Improvements to Mechanical Citrus Harvester

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Nelson Harvesters Pty Ltd

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IMPROVEMENTS TO MECHANICAL CITRUS HARVESTER.

HORTICULTURE AUSTRALIA LIMITED

PROJECT NUMBER CT09049

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This is the final report of the above project. It covers the conduct and results of the project in detail, and also includes media and technical summaries.

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MEDIA SUMMARY

The dream of mechanical harvesting for citrus crops destined for the juicing industry is now well down the path to reality for Australian farmers.

Nelson Harvesters, with the financial assistance of Horticulture Australia Limited, has produced a machine that can harvest modern high-yielding orchards with consistent tonnages per day and ease for the grower. Labour requirements are about one tenth of the traditional method of pickers and ladders.

Nelson Harvesters is a small business that builds specialised machinery and offers growers a contract harvesting service to provide extended real life working conditions. The citrus harvester has been used for 3 seasons, has over 1000 hours on the clock and harvested its 100th semi-trailer load in October 2010.

Leeton in the Riverina district of NSW has become the centre of the Australian citrus industry particularly with the demise of the Murray valley orchards. Severe water shortages in the last 10 years have seen resources redirected to more profitable crops. In 2010 the harvester worked on two medium-sized orchards that supply the National Foods factory in Leeton.

Following substantial engineering changes in early 2010, tonnages per hour are up 30% from last year. After initial scepticism, major players in the industry are starting to accept Australian-made mechanical harvesting is here to stay and now expect improvements before the start of every season.

Nelson Harvesters has satisfied itself that the machine now has both the performance and durability to be an attractive proposition for third parties. Contract harvesting is an excellent way to prove a machine, but it is incapable of providing a sufficient return on investment. In order to maintain R & D spending and a reasonable economic return efforts will be made in the coming months to canvass interest from the big international machinery companies and/or the giant operators in Brazil.

TECHNICAL SUMMARY

The prototype machine is towed and powered by a tractor that is offset. It is a similar arrangement to tractor-drawn grape harvesters. The trees enter the body of the machine where 500 metre-long fibreglass rods are vigorously shaking. The crop is dislodged and falls into a series of conveyors. Leaf debris is removed by cleaning fans.

The 500 rods are carried on two masts that slide on overhead tracks placed at 90 degrees to the direction of travel. An operator controls the position of the picking heads relative to the maximum density of crop. Minimum tree damage and up to 100 % removal can be achieved.

Overall view of machine

The 2010 modifications have been designed to get more tonnes through the delivery system per hour. Substantial improvements had been made in 2009 to half of the conveyors in the machine. The 2010 alterations succeeded in matching the capacity of the remaining conveyors.

Ten tonnes per hour has become Nelson Harvesters' target yield. This figure is sufficient to supply the total needs of a medium-sized juice factory and about one third of the capacity of the large Australian processors.

It was estimated in the HAL application that yields of greater than 15 tonnes per hectare are required to allow the harvester to run at this level. That figure has proven way short of the mark. However, at 25 tonnes per hectare the machine will comfortably harvest 10 tonnes per hour.

Engineering changes completed within the scope of this HAL project were as follows.

1. Both of the large bucket conveyors were replaced with superior units of twice the original capacity. They were easier to adjust, damaged less fruit and eliminated an annoying characteristic of the earlier ones to recycle a small percentage of the crop.

2. Both the mini conveyors where relaced with a snug design that gave twice the capacity with only marginally more space required.

3. A new large-capacity cross conveyor was added. It will never spill fruit and bruising has been eliminated.

4. A third blower was added to the machine in 2010. It is best seen as a work in progress at this stage. It does an excellent job of separating trash and uses very little horsepower. Unfortunately the debris is shot straight in the air and then some of it either lands on the harvester or falls into the chaser bins. A return chute needs to be added to complete the job.

5. A special purpose side-tipping trailer was built to receive the crop from the harvester and transfer it to semitrailers. Citrus crops have a few unique characteristics that provide significant challenges to the designer. Crop loads are very heavy, tree rows are narrow, wet winter weather is expected, oranges need 30 degrees of slope before they will run when packed on top of each other and semitrailers must be full to water line to achieve maximum vehicle weight.

6. Part of the main frame has been strengthened to carry the weight of the overhead conveyor, and new bucket conveyors.

7. Health and safety issues have been addressed.

INTRODUCTION

Nelson Harvesters was established in 1991 to start a walnut and almond farming business near Barooga in NSW. To supplement income in the early years the business did contract harvesting and tractor work for local horticulturalists. Building machinery was integral to its plans. The boom in the Australian olive growing industry was watched with a certain amount of amazement, as the lack of suitable harvesters was obvious from day 1.

