% of crop per working day.

These modifications are aiming toward better financial returns for growers, juicing factory and machine operator/owner.

TECHNICAL SUMMARY

The prototype machine is towed by an off-set tractor and straddles the tree lines. The trees enter the body of the machine with the trunks passing through a series of fish plates, while from each side of the machine slowly rotating spindles, from each of which protrudes approximately 400 vigorously vibrating rods, close in and return knocking the fruit to the floor of the machine. By a series of conveyors, the fruit, after passing through cleaning blowers, is deposited into a ferry bin hauled by a second tractor.

The modifications made with HAL support are:

1. The conveyor discharge system has been split into more separately controlled parts so as to allow for quicker clearing of blockages.

2. A new over the row conveyor has been built to pass fruit across the adjacent tree row and into the ferry bin trailer. The trailer needs to be in the adjacent row in case it is filled with fruit before harvesting of a heavy crop in a long tree row is complete.

3. The cross conveyor at top of machine has been rebuilt to increase its capacity.

4. A weatherproof camera system to monitor discharge system has been installed. Four cameras focus on parts of the rear of the machine where blockages are most likely to occur.

5. The fishplates have been remounted to minimise fruit falling through gaps often caused by less than dead straight tree rows.

6. A size grading chain has been fitted to the over the row conveyor to separate out fruit, which is unacceptably small for the juice factories.

7. Part of the main frame has been strengthened to carry the weight of the overhead conveyor.

8. New blowers have been built which will better remove leaves, dead twigs and branch material from the discharge system. Included in this is a device to chop up twigs about to enter the bucket conveyor.

9. The floor conveyors have been replaced with more suitable components that don't have sharp edges and have far more capacity than the olive variant.

The extent of these modifications could indicate the prototype machine did not perform well during the 2008 trials. On the contrary, perhaps to the surprise of Nelson, selected growers and representatives of the 2 juicing factories, the prototype machine performed very well. But all recognised substantial modifications were needed to prepare it for a full commercial harvest.

INTRODUCTION

In 2001 Nelson watched with interest the beginning and rapid growth of the Australian olive industry. Large and well-funded groves were springing up everywhere. The industry seemed confident that modified nut harvesters that used the shake and catch principal would cover their harvest needs. The two biggest players had great faith in an unproven machine from Argentina that straddled the tree row and beat the crop off with plastic rods.

Nelson at the time was farming nuts, contracting and building relatively simple machines for its own use. Trials in 2001 on olives confirmed forever that modified nut harvesters were never going to really work on olives.

The company decided to build a straddle harvester and offer growers a contract harvesting service. The intention was to make significant improvements during the off seasons until a machine with a high level of performance had been achieved.

It was expected to be a long-term project that would lead to manufacturing options, possible joint ventures or sale of the intellectual property once a proven and widely accepted machine had been produced.

The most recent olive harvesting season was 3 years ago and it was an outstanding success. Of the 15 harvesters operating at Timbercorp that season, we had arguably the most reliable machine and certainly the one best suited to difficult varieties. The machine ran 24 hours a day, was unaffected by rain, quite capable in mud and harvested over 2000 tonne of olives.

It took 6 years of hard work, a very large sum of money and constant innovation to produce the successful run on olives in 2007. Two prototypes and continuous alterations to get greater performance or longer component life dominated the 9 months of the year when we were not harvesting.

Our engineering skills, trials and successful harvesting runs had to develop quickly to match the rapid increases in trees size, crop loads and harvested hectares. In a 5-year period we worked on most of the managed investment schemes and larger privately owned groves in the eastern states. Unfortunately for us the Australian Olive industry got very wobbly soon after the 2007 season and ended with the spectacular collapse of Timbercorp and Great Southern earlier this year.

Perhaps sensing the impending judgement day for the olive industry, we got involved with the Australian citrus industry in May 2007.

The Orange Juice Industry.

The orange juice industry in Australia is large, well established and stable. Severe drought and restricted irrigation water availability are knocking the Murray Valley growers hard, but the engine room has always been the irrigation areas feeding off the Murrumbidgee River in Western NSW. High security water users in those areas are in relatively good shape and there is a strong feeling of optimism for the new varieties of juicing fruit, combined with mechanical harvesting.

At the request of several citrus growers in the Riverina, Nelson was asked to trial its machine on recently planted varieties of juicing oranges. The machine, hauled by its tractor, was transported in June 2008 from West Footscray to Hillston by public road, (it can cover up to 300k per day). During the following 5 weeks, onsite modifications were carried out to adjust components for citrus use. Modifications made are largely based on the principle of trial and error - there is no manual to follow. A period of harvesting in Hillston, on a contract basis, of Salustiana, Parson's Brown, Pineapple and Hamlin varieties then followed.

The machine was taken to Forbes and the Leeton district and again the trials and contract harvesting on the above varieties were successful. During this time minor adjustments were being constantly made.

The trials were on 2 to 3 year old trees planted with the aim of being mechanically harvested.

At the request of the organising committee, the machine was demonstrated at the Australian Citrus Industry Conference held at Griffith in October 2008. The demonstration was well received and was made on 7-year old Pira Lima variety that had been pruned for mechanical harvesting. Over 150 growers and others attended, including representatives of many of the bigger growers and 2 juice processing companies.

In November another trial was conducted at Leeton. This time the variety was 30-year old Valencia, a variety that bears in summer. The summer fruit was easily removed, minimal damage was done to the trees and those who witnessed the trial felt an acceptably small amount of the developing next season's crop was disturbed. A further trial on this variety was conducted in December and confirmed the level of such loss was acceptable. However the machine had difficulty in coping with the old dead twig and branch matter that builds up in well-established Valencia trees.