It was decided in 2001 to build a special purpose olive 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 4 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 effectively ended with the spectacular collapse of Timbercorp and Great Southern in 2009.

The Orange Juice Industry

The fresh orange juice industry in Australia is medium sized, 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.

New citrus growing areas are opening up at Forbes, Narromine, Moree and Gunnedah on the North Western slopes and plains of NSW. Substantial hectares of common oranges have been planted in the last 5 years, all in configurations to suit mechanical harvesting.

In 2008 at the request of several citrus growers in the Riverina, Nelson Harvesters 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 has worked in Forbes, Hillston and Leeton in the last 2 years. A grower in Gunnedah is keen to add him to the list for 2011. The following year is likely to see crops at both Narromine and Moree. There are hundreds of kilometres between all these locations, which takes considerable time out of the limited harvest window.

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 people attended, including representatives of the bigger growers and 2 juice processing companies.

In November 2008 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. Twelve months later, over $100,000 was spent on modifications at Nelson Harvesters' current yard at West Footscray Victoria 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 Nelson Harvesters. Since day one everything has been drawn using two-dimensional AutoCAD. Three-dimensional AutoCAD is used with increasing regularity and may in time become the main drawing package.

Nelson Harvesters (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 Nelson Harvesters. 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.

Nelson Harvesters owns the usual range of equipment found in a small steel fabrication business. Welders, drills, oxy set, hand tools, benches, vices, lifting gear, painting tools hydraulic hose making equipment 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 Nelson Harvesters engages a mechanical engineer who can add a "sounding board" aspect, used to refine Andrew's ideas.

Harvesting crops that are full of acid and sugar is tough on machinery. Sugars make the machine sticky which slows movement of chains, belts and other moving parts. One of the design criteria is ease of cleaning with a mobile pressure washer.

Citric acid is quite strong and damages many coatings. Zinc applied in baths (galvanising) or electrically has shown very little resistance to citric acid. All paintwork

fades very quickly. In 2010 new components where nickel-plated. It seems to be holding up well.

The business is for the first time considering not just the function of a component it designs but how much effort is required to manufacture it using different 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 2010 modifications were made, consists 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.

A detailed description and photographs of the prototype machine were included in the Interim Report of HAL Project 9049.

2010 MODIFICATIONS

Bucket conveyors with a superior design and 100 percent more capacity.

It was obvious in the 2009 season that the bucket conveyors were well short of capacity. They had originally been designed to deliver 3 tonne of olives per hour and 4 or maybe 5 tonne of oranges were their limit.

Conveyors inside harvesting machines often require twice their rated capacity to deal with the surging nature of fruit flowing through the machine. Crop loads vary from tree to tree, one end of the row to the other and quite commonly from one side of a tree to the other side. To produce a steady stream of say 5 tonne per hour it is necessary to carry short surges of close to 10 tonne per hour.

Even closely planted trees with even crop loads and a constant ground speed produce short and even surges of fruit through the machine.

New bucket conveyors

The new bucket conveyors are a good piece of design and fabrication work. Features include:

- One piece sides that where plasma cut for accuracy;

- Take up bearing for easy chain tensioning;
- Large tapco buckets (14 * 7);
- 2060 extended pitch chain;
- Nickel plated sprocket rollers;
- Cleaning / drainage holes; and
- 30mm nuts welded to shaft ends to be used for clearing jams.

The design allows the mini conveyors to be passed through the frame to ease maintaince on them.

The bucket conveyors need to be strongly built. They are constantly coming into contact with the ground when crossing drains and rough ground. Occasionally they thump heavily onto bitumen roads when harvester wheels go through potholes. They are made of fully welded 5 mm plate with plenty of extra steel for strength.

Compact high-flow mini conveyors

The mini conveyors are used to transfer fruit from the floors of the harvester to the outsides of the machine where the buckets lift them. Space restrictions mean the units have to be compact which often means difficult to inspect, hard to maintain and prone to jamming and fouling. Having experienced all of these problems in the past Nelson Harvesters put a big effort into getting the design right.

New and old mini conveyors

They have the following features

- Greasable bearings;
- Compact take up housings;
- Custom made 60mm slotted rollers;
- Special conveyor material designed for small radius rollers;
- Easily accessible cleaning holes that will accommodate a pressure washer nozzle;
- Full nickel plating; and
- 4 bolt removal/installation.

New cross-conveyor

The cross conveyor gathers fruit from both the bucket conveyors and takes it to the side of the machine where is slides into the over the row conveyor. It's the most obvious example of the surge / lull nature of harvester conveyors. Both bucket conveyors dump onto this conveyor so the load goes from nothing one second to 8 kg the next.

New cross-conveyor

It is a fairly simple unit that needs to be strongly build. Not only is half the weight of the bucket conveyors carried on it but it is the most likely thing to get smacked by a gum tree during transport on the public roads.

Third trash separation blower.

It was obvious that a third blower was necessary during the 2009 season. The machine is similar to grape, tomato and potato harvesters in the problems it has with trash removal. A one-minute malfunction can result in a large, visible quantity of leaves being dumped into haul-out trailers. Processors of all these crops complain loudly about leaf debris mixed with the crop, particularly when they have to pay for it.

Third blower

Blowers mounted at an early part of the harvesting mechanism are good because they save trash from building up further down the chain. Unfortunately they often have to function as suckers which means the trash gets put through the unit itself. Abrasion, wear, blockages, high horsepower requirements, noise and a stream of high-speed debris that needs to be kept away from people's eyes and paintwork are the obvious

problems. Keeping the stream of air and debris away from the soil surface is also important as it raises clouds of dust.

We experience all these problems with blowers, but managed to reduce their impact in 2010 by adding a third blower. It was mounted in a downstream position and could function as a blower rather than a sucker. Blockages, noise, horsepower and malfunctions have been reduced dramatically.

The blower is a small unit that was purchased second-hand. The idea, mounting position and ductwork are excellent, but the blower itself needs to be made to the same design we used for the 2009 units as that design has perfect alignment between all the bearings, which guarantees a long and trouble free life.

Frame alteration and strengthening

In the last 2 seasons we have tripled the machine's capacity to clean and deliver oranges over the row and into receival trailers. Every part of the system is now larger and heavier than it was 3 years ago. Steel gussets and tube have been added in several places to hold the show together.

Health and safety compliance

A health and safety consultant reviewed the machine 12 months ago. Three significant improvements have been made as part of the 2010 alterations.

The access ladders at the back of the machine now have a 25mm post running to the top, which is an anchor point for safety harness equipment. A platform has been made to ease the transition from climbing to walking. The electric shutdown switches mounted at the back of the harvester are now closer to the back of the machine and do not require a stretch to reach them.

Side tipping trailer

The Australian juicing industry and citrus crops have characteristics that make the post-harvest handling of the crop difficult. Trailer builders need to consider the following

1. The second largest juice factory is 500 km from the main growing area meaning trucks must be full to maximum gross weight to make for efficiency.
2. Oranges will not roll over each other until they are at 30 degrees slope. It is a steeper angle than almost all other materials.
3. Varieties suitable for mechanical harvesting are mature in August and September which are the wettest months of the year and consequently the least suitable for heavy machinery.
4. Modern orchard configurations typically have very narrow paths between tree rows so trailers with wide wheel tracks that are inheritantly stable cannot be used.
5. Yields per hectare are expected to be in excess of 50 tonne per hectare. Much greater yields than all other crops give added importance to getting the trailers right.

New trailer

Trailers used in the wine grape industry, sugar industry and the tomato industry were considered for use in bulk mechanical harvested oranges and found to be unsuitable. HAL assisted Nelson Harvesters to build a special to overcome these obstacles to safe and efficient harvesting.

The design requirements for the new trailer were:

Capacity	4 – 5 tonne
Wheel track	no greater than typical 100 hp tractor
Tractor requirement	no bigger than most orchardists use
Other	easily moved from one tractor to another
Tipping	must tip into high sided aluminium trailers used in the grain industry
Fine tune	To ease filling to maximum truck capacity without spilling onto ground

New trailer tipping

The trailer fulfilled all of these requirements. It was used for the whole of harvest, tipped 300 tonne of oranges and didn't miss a beat. The fine tune mechanism worked very well and was commented on by several observers.

Regular inspections showed a mixture of a small design error and a purchasing mistake was allowing movement in the swing out leg used to stabilise the trailer during tipping. It is something that needs to be rebuilt before the start of next season.

With the benefit of hindsight a seventh design requirement should have been added. Being able to tip the trailer in ordinary paddock conditions rather than having to haul the load to gravel pads placed around the orchards would be of great benefit.

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.

THE 2010 SEASON AND RESULTS

Mechanical harvesting cannot be seen as a stand-alone activity. Its success is determined by year round activities in the orchard and timing issues set by the juice factories.