The industry, from the Chief Executive of Citrus Australia Limited down, is interested in mechanical harvesting in order to lessen its dependence on labour, where it is in fact available, with its consequent cost and reliability issues.

In addition, mechanical harvesting is perhaps 10 times faster than hand harvesting. With rapidly expanding crops of juicing varieties, some with limited optimum

harvesting windows, and the vicissitudes of weather, the timing of the harvest becomes critical.

MATERIALS AND METHODS

The current machine (the 4th prototype harvester built by Andrew Nelson) was manufactured in 2005-2006 at premises in Barooga NSW with the main frame built by a steel fabricator in Albury. Twelve months later, over $100,000 was spent on modifications at Nelson's current yard at West Footscray Vic in preparation for what became the final olive season.

Andrew Nelson is the prime designer and assembler. Based on a working lifetime in agriculture, originally as a walnut and almond grower who designed and manufactured much of his own harvesting machinery, he takes an educated guess on what to build. He makes site modifications "on the run" and as necessary subsequently makes more significant modifications for the following season

Full use is made of both computer aided design and computer aided manufacturing by the company. Since day one everything has been drawn using 2 dimensional autocad. Three-dimensional autocad is used with increasing regularity and may in time become the main drawing package.

The company (started in 1992) is fortunate to have existed during a time of rapid development in the steel fabrication industries. Traditional methods of marking out, drilling, cutting and welding all by skilled tradesmen are well understood and still used by the company. The ease, accuracy and ability to effortlessly make multiples by using computer guided tooling is appreciated and now widely use to make harvester components.

Engineering drawings are emailed directly to fitting and turning shops for both milling and lathe work. Similar drawings are sent to plate shops for cutting with laser beams or high definition oxy acetylene equipment.

The company owns the usual range of equipment found in a small steel fabrication business. A 3 phase mig welder, drills, oxy set, hand tools, benches, vices, lifting gear, painting tools hydraulic hose making equipment etc etc. A forklift is mounted to the front of a tractor.

Folding, rolling, guillotine and press work are all done by outside workshops

As required the company engages a mechanical engineer based in Echuca who can add a "sounding board" aspect, used to refine Andrew's ideas

Andrew has assembled a team of skilled boilermakers, hydraulic and electrical personnel who are called upon as appropriate. Being a very small organisation, decision-making and implementation times are kept to a minimum.

How the harvester works

The prototype machine, on which HAL-funded 2009 modifications were made, consisted of the working harvester drawn by an off-set tractor. It straddles the tree line. The trees enter the machine, passing through fishplates, which allow the tree trunks to pass and then spring shut to avoid fruit loss. Slowly rotating side-mounted spindles from each of which protrudes approximately 400 vigorously vibrating rods, then close in from either wall of the machine. They shake the vegetation, knocking the fruit to the base of the machine before returning to their original positions. By a series of conveyors the fruit, after passing through blowers which separates out leaves, twigs and other matter is deposited into a ferry bin drawn by a 2nd tractor.

Photo 1 - Overall views of machine. This photo shows the machine in its working setup. The tractor driver positions the harvester so the trees pass through the centre of the machine. Trees up to 4000mm high and 2400 mm wide can pass through the harvesting chamber. It is a very large machine that is best suited to large orchards with long rows and plenty of turning room at the headlands. With 2 escort vehicles it can travel 350 km a day. Approximate road km in the last 7 years is 10,000.

Photo 2 - Overall view of machine. Photo 2 shows the working end of the harvester. Layers of vigorously shaking fibreglass rods dislodge the fruit and 8 conveyors transfer the crop to the chaser bin towed by a 2nd tractor in an adjacent tree row. Cleaning fans separate trash. "Fish plates" from the grape harvesting industry create a moving seal around the tree trunks to prevent losses onto the ground. Despite having an internal length of over 7000mm, only small quantities of fruit are lost through the front and back.

Photo 3 – The machine's turning ability

The slewing hitch and vertical pull (that eliminates binding up) allow a relatively tight turning circle of 14 metres diameter. The company has great faith in the tractor drawn idea.

Funds can be spent developing picking and delivery systems leaving very complex engineering jobs of power, transmission, steering, brakes and comfortable cabins to the tractor manufacturers.

The tractor can be uncoupled during the off-season for other farming or contracting work.

Photos 4 and 5 - Line of trees about to enter machine

Straight tree lines, upright tree trunks, good weed control and the removal of low hanging branches produce good harvesting conditions. Planting on mounds is generally good. This grower could expect 95 % removal and collection.

The harvester dimensions are more than adequate for these close planted (1800mm Centre – Centre) trees even at maturity. Very large tyres and 4800mm wheel track keep soil compaction away from the root zone. This machine has worked comfortably during and after 45 mm of rain on a heavy soil. Light soils allow 24 hour operation.

2009 MODIFICATIONS

1. Split the Conveyor System

Splitting the conveyor discharge system into more separately controlled parts allowed for quicker clearing of blockages. This was achieved by putting an easily accessible priority valve into the hydraulic circuit so flows to the large floor conveyors could be stopped but everything else let run. As has always been the case we can slow the system down with the engine revs and stop it at five different places to reduce build up once a blockage occurs. Ordinary 32 mm hexagon nuts where welded to shaft ends in the bucket conveyors so a shifter could be used to turn them backwards or forwards to release sticks.

This splitting was achieved by separating the controls for various parts of the hydraulic system. The separated controls are located both in the lead tractor and the operator's box situated to one side of the machine. The criterion for this modification was to reduce down-time by 5%. Other elements to this year's improvements worked so well that the splitting function is very rarely used. The cameras allow the tractor driver such a good view of the discharge conveyors that large messy blocks have been eliminated.

2. Build a New Overhead Conveyor

Building a new overhead conveyor allowed fruit to pass across the adjacent tree row and fall into the new chaser bin. The trailer needs to be in the adjacent row in case it is full before the end of the row.

The overhead conveyor was made from custom rolled C-section purlins that are 300mm deep and 100mm wide. Webbing is RHS. The conveyor is 4000mm long in standard trim but a bolt in section extends it another 2000mm for use in wide spaced tree rows. It has both lift and slew functions that are controlled from the head operator's cabin.

Rather than use a conventional rubber belt, we built what is generally called a grader chain. The gaps between bars are 50 mm and the chain does an excellent job of sorting out undersize fruit (sub 50 mm) and dumping it on the ground. The bars are carried on twin attachment chains that have rollers to ease metal to metal contact.

Undersize immature fruit that is hard and green is a real problem in some of the new “common orange” varieties. It is hoped the occurrence will diminish as the trees mature but in the meantime it is causing problems in the orchard and probably reducing yields.

All conveyor components have been zinc plated which is having some protective value against the acidic nature of oranges.

The criterion for this modification, plus the positive impact of the new trailer, which has a capacity of 10 tonne, was to reduce downtime by a further 15 %. This criterion was again 100% achieved. The full benefit of the over the row conveyor will be realised next year when a second chaser bin and tractor are added to the assembly. It will then become a genuine non-stop operation.

The grader chain is an excellent addition to the harvester and it gives all the operators satisfaction to see a stream of nuisance green oranges falling on the ground. The growers are pleased to see the immature oranges removed from the tree. They can be a serious problem in several of the new “common orange’ varieties and it is hoped that as the trees mature the problem will diminish.

Photos 6 - Conveyor slewed to 90 degrees from the machine for harvesting, but is parallel when machine not harvesting. Bolts for the 2000mm extension can be seen.

Photo 7 - shows take-up bearings for chain adjustment and 2 pivot points. 200cc hydraulic motor cannot be seen. Conveyor is positioned for turning at headlands.

3. Strengthen Main Frame.

The overhead conveyor is a substantial piece of steel work that weights approx 400 kg and has large forces associated with it due to its 6000 mm length. Mounting it to the side of the harvester about 3 metres up from the ground required some additional heavy steel framework.

Lighter bracing and hydraulic hose brackets where added as well. The heavy steel work is 125 * 125 *4 RHS that has been triple welded. It seems likely that another leaf separation blower will be required and we are fortunate that there is enough room between the upper and lower brackets to fit in another unit.

Photo 8 – Strengthen main frame to carry overhead conveyor.

Photo 8 shows unpainted framework to carry the Overhead conveyor. It is 125 * 125 RHS and light bracing. Hinge is 50mm ground bar carried in DU bushes. The tail end of the lift cylinder can be seen. Harvester tyres are 1700 mm in diameter.

The criterion for this modification was to reduce by 90% undersized fruit arriving at the juice factory. This criterion has been 100% achieved.

Some leaf material that isn't picked out by the blowers is carried on the grader chain (to our surprise) and deposited into the chaser bin.

Photos 9 and 10 - Ram and grading mechanism. The conveyor has been built to have a capacity of 10 tonne per hour which is becoming accepted as an industry wish (at the moment no harvester comes close).

Photos shows all zinc plated construction to resist corrosive characteristics of orange juice.

4. Rebuild Cross Conveyor

The reason for rebuilding the cross conveyor at the top of the machine is to give it greater capacity. This was a relatively simple job. Better tensioners, bigger bearings, a lower profile allowed and bigger openings in the bucket conveyors allowed a greater flow of fruit along the conveyor.

5. Weather Proof Camera System.

As part of preparations to handle vastly increased tonnages per hectare (compared to olives) we decided to install a remote camera system to monitor the 6 conveyors that experience told were most likely to overload. The cameras, control box and TV screen came straight from the security industry. The cameras have infrared capacity and work well at night. The screen is mounted in the tractor and is used to set the level of the harvester so ground clearance is minimised and effective picking zone maximised.

There are 4 cameras mounted at the rear of the machine of which 2 are focussed on the back end of the 2 floor conveyors and 2 are focussed on the mini conveyors delivering fruit to the bucket conveyors. The purpose of the cameras is to check whether branch and twig material is threatening to block the flow of fruit or the amount of fruit on a conveyor is too great and likely to cause fruit to fall from the machine or be damaged.

6. Remount The Fish Plates.

Trials in 2008 showed too much fruit was falling through the fishplates and being lost on the ground. More overlap and a greater fall in the plate itself were required.

This exercise proved to be more difficult than expected. Sample new, larger fishplates were acquired. They proved to be unsatisfactory as they became soft and pliable in hot sun. Thus an alternative solution was adopted and the mounting of the old fishplates was altered. New mounting bars were fixed to the main frame for that part of the fishplates where fruit was most likely to be lost. The original fishplates and their spring-loaded hinges were then bolted to these mounting bars. This process closed the gap; in fact one line of fishplates now overlaps the other (causing no impediment to the passing tree trunks).

Photo 11 - Amalgam of new (at tractor end) and original fishplates

Photos 12, 13 and 14 - Stages of fishplate replacement

The American made fish plates are very strong and it was decided to remount them rather than make new plates.