The group of new varieties the machine works best on are often described as common oranges. Their value to the citrus industry is twofold. First, their ideal harvest time is immediately after the end of a normal Valencia season, which is say mid-July. Secondly, the entire crop can be harvested before flowering and sometimes even bud swell. There is no need to selectively pick and the tree gets a short spell before the start of the next growing season. Over a 10 year period this will be the pattern but season to season will produce wide variations.

Weather events will always have a large impact on horticultural activity. Two abnormal events during the growing season set the tone for 2010 harvest. Four days of hot and very windy weather in late October 2009 shrivelled flowers and fruitlets on most varieties and all locations. Yields at Australia's biggest grower of common oranges were only 20% of expectation. Everyone else suffered serious reductions as well.

An unrelated but equally significant event occurred in Feburary 2010 when 125mm of rain sized up an otherwise disappointing Valencia crop far more than expected. National Foods (the biggest processor in the country) had shut a factory in South Australia, bought as much uncontracted fruit as possible to fill the expected short Valencia crop and left its long-term Valencia growers carrying their crop until it could be processed.

The growers of common oranges sat nervously through August hoping the factory would start receiving their fruit before it fell on the ground. A wet winter added further delays.

A late start, sticky easily damaged fruit, sodden soils and continuing heavy rainfall made for difficult harvesting conditions from the first day of harvest. There was no time to tweek the machine during harvest. It was a race to get the main variety into the factory before it fell on the ground.

The results

The citrus harvester we have spent nine years working on has continued its strong and steady advances for the 2010 season.

Yields per hectare were well below expectations for all varieties in all locations due largely to the hot windy weather in October. The heaviest sustained picking we worked

on during 2010 was 22 tonne per hectare. It is not a yield that allows the harvester to work at it maximum.

Notwithstanding the yield problems the machine worked in excess of 75 hours at the rate of 9.3 tonne per hour. Short bursts would have been in excess of 11 tonne per hour.

Comparative Harvest Statistics

	2008	2009	2010
Starting date		17 July	22 August
Finishing date		15 September	11 October
Tonnage	360	1105	1089
Number of harvesting days	33	37	31
Average tonnes per day	10.9	29.86	35
Number of engine hours	362	381	314
Average tonne per engine hour	1	2.9	3.4
Highest tonnage in a day		56.5	52.5

Fruit damage has been a problem in earlier seasons, but was virtually eliminated in the 2010 season. Large open buckets in the conveyor system and bigger channels in the mini conveyors have done much to reduce the crowding to fruit in the discharge system. Damage is now estimated to be less than 1%.

These results show an average productivity improvement of 20% over 2009. Given that the yields per hectare were the same or marginally lower, it is a very pleasing result and fully justifies the involvement of Horticulture Australia Limited in the 2010 Modifications.

DISCUSSION

Long-term future

Nelson Harvesters' long-term business plan has always been to develop a single harvester year after year until it has reached a high standard of performance and durability.

By offering a contract harvesting service to growers, Nelson Harvesters gets to work long hours in real life conditions and to introduce the machine to the industry at the same time. It is fortunate for both the industry and Nelson Harvesters that the trials in 2008 were the first year the industry set a small crop on the new varieties. It will remain a challenge to keep machinery developments level with yield growth over the next 2 or 3 years.

Economics and common sense say it will always be a difficult job to continue developing a machine when the main source of capital investment is the income generated from a single machine contracting service. Large manufacturers budget millions of dollars and teams of engineers to projects like this one.

The business has had limited success obtaining financial help from the big players in the local industry. Twynam Agricultural Group has given a modest interest free loan and National Foods Limited has offered no assistance of any commercial value. The help Nelson Harvesters gets from Horticulture Australia Limited is of real value and has allowed us to develop the machine much faster than was otherwise possible.

Andrew Nelson as the general manager of the business has some concerns about the long-term suitability of the picking mechanism to work on medium to large size trees. It is a concern also expressed by the manager of the largest citrus grove in the country. A meeting held on 12 October 2010 concluded with some enthusiasm to explore the possibilities of an alternative mechanism. At the moment the alternative is just an engineering drawing stored on a Nelson Harvesters computer.

Nelson Harvesters is aware that the idea of mechanically harvesting oranges for the juice industry is a logical step down the path of mechanization of agriculture. Australia currently grows about 1% of the world's citrus crops. The big players in this country are dwarfed by their foreign competitors. It has been our intention to offer the machine and associated engineering drawings to interested parties sometime in the future.

Nelson Harvesters is currently in very preliminary discussions with growers/machinery importers in New Zealand, Spain and Chile.

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 nine 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.

Three 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.

The Northern and Riverina areas combined have 820 hectares of young and healthy trees planted in perfect citrus growing locations that are starting to bear crops. At a 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.

The Nelson Harvester

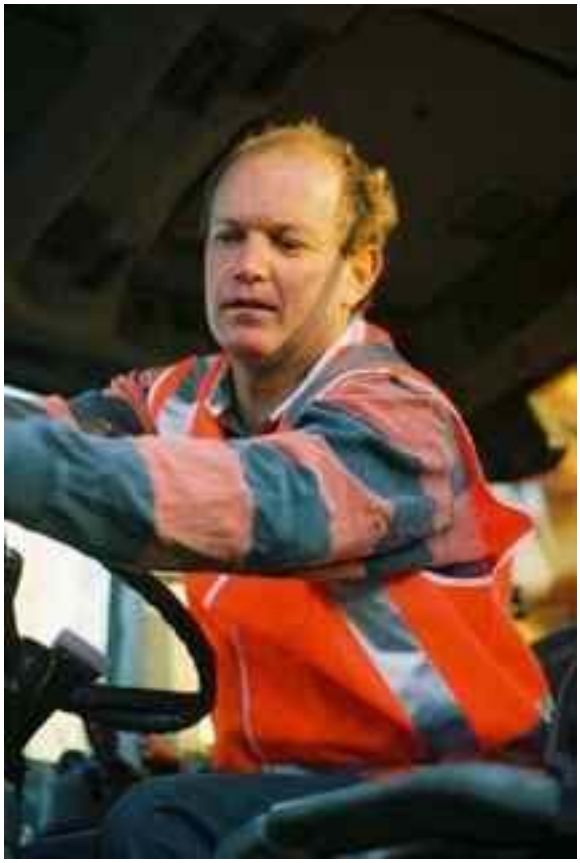
In its pre-2009 form, the harvester was a very capable olive harvesting machine. It could harvest all varieties, collect 2 – 3 tonnes per hour and straddle a tree 4,500 mm high and 2,200 mm wide. It was capable of running 24 hours a day and was in every sense a competitive machine compared to the million-dollar 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 such disastrous results that no one wanted to try again.

Nelson Harvesters' 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 Harverters and all players in the industry Nelson Harvesters 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.



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 150kg 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 incapable operators.

TECHNOLOGY TRANSFER

This season we had visits from all the major growers of juicing fruit. They are now well aware of the improvements we are making from one season to the next. In an interesting twist the growers of common oranges are generally new to the industry and evenly spread along the western rivers of NSW. In the last 5 years plantings have gone in at Moree, Gunnedah, Narromine, Forbes, Leeton and Hillston.

The orchards are all well managed, closely planted and expecting to use mechanical harvesting.

There is some chance an engineering drawing of an alternative picking mechanism may be taken to the prototype stage in a cooperative arrangement with one of these growers.

In the citrus industry Nelson Harvesting has maintained its initial enthusiasm for a cooperative approach to developing the machine and associated orchard activities with growers and processors. Each party is dependant on the others to do its activities properly and at the best time.

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 taller than 3.5 metres.

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.

The machine at the end of 2010 is a vastly better harvester than it was in early 2008. Its capacity has been increased from 3 tonne per hour to between 8 and 10 tonne per hour.

It is well suited to working on modern high density citrus orchards for the first, second and third harvests. Yields of up to 25 kg per tree can be picked, cleaned of leaf debris and delivered to side tipping farm trailers. A modern grove typically has 1000 trees per hectare, hence it is a yield of 25 tonne per hectare. That capacity would be more than double that required by any other fully mature tree crop grown in temperate climates e.g almonds, walnuts, olives or prunes.

Its also a fact that most new citrus orchards in Australia have been based on two trial plots planted 15 years ago. They have been consistently getting 80 tonne per hectare which puts them into the class of highest yielding citrus groves in the world.

It is Nelson Harvesters opinion that 3 and possibly 4 substantial improvements need to be made before tackling such giant crops.

1. A complete reworking of the hydraulic system to get the most out of the much improved conveyor system.
2. Greater use of camera,s and GPS guidance systems to steer the harvester down tree rows
3. Better performance in mud and at slippery row ends by redistributing weight and possibly adding bigger wheels & tyres
4. Investigating an alternative picking mechanism that may be better suited to working in medium to large size trees. This is likely to be a 2 year trial before we would feel comfortable mounting such a picking mechanism into the harvester.

Nelsons would like to continue developing the mechanical harvesting of citrus with assistance of HAL. It is in preliminary discussions with major players in the Australian citrus industry who might be able to help the company come up with its 58 % contribution.

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