Note the new yellow steel tubes, known as flight bars, which scrape along the 2 harvester floors moving the fruit to the rear of the machine. Although the original flight bars were satisfactory to move olives, they were unsatisfactory for the movement of citrus.

7. Build New Trash Separation Blowers.

The original HAL proposal included a small sum to get the maximum performance out of the existing blowers. The work was carried out and the improvement was negligible. The company is very conscious that the crops and loads on the harvester are going to increase by a factor of 3 for the next year or two and it was decided new high capacity blowers would be required. HAL accepted an amendment and agreed to redirect some funding towards building new blowers.

It was all a rushed exercise but an outstanding result. Blowers are big users of horsepower and care needs to be taken with airflows to get the best possible trash separation. The company have built blowers in the past and less than a month after getting approval from HAL, we were mounting 2 large, strong and beautifully smooth blowers into the machine. They include a device to chop up twigs and small branches about to enter the bucket conveyors or block the inlet ducting to the blowers.

Blocked blowers was one of the more obvious problems we experienced in 2008. Trials on 30 year old, woody Valencia trees in December 2008 showed some promise except for the blocking of the blowers.

Photo 15 – Bigger, more powerful blower

The blowers are a nice piece of engineering. They are readily disassembled, very strong, all the bearings are absolutely true and there are no flexible couplings. The shaft is 35 mm and replaceable pieces of hydraulic hose serve as “stick

flickers" to keep the inlet clear of trash. The hydraulic motors have 1' gears. They have been balanced to the second highest turbine rating and run very smoothly. We ran out of time to paint them, it will happen this coming summer.

8. Conveyor Extension for Working in Wide Spacings

Planners of the new orchards intended for mechanical harvesting have gone for either wide (7 metre) or narrow (5 metre) row spacings. There are merits in both, but swapping from one grove to another presents a few problems for the harvesting contractor. It is necessary to have a removable extension for the over the row conveyor and some catching equipment mounted onto chaser bin trailers.

Photo 16 - removable extension.

9. Make New Floor Conveyors

The floor conveyors are a major part of the harvester. They gather fruit that is scattered over the entire harvester floor and pull it backward towards the mini conveyors and the cleaning fans. The machine as it stood in 2008 damaged too many oranges with sharp edges. Lacking lubrication supplied by squashed olives it was also noisy and hard-wearing.

The angle iron “scrapper bars” were spaced on 380 mm centres, which was deemed too far apart to deal with heavy citrus crops. New floor conveyors where built with HAL funding. Angle was replaced by 20 mm RHS, sprocket rollers and idler rollers replaced all sliding metal to metal contact and the gaps between bars was reduced by 100 mm.

There is over 28 metres of chain in each floor conveyor and stretching and consequent adjusting are still quite time consuming jobs. The company will make investigations into spring loaded automatic tensioners this off-season.

The modified floor conveyors have been very successful. What was our most common cause of stopping mid row has become the best performing conveyor.

Photos 18 and 19 - New floor conveyors

In this section of the Report several statements have been made to the effect that a stated criterion has been 100 % achieved. The next section of this Report sets out the justification for making these statements.

RESULTS

1. Leeton NSW (immature fruit)

The machine was taken to Leeton in mid-July 2009 and trials were conducted. However the trees made available by a co-operative grower were not ready to be harvested, so the trials were very limited. Details were:

1. Dates: 17 – 20 July
2. Weather: wet ground, temperature 6 – 16 C
3. Soil: heavy red
4. Season status: very early
5. Fruit maturity: very immature
6. Abscission rating: very high
7. Variety: Salustiana and Hamlin
8. Tree age: 1st and 2nd season harvests
9. Tree damage: foliage significantly disturbed

Because of the immaturity of the fruit, very little harvesting was carried out. However, time was spent testing the machine, now with its 2009 modifications, in field conditions. Consequently, adjustments were made to the new blowers and the side tipping trailer.

It should be noted that trees fully recover from foliage disturbance. Such disturbance occurred in 2008 at Forbes, when similar immature fruit was harvested very early in that season. Twelve months later the trees had totally recovered and set 14 tonne per hectare for the second harvest.. Nonetheless it is prudent for the sake of the tree and the machine for harvesting to await greater fruit maturity

2. Forbes NSW (fruit barely mature)

On 22 July the machine was transported to Jemalong 20k west of Forbes, being 300k north-east of Leeton. At Jemalong the fruit was more mature, the weather conditions were slightly warmer, the season was further advanced, the ground

conditions were dryer and the machine in 38 engine hours over a 5-day period harvested 150 tonnes of fruit. Details were:

1. Date 25 – 29 July
2. Weather: wet ground (18m of rain falling on one day), 1 – 18 C
3. Soil: light silt
4. Season status: early
5. Dates Fruit maturity: bordering on maturity
6. Abscission rating: just acceptable
7. Variety: Salustiana and Hamlin
8. Tree age: planted Sep 2006 (1st season harvest) and planted November 2005 (2nd season harvest)
9. Tree spacing: 1.8
10. Row spacing: 7m
11. Tree damage: nil permanent, some foliage disturbance
12. Downtime: nil
13. Fruit recovery rate: 95%
14. Grading out: 100%
15. Tonnage 150

The harvesting carried out at Jemalong was in 2 of several sections of the extensive orchard. The trees had been sprayed with the abscission chemical ethylene that worked very well to reduce the amount of shaking power required to dislodge the fruit.

In 20 machine engine hours part of the section planted in September 2006, consisting of 6,650 Hamlin trees, in row lengths of 342 m, were harvested. The ground speed was between 700 and 800 metres per hour and the fruit recovered was at an average rate of 2.5 tonne per hour.

The machine then moved to an area planted in November 2005. In 18 machine engine hours 3,652 Hamlin and Salustiana trees, in row lengths of 600 m were harvested. Despite a higher crop rate, the ground speed of between 700 and 800 metres per hour was maintained. The fruit recovered was at an average rate of 4.5 to 5.5 tonne per hour.

3. Leeton NSW - (mid-season)

The machine returned to Leeton on Wednesday 5 August

First orchard - Stanbridge

1. Dates: 4 August – 15 August
2. Weather: fine and sunny temp 5 – 15 C
3. Soil: heavy red / grey
4. Season status: early - mid
5. Fruit maturity: mature
6. Abscission rating: acceptable
7. Variety: Salustiana and Hamlin
8. Tree age: planted Sep 2006 (1st season harvest) and planted November 2005 (2nd season harvest)
9. Tree spacing: 2 0m
10. Row spacing: 5m
11. Tree damage: nil permanent, some foliage disturbance
12. Downtime: nil
13. Fruit recovery rate: 98%
14. Grading out: 100%
15. Tonnage 434

Second orchard - Murrumi

1. Dates: 16 August – 27 August
2. Weather: fine and sunny temp 5 – 15 C
3. Soil: fine red windblown sand
4. Season status: mid
5. Fruit maturity: mature
6. Abscission rating: acceptable
7. Variety: Salustiana and Hamlin
8. Tree age: 2nd season harvest
9. Tree spacing 1.8
10. Row spacing: 4.8m
11. Tree damage: nil permanent, no foliage disturbance
12. Downtime: nil
13. Fruit recovery rate: 98%
14. Grading out: 100%
15. Tonnage 352

4. Forbes mid season

On 6 September 2009 we returned to the Jemalong property

1. Date 7-10 September
2. Weather: Fine and sunny 5-18 C
3. Soil: light silt
4. Season status: mid
5. Fruit maturity: mature
6. Abscission rating: acceptable
7. Variety: Hamlin and a small quantity of McMahon
8. Tree age: planted Sep 2006 (1st season harvest) and planted November 2005 (2nd season harvest)
9. Tree spacing: 1.8
10. Row spacing: 7m
11. Tree damage: nil permanent, some foliage disturbance
12. Downtime: nil
13. Fruit recovery rate: 98%
14. Grading out: 100%
15. Tonnage 140

5. Forbes end season

On 28 September 2009 we are scheduled to return to the Jemalong property to harvest a final 50 tonnes of McMahons. The results of that harvest will be incorporated in any future reports to HAL.

6. Summary

The 2008 tonnage was 360. The 2009 tonnage was 1155 (as noted above there is a further 50 tonnes to be harvested at Jemalong at the time of writing this report). The harvester improvements created a 330% increase in yield. Engine hours were up by less than 5% and the number of harvesting days was only 4 more. These results are very pleasing and fully justify the involvement of Horticulture Australia Limited in the 2009 Modifications.

DISCUSSION

What follows is intended as a general discussion of the citrus industry and how mechanical harvesting fits into the picture. Figures are accurate for the sake of discussion.

Developing mechanical harvesters for tree crops is a more difficult job than development of harvesters for many other crops. Trees are obviously quite large and permanent. Damage to both tree and harvester must be avoided during the harvesting process

By comparison, in broad acre crops like wheat, the plant is dead, dry and readily crushed as the harvester separates grain from trash. Grains are generally stripped at dry times of the year. It is not uncommon for a harvester to strip 35 tonne per hour.

More difficult crops like potatoes and tomatoes need to be handled carefully but at least the plant can be destroyed during the harvesting process.

Building harvesters for wine grapes is a tough job. Not only must the trellising remain intact, but the crop is very liquid in the harvester and losses must be prevented. Grape growers will disagree, but the foliage and shoots on a grape vine are nearly completely removed during winter pruning so damage to them during the harvesting process is less detrimental to the plants long-term health than extensive leaf removal on citrus trees.

Yields of greater than 50 tonne per hectare are expected in new citrus groves versus 10 – 15 for grapes. This obviously puts extra loads into the harvesting machine and the whole harvesting operation. "Common Oranges" are going to be a winter-harvested crop in western NSW, which adds to pressures on growers and contractors. Wet winters are increasingly rare but frost and freezing conditions are common events. Both stop the harvest.

1. Common oranges

The 4 varieties that generally make up the group called common oranges have in fact been around for ages, but it is only recently that Australian growers and processors have decided to make use of a unique characteristic they have. The group are well suited to mechanical harvesting because the number of days from flowering to maturity is approximately two to three times as long as a Valencia type orange. This means complete removal of the crop with mechanical means is possible before the following seasons bloom commences. Valencias by comparison ripen during and after the following bloom and hold onto the tree (retaining their juice characteristics) for 8 months or longer.

Approximately 200,000 tonnes or oranges are grown in the Riverina area of NSW. It is the most important citrus area and has better short to medium-term prospects than Murray River locations because of the irrigation water situation.

120,000 tonnes are Valencia and the balance is Navels, which aren't suitable for the fresh juice market because of the short shelf life of the juice.

The harvester has been trialled very successfully on Valencia oranges in early and late December 2008. The time was chosen to minimise losses to the following seasons crop by harvesting when that fruit was 15–20 mm in diameter and hard and green. Removal of the intended crop was complete and loss of the green ones negligible (the NSW Department of Agriculture supervised the trial).

Despite this success it seems unlikely that large tonnages of Valencias will be harvested mechanically for the next 5 years. Orchards are old, full of dead wood, branching from almost ground level and don't have long runs or sufficient room at the headlands for the harvester to work. It is likely that new orchards will need to be planted with mechanical harvesting in mind before substantial tonnages are possible.

Based on 2 years' experience, the company can make the following comments on mechanical harvesting of the 4 "new" varieties of common oranges.

Hamlin

A mid season variety that is easy to remove but has a narrow harvesting window. Maturity to fruit fall is 2 weeks. G.A, sticktight and Ethylene are being trialled to extend the season. It has a tendency to throw a lot of immature off-season green fruit in young trees.

Salustiana

Much harder to harvest than expected. It will require successful manipulation with sprays to fulfil its potential as an early season variety.

Parsons Brown

Medium difficulty, hangs on tree well and throws lots of off-season green fruit.

Pineapple

Short dumpy stature of tree will need training to be suitable for machine harvesting but easy to remove variety.

McMahon

Not really a common orange but a very early Valencia. Fits mechanical harvesting well as the last variety to mature Easy to remove.

2. The Juicing Fruit Industry

Approximately 10 years ago, National Foods at Leeton decided on a major change to its operations. Rather than stretch Valencia orange harvesting over 11 months of the year and fill the 12th month with odds and ends, it was decided to close the Valencia season back to 9 months (where it more naturally sat) and encourage growers to plant the so called common oranges to fill the remaining 3 months. Better juice would be available, the Valencia trees could rest between crops and mechanical harvesting could be used on the new plantings. It was a well-conceived long-term business plan that has become the envy of other juice companies.

Of the National Foods contracted new plantings, approximately 250 hectares has been planted with the intention of machine harvesting. All growers have been secretly hoping a harvester would come along that could take off their Valencias as well.

Approximately 3 years later a group of predominantly cotton growers from northern NSW decided to diversify into intensive horticultural crops. The idea of machine harvesting oranges for juicing had great appeal for them. Gusto, money and expertise in row cropping saw greater hectares planted over 3 years than the carefully conceived National Foods program based 500 km south.

Combined the Northern and Riverina areas have 820 hectares of young and healthy trees planted in perfect citrus growing locations that are starting to bear crops. At a very conservative yield of 50 tonne per hectare it is likely 40,000 tonne of crop will need harvesting in say 5 years time.

Without the manipulation by as yet unproven and unregistered chemicals its likely this volume of crop will need to come off over a 10 week period (say 1 July to 15 September)

This equates to 4000 tonne per week.

In 2009 The Nelson harvester worked from July 26 to 10 September for an average of 12 hours a day, picked 1155 tonne. This equates to 172 tonne per week.

Clearly, very rapid improvements need to be made to the harvester so that new improved machines can be manufactured in 2 or 3 years time. See section titled Future for more discussion on this aspect.

3. The Nelson Harvester

In its pre-2009 form, the Nelson harvester was a very capable olive harvesting machine. It could harvest all varieties, collect 2 – 3 tonnes per hour and straddle a tree 4,500 mm high and 2,200 mm wide. It was capable of running 24 hours a

day and was in every sense a competitive machine when compared to its competitor, the million-dollar Colossus harvester.

Trials in 2008 on young citrus trees showed great potential, but also exposed what would be a giant deficiency in all olive harvesters intended for conversion to citrus work. Cleaning and delivery systems built for 3000kg of olives an hour were going to fall flat on their face when pushed to little over the same weight in oranges. Given the proven yields in excess of 50 tonne per hectare on close-planted oranges, it was apparent the systems would need many times their existing capacity.

Maqtec trialled a Colossus on citrus in Hillston in 2005/6 with unsuccessful results.

Nelson's machine with its simple construction and modular type assembly was better suited to the long-term project of doubling, then tripling then quadrupling its delivery capacity.

Fortunately for Nelson and all players in the industry the company got involved in the citrus business from before the day the first new orchard had its first very light crop. Keeping ahead of the projected tonnes is going to take rapid and successful improvements in all aspect of the harvesting operation. Growers, road transport companies and the processors are all going to adjust their thinking to getting large amounts of crop off quickly and during the coldest and historically wettest months of the year.

Our company's business plan hasn't changed since 2001. It is our intention to develop, trial and work a single machine until it is well proven and accepted. Once that day arrives we will have the option of building machines for sale to growers or contractors or for our own use. Joint ventures with machinery companies, sale or licensing of intellectual property all become options for the dissemination of knowledge and profit for the company.

The modifications described in this report have been very successful. A 3 tonne per hour harvester has been transformed to 5.5 to 6 tonne per hour machine without affecting reliability or durability. Both measures have been increased substantially.

The over the row conveyor allows genuine non-stop operation and will be fully used in 2010 when a second chaser tractor and bin are added.

The size grading chain removes immature fruit from the tree (which delights the grower) but separates it from the load (which pleases the processors).

Fruit damage is still an issue, but it didn't increase despite almost twice the fruit being harvested per hour. The company believes that reducing damage and the impact of damage will require manipulation of harvest timing with sprays, more improvement of the harvester and a different processing schedule in the factory. Machine harvested fruit will require priority over hand picked fruit, particularly the Hamlin variety that has a thin skin.

With the 2009 machine modifications having been made and on the basis of mature fruit:

- the machine downtime while working in the tree rows was virtually nil, as the new floor conveyors, top cross conveyor and overhead conveyor and the split discharge system and camera systems worked almost perfectly;
- minimal leaves and no twigs or trash remained in the discharge system as the modified blower system also worked very well;
- very little permanent tree damage was sustained on trees ready for harvest;.
- little foliage disturbance occurred from mid season onwards;
- fruit recovery was 98%; and
- the grading mechanism was 100% successful.

One significant breakdown occurred during the 2009 harvest. The flange that holds one of the picking masts sheared off. Although an identical failure occurred 5 years ago on a much more lightly built mast, we were still surprised. Over 750mm of steel and weld had to shear off to cause separation. The steel was 12mm thick and a superior grade of line pipe. All welds were properly run.

It took 2 men and a machine shop 1.5 days to remove, repair and refit the broken pieces.

4. Field Delivery

Picking and cleaning very heavy yields per hectare is going to be a difficult job for any harvesting contractor. Although a much easier job for an engineer, the removal of 50 tonne per hectare and delivery into large high-sided aluminium semitrailers is going to be a difficult logistical exercise.

Traditionally citrus growers have used small plastic bins with a capacity of 400kg to move their crop out of the orchard. Small trailers, small tractors and a forklift are used to move the bins and load them into waiting semitrailers. It takes 63 bins to fill a semitrailer and an hour and a half on the forklift.

Photo 20 - Traditional bins

Seeking to speed up the field removal operation, the company designed and constructed a new trailer, with a capacity of 10 tonne. The bin is hydraulically side-lifted so that the fruit is tipped directly into the waiting semi-trailer. Between 3 and 4 loads fills a semitrailer. This exercise was not included in the HAL project as the design and construction commenced before HAL approved the other modifications.

Photo 21 - New trailer

When this system is refined, it will speed up further the transfer of fruit to the semi-trailer and thus capitalise on the significantly improved performance of the harvesting machine.

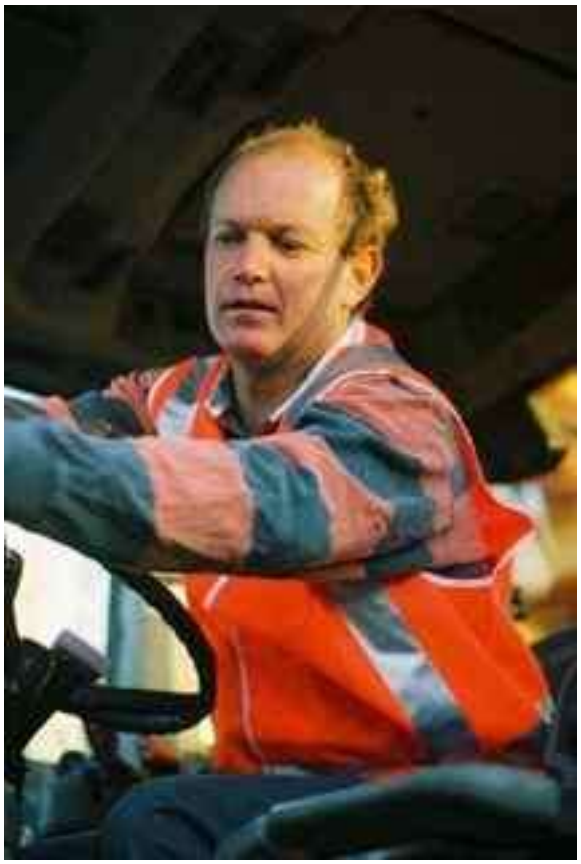
Whilst at Forbes an occupational, health and safety consultant reviewed the machine and assessed that it was close to being in accordance with relevant standards. Work needs to be done on this area before 2010.

Photo 22 - Machine lining up

These trees are second harvest Hamlin's that were carrying 31 tonne per hectare. Ground speed dropped dramatically so the crop could be cleared through the system without either loss or damage. The new HAL funded conveyors performed well but the remaining conveyors left over from olive harvesting days where gasping.

The company believe the picking mechanism was probably capable of 10 tonne per hour in this crop. Rough " back of the envelope " sketches have been drawn for a picking mechanism capable of 15 tonne per hour and across a range of crop yields.

Photo 23 - Andrew Nelson in lead tractor



The machine in its current form requires very capable operators. Trees pass through the harvester at the rate of 5 a minute and over 100kg of fruit is picked, cleaned and delivered in the same time. It is noisy, shakes a lot and can be dusty. A high level of concentration is required to keep the machine running smoothly. 9 hydraulic cylinders need regular tweaking and 8 different conveyors need to be constantly monitored. It is not a machine that is forgiving of careless or inexperienced operators.

Photo 24 - Looking through machine

Photo 25 - Line of trees ready for 2nd year harvest.

Photo 26 - trees entering machine

Note the picking head operators cabin. Visibility of tree and picking rods is excellent.

Photo 27 - Action photo of harvester and chaser bin working together.

View from platform mounted on back of harvest trailer.

5. The Future

Building prototype machinery is a difficult and expensive business. Generally only large machinery companies have the financial and engineering resources to sustain continued losses and the disappointment as bright ideas turn to powder in the harsh environment of Australian agriculture.

Nelson has always tried to keep machinery simple and robust, but greater demands seem to inevitably lead to more sophistication. We have been very fortunate that bad ideas have always been culled before harvest begins and to date we have never had a mechanism prove a failure on day one of harvest.

Good as this may sound the inverse is often true as well. We have rarely produced a mechanism that cannot have substantial improvements for the following season. Generally it's a matter of adding more bits to the mechanism rather than cutting whole pieces out and starting again. The business of constant development is very expensive.

Harvesting citrus mechanically isn't a very lucrative business. We charge growers slightly less than the cost of hand picking which is $ 80 per tonne plus the cost of owning and moving hundreds of plastic bins. Growers pay all diesel bills and provide a tractor driver for the chaser bin tractor. The cost probably

ends up being comparable to the cost of hand labour. We are fortunate that the 3 main growers we work for consider us an investment for the future and are willing to support us when they already have the equipment for successful hand harvesting.

The company harvested 1155 tonne in season 2009. At $75 a tonne it's a gross income of $83,000. Clearly it's not enough to pay wages, overheads, repay debt and develop a harvester.

Putting aside for the moment the issue of harvesting fees, a critical factor for growers is to harvest fruit in what are short harvesting windows. It is in this regard that mechanical harvesting comes into its own. In its present form the machine can pick 5 times more than an average size crew (5) of gun pickers. Cold or wet conditions don,t slow us down and with lights we can work for as many hours per day as fruit conditions permit.

In season 2009 we worked from 26 July until 10 September.

- 45 days were available to work.
- We harvested for 37 of them.
- 3 days were forced holidays when the factories were not ready for receival.
- 4 days were spend either cleaning or travelling between properties.
- 1.5days were spent fixing a major breakdown.

We harvested 1155 tonne with a daily average of 29.7 tonne.

In my experience as a contract harvester, these working day figures will be difficult to improve on. During the 45 days we did 320 engine hours harvesting and 40 hours travelling on bitumen roads (more than many farmers do in a year). An average of 8.6 harvesting hours per harvesting day.

Generally we were in the orchard for 12 hours to get the 8.6 harvesting hours. The biggest cause of lost time and lower than might be expected daily tonnages was the lack of a second tractor and chaser bin. The harvester stopped for between 30 and 40 minutes every time the trailer filled up. At an average of 4 trailer loads a day it equates to 2.3 hours per day

29.7 tonne per day divided by 8.6 hours is 3.4 tonne per hour.

6. Status Quo Scenario For 2010.

Assuming we add a second tractor and chaser bin to the harvesting operation but leave all other things as they are I estimate we will harvest an additional 30% of crop per working day.

Adding a second crew so the machine could be run from 7am to midnight takes the daily average to 54.5 tonne per day. I think it is very unlikely the machine will ever run from midnight to 7am during the winter months because the frosts and freezing conditions during those hours will be far too damaging to the fruit.

Assuming the harvest season in the Riverina can be stretched to 55 days (26 July to 20 September) it will allow the machine to harvest 2995 tonne.

All growers are reluctant to estimate yields 10 months in advance so what follows is an educated guess. My estimates for the 4 likely customers for our contracting service

Grower 1	1200 tonne
Grower 2	1800 tonne
Grower 3	900 tonne
Grower 4	800 tonne
Total	4700 tonne

A 1705 tonne shortage of harvesting capacity is serious enough, but the following year it is likely to be a 7000 tonne shortage.

It seems obvious that the next round of capacity increases need to start almost immediately.

Photo 30 - Oranges as harvested

TECHNOLOGY TRANSFER

The 2008 trials were observed by a number of key growers and representatives of 2 juice companies.

The machine was then demonstrated at the 2008 Australian Citrus Industry Conference before 150 citrus growers, representatives of juicing companies, representatives of the NSW Department of Agriculture and other interested parties. A description of the machine, including several photographs, was contained in the Conference Brochure. Copies of a video recording were distributed to selected persons and are available to interested parties.

The 2009 Leeton preliminary trials were observed by some local growers and a representative of the local juice company.

The 2009 Forbes trials were observed by the participants at a field day. 30 growers and potential growers from Northern NSW and a representative from both the major juice factories attended

Almost all growers or potential growers planting, or proposing to plant, the new juicing varieties and intending to mechanically harvest are aware of the machine and are following its progress closely.

A photograph of the machine taken at the 2008 Australian Citrus Industry Conference appears on the current web site of Citrus Australia Limited.

A presentation will be made to the coming 2009 Conference to be held in November at Mildura Vic.

RECOMMENDATIONS

To achieve the best results from mechanical harvesting the grower must set out and plant his orchard having regard to the requirements of the mechanical harvester. The following factors should be considered:

- the ground must be reasonably level, if gently sloping, the slope must be consistent;
- the soil should be well drained;
- headlands must be wide enough for the machine - preferably 15 metres;
- permanent obstructions e.g. irrigation equipment must be carefully positioned;
- the rows should be straight and long; 600 metres is fine, 1000 metres is better;
- the trees should be trained to 650mm before being allowed to branch;
- Tree spacing should not exceed 2400mm within the tree row. 2000mm seems best;
- the rows should be spaced to accommodate the machine which is 5.5m wide; and
- the trees should not be allowed to grow too tall.

Uniformity of the orchard will produce the best harvesting results.,

There is great wisdom in grower and mechanical harvester working together from an early stage to maximise productivity.

ACKNOWLEDGEMENTS

Nelson Harvesters acknowledges, with grateful thanks, the support and enthusiasm of a number of persons dedicated to the development of mechanical harvesting. They include Alan Harrison of Leeton, who, with his father before him, has been dreaming of the idea for many years. Other keen supporters are Pierre Janse Van Rensburg and Twynam Agribusiness Ltd, John Davidson and National Foods Ltd (the operator of the Berri Juicing Plant at Leeton), Ms Judith Damiani and Citrus Australia Limited and Golden Circle (the operator of a juicing plant in Melbourne). Some of these supporters have also made financial contributions. A tribute must also be paid to a skilled and dedicated employee Dean Perret.

Nelson Harvesters also acknowledge the funding provided by Horticulture Australia Limited